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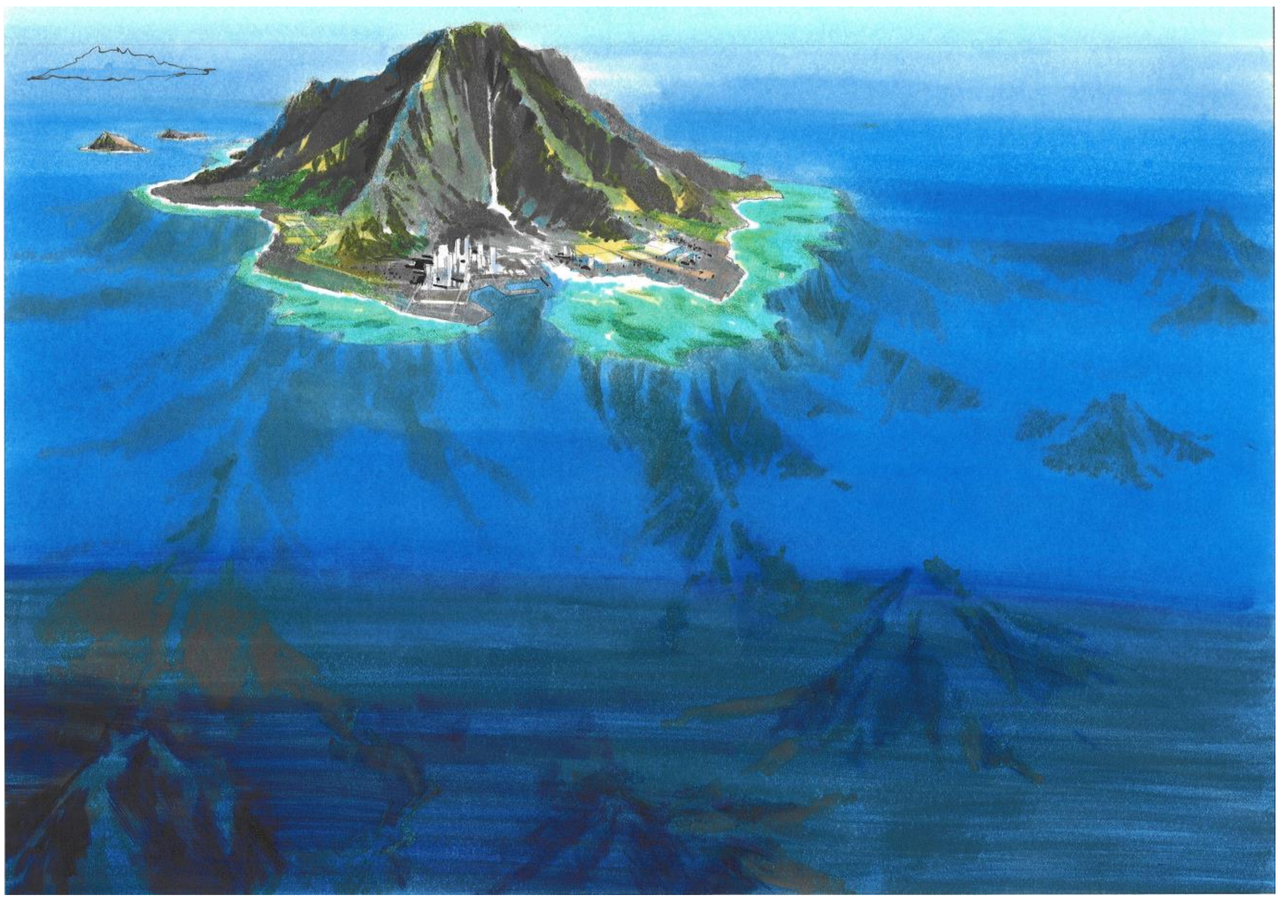
Essential Fish Habitat Descriptions for Western Pacific Archipelagic and Remote Island Areas Fishery Ecosystem Plan Management Unit Species

(Crustacean, Bottomfish, Precious Coral, Coral Reef Ecosystem)



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1. CRUSTACEAN SPECIES

This section is divided up between spiny lobster, slipper lobster, and Kona crab in Hawaii and spiny lobster in the other islands of the Western Pacific Region. This is because the only significant fisheries for crustaceans, primarily spiny lobsters and slipper lobsters, are found in Hawaii. Moreover, these fisheries use traps, which are not used extensively for crustaceans outside of Hawaii, and which are used in Hawaii to target other crustaceans such as Kona crab and white crabs. Moreover, while other spiny lobsters are widespread in the Pacific Islands and the US Western Pacific Region, the target of the lobster fishery in Hawaii, *Panulirus marginatus*, is found only in Hawaii, Johnson Island and Wake Island. Further, a major component of the Hawaii lobster fishery is the slipper lobster *Scyllarides squammosus.* Slipper lobsters, which are not targeted to any extent by other fisheries in the Western Pacific, may be taken opportunistically by divers.

Throughout the other Pacific Islands, including American Samoa, Mariana Islands and the Pacific Remote Islands, the most common spiny lobster found on rocky and coral reefs, apart from Hawaii, is *Panulirus penicillatus*, while other species such as *P. versicolor*, *P.ornatus* and *P.longipes* have also been observed, but are much less common.

1.1 <u>Hawaii</u>

1.1.1 Habitat

Adult spiny lobsters are typically found on rocky substrate in well protected areas, in crevices and under rocks (Pitcher 1993, FAO 1991). Spiny lobsters found in Hawaii include both *Panulirus marginatus* and *P. penicillatus.* However, most fishing for lobsters in Hawaii is targeted at *P. marginatus* and the slipper lobster *Scyllarides squammosus, and these species are the focus of this review.* An extensive review of the EFH for *P. penicillatus* is included in the FEPs for Mariana Islands, American Samoa and the PRIAs.

Unlike many other species of *Panulirus*, the juveniles and adults of *P. marginatus* are not found in separate habitat apart from one another (MacDonald and Stimson 1980, Pitcher 1993, Parrish and Polovina 1994). Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters (MacDonald and Stimson 1980, Parrish and Polovina 1994). Juvenile and adult *P. marginatus* do utilize shelter differently from one another (MacDonald and Stimson 1980). Similarly, juvenile and adult *P. pencillatus* also share the same habitat (Pitcher 1993).

In the NWHI, *P. marginatus* is found seaward of the reefs and within the lagoons and atolls of the islands (WPRFMC 1983). Uchida (1986) reports that *P. penicillatus* rarely occurs in the commercial catches of the NWHI lobster fishery. In the NWHI, *P. pencillatus* is found inhabiting shallow waters (<18 m) (Uchida and Tagami 1984).

In the NWHI, the relative proportion of slipper lobsters to spiny lobsters varies between banks; several banks produce relatively higher catch rates of slipper lobster than total spiny lobster (Uchida 1986; *Clarke et al. 1987, WPRFMC 1986). The slipper lobster is taken in deeper waters than the spiny lobster (Clarke et al., 1987, WPRFMC 1986). Uchida (1986) reports that the highest catch rates for slipper lobster in the NWHI occur between the depths of 20▪55 m.

Pitcher (1993) observes that, in the southwestern Pacific, spiny lobsters are typically found in association with coral reefs. Coral reefs provide shelter as well as a diverse and abundant supply of food items, he notes. Pitcher also states that in this region, *P. pencillatus* inhabits the rocky shelters in the windward surf zones of oceanic reefs, an observation also noted by Kanciruk (1980). Other species of *Panulirus* show more general patterns of habitat utilization, Pitcher continues. At night, *P. penicillatus* moves on to reef flat to forage, Pitcher continues. Spiny lobsters are nocturnal predators (FAO 1991).

1.1.2 Morphology

Spiny lobsters are non-clawed, decapod crustaceans with slender walking legs of roughly equal size (Uchida 1986, FAO 1991). Spiny lobster have a large spiny carapace with two horns and antennae projecting forward of their eyes and a large abdomen terminating in a flexible tailfan (FAO 1991).

Uchida (1986) provides a detailed description of the morphology of the slipper lobsterv *Scyllarides squammosus* and *S. haanii*. He notes that the two species are very similar in appearance and are easily confused (Uchida 1986). The appearance of the slipper lobster is notably different than that of the spiny lobster.

1.1.3 Reproduction

Spiny lobsters (*Panulirus* sp.) are dioecious (Uchida 1986). Generally, the different species of the genus *Panulirus* have the same reproductive behavior and life cycle (Pitcher 1993). The male spiny lobster deposits a spermatophore or sperm packet on the female♣s abdomen (WPRFMC 1983, Uchida 1986). In *Panulirus* sp., the fertilization of the eggs occurs externally (Uchida 1986a). The female lobster scratches and breaks the mass, releasing the spermatozoa (WPRFMC 1983). Simultaneously, ova are released for the female♣s oviduct and are then fertilized and attach to the setae of the female♣s pleopod (WPRFMC 1983, Pitcher 1993). At this point the female lobster is ovigerous, or ■berried● (WPRFMC 1983). The fertilized eggs hatch into phyllosoma larvae after 30■40 days (MacDonald 1986, Uchida 1986). Spiny lobsters are very fecund (WPRFMC 1983). The release of the phyllosoma larvae appears to be timed to coincide with the full moon and dawn in some species (Pitcher 1993). In *Scyllarides* sp. fertilization is internal (Uchida 1986b).

1.1.4 Larval Stage

Very little is known about the planktonic phase of the phyllosoma larvae of *Panulirus marginatus* (Uchida et al. 1980). After hatching, the ■leaf-like● larvae (or phyllosoma) enter a planktonic phase (WPRFMC 1983). The duration of this planktonic phase varies depending on the species and geographic region (WPRFMC 1983). The planktonic larval stage may last from 6 months to 1 year from the time of the hatching of the eggs (WPRFMC 1983, MacDonald 1986). There are 11 dissimilar morphological stages of development that the phyllosoma larvae pass through before they transform into the postlarval puelurus phase (Johnson 1986, MacDonald 1986).

The pelagic phyllosoma stage of development is followed by the puerulus stage. The puelurus stage lasts 6 months or less (WPRFMC 1983). Spiny lobster pueruli are free-swimming and actively return to shallow, nearshore waters in preparation for settlement (WPRFMC 1983, MacDonald 1986). Johnston (1973) reports that the phyllosoma phase of some species of the genera *Scyllarides* is somewhat shorter. MacDonald and Stimson (1980) found pelagic, puerulus larvae settlement to occur at approximately 1 cm in length. MacDonald (1986) found puerulus settlement occurred primarily at the new moon and first quarter lunar phase in Hawaii. The settlement of puerulus is higher in the central portion of the Hawaiian Island chain than what, and it is higher in the NWHI than around the MHI (MacDonald 1986).

There is a lack of published data pertaining to the preferred depth distribution of phyllosoma larvae in Hawaii. However, the depth distribution of phyllosoma larvae of other species of *Panulirus* common in the Indo-Pacific region has been documented. Phillips and Sastry (1980) reports that the newly hatched larvae of the western rock lobster (*P. cygnus*) is typically found within 60 m of the surface. Later stages of the phyllosoma larvae are found at depths between 80■120 m. *P. cygnus* undergoes a diurnal vertical migration, ascending to the surface at night, descending to lower depths during the day, the authors add. The authors also note that research has shown that early phyllosoma larvae display a photopositive reaction to dim light, In the Gulf of Mexico, the depth to which *Panulirus* larvae descend is restricted by the depth of the thermocline, Phillips and Sastry note.

MacDonald (1986) state that after settlement the pueluri molt and transform into post-pueruli, a transitional phase between the pelagic phyllosama phase and the juvenile stage. Yoshimura and Yamakawa (1988) note that very little is known about the habitat requirements of Palinurid pueruli after settlement occurs. However, Pitcher (1993) states that the post-pueruli of *Panulirus penicillatus* has been observed inhabiting the same ■high-energy reef-front habitat• as adults of the species. Studying the benthic ecology and habitat utilization of newly settled pueruli and juveniles of the Japanese spiny lobster (*P. japonicus*), Yoshimura and Yamakawa (1988) conclude that microhabitats, such as small holes in rocks and boulders and algae, provide important habitat for the newly settled pueruli and juvenile lobsters. The Japanese spiny lobster is found inhabiting shallow waters at depths of 1■15 m on rocky bottom (FAO 1991).

The oceanographic and physiographic features that result in the retention of lobster larvae within the Hawaiian archipelago are not understood (WPRFMC 1983). Johnston (1968) suggests that fine-scale oceanographic features, such as eddies and currents, serve to retain phyllosoma larvae within the Hawaiian Island chain. In the NWHI, puerulus settlement appears to be linked to the north and southward shifts of the North Pacific Central Water (NPCW) type (MacDonald 1986). The relatively long pelagic larval phase for palinurids results in very wide dispersal of spiny lobster larvae; palinurid larvae are transported up to 2,000 miles by prevailing ocean currents (Johnston 1973, MacDonald 1986).

1.1.5 Life Histories and Habitat Descriptions for Crustacean Species

1.1.5.1 Habitat Description for Hawaiian Spiny Lobster (*Panulirus marginatus and Scyllarides squammosus*)

<u>Management Plan and Area</u>: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

The Hawaiian spiny lobster, within the Council's jurisdiction are managed under the FMP for the Crustaceans of the Western Pacific Region

<u>General Description and Life History</u>

The Hawaiian spiny lobster (*Panuliris marginatus*) is endemic to the Hawaiian Islands and Johnston Atoll (Brock 1973, FAO 1991). The relative abundance of *P. marginatus* at Johnston Atoll is very low (Brock 1973). The spiny lobster is distributed throughout the entire NWHI, from Kure Atoll to Nihoa (Uchida 1986a). *P. marginatus* is the principal species landed in the NWHI spiny lobster fishery (WPRFMC.1983).The reported depth distribution of this species in the NWHI is 5–100 fm (WPRFMC 1983). While this species is found down to depths of 100 fm it usually inhabits shallower waters (FAO 1991). Uchida and Tagami (1984) report that *P. marginatus* is most abundant in waters of 90 m or less. Moffitt (1998, pers. comm.) states that spiny lobster are found in greatest abundance between the depths of 10–50 fm. At Maro Reef, in the NWHI, large adult spiny lobsters have been captured at depths as shallow as 10 feet (Moffitt 1998, pers comm.).

Uchida and Tagami (1984) note that within the NWHI, there is a dramatic shift between depth and relative abundance. They report that in the vicinity of the northern most islands and banks relative abundance of spiny lobsters was highest at depths of 19–54 m and that at the lower end of the chain the highest abundance of spiny lobsters were observed between 55–73 m. North of Maro Reef the highest relative abundance of spiny lobsters is found at shallower depths, they continue. They suggest that this variability may be due to differences in the temperature regime in the NWHI.

P. marginatus is typically found on rocky substrate in well-protected areas such as crevices and under rocks (FAO 1991). During the day, spiny lobsters are found in dens or crevices in the company of one or more other lobsters (WPRFMC 1983). MacDonald and Stimson (1980), studying the population biology of spiny lobsters at Kure Atoll in the NWHI, found that 57% of the dens examined were inhabited by solitary lobsters. The remaining 43% were occupied by more than one lobster, with adult and juvenile lobsters of both sexes often found sharing the same dens. However, the authors note, adult and juvenile spiny lobsters exhibit distinctly different den occupancy patterns, with juveniles (less than 6 cm in carapace length) typically in multiple occupancy dens with other lobsters. Adult and juvenile spiny lobsters are not segregated by geographic area or habitat type at Kure Atoll, MacDonald and Stimson observe. They found that juvenile spiny lobsters do not utilize separate nursery habitats apart from the adult lobsters. The larval spiny lobster puerulus recruits directly to the adult habitat (Parrish and Polovina 1994). This is in contrast to the juveniles of other species of spiny lobsters that tend to reside in shallow water and migrate to deeper, offshore waters as they mature (MacDonald and Stimson 1980).

There are limited data available concerning growth rates, reproductive potentials and natural mortality rates at the various life history stages (WPRFMC 1983). The relationship between egg production, larval settlement, and stock recruitment are poorly understood (WPRFMC 1983).

<u>Egg and larval distribution</u>

The Hawaiian spiny lobster (*P. marginatus*) is dioecious (Uchida 1986a). The male spiny lobster deposits a spermatophore or sperm packet on the female♣s abdomen (WPRFMC 1983, Uchida 1986a). In *P. marginatus*, fertilization of the eggs occurs externally (Uchida 1986a). The female lobster scratches and breaks the mass, releasing the spermatozoa (WPRFMC 1983). Simultaneously, ova are released for the female♣s oviduct, where they are then fertilized and attach to the setae of the female♣s pleopod (WPRFMC 1983). At this point the female lobster is ovigerous, or ■berried• (WPRFMC 1983). The fertilized eggs hatch into phyllosoma larvae after 30■40 days (MacDonald 1986, Uchida 1986a). The spawning season for *P. marginatus* varies throughout the Hawaiian Island chain (Uchida 1986a). In the northwestern end of the NWHI spawning occurs primarily during the early summer months (Uchida et al. 1980, Uchida, 1986a). MacDonald and Stimson (1980) found ovigerous females at Kure Atoll between the months of May to September. Uchida et al (1980) found the peak abundance of ovigerous female lobsters at Nihoa, French Frigate Shoals between late summer and early winter. It is believed that reproduction is nearly continuous in the warmer waters south of Maro Reef in the NWHI (WPRFMC 1983). Around the island of Oahu spawning occurs year-round (Uchida 1986a). In the MHI, peak spawning activity occurs between the months of May and August with a minimal amount of activity from November to January (Uchida 1986a). Egg-bearing females are found year-round in the MHI (WPRFMC 1983).

Spiny lobsters are very fecund (WPRFMC 1983). Honda (1980) found that fecundity increased with size. Most female spiny lobsters reach sexually maturity at 2 years of age (WPRFMC 1983). Estimating size at maturity for male and female spiny lobsters at Necker Island and Oahu, Prescott (19 *) concludes the Necker Island females reach sexual maturity at 60.7 mm, males at 59.2 mm, while Oahu females reach sexual maturity at 58.6 mm, males at 63.6 mm. At Necker Island the smallest mated lobster observed was 48.3 mm; it is not conclusive that the ovaries of females are mature at this size (Uchida and Tagami 1984). Growth rates for male spiny lobsters at Necker Island have been calculated as follows: 3.7 cm CL at 1 year, 5.7 cm at 2 years, 7.3 cm at 3 years, 8.5 cm at 4 years, 9.4 cm at 5 years and 10.1 cm in 6 years (Uchida 1986a). Due to insufficient data the growth of females has not been calculated (Uchida 1986a).

<u>Larvae</u>

After hatching, the larvae (or phyllosoma) enter a planktonic phase (WPRFMC 1983). The duration of this planktonic phase varies depending on the species and geographic region (WPRFMC 1983).Very little is known about the planktonic phase of the phyllosoma larvae of *P. marginatus* (Uchida et al.1980). The planktonic larval stage may last from 6 months to 1 year from the time of the hatching of the eggs (WPRFMC 1983, MacDonald 1986). There are 11 dissimilar stages of development that the phyllosoma larvae pass through before they transform into the postlarval puelurus phase (Johnson 1968, MacDonald 1986).

The pelagic phyllosoma stage of development is followed by the puerulus stage. Spiny lobster pueruli are free-swimming and actively migrate into shallow, near-shore waters in preparation for settlement (WPRFMC 1983, MacDonald 1986). The puelurus stage lasts 6 months or less (WPRFMC 1983). MacDonald and Stimson (1980) found pelagic, puerulus larvae settlement to occur at approximately 1 cm in length. After settlement the pueluri molt and transform into postpueruli, a transitional phase between the pelagic phyllosama phase and the juvenile stage (MacDonald 1986)**.**

It is believed, that because of the endemic nature of *P. marginatus* in the Hawaiian archipelago, the resident population is the source of larval recruits (Uchida et al. 1983). Shaklee (1962) found no genetic variation within the various spiny lobster populations at the different islands and banks in the NWHI chain. These data suggest that a single stock of spiny lobster exists in the NWHI (WPRFMC 1983). Recruitment of puerulus lobster larvae occurred at Kure Atoll beginning in the spring and lasting to October; no recruitment occurred from October to March (MacDonald and Stimson 1980). The distribution of lobster larvae in the waters surrounding the banks and islands of the NWHI is patchy (Parrish and Polovina 1994). Settlement of palinurid larvae tends to be higher in the middle of the Hawaiian Island chain and higher in the NWHI than in the MHI (MacDonald, 1986).

There is evidence that the recruitment of puelerus lobster larvae is tied to the lunar phase with maximum recruitment occurring during the new moon and first quarter phases (MacDonald and Stimson 1980).

<u>Juvenile distribution</u>

Parrish and Polovina (1994) found that banks with summits deeper than 30 m had consistently lower catches of spiny lobster; six of eight banks surveyed with summits at depths greater then 30 m did not provide commercial quantities of spiny lobster. They suggest a depth threshold may prevent the successful settlement and/or survival of pueruli of the spiny lobster in commercial quantities at these banks.

Parrish and Polovina (1994) studied the production rates of three banks in the NWHI; two commercially productive banks, Maro Reef and Necker Island, and one commercially unproductive bank, Lisianski. In this study the percent coverage of the different substrate types were measured and classified into four habitat types. The intermediate relief habitat

(5–30 cm) was found to support the highest abundance of juvenile lobsters. Based on the results of their analysis, Parrish and Polovina conclude that the intermediate relief habitat provides optimal habitat for juvenile spiny lobster.This intermediate relief habitat rarely exceeded 10 cm in height and was comprised of macroalgaes including *Dictopterus* sp., *Sargassum* sp. and *Padina* sp. Parrish and Polovina determined that a much greater proportion of intermediate substrate exists at the two productive banks studied, Maro Reef and Necker Island, than at the unproductive bank, Lisianski Island. They conclude that the amount of suitable habitat may be a factor limiting the total abundance of adult lobster production. The intermediate relief habitat provides suitable habitat for the settlement, survival and growth of *P. marginatus* pueruli and post pueruli. It does not provide enough structural relief to support a community of predatory reef fish, Parrish and Polovina note. Furthermore, they add, the lack of structural relief provides little shelter or protection for fish that forage on juvenile lobster from large piscovores such as sharks and jacks.

Parrish and Polovina (1994) describe the substrate of Necker Island and Maro Reef as predominantly comprised of intermediate relief algal communities. However, prolonged changes in water temperature could greatly modify the algal abundance, they note. The effects of such changes might include increased predation, reduced recruitment and reduced availability of food, they conclude.

Annual exploratory trapping surveys at Maro Reef in the NWHI have been conducted by NMFS since 1994. Haight (1998) explains that the survey was designed to identify juvenile spiny lobster habitat and determine abundance. Preliminary results of this survey indicate that the northwestern portion of Maro Reef supports higher concentrations of juvenile *P. marginatus* than are found at other sample stations within the reef. The northwest portion of the reef extends outward from the lagoon and as a result is exposed to greater wave action and currents than other areas of Maro Reef, Haight observes. The benthic habitat at the northwestern site (site 1) is distinctly different from that of other sites sampled within Maro Reef, he continues. Of particular note was the predominance of live coral colonies of *Acropora* and *Pocillopora* corals, he observes. However, colonies of *Acropora* sp. coral were not found at any of the stations sampled within the reef and are rarely found outside the reef (F. Parrish, unpub. data. in Haight 1998). Three other sites—comprised of coral heads interspersed with barren sand patches and coral rubble—were sampled during the survey, and the majority of spiny lobsters found at them were adults (Haight 1998). The specific ecological and physical mechanisms that are responsible for higher abundance of juvenile spiny lobster at the northwestern portion of Maro Reef need further study.

MacDonald and Stimson (1980) found juvenile spiny lobsters to exhibit a restricted home range, while adult spiny lobsters displayed a much wider home. Uchida and Tagami (1984) observed that 90 percent of recaptured adult spiny lobsters showed movement of 5 nmi or less, while MacDonald and Stimson (1980) found spiny lobsters had a dispersal rate that rarely exceeded several hundred m.

<u>Adult distribution</u>

Spiny lobsters are distributed throughout the NWHI, from Nihoa to Kure Atoll (WPRFMC 1983). The distribution of adult spiny lobsters is uneven throughout the NWHI chain. Research conducted prior to advent of commercial exploitation of spiny lobsters found the greatest abundance of lobsters at Necker and Maro Reef in the NWHI (Uchida et al. 1980, WPRFMC 1983). Surprisingly, the benthic habitat of Maro Reef differs markedly from bottom conditions found at Necker Island (Uchida et al 1980, WPRFMC 1983). The substrate at Necker Island is largely composed of coral interspersed with sandy areas and sandstone outcroppings. The bottom at Maro Reef is primarily composed of coral rubble and sand, lacking the type of habitat features normally thought to be lobster habitat (WPRFMC 1983).

Uchida et al (1980) found significant differences in the average sizes among spiny lobsters populations at the various banks and islands they sampled. MacDonald and Stimson (1980) found there to be a seasonal variation in the size distribution of the spiny lobster population at Kure Atoll in the NWHI. Small lobsters were more abundant in the months of June to September while larger lobsters were found to be more abundant in January. These researchers found males to be more abundant than females throughout the year. Male spiny lobsters were also found to comprise the majority of individuals in the larger-sized class.

Spiny lobsters are nocturnal predators (FAO 1991). Spiny lobsters are regarded as omnivorous, opportunistic scavengers (Pitcher 1993). Food items reported from the diets of *Panulirus* sp. include echinoderms, crustaceans, molluscs (primarily gastropods) algae and seagrass (Pitcher 1993). The habitat description for *P. marginatus* is summarized in Table 1.

Table 1. Habitat Description for Hawaiian Spiny Lobster (*Panulirus marginatus*)

	Egg	Larvae	Juvenile	Adult
Duration	30–40 days.	Planktonic Phyllosoma stage (6–12 months), free-swimming pueruli stage (up to 6 months).	Not known	Not known
Diet	N/A	No information available	No information available	Diet of *Panulirus* sp. includes echinoderms, crustaceans, molluscs (primarily gastropods) algae and seagrass
Distribution	Release of phyllosoma larvae appears to be timed to coincide with the full moon and dawn (Pitcher 1993). In NWHI spawning takes place during summer months, in MHI spawning takes place year round.	In Hawaii, puerulus settlement occurrs primarily at the new moon and first quarter lunar phase (MacDonald 1986)	Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters.	
Location	female spiny lobster broods the eggs until they hatch	Puerulus larvae seem to have a low rate of settlement success and survival if summit of bank is deeper than 30 m.	Banks with summits deeper than 30 m support lower abundance of juvenile lobsters. The NW portion of Maro supports higher concentrations of juvenile lobsters.	NWHI, MHI, Johnston Atoll
Water Column	N/A	Pelagic - Palinurid larvae are transported great distances by the prevailing water currents, up to 2,000 miles	Benthic	Benthic
Bottom Type	N/A	N/A	Areas of intermediate relief habitat (5–30 cm) seems to provide optimal habitat for juveniles	Adults are typically found on rocky substrates in well protected areas, in crevices and under rocks.
Oceanic Features	female spiny lobster may move to areas of strong currents to release newly hatched larvae into the oceanic environment.	In the NWHI, settlement appears to be linked to the north and southward shifts of the North Pacific Central Water (NPCW) type.	No information available	No information available

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1.1.5.2 Habitat Description for Kona Crab (*Ranina ranina*)

Management Plan and Area: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland and Baker Islands and Wake Islands.

Very little is known about the life history of *Ranina ranina*. The kona crab is found in the northwestern Hawaiian Islands (NWHI) from Kure Atoll to Nihoa at depths of 24 to 115 m (Uchida, 1986; Edmonson, 1946). *R. ranina* is also found in the main Hawaiian Islands (MHI).

It is believed that female kona crabs obtain sexual maturity somewhere between 54.3 and 63 mm CL. Uchida (1986) reports that 60% of male kona crabs ∃60 mm were sexually mature.
Kona crabs are dioecious and display sexual dimorphism. The males tend to grow to a larger size (Uchida, 1986). The sex ratio of males to females has been found to be skewed in favor of males (Fielding and Haley, 1976; Onizuka, 1972).

This species spawns at least twice during the spawning season (Uchida, 1986). The female kona crab usually spawns a second time approximately nine days after the first bacth of eggs hatch. Fertilization of the eggs occurs externally. The fertilized eggs adhere to the females numerous seatae (Uchida, 1986). In the MHI, ovigerous females have been found to occur only from May to September (Uchida, 1986; Fielding and Haley, 1976). There are insufficient data available to define the exact spawning season in the NWHI (Uchida, 1986).

A small, directed fishery for kona crabs exists in the MHI. There is no directed fishery for kona crabs in the NWHI however it is taken incidentally in the spiny lobster fishery. The principal gear used in the fishery is the kona crab net. *R. ranaina* is also taken in lobster traps. In the MHI from 1961 to 1979 the average total landings for kona crab averaged 13,519 kg.

Egg and larval distribution

Kona crab eggs are spherical and orange. They hatch at approximately 29 days after fertilization (Uchida, 1986). About 5 days prior to hatching the eggs change from an orange to brown color at the onset of the eyed stage (Uchida, 1986).

Larvae

Little is known about the plankton larval stage of kona crabs. The first molt occurs at 7-8 after hatching, the second molt about seven days later (Uchida, 1986).

Juvenile distribution

There is no information available concerning the distribution or habitat utilization patterns of juvenile kona crabs.

Adult distribution

Adult kona crabs are found inhabiting sandy bottom habitat at depths between 24 to 115 m. Kona crabs are opportunistic carnivores that feed throughout the day. It buries itself in the sand where it lies in waits for prey or food particles (Uchida, 1986).

The Council has designated EFH for the juvenile and adult life stages of *Ranina ranina* as the shoreline to a depth of 100 m. EFH for this species larval stage is designated as the water column from the shoreline to the outer limit of the EEZ down to 150 m. The habitat description for Kona crab is summarized in Table 2.

Table 2. Habitat Description for Kona Crab (Ranina ranina)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Approximately 29 days after fertilization	Little is known about the duration of the plankton larval stage of kona crabs. The first molt occurs at 7-8 after hatching, the second molt about seven days later.	Not known	No inforamtion available
Diet	N/A	Not known	Not known	Kona crabs are opportunistic carnivores that feed throughout the day. It buries itself in the sand where it lies in waits for prey or food particles
Distribution: General and Seasonal	Fertilization of the eggs occurs externally. The fertilized eggs adhere to the females numerous seatae.	Little is known about the plankton larval stage of kona crabs	There is no information available concerning the distribution or habitat utilization patterns of juvenile kona crabs	Adult kona crabs are found inhabiting sandy bottom habitat at depths between 24 to 115 m.
Water Column	demersal	pelagic?	Demersal	demersal
Bottom Type	N/A	N/A	N/A	sandy bottom
Oceanic Features	N/A	Larvae are subject to advection by prevailing currents.	N/A	N/A

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1.1.5.3 Habitat description for *Panulirus penicillatus*, *P. versicolor*, *P.ornatus* and *P.longipes* in the Western Pacific Region

Management Plan and Area:

American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands. The spiny lobsters, within the Council's jurisdiction are managed under the FMP for the Crustaceans of the Western Pacific Region. Some information is also provided on the slipper lobsters of the genus Parribacus, which was also observed in recent surveys in Americasn Samoa.

General Description and Life History

Scyllarids and palinurids are commonly considered to be opportunistic omnivorous i.e. they are able to feed on a wide range of food (Phillips et al., 1980). Chambers and Nunes (1975) indicated that the diet of *P. penicillatus* in American Samoa was "primarily, if not solely, algae". However, other studies showed that this species also feeds on Annelids Polychaetes, Mollusks (Gastropods and Bivalve), Crustaceans, and Echinoderms (George, 1972; Prescott in Pitcher, 1993). Whereas only a few studies have dealt with the slipper lobster diet, they showed similar patterns to that for spiny lobsters (Lau, 1987; Spanier, 1987). These organisms are are able to select their food according to availability and density. Thus, individuals of the same species but which are living in different areas can have different diets implying important differences in growth rates (Morgan, 1980; McKoy & Esterman, 1981; Edgar, 1990).

Lobsters, as other Crustaceans, increase in size by molting, while the growth of tissues (and thus the weight) is continuous. The growth rate decreases with age, and the inter-molt duration increases. During the molt, most of the calcified components are replaced. *P. penicillatus* is sexually dimorphic for size, with males reaching larger sizes than females. The largest males can weight 3 kg (6.5 Lb) for 16 cm (6 ¼ in) of Cephalothoracic (or Carapace) Length (CL: measured from the basis of the supraorbital spines to the end of the cephalothorax) (Richer de Forges & Laboute, 1995).

Reproduction

For crustaceans, the reproductive season is determined by photoperiod and luminosity (Lipcius & Cobb, 1994). As a result, lobsters from temperate and sub-tropical waters have only one spawning period (Chubb, 1994; Kittaka & MacDiarmid, 1994) whereas numerous tropical species are able to spawn nearly year-round, and some individuals are able to spawn several times in the same year (Berry, 1971; Moore & MacFarlane, 1984; Juinio, 1987). In Hawaii, 40 % of the *P. penicillatus* females are berried (with eggs under the abdomen) (McDonald, 1971, 1979) at any time, and some females spawn 2 or 3 times a year (Juinio, 1987; Plaut, 1993).

Fertilization is external (Lyons, 1970; Morgan, 1980); the male deposits a spermatophore, via paired penile projections at the base of the fifth walking legs, onto the female sternum. This spermatophoric mass becomes black and is butterfly-shaped for spiny lobsters and covers the two first pairs of pleopods in *Parribacus* spp. The female is then called 'tarred'. After a few days, the female spawns several thousands of oocytes from the paired gonopores situated at the base of the third walking legs, into a 'chamber' formed by curving the abdomen under the sternum. The female scrapes the spermatophore with special chelae (claws or pincher) on the dactyl (last segment) of the fifth walking legs, to release the sperm which fertilizes the oocytes during the transit (Berry, 1970; Lipcius & Herrnkind, 1987; Pitcher, 1993). The fertilized eggs adhere to the ovigerous setae of the internal part of the biramous pleopods (Berry, 1970) (see Appendix I). In the literature, the smallest *P. penicillatus* berried females measured from 4.08 cm of CL (1.6 inches) in Philippines (Juinio, 1987) to 6.20 cm (2.45 inches) in the Marshall Islands (Ebert & Ford, 1986). No information on any *Parribacus spp*. reproduction is available in the literature.

<u>Eggs</u>

Following courtship, several hundred thousand eggs are extruded from the paired gonopores at the base of the third walking legs into a chamber formed by curving the abdomenover the sternum. The eggs are carried under the tail of females for about a month before the phyllosoma larvae are released.

<u>Larvae</u>

After 1 to 9 weeks of incubation [20 to 35 days for *P. penicillatus* (Juinio, 1987; Plaut, 1993)], larvae are released in the field (George, 1958; Chittleborough, 1974, 1976; Nair et al., 1981; Pitcher, 1993). Among spiny lobsters, hatching always occurs in an area allowing the larvae to quickly drift offshore (Phillips & Sastry, 1980; Coutures, 2000b), which implies that sometimes there is migration from coastal to oceanic areas (Moore & MacFarlane, 1984; MacFarlane & Moore, 1986; Coutures, 2000b).

The larvae of Palinuroidea (spiny lobster or Palinuridae, slipper lobster or Scyllaridae, and Synaxidae or coral lobsters) is called phyllosoma (from Greek "phyllo" leaf, and "soma" body), a flat, transparent, leaf-like larva, which corresponds to the Crustacean zoea stage.

The outstanding feature in the life history of the Palinuroidea is the exceptional duration of their larval phase, which varies among spiny lobsters from 6 to 12 months according to the species (Phillips & Sastry, 1980; Booth & Phillips, 1994) and even 24 months for *Jasus edwardsii* (Lesser, 1978), a species occurring in New Zealand and South Australia, and from 1 to 9 months for slipper lobsters (Sims, 1965; Robertson, 1968a,b, 1969a,b; Takahashi & Saisho, 1978; Ito & Lucas, 1990; Marinovic et al., 1994; Mikami & Greenwood, 1997). During the larval phase, phyllosomata can travel great distances, e.g. Johnson (1974) caught one *Panulirus penicillatus* phyllosoma in the Pacific Ocean 3,700 km from the Galapagos Archipelago, which was the closest hatching site. Mechanisms allowing phyllosomata to come back to the coast have been shown only for a few species, especially for *Panulirus cygnus* in the southwest of Australia (see Pearce & Phillips, 1980; Phillips et al., 1991; Pearce et al., 1992). However, for species with a wide geographic distribution such as *P. penicillatus* and *P. parribacus*, the larval dispersion implies that recruits can come from adults living at great distances (Lyons, 1980, 1981; Menzies & Kerrigan, 1980). Oceanic currents and gyres seem important in the transport, and the dispersion, and thus, in the “oceanic routes” used by phyllosomata (Yeung & McGowan, 1991; Booth & Phillips, 1994).

During their larval development, phyllosomata increase in size and general shape through numerous molts. For the species studied, systematicians have described 7 to 12 larval stages which characterize the growth by appearance of anatomic features (e.g.: Stage I, 3 pairs of pereiopods, stage II: bud of the fourth one), and characteristic measurements (Phillips & Sastry, 1980).

The different larval stages of *P. penicillatus* have been described by Johnson (1968) and Michel (1969, 1971). The duration of the larval species has been estimated to be 7 - 8 months for this species (Johnson, 1971).

For *P. caledonicus*, stage I is the only stage to have been described so far with certainty (Coutures, 2001b). It must be noted that in the Pacific, Parribacus species form a complex including a widely distributed species – *P. antarcticus* – and 5 allopatric species (without overlap of their adult distributions). Larvae of this complex are very similar (Coutures, 2001b), and sometimes impossible to separate (Prasad & Tampi, 1960; Michel, 1971; Berry, 1974). Furthermore, some giant larvae – from 6.5 to 8 cm (2.55 to 3.14 inches) of total length, without pereiopods - have been caught in the Pacific, Indian, and Atlantic Oceans, that would correspond to the late-stage of *P. antarcticus* (Johnson, 1951; Robertson, 1968c).
When phyllosomata have reached the last larval stage, have enough body reserves, and may be after stimulation from a coastal signal (Booth, 1986; Phillips & McWilliam, 1986a; Booth & Phillips, 1994; McWilliam & Phillips, 1997), they metamorphose into post-larvae called nisto for slipper lobsters and puerulus for spiny lobsters (Lyons, 1970).

<u>Juvenile distribution</u>

Puerulus and nistos differ from juveniles by the absence of calcification and lack of pigmentation, except for the eyes and a few streaks and points on the antennas (Phillips & Sastry, 1980) (Figure 6). The carapace is smoother, pleopods bear long setae (Phillips & Penrose, 1985), the body is longer, antennas are longer (only for spiny lobsters), and sometimes they terminate in a spatula (Serfling & Ford, 1975; Briones-Fourzan) (Fig. 5). According to numerous authors (Serfling & Ford, 1975 ; Sweat, 1968; Witham et al., 1968; Phillips, 1972; Phillips & Olsen, 1975; Serfling & Ford, 1975; Phillips et al, 1978; Lyons, 1980; Calinski & Lyons, 1983; McDonald, 1986; Hayakawa et al., 1990; Coutures, 2000a, 2001a; Coutures & Chauvet, 2002), the behavior of pueruli and nistos would be to actively swim to benthic coastal habitats (with the aid of their pleopods) before settling onto the benthos. For example, the puerulus of *Panulirus cygnus* can swim from 20 to 60 km (12.5 to 37.5 miles) (Phillips & Penrose, 1985), in 5 to 15 days (Lemmens, 1994). The post-larvae begins to be colored as soon as it settles on the bottom. The first molt occurs 8 to 10 days after settlement (Phillips & Sastry, 1980). Although it is not the case for all species, *Panulirus penicillatus* and *Parribacus caledonicus* settle in the same habitat as the adults (McDonald, 1971; Nunes & Chambers, 1975; Pitcher, 1992, 1993; Coutures, 2000a; Coutures et al., 2002), i.e. just in front of the breakers.

The puerulus of *Panulirus penicillatus* has been described by Michel (1971): it measures about 1 cm (0.4 inch) of CL. The nisto of *Parribacus caledonicus* has not been described yet but it is likely to be similar to congeners which reach sizes varying from 5 to 5.82 cm (2-2.3 inches) (Rathbun, 1903; Coutures et al., 2002).

Small juvenile *P. pencillatus* of this species have not been observed but it is assumed that they occupy the same habitat as the adults on the windward exposures of fringing rock or coarl reefs. *P. versicolor* juveniles inhabit inshore areas as well as the more typical adult reef. Post larvae are often seen under floating moorings and rafts. It is not known whether these lobster move to the reef successfully or whether they die.

Adult distribution

Virtually all shallow water habitats in the tropical western Pacific are occupied by one or more species of spiny lobster. Each species has a preferred habitat, however, there is a Great deal of overlap and it is not uncommon to find 2-4 species cohabiting on a single reef in locations such as the south coast of Papua new Guinea. Certain species are more specific in their habitat requirements than others. The greatest constrats is perhaps between *P. ornatus* and *P.penicillatus*. *P ornatus* has been found from a depth of 100 fathoms on the outer slope of the Great Barrier Reef to areas with extremely high sediment load and reduced salinity near the mouth of the Fly River in Papua New Guinea. *P. penicillatus* is found across nearly a 60 degree range in latitude, from rocky shores to coral reefs, but with the common feature of clear oceanic waters and high energy wave action typical of windward exposures. This habitat is remarkably similar in terms of salinity, dissolved oxygen, and turbidity and the variability of these factors despite latitudinal changes.

The preferred habitat of *P. pencillatus* as discussed above is the windward exposures of fringing rock or coarl reefs. It shelters in deep recesses during the day at depths to ten meters and frequently much shallower than that. At night it forages over the reef face, crest and flats, thus exploiting a much larger habitat than where it shelters during the day. It is also common on leeward barrier reefs and in reef passages when there is sufficient water movement. The larvae likely settle in the adult habitat, settling in deep caves and crevices used by the adults to shelter in the day.

P. longipes is generally found in the lower energy zones behind the reef crest and at the lower boundary of the the distribution of *P. peniciullatus*, i.e. away from areas of intense wave action. *P. versicolor* dominates in still lower energy areas, frequently among live acroprora and other reef building coral. It is less cryptic than either *P. penicillatus* or *P. longipes* and can frequently be seen during the day in coral bommies or under plate corals. *P. versicolor* appears to be more tolerant of terrestrial influences than either *P. longipes* or *P. penicillatus* and can be found on reefs exposed ro high turbidity and reduced salinity.

P. ornatus is the most common in areas with a strong terrestrial influence. It is frequently found on lagoon bottoms and deep channels emanating from mangrove communities. In Papua New Guinea it makes a 500 km breeding migration, passing through a variety of habitats in its life cycle, but elsewhere in its distribution large scale migrations have not been noted, and it is likely more resident in one habitat. Some larval settlement is known to take place in its reef habitat.

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2. PRECIOUS CORALS SPECIES

2.1 General Distribution of Precious Corals

Besides the references noted, the Council♣s 1979 environmental impact statement and FMP for the precious corals fisheries in the western Pacific region as well as Amendments 1 and 2 to the FMP and their accompanying environmental assessments were sources for the following sections. The precious corals included in the Precious Corals FMP are shown in Table 3.

Table 3. Precious corals covered under the Precious Corals FMP.

Species	Common name
Corallium secundum	Pink coral
Corallium regale	Red coral
Corallium laauense(sp)	Red coral
Gerardia sp.	Gold coral
Narella sp.	Gold coral
Calyptrophora sp.	Gold coral
Callogorgia gilberti	Gold coral
Lepidisis olapa	Bamboo coral
Acanella sp.	Bamboo coral
Antipathes dichotoma	Black coral
Antipathes grandis	Black coral
Antipathes ulex	Black coral

Precious corals are known to exist in American Samoa, Guam, Hawaii and the Northern Mariana Islands, as well as other US possessions in the Pacific. However, very little is known about their distribution and abundance. A summary of the known distribution and abundance of precious corals in the western Pacific region follows.

American Samoa

There is little information available for the deepwater species of precious corals in American Samoa. Much of the information available comes from the personal accounts of fishermen . All known commercial quantities of *Corallium* sp. occur north of 19°N (Grigg 1984). In the South Pacific there are no known commercial beds of pink coral (Carleton and Philipson 1987). Survey work begun in 1975 by the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC) has identified three areas of *Corralium* off Western Samoa: off eastern Upolu, off Falealupo and at Tupuola Bank (Carleton and Philipson 1987). Pink coral has been reported off Cape Taputapu, but no information concerning the quality or quantity of these corals or the depths where they occur is available. Unidentified precious corals have also been reported in the past off Fanuatapu at depths of around 90 m. Precious corals are known to occur at an uncharted seamount, about three-fourths of a mile off the northwest tip of Falealupo Bank at depths of around 300 m.

Commercial quantities of one or more species of black coral are known to exist at depths of 40 m and deeper. However, these are found in the territorial waters of American Samoa and, therefore, are not subject to the Council♣s authority.

Guam and the Commonwealth of the Northern Marianas

There are no known commercial quantities of precious corals in the Northern Mariana Islands archipelago (Grigg and Eldredge 1975). In the past, Japanese fishermen claimed to have taken some *Corralium* north of Pagen Island and off Rota and Saipan.

Hawaii

In the Hawaiian Islands, there are six known beds of pink, gold and bamboo corals (Grigg 1974) (Table 4).

- X In the MHI, precious coral beds have been found only in the deep inter-island channels and off promontories such as Keahole Point on the Big Island of Hawaii.

- X Also in the MHI, the Makapuu bed is located off Makapuu, Oahu, at depths of between 350 and 450 m. Discovered in 1966, it the only precious coral bed that has been accurately surveyed in the Hawaiian chain. Its total area is about 4.5 km^2. Its substrate consists largely of hard limestone (Grigg 1988). Careful examination during numerous dives with a submersible has determined that about 20% of the total area of the Makapuu bed is comprised of irregular lenses of thin sand, sediments and barren patches (WPRFMC 1979). These sediment deposits are found primarily in low lying areas and depressions (Grigg 1988). Thus, the total area used for extrapolating coral density is 3.6 km^2, or 80% of 4.5 km^2 (WPRFMC 1979). The preliminary results of a recent resurvey of the Makupuu bed show that the bed may actually be as much as 15% larger then previously thought (Grigg 1998, pers. comm.).

- X Also in the MHI is a bed off Kaena Point, Oahu.

- X In the NWHI, a very small bed of deepwater precious corals have been found on WesPac bed, between Nihoa and Necker Islands and east of French Frigate Shoals. This bed is not large enough to sustain commercial harvests. However, large areas of potential habitat exist in the NWHI on seamounts and banks near

400 m depth. Based on the abundance of potential habitat it is thought that stocks of precious corals may be more abundant in the northwestern end of the island chain.

X A small precious coral bed has also been discovered at Brooks Banks, located near Cross Seamount southwest of the island of Hawaii. This bed is no large enough to sustain commercial harvests

X Precious corals have also been discovered at the 180 Fathom Bank, north of Kue Island, in EEZ waters surrounding Palmyra Island, a US possession in the western Pacific. The extent of this bed is not known. While little is known about the distribution and abundance of precious corals in the western Pacific region, it is almost certain that undiscovered beds of precious corals exist in the EEZ waters of the region covered by the Council.

Table 4. Location of known precious coral beds. Source: WPRFMC 1979

Description	Lat. N	Long. W.	Area in km^2
Off Keahole Point, Hawaii	19°46.0'	156°06.0'	0.24
Off Makapuu, Oahu	21°18.0'	157°35.5'	4.2
Off Kaena Point, Oahu	21°35.4'	158°22.9'	0.24
WesPac Bed, between Nihoa and Necker Islands	23°18'	162°35'	0.8
Brooks Banks	24°06.0'	166°48'	1.6
180 Fathom Bank, north of Kue Island	28°50.2'	178°53.4'	0.8

2.2 Systematics of the Deepwater Coral Species

Precious corals have a global distribution (Grigg 1993). The richest beds are found on seamounts in the western North Pacific Ocean and the western Mediterranean Sea. Precious corals are found principally in three orders of the class Anthozoa: Gorgonacea, Antipatharia, and Zoanthiae (Grigg 1984). In the western Pacific region, pink coral (*Corallium secundum*), gold coral (*Gerardia sp*. and *Parazoanthus sp*.), black coral (*Antipathes* sp.) and bamboo coral (*Lepidistis olapa*) are the primary species/genera of commercial importance. Of these, the most valuable precious corals are species of the genus *Corallium*, the pink and red corals (Grigg 1984). Pink coral (*Corallium secundum*) and Midway deep-sea coral (*Corallium* sp. nov) are two of the principal species of commercial importance in the Hawaiian and Emperor Seamount chain♣s (Grigg 1984). *C. secundum*, is found in the Hawaiian archipelago from Milwaukee Banks in the Emperor Seamounts (36°N) to the Island of Hawaii (18°N); *Corallium* sp nov. is found between 28°▪36°N, from Midway to the Emperor Seamounts (Grigg 1984).

In addition to the pink corals, the bamboo corals, *Lepidistis olapa* and *Acanella* sp., are commercially important precious corals in the western Pacific region (Grigg 1984). Pink coral and bamboo coral are found in the order Gorgonacea in the subclass Octocorallia of the class Anthozoa, in the Phylum Coelenterata (Grigg, 1984). The final two major groups of commercially important precious corals, gold coral and black coral, are found in separate orders, Zoanthidea and Antipatharia, in the subclass Hexacorallia in the class Anthozoa and the phylum Coelenterata. The gold coral, *Gerardia* sp., is endemic to the Hawaiian and Emperor Seamount chain (Grigg 1984). It inhabits depths ranging from 300▪400 m (Grigg 1974, 1984). In Hawaii, gold coral, *Gerardii* sp., grows in association with *Acanella* as a parasitic overgrowth (Brown 1976, Grigg 1984). Gold coral is, therefore, only found growing in areas that were previously inhabited by colonies of *Acanella* (Grigg 1993).

Grigg (1984) classifies black corals in the order *Antipatharia*. Grigg says there are 200 known species of black coral that occur in the oceans of the world, and of this total, only about 10 species are of commercial importance, almost all of which are found in the genus *Antipathes*.

Many species of gorgonian corals are known to occur within the habitat of pink, gold and bamboo corals in the Hawaiian Islands. At least 37 species of precious corals in the order Gorgonacea have been identified from the Makapuu bed (Grigg and Bayer 1976). In addition, 14 species of black coral (order Antipatharia) have been reported to occur in Hawaiian waters (Grigg and Opresko 1977, Oishi 1990).

2.3 Biology and Life History

Precious corals may be divided into two groups of species, the deepwater species and the shallow water species, based on the depths that they inhabit. In the EEZ waters of the western Pacific region, precious corals are found in two principal depth zones: 350–450 m and 1,000–1,500 m (Table 5). In the Hawaiian Islands, these two zones comprise 1,700 nm^2 and 5,900 nm^2 of potential habitat, respectively, and range from 18^o N to 35^o S.

The deepwater precious coral species include pink coral (*Corallium secundum*), gold coral (*Gerardia sp*., and *Parazoanthus sp*.) and bamboo coral (*Lepidistis olapa*). As previously discussed, the most valuable precious corals are in the genus *Corallium* (Grigg 1984). There are seven varieties of pink and red precious corals in the western Pacific region, six of which are recognized as distinct species of *Corallium* (Grigg 1981). As mentioned, the two species of *Corallium* of commercial importance in the EEZ around the Hawaiian Islands are *C. secundum* (pink coral) and *Corallium* sp. Nov. (Midway deep-sea). The Midway deep-sea coral (*Corallium* sp. Nov), a previously undescribed species of *Corallium*, was discovered in 1980–1981 by Japanese vessels fishing for precious corals on the Emperor Seamounts northwest of Midway Island. The discovery of this rich, unexploited deepwater precious coral species resource underscores the potential of the coral fishery in the NWHI.

The second group of species is found in shallow water between 30 and 100 m (Grigg 1993). The shallow water fishery is comprised of three species of black coral, *Antipathes dichotoma*, *A. grandis* and *A. ulex*, which have historically been harvested in Hawaii (Oishi 1990). In Hawaii, *A. dichotoma* accounts for around 90% of the commercial harvest of black coral (Oishi 1990). *A. grandis* accounts for 9% and *A. ulex* 1% of the total black corals harvested. In Hawaii, roughly 85% of all black coral harvested are taken from within state waters. Black corals are managed jointly by the State of Hawaii and the Coucnil. Within state waters (0–3 nmi), black corals are managed by the State of Hawaii (Grigg 1993).

Table 5. Depth zonation of all species of precious coral in the Western Pacific. (Source: Grigg 1993)

Species and Common Name	Depth Range (m)
Corallium secundum Angle skin coral	350■475
Corallium sp nov. Midway deepsea coral	1,000■1,500
Gerardia sp. Hawaiian gold coral	300■400
Lepidisis olapa bamboo coral	350■400
Antipathes dichotoma, black coral	30■100
Antipathes grandis, pine black coral	45■100
Antipathes ulex, fern black coral	40■100
Antipathes anguina, wire black coral	20■60

While different species of precious corals inhabit distinct depth zones, their habitat requirements are strikingly similar. Grigg (1984) notes that these corals are non-reef building and inhabit depth zones below the euphotic zone. In an earlier study, Grigg (1974) determined that precious corals are found in deep water on solid substrate in areas that are swept relatively clean by moderate to strong bottom currents (>25 cm/sec). Strong currents help prevent the accumulation of sediments, which would smother young coral colonies and prevent settlement of new larvae. Grigg (1984) notes that, in Hawaii, large stands of *Corralium* are only found in areas where sediments almost never accumulate. He also notes that 1971■75, surveys of all potential sites for precious corals in the MHI conducted using a manned submersible show that most shelf areas in the MHI near 400 m are periodically covered with a thin layer of silt and sand. Grigg (1988) concludes that the concurrence of oceanographic features (strong currents, hard substrate, low sediments) necessary to create suitable precious coral habitat are rare in the MHI.

The habitat sustaining precious corals is generally in pristine condition. There are no known areas that have sustained damage due to resource exploitation, notwithstanding the alleged heavy foreign fishing for corals in the Hancock Seamounts area. Although unlikely, if future development projects are planned in the proximity of precious coral beds, care should be taken to prevent damage to the beds. Projects of particular concern would be those that suspend sediments or modify water-movement patterns.

There is a correlation between the location and abundance of *Corallium* beds and the Kuroshio Current in the western Pacific region (Grigg 1984). This relationship further illustrates the importance of suitable current regimes in determining suitable precious coral habitat. Currents also play an important ecological role in transporting food to and carrying wastes away from corals.

There has been very little research conducted concerning the food habits of precious corals. Precious corals are filter feeders (Grigg 1984, 1993). The sparse research available suggests that particulate organic matter and microzooplankton are important in the diets of pink and bamboo coral (Grigg 1970). Many species of pink coral (*Corallium*), gold coral (*Gerardia*) and black coral (*Antipathes*) form fan shaped colonies (Grigg 1984, 1993). This type of morphological adaption maximizes the total area of water that is filtered by the polyps (Grigg 1984, 1993). Bamboo coral (*Lepidisis olapa*), unlike other species of precious corals, is unbranched (Grigg 1984). Long coils that trail in the prevailing currents maximize the total amount of seawater that is filtered by the polyps (Grigg 1984). While clearly, the presence of strong currents is a vital factor determining habitat suitability for precious coral colonies, their role to date is not fully understood.

Precious corals are known to grow on a variety of bottom substrate types. Precious coral yields, however, tend to be higher in areas of shell sandstone, limestone and basaltic or metamorphic rock with a limestone veneer.

Light is one of the most important determining factors of the upper depth limit of many species of precious corals (Grigg 1984).The larvae of two species of black coral, *Antipathes grandis* and *A. dichotoma*, are negatively phototaxic**.**

Grigg (1984) states that temperature does not appear to be a significant factor in delimiting suitable habitat for precious corals. In the Pacific Ocean, species of *Corallium* are found in temperature ranges of 8^{o} to 20^{o}C, he observes. Temperature may determine the lower depth limits of some species of precious coral, including two species of black corals in the MHI, he suggests. In the MHI, the lower depth range of two species of black corals (*Antipathes dichotoma* and *A. grandis*) coincides with the top of the thermocline (about 100 m), Grigg observes.

In pink coral (*Corallium secundum*), the sexes are separate (Grigg 1993). Based on the best available data, it is believed that *C. secundum* becomes sexually mature at a height of approximately 12 cm (13 years) (Grigg 1976). Pink coral reproduce annually, with spawning occurring during the summer, during the months of June and July. Coral polyps produce eggs and sperm. Fertilization of the oocytes is completed externally in the water column (Grigg 1976, 1993). The resulting larvae, called planulae, drift with the prevailing currents until finding a suitable site for settlement.

Pink, bamboo and gold corals all have planktonic larval stages and sessile adult stages. Larvae settle on solid substrate where they form colonial branching colonies. Grigg (1993) notes that the length of the larval stage of all deepwater species of precious corals is not known. Clean swept areas exposed to strong currents provide important sites for settlement of the larvae, Grigg adds. The larvae of several species of black coral (*Antipathes*) are negatively photoactic, he notes. They are most abundant in dimly lit areas, such as beneath overhangs in waters deeper than 30 m, he observes. In an earlier study, Grigg (1976) found that ■[w]ithin their depth ranges, both species are highly aggregated and are most frequently found under vertical dropoffs. Such features are commonly associated with terraces and undercut notches relict of ancient sea level still stands. Such features are common off Kauai and Maui in the MHI. Both species are particularly abundant off of Maui and Kauai, suggesting that their abundance is related to suitable habitat. Off of Oahu, many submarine terraces that otherwise would be suitable habitat for black corals are covered with sediments, Grigg (1976) adds.

Grigg (1993) observes that precious corals have low recruitment and mortality. They are slow growing and long lived, believed to reach the age of 75 years and older, he notes. Common causes of mortality include smothering by sediments and toppling of colonies due to erosion of the substrate, he concludes. (Another cause is worms boring into the colony, weakening it and causing it to collapse.)

A variety of invertebrates and fish are known to utilize the same habitat as precious corals. These species of fish include onaga (*Etelis coruscans*), kahala (*Seriola dumerallii*) and the shrimp (*Heterocarpus ensifer*). These species do not seem to depend on the coral for shelter or food.

Densities of pink, gold and bamboo coral have been determined for an unexploited section of the Makapuu bed (Grigg, 1976). As noted in the FMP for precious corals, the average density of pink coral in the Makapuu bed is 0.022 colonies/m^2. This figure was extrapolated to the entire bed (3.6 million m^2), giving an estimated standing crop of 79,200 colonies. At the 95% confidence limit, the standing crop is 47,500 to 111,700 colonies. The standing crop of colonies was converted to biomass ($3N_iW_i$), resulting in an estimate of 43,500 kg of pink coral in the Makapuu bed.

In addition to coral densities, Grigg (1976) determined the age-frequency distribution of pink coral colonies in Makapuu bed. He applied annual growth rates to the size frequency to calculate the age structure of pink coral at Makapuu Bed (Table 6).

Table 6. Age-Frequency Distribution of Corallium secundum (Source: Grigg 1973)

Age Group (years)	**Number of Colonies**
0–10	44
10–20	73
20–30	22
30–40	12
40–50	7
50–60	0

Estimates of density were also made for bamboo (*Lepidisis olapa*) and gold coral (*Gerardia* sp.) for Makapuu bed. The distributions of both these species are patchy. As noted in the FMP, the area where they occur comprises only half of that occupied by pink coral (1.8 km^2). Estimates of the unexploited abundance of bamboo and gold coral were 18,000 and 5,400 colonies, respectively. Estimates of density for the unexploited bamboo coral and gold coral in the Makapuu bed are 0.01 colonies/m^2 and 0.003 colonies/m^2. Using a rough estimate for the mean weights of gold and bamboo coral colonies (2.2 kg and 0.6 kg), a standing crop of about 11,880 kg of gold coral and 10,800 kg for bamboo for Makapuu bed was obtained.

Growth rates for several species of precious corals found in the western Pacific region have been calculated.

Grigg (1976) determines that the height of pink coral (*C. secundum*) colonies increases about 0.9 cm/yr up to about 30 years of age. As noted in the FMP for precious corals, the height of the largest colonies of *Corallium secundum* at Makapuu bed rarely exceed 60 cm. Colonies of gold coral are known to grow up to 250 cm tall while bamboo corals may reach 300 cm. The natural mortality rate of pink coral at Makapuu bed is believed to be 0.066, equivalent to an annual survival rate of about 93%.

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3. BOTTOMFISH SPECIES

3.1 Bottomfish Habitat

Unlike the US mainland with its continental shelf ecosystems, the Pacific islands are primarily volcanic peaks with steep drop-offs and limited shelf ecosystems (Ralston 1979). Bottomfish are found concentrated on the steep slopes of deepwater banks of these islands. In the Hawaiian deep-sea handline fishery, 13 species of snappers and jacks and one species of grouper are commonly caught at depths of 60 to 350 m (Ralston and Polovina 1982). As noted in Amendment 2 of the Fishery Management Plan (FMP) for Bottomfish and Seamount Groundfish Fisheries, these depths have insufficient sunlight to support an abundance of coral or algae (calcareous or otherwise); however, some corals, particularly black coral (*Antipathes* spp.), have been observed at depths of 15 to 50 fathoms, which correspond to shallow bottomfish habitat.

The habitat of six of the most important Northwestern Hawaiian Islands (NWHI) bottomfish tend to overlap, as indicated by the depth range at which they can be hooked. Even with this overlap, certain species are still more common at specific depths. As noted in Amendment 2 of the bottomfish FMP, adult bottomfish in the NWHI are found at depths of from 40 to 145 fathoms (Table 7).

Table 7. Habitat depth range for dominant Northwestern Hawaiian Islands Bottomfish.

Species	Hooking Depth Range (Fa)	Average
Opakapaka	30-110	70
Onaga	100-150	125
Hapu‘upu‘u	50-150	100
Butaguchi	40-100	70
Ehu	110-180	145
Uku	20-60	40

In a five-year study of the bottomfish fishery resource of the Northern Mariana Islands and Guam, Polovina et al. (1985) found bottomfish species to be stratified by depth with three broad distributions located throughout the archipelago. Between 164 and 183 m, black trevally (*Caranx lugubris*), yelloweye opakapaka (*Pristipomoides flavipinnis*), pink opakapaka (*P. filamentosus*) and lehi (*Aphareus rutilans*) are common; between 183 to 201 m, yellowtail kalekale *(P. auricilla*), kahala (*Seriola dumerili*) and gindai (*P. zonatus*) are most abundant; and at depths of greater than 201 m, *Pristipomoides sieboldii* (pink kalekale), onaga (*Etelis coruscans*), ehu *(E. carbunculus*) and *Epinephelus sp* were the most abundant (Table 8).

Table 8. Depth distribution of bottomfish species

Scientific Name	Mean Depth		
From 164 to 183 m	M	Fathoms	N
Caranx lugubris (black lugubris)	166	91	270
Pristipomoides flavipinnis (yelloweye opakapaka)	170	93	499
Pristipomoides filamentosus (pink opakapaka)	170	93	191
*Aphareus rutilans (*lehi*)*	174	95	81
From 183 to 201 m			
Pristipomoides auricilla (yellowtail kalekale)	188	102	1,166
Seriola dumerili (kahala)	196	107	47
Pristipomoides zonatus (gindai)	199	109	3,890
>201 m			
Epinephelus sp	214	117	38
Pristipomoides sieboldii (pink kalekale)	214	117	200
Etelis coruscans (onaga)	218	119	200
Etelis carbunculus (ehu)	225	123	950

However, depth alone does not assure satisfactory habitat. As noted in Amendment 2 of the bottomfish FMP, variations in catch rates along the same depth contour indicate that the quantity and quality of benthic habitat are also both important. The underwater habitat of bottomfish consists of a mosaic of sandy and rocky areas. In the NWHI the benthic topography varies dramatically from abrupt drop-offs associated with pinnacles and banks to gently sloping atolls.

Within their natural habitat, bottomfish populations are not evenly distributed but are found dispersed in a non-random, patchy fashion. As noted in the bottomfish FMP, adult bottomfish in the NWHI are found in habitats characterized by a hard substrate of high structural complexity. Areas of increased bottom complexity●such as pinnacles, drop-offs and other high relief, rocky substrate●are prime fishing grounds (Ralston 1979). In his study of the Penguin Bank in the Hawaiian Islands, Haight (1989) observed aggregations of up to 100 opakapaka *(Pristipomoides filamentosus)* and lehi (*Aphareus rutilans)* 2■10 m above high-relief coral bench substrate and in the vicinity of underwater headlands and promontories. Areas of high relief form localized zones of turbulent vertical water movement, which may increase the availability of prey (Haight et al. 1993).

The distribution of some species of deepwater snappers also appears to be closely related to current flow. Ralston et al (1986) found that the up-current side vs. the down-current side of Johnston Atoll supported higher densities of opakapaka. It is hypothesized that water flow may enhance food supplies in certain areas (Haight 1989; Parrish et al. 1997).

While bottomfish species are attracted to similar habitat, there appears to be negligible multi-species interaction (Ralston and Polovina 1982). Polovina (1987) found a weak predator-prey relationship among the species of the NWHI bottomfish complex. As noted in Amendment 2, the establishment of territorial strongholds by individual species may account for the low multi-species interaction. Amendment 2 also notes that variations are known to occur in the way different bottomfish utilize habitat.e.g., opakapaka are believed to migrate into shallower depths during the night hours; onaga are caught in considerably deeper water than other species of snappers and in association with abrupt relief zones, such as outcroppings, pinnacles and drop-offs; and groupers generally are much more sedentary than snappers and are more dependent on hard substrates. Haight (1989) found that niche overlap between species of deep-slope snappers on Penguin Bank, in terms of forage habitat and forage period, was reduced by the individual species's different depth and dietary preferences.

3.2 Bottomfish Yield

Bottomfish production off western Pacific islands is inherently limited because only a narrow portion of the ocean bottom satisfies the depth requirements of most bottomfish species. Since bottomfish are typically found concentrated in the steep drop-off zones around the 100-fathom isobath, the length of the 100-fathom isobath is commonly used as an index of bottomfish habitat (Polovina, 1985).

Bottomfish yield estimates in the western Pacific bottomfish fishery are usually estimated on the basis of yield per nautical mile of the 100-fathom contour that surrounds an island or bank (Polovina, 1985). Beginning in 1980, the National Marine Fisheries Service (NMFS) conducted a five-year resource assessment of the fishery resources of the Mariana archipelago. This resource assessment was designed to quantify the sustainable yield and distribution of the fishery resources, including bottomfish, of Guam and the Northern Mariana Islands. A systematic fishing survey of the bottomfish resources at depths of 125–275 m of 22 islands and banks in the Mariana archipelago was conducted (Polovina et al. 1985). In this study Eteline snappers, particularly *Pristipomoides zonatus*, *P. auricilla*, and *Etelis carbunculus*, dominated the catch (Dalzell and Preston 1992). In addition, bathymetric surveys were conducted at 11 banks and islands where the bathymetric data were insufficient to conduct fishery resource assessment work (Polovina et al. 1985).

As part of this resource assessment, a depletion experiment was carried out at Pathfinder Reef, a seamount west of the main islands. The results of this experiment were used to estimate the unexploited biomass at 288 tons for the archipelago. The estimated yield of 403 lb of bottomfish per year per nautical mile of 100-fathom isobath appears to be representative of the maximum sustainable yield (MSY) that can be expected from bottomfish resources of tropical islands in the Pacific, as noted in Amendment 1 of the bottomfish FMP. Applying this figure to the estimated length of the bottomfish habitat in American Samoa and Guam, an estimate of MSY of bottomfish can be derived for each area. As noted in Amendment 1 of the bottomfish FMP, American Samoa, with approximately 196 nautical miles of 100-fathom isobath, can expect a MSY of 79,000 lb per year, and Guam, with approximately 138 nautical miles of 100-fathom isobath, can expect an MSY of 56,000 lbs per year (Tables 9 and 10).

Table 9. Index of bottomfish habitat. (Source: Amendment 1 of bottomfish FMP).

Island Area	Approximate Length of 100-fathom Isobath, nm (km)
American Samoa	196 (313)
Guam	138 (255)
Main Hawaiian Islands	997 (1,846)
Northwestern Hawaiian Islands	1,231 (2,280)

Table 10. Extent of Approximate Bottomfish Habitat and Yield for American Samoa and Guam.

Island Area	Approximate Length of 100-fathom Isobath (nm)	Approximate Maximum Sustainable Yield (MSY) of Bottomfish (lbs)
American Samoa and Offshore Banks	196	78,988
Guam and Offshore Banks	138	55,614

Based on remote operational vehicle (ROV) and manned submersible observations, maximum densities of deepwater snappers on Penguin Bank were calculated to be 1.06 fish/m^2 to 1.37 fish/m^2 (Haight 1989).

3.3 Biological Information

As noted in Amendment 3 of the bottomfish FMP, bottomfish resources of the western Pacific region can be divided into three broad classes relative to their vertical distribution on the islands♣ shelves and slopes: the reef fish complex, occupying shallow reefs, bays and lagoons; the bottomfish complex, inhabiting the outer shelf and deep slopes; and the groundfish complex, associated with seamount summits. The bottomfish complex includes at least 65 species of four families: snapper (Lutjanidae), groupers (Serranidae), jacks (Carangidae) and emperor fish (Lethrinidae). These species are primarily caught by hook-and-line fishing gear. About 20 of these species are landed in substantial quantities.

Species composition and relative abundance of bottomfish management unit species (BMUS) in the western Pacific have regional variations. For example, Uchiyama and Tagami (1984) observed considerable variation throughout the NWHI; the most notable trend was a predominance of opakapaka at French Frigate Shoals, Brooks Banks and

Necker Island and of ehu (*Etelis carbunculus*) west of Lisianski Island. The principal species of NWHI bottomfish and seamount groundfish are shown in Table 11.

As noted in Amendment 2 of the FMP, although 15 bottomfish species are included in the management unit, four species account for 95% of the 1986 landings of NWHI bottomfish (Table 12).

In a five-year study of the bottomfish fishery resource of the Northern Mariana Islands and Guam, Polovina et al. (1985) found gindai (*Pristipomoides zonatus*) accounted for 51.2 percent of the total catch, while gindai, ehu and yellowtail kalekale (*P. auricilla*) accounted for 79.1 percent of the total bottomfish catch.

Table 11. Bottomfish Management Unit Species (BMUS)

Scientific Name	Common Name	American Samoa	Guam/ NMI	Hawaii
Bottomfish				
Aphareus rutilans	red snapper/silvermouth	palu-gutusiliva	maraap tatoong	lehi
Aprion virescens	gray snapper/jobfish	asoama	tosan	uku
Caranx ignobilis	giant trevally/jack	sapoanae	tarakito	white ulua/pauu
C. lugubris	black trevally/jack	tafauli	trankiton attilong	black ulua
Epinephelus fasciatus	blacktip gouper	fausi	gadao matai	
E. quernus	sea bass			hapuupuu
Etelis carbunculus	red snapper	palu-malau	guihan boninas	ehu
E. coruscans	red snapper	palu-loa	onaga	onaga
Lethrinus amboinensis	ambon emperor		mafuti/lililok	
L. rubrioperculatus	redgill emperor	filoa-paoomumu	mafuti tatdong	
Lutjanus kasmira	blueline snapper	savane	sas/funai	taape
Pristipomoides auricilla	yellowtail snapper	palu-iusama	guihan boninas	yellowtail kalekale
P. filamentosus	pink snapper	palu-enaena	guihan boninas	opakapaka
P. flavipinnis	yelloweye snapper	palu-sina	guihan boninas	yelloweye opakapaka
P. seiboldi	pink snapper		guihan boninas	kalekale
P. zonatus	snapper	palu-sega	guihan boninas/gindai	gindai
Pseudocaranx dentex	thicklip trevally		terakito	butaguchi/pig ulua
Seriola dumerili	amberjack		guihan tatdong	kahala
Variola louti	lunartail grouper	papa	bueli	
Seamount Groundfish:				
Beryx splendens	alfonsin			kinmedai (Japanese)
Hyperoglyphe japonica	ratfish/butterfish			medai (Japapanese)
Pseudopentaceros richardsoni	armorhead			kusakari tsubodai (Japapanese)

Table 12. Principal species of NWHI bottomfish and their percentages of the 1986 NWHI bottomfish lands (Source: FMP for Bottomfish and Seamount Groundfish Fisheries)

Local Name	Common English Name	Percent of 1986 Landings of NWHI Bottomfish
Opakapaka	pink snapper	36.9
Onaga	longtail snapper	13.3
Hapuupuu	seabass	25.9
Butaguchi	thick-lipped trevally	19.6
Ehu	squirrelfish snapper	3.7
Uku	gray snapper	1.0

3.4 Life History

Despite the importance of bottomfish and seamount groundfish species in the western Pacific, the life histories of most of the species are not well known.

3.4.1 Eggs and larval stages

There have been very few taxonomic studies of the eggs and larval stages of snappers (lutjanids) and groupers (epinepheline serranids), and, currently, very few larvae can be identified to species. Leis (1987) provides a detailed review of the early life history of tropical groupers (Serranidae) and snappers (Lutjanidae), which includes the following information: Grouper and snapper larvae tend to be more abundant over the continental shelf than in oceanic waters. An exception is the larvae of the subfamily eteline lutjanid, which are generally more abundant in slope and oceanic waters than over the continental shelf. During the day, grouper and snapper larvae tend to avoid surface waters. At night they are more evenly distributed vertically in the surface water column. During the winter months larvae of most species are much less abundant. Very little is known about the food habits of serranid and lutjanid larvae. What is known is based on limited laboratory data. More research is needed on all aspects of the early life history of snappers and groupers, including feeding, growth and survival; ecology of early life history stages around oceanic islands; year-to-year variation in spatial and temporal patterns; and return of young stages to adult habitat from the pelagic larval habitat.

3.4.2 Juvenile

During 1988, the NOAA Fisheries♣Honolulu Laboratory initiated an investigation to identify the habitat requirements of juvenile snappers in the Hawaiian Islands. The preliminary investigations have demonstrated the presence of juveniles of both recreational and commercially important snappers (*Pristipomoides filamentosus*, *Aprion virescens*, *Aphareus rutilans*) in a habitat relatively close to the fishing grounds for adults but not where the adults congregate. Although the boundaries of the habitat and the characteristics that make it attractive to juveniles remain to be defined, initial results indicate juveniles occupy a flat, open bottom of primarily soft substrate in depths ranging from 40 to 73 m. There is strong evidence that juvenile snappers utilize habitat that is quite different then the adults (Parrish, 1989; Haight, 1989; Moffitt and Parrish, 1996; Parrish et al., 1997). Parrish (1989) identified an aggregation of juvenile *A. virescens* and *P. filamentosus* ■in 30 to 80 m of water over soft, flat bottom substrate.• The occurrence of juvenile snappers in relatively shallow water and featureless bottom habitat indicates the need to reconsider the importance of an area of ocean bottom previously thought to be of minimal importance as fishery habitat.

3.4.3 Adults

The habitat utilization patterns of adult bottomfish are described in detail in section 1.1 and the following species profiles.

3.4.4 Forage and prey (feeding habits and principal prey)

Very few food habit studies of groupers and snappers have documented the depth at which feeding occurs. Without data on feeding depths it is difficult to identify the specific depth range that constitutes a species feeding habitat. Food habit studies of deepwater snappers are especially difficult because gut contents are frequently lost due to regurgitation when specimens are bought to the surface from great depths. Parrish (1987) provides a detailed review of the trophic biology of snapers and groupers, which includes the following information:

The reported depth range of many species of snappers and groupers is very great and often changes with age. A small number of snapper species and a considerably larger list of groupers appear to be restricted to feeding almost entirely in waters a few tens of m deep. By contrast, a good many snappers and a very few groupers appear to feed almost entirely in deep water down to depths of 400▪500 m. Of the remaining fishes for which some information is available, many species of both families seem to cover a range of intermediate depths. Several occur very shallow as well as fairly deep, while others appear limited to an intermediate range. In both families there are a few species that occur shallow enough, commonly enough, to distinguish them from the deepwater group,: but they are also commonly caught considerably deeper than the intermediate group (150▪200m) (Table 13).

Table 13. Likely depth ranges for major feeding of snapper and grouper management unit species. Source: (Parrish 1987).

Shallow (To a few tens of m)	**Intermediate** (Shallow to over 100m)	**Mixed** (Intermediate to deep)	**Deep** (Mostly over 100 m to 500 m).
[1]*Aprion virescens* (uku)	*Lutjanus kasmira* (blueline snapper)		*Etelis carbunculus* (ehu)
			Etelis coruscans (onaga)
			Pristipomoides auricilla (yellowtail kalekale)
			Pristipomoides filamentosus (opakapaka)
			Pristipomoides flavipinnis (yelloweye opakapaka)
			Pristipomoides sieboldii (kalekale)
			Pristipomoides zonatus (gindai)
			Epinephelus quernus (hapuupuu)

Based on the review of the available literature, Parrish (1987) concluded that snappers engage in widespread, nocturnal foraging; groupers feed at all times of day, but particularly near dusk and dawn; and most species of groupers take most of their prey at or very close to the bottom. The food habits of very young juvenile snapper and grouper are often different from those of adults.

Both groupers and snappers are omnivorous, opportunistic carnivores. Their diets include a wide range of food items dominated by fish, crabs, shrimp and other benthic crustaceans, especially stomatopods and lobsters. Cephalopods are another common diet component, especially for snappers, which also eat large plankton, including particularly pelagic urochordates and gastropods. Planktonic forms of prey are surprisingly important for snappers, both in bulk consumed and frequency of occurrence, especially for many deepwater species. Major planktonic food items include pelagic urochordates (Pyrosomida, Salpidae, and Dolioda) and pelagic gastropods (pteropods and heteropods) In most, but not all cases, these planktonic food items occur in species believed to forage somewhat above the bottom. While surprisingly common in the diets of snappers, planktonic animals have not been reported in the diets of groupers. As a whole, the diet of snappers is considerably broader than that of groupers and includes a wider range of non-crustacean benthic organisms.

3.4.5 Reproductive biology

Grimes (1987) provides a detailed review of the reproductive biology of the Lutjanidae. In the lutjanids, spawning take place at night, and is apparently timed to coincide with spring tides at new and full moons. ■Courtship behavior culminates in an upward spiral swim, with gametes released at the apex,• Grimes observers. ■Many features of the reproductive biology of lutjanids (e.g., spawning site preference, spawning seasonality, lunar periodicity and spawning behavior) appear to be a strategy to introduce gametes into an environment where predation is relatively less intense,•Grimes adds. However, the strategy must also assure that young juveniles are returned to suitable, but patchy habitat for settlement. *Aprion virescens* feeds high in the water column, i.e., in shallow water, as well as at greater depths near the bottom.

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3.5 Life Histories and Habitat Descriptions for Bottomfish Species

3.5.1 Habitat description for *Aphareus rutilans* (red snapper, silvermouth)

<u>Management Plan and Area</u>: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

Aphareus rutilans is a member of the family Lutjanidae and the subfamily Etelinae and is one of two species of snappers found in the genus *Aphareus*. The English common name of this species is red snapper or silvermouth. In American Samoa it is known as palu-gutusiliva; in Hawaii, lehi; in Guam and Northern Mariana Islands, maraap tatoong.

Allen (1985) describes the geographical distribution of *A. rutilans* as widespread throughout the tropical Indo-Pacific Ocean. It is found from East Africa in the west to the Hawaiian Islands in the east and from southern Japan southward to Australia. It inhabits hard rocky bottoms and coral reefs at depths of 6 m to at least 100 m and is typically found singularly or in small groups, well above the bottom.

According to Allen, the medium-sized snapper is reported to reach a maximum length of about 80 cm. The reported life span of snappers ranges between 4 and 21 years, with larger species generally tending to have longer life spans of between 15 to 20 years. Lutjanids reach sexual maturity when they♣ve reached between approximately 43% and 51% of their maximum total length.

The lutjanids are dioecious (separate sexes) and display little or no sexual dimorphism in color patterns or physical structure (Allen 1985). At Vanuatu, spawning reportedly occurs during spring and summer but with a peak activity occurring during November and December. Lutjanids are batch spawners, with females spawning several times over the course of spawning season.

A. rutilans is an important commercial species in the island areas of the Indo-Pacific region and is one of the principal target species in the Hawaiian deep-slope handline fishery, Allen notes. It is caught primarily by handlines or bottom longlines, he adds.

<u>Egg and Larval Distribution</u>

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. According to Leis (1987), lutjanids eggs typically are less than 0.85mm in size and hatch in 17▪36 h depending on water temperature.

Little is known about this species larval life history stage. Newly hatched lutjanid eggs are typical of other pelagic larvae. They have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. The duration of the pelagic phase of lutjanids has been estimated to range from 25 to 47 days (Leis 1987). Snapper larvae are subject to advection by ocean currents (Munro 1987). It is thought that the pelagic phase of eteline lutjanids, such as *A. rutilans*, is longer than that of *Lutjanus* spp., and size may be a more important factor than age in determining when larval settlement occurs in lutjanids (Leis 1987).

<u>Juvenile</u>

There is virtually no information available concerning the life history and habitat requirements of the juveniles of this species. Parrish (1989) found that the diet of juvenile *Pristipomoides filamentosus* (red snapper or opakapaka), an eteline snapper, consists primarily of small crustaceans. Other prey items include juvenile fish, cephalopods, gelatinous plankton and fish scales.

<u>Adult</u>

Deepwater snappers, such as *A. rutilans*, are found on the steep slopes and deepwater banks of Pacific islands. Adults aggregate near areas of high bottom relief (Parrish 1987). Mixed groups of 50■100 individual snappers are known to aggregate above high relief structures.

The diets of deepwater snappers, such as *A. rutilans* are poorly understood. Parrish (1987) list of prey items include pelagic tunicates, fish, shrimp, cephalopods, gastropods, planktonic urochordates and crabs. He reports that snappers feed mostly at night and forage over a wide area, but notes that the depths at which snappers feed are not well documented. Most of the fishing effort for deepwater snappers, such as *A. rutilans* occurs in the steep drop-off zone that surrounds the islands and banks of the Hawaiian archipelago (Ralston and Polovina 1982).

<u>Essential Fish Habitat</u>: Deep-water bottomfish complex (100-400 m). The EFH for *A. rutilans* is shown in Table 14.

Table 14.Habitat description for *Aphareus rutilans* (red snapper, silvermouth)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17▪36 h depending on water temperature.	25 to 47 days (Leis 1987).	UK	4 and 21 years
Diet	N/A	Unknown (UK)	UK	pelagic tunicates, fish, shrimp, cephalopods, gastropods, planktonic urochordates and crabs.
Distribution: General and Seasonal	UK	UK		widespread throughout the tropical Indo-Pacific Ocean.
Water Column	Pelagic	Pelagic	Demersal	Found on the steep slopes and deepwater banks of Pacific islands.
Bottom Type	N/A	N/A	UK	Inhabits hard rocky bottoms Adults aggregate near areas of high bottom relief
Oceanic Features	Subject to advection by ocean currents	Subject to advection by ocean currents	N/A	N/A

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3.5.2 *Aprions virescens* (Gray snapper, jobfish, uku)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands..

Aprion virescens is an eteline snapper in the family Lutjanidae. English common names for this species include jobfish and gray snapper. The Hawaiian name for the species is uku.

A. virescens is widely distributed throughout the Indo-Pacific region from Hawaii to East Africa (Druzhinin 1970, Tinker 1978).

It comprises a major portion of the total bottomfish caught in Hawaii, second only to the *Pristipomoide filamentosus* (red snapper, or opakapaka) in total landings. According to the *1996 Annual Report Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region,* reported landings in 1996 for *A. virescens* was approximately 49,000 lb from the MHI and an additional estimated 28,000 lb from the NWHI, or roughly 11% of the total reported BMUS landings in the Hawaiian Islands that year (WPRFMC 1997). Kramer (1986) reports that *A. virescens* is caught only at Nihoa Island, Brooks Banks, St. Rogatien Bank and Midway Islands in the NWHI. However, in a survey of the nearshore fishery resources of the NWHI, uku were also observed at Necker Island, French Frigate Shoals and Pearl and Hermes Atolls (Okamoto and Kanenaka 1983).

In American Samoa, *A. virescens* is the fourth most important species in terms of total weight landed (11%) based on estimated total 1996 bottomfish landings published in the *1996 Annual Report Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region*. In Guam, it was the third most abundant species caught in a 1995 creel survey of the bottomfish resources of Guam. According to the 1996 annual report, *A. virescens* made up approximately 10% of the total reported BMUS landings in Guam in 1996. The species is much less abundant in the Northern Mariana Islands. In a fishery assessment of the deepwater bottomfish in the Mariana archipelago, it comprised less than one tenth of 1 percent of the total catch (Polovina 1987).

Ralston and Polovina (1982) report that most of the fishing effort for deepwater bottomfish species occurs in the steep drop-off zone that surrounds the islands and banks of the Hawaiian archipelago. They also state that a rough estimate of the total amount of bottomfish habitat can be calculated by measuring the 100-fathom isobath that surrounds an island or bank. They estimate that 1,025 nmi of 100-fathom isobath surrounds the MHI. Dalzell and Preston (1992) estimate that American Samoa has 143.3 nm of 100-fm isobath, and the Northern Mariana Islands and Guam collectively have 485 nmi of 100-fathom isobath.

It has been shown that the distribution of deepwater snappers is non-random, with large aggregations form near areas of prominent relief features such as headlands and promontories (Ralston et al. 1986). Haight (1989) reports that if high relief, hard substrate is used as the criterion of habitat suitability for deepwater snappers only a 14% of the total area of Penguin Bank would be potential habitat. Based on the results of a depletion experiment carried out at pathfinder reef in the Northern Mariana Islands, an estimation for exploited biomass of 2.0 ton/nautical of 100-fathom isobath was calculated (Polovina et al. 1985, Polovina and Ralston 1986).

Eggs and Larval Distribution

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. According to Leis (1987) lutjanids spawn small, pelagic, spherical, eggs that are typically less than 0.85 mm in size and that hatch in 17▪36 hours depending on species and water temperature.

Very little is known about this species♣s larval life history stage. The relatively low abundance of lutjanid larvae in plankton samples makes ecological studies of them difficult. Hoss et al. (1986, in Sale 1991) found that lutjanid larvae were most abundant above 40 m in Caribbean Sea. Leis (1987) describes newly hatched lutjanid eggs as typical of other pelagic larvae; they have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. The duration of the pelagic phase of lutjanid has been estimated to range from 25 to 47 days, Leis states. He also notes that the pelagic phase of eteline lutjanid, such as, is longer than that of *Lutjanus* spp and that size may be more important than age in determining when larval settlement occurs.

Juvenile

There is very little information available concerning the distribution and habitat requirements of the juvenile stage of this species. Parrish (1989) observed a dense aggregation of juvenile *A. virescens*, *Pristipomoides filamentosus* (pink snapper, or opakapaka) and *Aphareus rutilans* (red snapper, sivermouth, or lehi) offshore of Kaneohe Bay on the island of Oahu in an area of very low relief, at depths of 65▪100 m. The predominant species collected at this site was *P. filamentosus*, of which the greatest abundance was located in an area comprised of soft, fine clay-silt sediments. In contrast, five juvenile uku were caught at depths of 40 m where the bottom substrate was comprised of hard, flat coarse sand, covered with *Halimeda* algae.

The flat, featureless habitat apparently favored by juvenile snappers is very different from the high relief areas preferred by adults of the family. It is thought that the habitat preferred by the juvenile may provide the advantage of reduced predation pressure and lessened interspecific competition. It is believed that areas of uniform sediment type are an important substrate feature for juvenile snapper (Parrish et al. 1997).

Adult

In Guam, *A. virescens* are found along the outer reef slopes, in deep channels and in shallow lagoons at depths of 3■180 m (Amesbury and Myers 1982). Druzhinin (1970) reported *A. virescens* at depths as great as 150 fathoms. Talbot (1960) reported that *A. virescens* was more abundant in shallow water over coral reefs along the coast of East Africa.

Haight (1989) found the diet of *A. virescens* on Penguin Bank in the MHI to include fish (89%), larval fish (6%), planktonic crustaceans (1%), shrimp (3%) and crab (1%). Talbot (1960) reported the diet of *A. virescens* on the coast of East Africa to consist of fish (49%), plankton (17%), cephalopods (14%), nonplanktonic crustaceans (12%) and others (8%). Unlike most other deepwater species of lutjanids, *A. virescens* has feeding habits that do not seem to be constrained by substrate association (Parrish 1987). The species forages throughout the water column, feeding high in the water column as well at greater depths (Ralston 1979, Parrish 1987). *A. virescens* is the only lutjanid that is regularly caught at or near the surface with a lure (Kramer 1986). Haight (1989) found the greatest CPUE (fish/line-h) at depths of 50■100 m on Penguin Bank in the MHI. Haight (1989) reports that *A. virescens* feed during daytime hours. The landings for this species are seasonal. In Hawaii, the majority of the landings are made June■December (Ralston 1979, Haight 1989).

A. virescens reach sexual maturity at approximately 438 cm (SL) (Grimes 1987). Lutjanid species associated with islands obtain sexual maturity at a relatively larger size than continental species. Likewise, deepwater species mature at a relatively larger size than shallow water species (Grimes 1987). There is a consistent difference between percentage of maximum length and when sexual maturity is obtained between continental and insular species. Amesbury and Myers (1982) report that uku in Palau form large spawning aggregations January■May on the outer reef slope on or just after a new moon. In Hawaii, *A. virescens* spawn during the summer months (Ralston 1979).

Essential Fish Habitat: Shallow-water species complex (0-100 m). The EFH for *A. virescens* is shown in Table 15.

Table 15. Species: Aprions virescens (Gray snapper, jobfish, uku)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17▪36 h incubation time depending on the species and the water temperature (Leis 1987)		No information available	
Diet	N/A	No information available	(No information available for this species)	Fish (89%), larval fish (6%), Planktonic crustaceans (1%), shrimp (3%) and crab (1%), (Haight 1989).
Distribution: General and Seasonal	*Aprion virescens* form large spawning aggregations in Palau* Spawning in lutjanids typically occurs at night during spring tides (new moon and full moon) (Grimes 1987).			
Location			40 m, hard, flat, course sand bottoms (Parrish 1989)	
Water Column	Pelagic	Pelagic, lutjanid larvae were found to be most abundant above 40 m in the Caribbean Sea (Hoss et al. 1986).		Demersal
Bottom Type	N/A	N/A	Hard, flat, course sand bottom	
Oceanic Features	Lutjanid eggs are subject to advection by ocean currents (Munro 1987	Lutjanid larvae are subject to advection by ocean currents (Munro 1987)	It is thought that distribution of juvenile snapper within its preferred habitat type may be closely related to water flow	

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3.5.3 Habitat description for large jacks: *Caranx ignobilis* (giant trevally/jack); *Pseudocaranx dentex* (thick-lipped trevally, or butaguchi); *Seriola dumerili* (greater amberjack, or kahala); *Caranx lugubris* (black trevally/jack)

<u>Management Plan and Area</u>: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

Because of the great similarity in habitat utilization patterns, a single, general habitat profile has been prepared for the following closely related BMUS: *Caranx ignobilis* (giant trevally); *Pseudocaranx dentex* (thick-lipped trevally, or butaguchi); *Seriola dumerili* (greater amberjack, or kahala); *Caranx lugubris* (black trevally/jack). Where available information has been provided on a species specific level.

Large carangids, or jacks, form an important component of shallow water reef and lagoon fish catches throughout the Pacific Islands The species are found distributed throughout tropical and subtropical waters of the Indo-Pacific region in shallow coastal areas and in estuaries and on reefs, the deep reef slope, banks and seamounts, notes Sudekum et al. (1991). Despite their importance to fisheries, little is known about the basic biology and habitat requirements of the large jacks, the authors add.

Caranx ignoblis is one of the most abundant species of jacks found in Hawaii, (Sudekum et al. 1991). Seki (1986) notes that *Pseudocaranx dentex* is rarely caught in the MHI, but is abundant in the NWHI where it is found at depths of 18–183 m. In addition to living on deeper reef slopes and banks, *P. dentex* can also be found in near-shore areas in large schools of 200–300 fish, Seki observes. *Seriola dumerili* is commonly found inhabiting the inner reefs and outer slopes of island shelves to depths of 250 m (Humphreys 1986). It has been observed at depths of up to 335 m (Myers 1991, Ralston et al. 1986). *Caranx lugubris* occurs singularly or in small groups on offshore banks and along the steep outer reef slopes at depths of 12 to 354 m (Myers, 1991). This circumtropical species appears to be confined to clear, offshore waters at depths of 25 to 65 m (Smith and Heemstra, 1986). *C. lugubris* is the most common carangid taken from offshore banks in the Marianas.

Jacks are highly mobile, wide-ranging predators that travel throughout the water column from the surface to depths of 250 m, although they are closely more affiliated with demersal habitats and feeding on benthos (Uchida and Uchiyama 1986, Sudekum et al. 1991).

Sudekum et al (1991) found that *C. ignoblis* reached sexual maturity at about 3.5 years (60 cm). *C. ignoblis* is the largest of the jacks found in the Indo-Pacific region and may obtain a total weight of over 50 kg with a lifespan in excess of 15 years (Lewis et al. 1983). *S. dumerili* reaches sexual maturity at about 54 cm, when it is between 1 and 2 years old (Kikkawa and Everson 1986, Uchida and Uchiyama 1986). *C. lugubris* reach sizes of up to 85 cm (Randall et al., 1990).

The sex ratio of females to males for *C. ignoblis* in Hawaii was slightly skewed in favor of females●1:1.39 (Sudekum et al. 1991). In contrast, Lewis et al. (1983) report a sex ratio in favor of male *C. ignoblis* of nearly 2:1 in Fiji.

In Hawaii, peak spawning for *C. ignoblis* occurs between May and August. Gravid fish of are found between April and November in the NWHI (Sudekum et al. 1991). In Fiji, Lewis et al. (1983) found that a fairly brief spawning period occurs from October to December, with peak activity in late October to early November. Johannes (1981) reports that *C. ignoblis* spawns in pairs within larger aggregations during new and full moon events. Myers (1991) reports that *C. ignoblis* gather to spawn on offshore banks and shallow seaward reefs. Humphreys (1986) reports that in the NWHI, *S. dumerili* spawn throughout the year with peak activity occurring in April.

Jacks are taken principally by deep-sea handline gear as well as traps (Seki 1986). As commercial landing data for carangids are often combined, accurate catch data for individual species are usually not available. In American Samoa, Guam and the Northern Mariana Islands jacks as a group account for between 3% and 8% of the reported bottomfish landings. Landings of jacks in Guam comprise mainly a mix of *C. ignoblis* and *C. malampygus* (WPRFMC 1997). *C. lugubris* is an important food fish in the Marianas despite concerns about ciquatera (Myers, 1991).

S. dumerili is nowadays landed in insignificant amounts in Hawaii but used to be an important component of bottomfish landings in Hawaii. The decline in landings is due principally to its association with ciguatera intoxications and a ban on commercial sales of this species (Uchida and Uchiyama 1986). *P. dentex* accounts for approximately 15% of the total catch in the NWHI bottomfish fishery (WPRFMC 1997).

<u>Egg and Larval Distribution</u>

The available literature describing the egg and larval stages of tropical marine fish is exceedingly sparse. According to Miller et al. (1979), the available information demonstrates that carangid larvae are common in the near-shore waters of Hawaii. Caragnid eggs are planktonic, spherical and 0.70-1.3 mm in diameter (Laroche et al., 1984; Miller et al. 1979). One to several oil globules are usually present (Laroche et al., 1984). Caragnid eggs hatch in 24 to 48 hours after spawning at water temperatures of 18 to 30 CE (Laroche et al., 1984). The identification of carrangid eggs to even the family level is frequently impossible because their similarity in size and appearance to many other marine fishes (Laroche et al., 1984).

Carangid larvae are relatively small, 1.0 to 2.0 mm, at hatching (Laroche et al., 1984). Larvae have a relatively large yplk sac and possess an oil globule at the anterior end of the sac (Laroche et al., 1984). The lack of diagnostic morphological features makes it difficult to identify newly hatched carangid larvae to even the family level (Laroche et al., 1984).

Miller et al. describe *Seriola* sp. larvae as moderately deep-bodied and large-headed and possessing well-developed preopecular spines. In a survey of larval distribution in near-shore waters of Hawaii, *Seriola* sp. were found to be relatively uncommon, the authors add.. The researchers also found that more *Seriola* sp. larvae were taken in summer than in winter, although not significantly. They also found that *Seriola* sp. larvae were more common in offshore than in near-shore tows. The early life history of *C. lugubris* is poorly known.

<u>Juvenile</u>

Juvenile *C. ignoblis* are often found in near-shore and estuarine waters (Lewis et al. 1983) and in small schools over sandy inshore reef flats (Myers 1991).
There a few food habit studies available for the genus *Seriolla*. The feeding habits of a *S. quinqueradiata*, a related species, indicates that juveniles prey on the larvae and juveniles of Mullidae, Engraulidae, Scomberesocidae and planktonic crustaceans.

<u>Adult</u>

C. ignoblis is predominantly piscivorus in itsr diet, fish comprising >90% of its diets(Sudeum et al. 1991, Parrish et al. 1980). This fish also preys on crustaceans, gastropods and cephalopods. Sudekum et al. (1991) found that the diet of *C. ignoblis* included abundant (13.6%) parrotfish (Scaridae), as well as roundscads or opelu, wrasses (Labridae), bigeyes (Priacanthidae) eels (Muraenidae, Congridae), cephalopods and crustaceans (crabs, shrimp and lobsters).

The predominance of reef fishes in the diet of *C. ignoblis* strongly suggests that shallow-water reef habitats are of prime importance as foraging habitat for large jacks. However, the occurrence of small pelagic fish such as roundscads and squid in the diets of these species diets indicates that time is also spent foraging in the water column (Sudekum et al. 1991). *C. ignoblis* appears to be primarily a nocturnal feeder (Sudekum et al. 1991, Okamoto and Kawamoto 1980) It has been estimated that *C. ignoblis* along with *C. melampygus,* another large jack may annually consume as much as 30,000 mt of prey at French Frigate Shoals in the NWHI (Sudekum et al. 1991).

S. dumerili is an opportunistic bottom feeder, with primary prey items comprising fishes, eels, groupers (Serranidae), bigeyes, crustaceans (crabs and shrimps) and octopus (Seki 1986, Humphreys 1980). Humphreys (1986) observes that *S. dumerili* diet in the NWHI is includes bottom-associated prey and octopus while in the MHI the primary prey items are pelagic species, such as roundscads. There is a significant shift in the diet of *S. dumerili* from cephalopods to fish as it increases in weight (Humphreys 1980).

All species of jacks may range throughout the water column, but they are associated primarily with demersal habitat.

Essential Fish Habitat: Shallow-water species complex (0-100 m). The EFH for large jacks is shown in Table 15.

Table 16. Habitat description for large jacks

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	24 to 48 hours after spawning at water temperatures of 18 to 30 CE	In Hawaii, *Seriola* sp. larvae are more common in offshore than in near-shore tows. The early life history of *C. lugubris* is poorly known.	*C. ignoblis* reached sexual maturity at about 3.5 years (60 cm). *S. dumerili* reaches sexual maturity at about 54 cm, when it is between 1 and 2 years old	*C. ignoblis* lifespan in excess of 15 years
Diet	N/A	No information available	There is a significant shift in the diet of some species of jacks from cephalopods to fish they increase in age	predominantly piscivorus, fish comprising >90% of its diets. Also preys on crustaceans, gastropods and cephalopods, eels. Shallow-water reef habitats are of prime importance as foraging habitat for large jacks. Time is also spent foraging in the water column.
Distribution: General and Seasonal		In Hawaii, *Seriola* sp. larvae were taken in summer than in winter, although not significantly.	often found in near-shore and estuarine waters and in small schools over sandy inshore reef flats	found distributed throughout tropical and subtropical waters of the Indo-Pacific region in shallow coastal areas and in estuaries and on reefs, the deep reef slope, banks and seamounts
Water Column	pelagic	pelagic	bentho-pelagic	bentho-pelagic, All species of jacks range throughout the water column, but they are associated primarily with demersal habitat.
Bottom Type	N/A	N/A	Jacks are found over a wide variety of bottom type, shallow-water reef habitats are prime foraging habitat	Jacks are found over a wide variety of bottom type, shallow-water reef habitats are prime foraging habitat
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

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3.5.4 Habitat description for *Epinephelus fasciatus* (blacktip grouper)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Epinephelus faciatus is a member of the Serranidae family, the groupers. The English common name of species is blacktip grouper. In American Samoa it is known as fausi; in Guam and Northern Mariana Islands it is gadao matai.

According to Heemstra and Randall (1993) *E. fasciatus* is a common worldwide with distinguishable populations in six areas: 1) Western Pacific, 2) Pacific Plate islands, 3) Marquesas Islands, 4) Japan, 5) Western Australia, and 6) Indian Ocean and Red Sea. In the Pacific, it is found from the Pitcairn Islands in the east to Australia in the west and as far north as Japan and Korea. In the Indian Ocean, this species ranges from the Red Sea to Western Australia. It is not found in the Hawaiian Islands.

Heemstra and Randall state that *E. fasciatus* inhabit coral reefs and rocky bottom substrate from the shore to a depth of 160 m. In Madagascar, where i t is one of the most abundant serranids found, it inhabits depths of 20 to 45 m.

The authors go on to say that, except for occasional spawning aggregations, most species of groupers are solitary fishes with a limited home range. Based on the results of tagging studies, it has been found that serranids are resident to specific sites, often residing on a particular reef for years.

Based on the available data, groupers appear to be protogynous hermphrodites. Heemstra and Randall note that, after spawning for one or more years, the female undergoes sexual transformation, becoming male.

According to the authors, some species of serranids spawn in large aggregations, others in pairs. Individual males may spawn several times during the breeding season. Some species of groupers are known to undergo small, localized migrations, of several km to spawn.

Because of its distribution and abundance in shallow waters, *E. faciatus* is an important food fish throughout its geographic range. According to Heemstra and Randall, the primary fishing gear types used to take this species includes hook-and-line, gill nets, spears, and traps.

Egg and Larval Distribution

According to Heemstra and Randall, serranid larvae are distinguishable by their ■kite-shaped• bodies and highly developed head spination. The pelagic, fertilized eggs of *E. faciatus* are spherical and transparent and range in size from 0.70 to 1.20 mm in diameter with a single oil globule 0.13 to 0.22 mm in diameter. Based on the available data, the length of the pelagic larval stage of groupers is 25■60 days. The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase, the authors note.

Juvenile

Very little is known about the distribution and habitat utilization patterns of this species. Research has found that transformation of pelagic serranid into benthic larvae takes place between 25 mm to 31 mm TL (Heemstra and Randall, 1993). The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools. There is no specific information available for the habitat utilization patterns of juvenile *E. fasciatus*.

Adult

E. fasciatus is a common species throughout its range. It inhabits coral reefs and rocky bottom from shallows to 160 m (Smith and Heemstra 1986).

Serranids typically are long-lived and have relatively slow growth rates; *E. fasciatus* reported to reach a maximum length of about 40 cm (Heemstra and Randall 1993).

Groupers are typically ambush predators, hiding in crevices and among coral and rocks in wait for prey (Heemstra and Randall 1993). Adults reportedly feed during both the day and night. Harmelin-Vivien and Bouchon (1976) report the diet of *E. fasciatus* includes brachyuran crabs, fishes, shrimps and galathied crabs (Heemstra and Randall, 1993). Other food habit studies identify octopus, crabs, stomatopods, fishes and ophiurids in the diet of *E. fasciatus* (Morgan 1982, Randall and Ben-Tuvia 1983).

Essential Fish Habitat: Shallow-water species complex (0-100 m). The EFH for *E. fasciatus* is shown in Table 17.

Table 17. Habitat description for *Epinephelus fasciatus* (blacktip grouper)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Serranid eggs incubate in 20-35 days	25▪60 days	Transformation of pelagic serranid into benthic larvae takes place between 25 mm to 31 mm TL	Serranids are long-lived , slow growing species.
Diet	N/A	No information available	No information available	The diet of *E. fasciatus* includes brachyuran crabs, fishes, shrimps and galathied crabs, octopus, stomatopods, and ophiurids
Distribution: General and Seasonal	Serranid eggs have a relatively long pelagic phase that results in wide geographic distribution	Serranid larvae have a long pelagic phase that results in wide geographic distribution		Common worldwide including western Pacific region
Water Column	pelagic	pelagic	demersal	demersal
Bottom Type	N/A	N/A	The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools. There is no specific information available for the habitat utilization patterns of juvenile *E. fasciatus*.	inhabits coral reefs and rocky bottom substrate from the shore to a depth of 160 m.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

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[WPRFMC] Western Pacific Regional Fishery Management Council. 1997. Bottomfish and seamount groundfish fisheries of the western Pacific region, 1996 annual report. Honolulu: WPRFMC.

3.5.5 Habitat description for *Epinephelus quernus* (sea bass, hapuupuu)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Epinephelus quernus is a member of the family Serranidae. The English common name of this species is sea bass. In Hawaii adults of this species are known as hapu. Juveniles are referred to as hapuupuu.

According to Heemstra and Randall (1993) *E. quernus* is endemic to the Hawaiian Islands and Johnston Atoll. It is the only grouper species native to the Hawaiian Islands, although a closely related species, *E. niphobles*, is found in the Eastern Pacific. *E. quernus* is found at a depth range of 20■380 m, the authors add.

Hook and line is the primary gear type used to take this species. Between the years of 1984■1995, *E. quernus* accounted for approximately 14% of the total deep-slope bottomfish landed in Hawaii (WPRFMC 1997).

Egg and larval distribution

Heemstra and Randall describe the small pelagic, fertilized eggs as spherical, transparent and 0.70■1.20 mm in diameter with a single oil globule 0.13■0.22 mm in diameter.

Serranid larvae are characterized by their ■kite-shaped• bodies and highly developed head spination, Heemstra and Randall note. Based on the best available data the length of the pelagic larval stage of groupers 25■60 days. The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase, the authors continue. Transformation of pelagic serranid into benthic larvae takes place between 25 mm and 31 mm TL.

Juvenile

Juvenile *E. quernus* are commonly taken in lobster traps in the NWHI. Besides this limited information there is no specific information available for the distribution, habitat requirements or habitat utilization patterns of juveniles of this species. However, the juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools (Heemstra and Randall 1993).

Adult

Adults of this species typically attain at least 80 cm total length and reach a weight of 10 kg (Heemstra and Randall 1993).

Heemstra and Randall note that groupers are typically ambush predators, hiding in crevices and among coral and rocks in wait for prey. Adults feed during both day and night, the authors add. Seki (1984) reports that the diet of *E. quernus* consists primarily of fish with crustaceans, particularly shrimp, being the next most abundant prey item.

Essential Fish Habitat: Deep-water species complex (100-400 m). The EFH for *E. querus* is shown in Table 18.

Table 18. Habitat description for *Epinephelus quernus* (sea bass, hapuupuu)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Serranid eggs incubate in 20-35 days	25▪60 days	Transformation of pelagic serranid into benthic larvae takes place between 25 mm to 31 mm TL	Serranids are long-lived , slow growing species.
Diet	N/A	No information available	No information available	*E. quernus* consists primarily of fish with crustaceans, particularly shrimp, being the next most abundant prey item.
Distribution: General and Seasonal	Serranid eggs have a relatively long pelagic phase that results in wide geographic distribution	Serranid larvae have a long pelagic phase that results in wide geographic distribution		*E. quernus* is endemic to the Hawaiian Islands and Johnston Atoll. It is the only grouper species native to the Hawaiian Islands.
Water Column	pelagic	pelagic	demersal	demersal
Bottom Type	N/A	N/A	Juvenile *E. quernus* are commonly taken in lobster traps in the NWHI. Besides this limited information there is no specific information available for the distribution, habitat requirements or habitat utilization patterns of juveniles of this species. However, the juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools	*E. quernus* is found at depths of 20▪380 m. It inhabits rocky bottom substrate.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

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[WPRFMC] Western Pacific Regional Fishery Management Council. 1997. Bottomfish and seamount groundfish fisheries of the western Pacific region, 1996 annual report. Honolulu: WPRFMC.

3.5.6 Habitat description for *Etelis carbunculus* (red snapper, ehu)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Etelis carbunculus is a red snapper that is known in Hawaii as ehu. It is widely distributed throughout the Indo-Pacific region from East Africa to the Hawaiian Islands and from southern Japan to Australia (Allen 1985; Everson 1984). Like most bottomfish species, *E. carbunculus* is important in western Pacific fisheries but its life history is not well known (Ralston 1979).

E. carbunculus are found concentrated on the steep slopes of deepwater banks of Pacific Islands in habitats characterized by a hard substrate of high structural complexity. They are found solitarily or in small groups in depths of 90 to 350 m (Allen 1985, Everson 1984, Ralston and Polovina 1982).

E. carbunculus reportedly obtain sexual maturity at about 29.8 cm FL (Everson 1986). Everson (1984) reports that the sex ratio is skewed 2:1 in favor of females over males. They reportedly reach a maximum length of 80 cm.

Everson (1984) reports that *E. carbunculus* are serial spawners, spawning multiple times during the spawning season, and that they have a shorter, more well-defined spawning period than do most other species of snappers, spawning from July to September in the NWHI. In Vanuatu spawning reportedly occurs throughout most of the year (Allen 1985).

E. carbunculus is an important commercial species throughout its range and is taken primarily with deepsea handlines. It is one of the principal species in the deepwater bottomfish fishery in Hawaii, accounting for approximately 7% of the total reported bottomfish landings in 1996 (WPRFMC 1997). NMFS data show that it is the predominant species of deepwater bottomfish in the NWHI west of Lisianski, accounting for 22.7% to 86.5% of the total bottomfish landed in these areas (Everson 1986; Uchiyama and Tagami 1984).

In American Samoa, *E. carbunculus* is one of the most valuable species landed and comprised almost 9% of the total reported bottomfish landings in 1996 (WPRFMC 1997).

In a five-year study of the bottomfish fishery resources of the Northern Mariana Islands and Guam, Polovina et al. (1985) collected more than 30 species of fish. *E. carbunculus* was one of the three most abundant species collected, accounting for 12.5% of the total fish collected.
In Guam, it comprised 4% of the total reported bottomfish landed in 1996 (WPRFMC 1997). Catch data for the Northern Mariana Islands are not available for this species.

Egg and Larval Distribution

In a detailed review of the early life history of tropical snappers, Leis (1987) points out that there have been very few taxonomic studies of the eggs and larval stages of lutjanids and that very few larvae can be identified to species. However, it is possible to distinguish *E. carbunculus* larvae from *E. coruscans* in specimens larger than 13.7 mm (Leis and Lee 1994).

Eteline snapper larvae are generally more abundant in slope and oceanic waters than over the continental shelf (Leis and Lee 1994, Leis 1987). During the day, snapper larvae tend to avoid surface waters, but at night they are more evenly distributed vertically in the surface water column, Leis notes (1987). During the winter months larvae of most species are much less abundant, he adds.

Juvenile

There is very little information available concerning the preferred habitat of juveniles of this species. Juvenile ehu are found dispersed in their natural habitat (Kelly 1998, Reseacrher Hawaii Institute of Marine Biology (HIMB), personal communication). Parrish (1989) demonstrated that the habitat requirements of the juveniles of several species of deepwater snappers are markedly different than those of adults.

Adult

The distribution and preferred habitat of adults of this species are described above.

In a detailed review of the trophic biology of snappers, Parrish (1987) states that, like most species of fully deepwater snappers, very little is known about the food habits of the *E. carbunculus*. Food habit studies of these species are difficult because gut contents are frequently lost due to regurgitation when specimens are brought to the surface from great depths, he explains. However, he notes, in the Mariana Islands important prey items in the diet of *E. carbunculus* include fish, benthic crustaceans and pelagic urochordates. Planktonic forms of prey are surprisingly important for snappers, both in bulk consumed and frequency of occurrence, especially for many deep-water species, Parrish adds. Major planktonic food items include pelagic urochordates (Pyrosomida, Salpidae, and Dolioda) and pelagic gastropods (pteropods and heteropods).

According to Parrish, the depths at which *E. carbunculus* feed are not well documented, but it is believed that most deep-water snappers, including this species, feed primarily at or near the bottom. There is also very little information available about the type of substrate where feeding occurs, he says. But, he notes, these species are usually caught in areas of rather high relief, particularly on the steep slopes of islands.

Haight (1989) found that the catch rate for *E. carbunculus* was highest between 200–250 m on Penguin Bank in the MHI. He also found that *E. carbunculus* fed primarily between 1800–2000, with fish comprising almost 98% of the prey items in the species's diet. Other prey items included copepods, shrimp, crabs and octopus. This species is known to be an aggressive feeder (Haight 1989, Ralston 1979).

<u>Essential Fish Habitat</u>: Deepwater bottomfish complex (100–400 m). The EFH for *E.s* is shown in Table 19.

E. carbunculus is found concentrated on the steep slopes of deepwater banks of Pacific Islands in habitats characterized by a hard substrate of high structural complexity (Ralston 1979, Ralston and Polovina 1982, Everson 1984, Polovina 1985, Haight 1989, Moffitt and Parrish 1996). Ehu is found concentrated between the depths of 90 to 350 m (Allen 1985, Everson 1984, Ralston and Polovina 1982).

Table 19. Habitat description for *Etelis carbunculus* (red snapper, ehu)

	Egg	Larvae	Juvenile	Adult
Duration	17▪36 h incubation time depending on the species and the water temperature	The pelagic larval phase of lutjanids life history last for 25▪-47 days and that size may be a more important factor than age in determining when settlement occurs. Size at settlement varies widely among species and ranges from 10-50 mm	No information available	No information available
Diet	N/A	No information available	No information available	The diet of *E. carbunculus* include fish, benthic crustaceans and pelagic urochordates
Distribution: General and Seasonal	Not well documented, widely distributed.	Eteline snapper larvae are more abundant in slope and oceanic waters than over the continental shelf	No specific information available, the habitat requirements of the juveniles of several species of deepwater snappers are markedly different than those of adults.	It is widely distributed throughout the Indo-Pacific region from East Africa to the Hawaiian Islands and from southern Japan to Australia
Water Column	Pelagic	Lutjanid larvae are known to avoid the surface layer during the day (Leis 1987). At night, snapper larvae are found more evenly distributed throughout the surface waters (Leis 1987).	Demersal: No specific information is available for the distribution and habitat preferences of juvenile onaga	Demersal, *E. carbunculus* is found concentrated on the steep slopes of deepwater banks of Pacific Islands in habitats characterized by a hard substrate of high structural complexity. Found concentrated between the depths of 90 to 350 m
Bottom Type	N/A	N/A	No information available	Areas of high relief, (e.g., steep slopes, pinnacles, headlands, rocky outcrops)
Oceanic Features	Lutjanid eggs are subject to advection by ocean currents	Lutjanid larvae are subject to advection by ocean currents	No information available	Areas of high relief form localized zones of turbulent vertical water movement. Higher densities of some eteline snapper species have been found on the up-current side islands, banks and atolls.

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3.5.7 Habitat description for *Etelis coruscans* (red snapper, onaga)

<u>Management Plan and Area:</u> American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

Etelis coruscans has the common English name of red snapper and is known in Hawaii as onaga. Ralston (1979), while noting that the life history of the *E. coruscans* is poorly understood, says the species is widely distributed throughout the Pacific region and extends into the Indian Ocean, with known occurrences in Hawaii, Samoa, the Mariana Islands, the Cook Islands, Tuvalu and Vanuatu.

An eteline snapper in the Lutjanidae family, *E. coruscans* is found in considerably deeper waters then other species of deep-slope snappers (Everson 1986, Moffitt 1993). It is caught at depth ranging from 100■160 fathoms (Ralston 1979). *E. coruscans* is found in association with areas of abrupt relief, such as steep drop-offs, ledges, outcrops and pinnacles (Everson 1986). Ralston (1979) determined that 92% of the total *E. coruscans* landed in Hawaii were taken in deep, offshore waters beyond the 3-mile limit of state jurisdiction.

According to the *1996 Annual Report for Bottomfish and Seamount Groundfish in the Western Pacific*, *E. coruscans* accounted for approximately 10% of the total reported bottomfish landings for the NWHI (311,000 lb) and almost 16% of the reported total landings of BMUS (421,000 lb) in the MHI and commanded the highest price per pound of any bottomfish species landed in Hawaii. It also accounted for 11% of the total reported BMUS landings (32,245 lb) in American Samoa and commanded the second highest price per lb of any species landed in the territory. In the Northern Mariana Islands, *E. coruscans* was the single most abundant bottomfish species landed in 1996, accounting for almost 29% of the total catch (52,967 lb), and commanded the highest price per pound of any bottomfish species landed in the the commonwealth, the annual report continues. In Guam, the species comprised only about 3% of the total reported bottomfish landings (54,122 lb), the report adds. While relatively uncommon in Guam, the *E. coruscans* is a highly prized species.

Haight (1989) studied the trophic relationships, density and habitat associations of deepwater snappers on Penguin Bank, Hawaii. Of the six species of lutjanid snappers collected in his study, *E. coruscans* made up 7% of the total catch. The size of the *E. coruscans* taken in this same study ranged from 26.5■74.4 cm FL.

Ralston (1979) says *E. coruscans* is known to reach sizes of up to 80 lb, but most commercially landed *E. coruscans* weigh between 1■15 lb. In the MHI most of the *E. coruscans* landed are taken from the Pengiun Bank■North Molokai region, Ralston adds. Landings of *E. coruscans* are seasonal in Hawaii, with CPUE increasing during the fall and early winter months, peak landings occurring in or around the month of December and minimum of *E. coruscans* landings occurring during the early summer months, Ralston observes.

A cluster analysis of bank catch composition in the Mariana archipelago determined that the banks can be grouped into three catch profiles, southern, northern and seamount clusters. The seamount cluster was characterized throughout the resource assessment by its higher proportion of *Etelis* species (*Etelis coruscans and E. carbunculus*), almost twice the amount of the other clusters (Polovina, 1985).

Lutjanids, such as *E. coruscans*, are hooked near or several m above the bottom (Moffitt 1993).

<u>Eggs and Larval Distribution</u>

There have been very few ecological or taxonomic studies of the eggs and larvae of *E. coruscans*. As discussed, most of the available data pertaining to the early life stages of lutjanids are broad, nonspecies specific in nature. Leis (1987) says lutjanids spawn small, pelagic, spherical, eggs that are typically less than 0.85 mm in size and that hatch in 17–36 hours depending on species and water temperature.

Little is known about this species’s larval life. Leis (1987) notes that newly hatched lutjanid larvae have unpigmented eyes, no mouth, a large yolk sac, spination of the head and fins, and limited swimming capabilities, he says. Lutjanid larvae are known to avoid the surface layer during the day, but, at night, they are found evenly distributed throughout the surface waters, he observes. The duration of their pelagic phase has been estimated to range 25–47 days, and larvae of eteline snapper, including those of *E. coruscans*, are found in greater abundance over oceanic and slope waters than over the waters of the continental shelf, he notes. It is thought that the pelagic phase of eteline lutjanids is longer than that of *Lutjanus* spp., and size may be a more important factor than age in determining when larval settlement occur, Leis says. Snapper larvae are subject to advection by ocean currents (Munro 1987).

<u>Juvenile</u>

Virtually nothing is known about juvenile *E. coruscans* life history and habitat requirements. Current research has shown that shallow, flat featureless areas may be essential habitat for growth and survival of juvenile *Pritipomoides filamentosus, Aprion virescens* and *Aphareus rutilans*. Research has identified two areas that support dense, persistent aggregations of juvenile snapper in relatively shallow water (65–100 m). Both are in the MHI—the first is off Kaneohe Bay on the island of Oahu, and the second, off the southwest coast of Molokai. The flat featureless substrate of these two sites is quite different than the high-relief, hard bottom that adult snappers are known to inhabit.

At the Kaneohe Bay site, an internal, semi-diurnal tide provides an influx of cold water to the area at high tide (Moffitt and Parrish 1996). It has been hypothesized that such a water flow may enhance food supplies in an area (Parrish et al. 1997). Parrish et al (1997) also found a significant correlation between juvenile snapper abundance and sources of coastal drainage at the site off of Molokai. Research to identify additional juvenile bottomfish nursery areas in the Hawaiian Islands is ongoing. Research to identify, describe and map nursery habitat areas for juvenile *E. coruscans* throughout the region is needed.

Adult

Adult *E. coruscans* are found in considerably deeper waters than other species of snappers (Everson 1986, Moffitt 1993). They are caught at depths ranging from 100 to 160 fathoms (Ralston 1979). They are found in areas of abrupt relief, such as steep drop-offs, outcrops, ledges and pinnacles. They grow to a much larger size (81 cm FL) than other species of *Etelis* and *Pristipomoides* and weigh up to 20 kg (Amesbury and Myers 1982). Everson (1986) reports the mean weights of males and females of the species to be 4.28 kg and 5.45 kg respectively in the NWHI.

Analyzing the CPUE distribution by depth intervals for all species landed, Haight (1989) found that *E. coruscans* are caught at the highest rate between depths of 250 and 300 m, the deepest region occupied by any of the snappers common to the Hawaiian Islands that have been collected. This compares with an average hooking depth of 125 fathoms in the NWHI noted in Amendment 2 of the bottomfish FMP and 119 fathoms in the Northern Mariana Islands observed by Polovina et al.(1985).

Peak feeding times for adult *E. coruscans* occur during daylight hours, with the highest catch rates between 0600■0800 hours (Haight 1989). *E. coruscans* feed at or near the bottom (Moffitt 1993), and their diet includes fish (76.4%), shrimp (16.4%), planktonic crustaceans (3.4%), chepalopods (2%), urocordates (1.5%) and crabs (.2%) (Haight 1989).

While little is known about the reproductive cycle of *E. coruscans* it is probably similar to ehu (Everson 1986). Polovina and Ralston (1986) estimate sexual maturity at two years of age. In the NWHI, ripe ovaries were collected from *E. coruscans* in August and September during a study that took place during the summer months only (Everson 1986). Grimes (1987) reports that deepwater snappers reach sexually maturity at approximately 50% of their total length.

Essential Fish Habitat: Deep-water complex (100-400). The EFH for *E. corsuscans* is shown in Table 20.

Table 20. Species: *Etelis coruscans* (red snapper, onaga)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17▪36 h incubation time depending on the species and the water temperature (Leis 1987)	Leis (1987) reports that the pelagic larval phase of lutjanids life history last for 25▪-47 days and that size may be a more important factor than age in determining when settlement occurs. Size at settlement varies widely among species and ranges from 10-50 mm	No specific information available	*Etelis coruscans* is a long-lived, slow growing species
Diet	N/A	No information available	Not known	fish (76.4%), shrimp (16.4%), planktonic crustaceans (3.4%), chepalopods (2%), urocordates (1.5%), crabs (.2%) (Haight 1989).
Distribution: General and Seasonal		Eteline snapper larvae are more abundant in slope and oceanic waters than over the continental shelf (Leis 1987)	The species is widely distributed throughout the Pacific region	The species is widely distributed throughout the Pacific region and extends into the Indian Ocean, with known occurrences in Hawaii, Samoa, the Mariana Islands, the Cook Islands, Tuvalu and Vanuatu.
Water Column	Pelagic	Lutjanid larvae are known to avoid the surface layer during the day (Leis 1987). At night, snapper larvae are found more evenly distributed throughout the surface waters (Leis 1987).	Demersal:	Demersal, 100-160 fathoms
Bottom Type	N/A	N/A	No specific information is available for the distribution and habitat preferences of juvenile onaga	Areas of high relief, (e.g., steep slopes, pinnacles, headlands, rocky outcrops)
Oceanic Features	Lutjanid eggs are subject to advection by ocean currents	Lutjanid larvae are subject to advection by ocean currents	No information available	Higher densities of some eteline snapper species have been found on the up-current side islands, banks and atolls.

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3.5.8 Habitat description for *Lethrinus amboinensis* (ambon emperor)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Lethrinus amboinensis is a member of the Lethrinidae family and the subfamily Lethrininae. It has the English common name of ambon emperor, while in American Samoa, it is commonly known as filoa-gutumumu and in Guam and the Northern Mariana Islands, as mafuti or lililok. It is absent from the Hawaiian Islands.

Carpenter and Allen (1985) present a major review of the known habitat requirements and life history of *L. amboinensis*. The species is found from southern Japan to northwestern Austalia and from Indonesia eastward through the Marshall Islands, Solomons, Samoa and the Marquesas. It is commonly confused with *L. microdon* and *L. olivaceus*, the authors note.

Very little is known about the biology of this species or its habitat utilization patterns. It is known to inhabit deeper waters of coral reefs and adjacent sandy bottom areas. According to Carpenter and Allen, lethrinids are found inhabiting coastal waters, including coral and rocky reefs, sandy bottoms, sea-grass beds and mangrove swamps.

The spawning behavior of lethrinids is poorly documented. Based on the limited data available, Carpenter and Allen describe a generalized pattern: Spawning is generally prolonged, occuring throughout the year. It is preceded by small, localized migrations at or near dusk. Peak spawning events occur on or near the new moon. Large aggregations of lethrinids have been observed spawning near the surface as well as at the bottom of reef slopes, the authors state.

Lethrinids are relatively long-lived, with an average age range of 7 to 27 years, Carpenter and Allen report. The average age of growth cessation for lethrinids is 11 years with a reported maximum size of approximately 70 cm total length. The males tend to be of a larger size than females. The ambon emperor is commonly taken at sizes ranging from 30 to 50 cm in total length, the authors add.

Lethrinids are of moderate to significant importance in commercial, recreational and artisanal fisheries throughout the tropical Pacific, Carpenter and Allen report. In American Samoa, *L. amboinensis* accounted for approximately 2% of the total landed bottomfish reported in the *1996 Annual Report of Bottomfish and Seamount Groundfish in the Western Pacific*. In contrast, *L. amboinensis* and *L. rubrioperculatus* accounted for approximately 18% and 20% of the total landed bottomfish in Guam and the Northern Mariana Islands, respectively, according to the 1996 annual report. In the case of the Northern Mariana Islands, there was a preponderance of *L. rubrioperculatus* in the total lethrinids landed. Emperors are taken primarily with handlines, droplines longlines and traps, the annual report notes. Carpenter and Allen (1989) say that lethrinids are important recreational target species in some countries, and some species of lethrinids are reported to be ciguatoxic.

Egg and Larval Distribution

Carpenter and Allen describe lethrinid eggs as pelagic, spherical and colorless, possessing an oil globule and ranging in size from 0.68 to 0.83 mm in diameter. The eggs typically hatch within 21 to 40 hours after fertilization occurs, they add.

Newly hatched lethrinid larvae range in size from 1.3 to 1.7 mm. The general physical characteristics include an unopened mouth, a large yolk sac, unpigmented eyes, variable body pigmentation and, most notably, extensively developed head spination and cheek scales, Carpenter and Allen report.

Juvenile and Adult

As discussed above, very little is known about the biology of *L. amboinensis* or its habitat utilization patterns. It is known to inhabit deeper waters of coral reefs and adjacent sandy bottom areas. Carpenter and Allen say lethrinids are found inhabiting coastal waters—including coral and rocky reefs, sandy bottoms, sea-grass beds and mangrove swamps—and adult *L. amboinensis* prey primarily on fishes and crustaceans.

Essential Fish Habitat: Shallow-water species complex (0-100 m)

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3.5.9 Habitat description for *Lethrinus rubriopeculatus* (redgill emperor)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Lethrinus rubrioperculatus is a member of the family Lethrinidae, the subfamily Lethrininae and the genus *Lethrinus*. The English common name of this species is redgill emperor. In American Samoa it is known as filoa-pa♣o♣omumu; in Guam and the Northern Mariana Islands it is called mafuti tatdong. *L. rubrioperculatus* is not found in the Hawaiian Islands.

Carpenter and Allen (1989) describe the geographical distribution of this species as being widespread in the Indo-Pacific region, from East Africa to the Marquesas, from southern Japan to Australia. Adults of this species are found inhabiting sand and rubble areas on outer reef slopes to depths of 160 m, the researchers note. Individuals of the species are commonly found at lengths of approximately 30 cm and that the maximum reported total length for this species is 50 cm, they add.

The common mode of sexuality in Lethrinids is sequential protogynous hermaphroditism. When lethrinids first obtain sexual maturity they are initially female, later they change. Carpenter and Allen say that this reproductive mode explains several aspects of lethrinid population structure: the sex ration is usually slightly in favor of females, and on average males tend to be larger then females. Research indicates that the sexual transformation occurs over a wide size range, the authors note.

L. rubrioperculatus is commonly taken with handlines, trawls and traps and is one of the most important commercial species of bottomfish in the Northern Mariana Islands, Carpenter and Allen continue.

Egg and Larval Distribution

Lethrinid eggs are pelagic. They are described by Carpenter and Allen as spherical, possessing an oil globule and between 0.68 and 0.83 mm in size. They hatch between 21 and 40 hours after fertilization. Newly hatched lethrinid larvae are 1.3■1.7 mm in length, with unpigmented eyes, unopened mouth, variable body pigmentation and a large yolk sac. Extensive spination of the head is a notable feature of lethrinid larvae♣s physical appearance, Carpenter and Allen note.

Juvenile

There is virtually no information available concerning the distribution or habitat utilization patterns of this species.

Adult

Adults of this species feed primarily on crustaceans, fish, echinoderms and molluscs (Allen 1985).

Essential Fish Habitat: Shallow-water species complex (0-100 m)

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3.5.10 Habitat description for *Lutjanus kasmira* (blue-lined snapper, taape)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Lutjanus kasmira is in the family Lutjanidae, subfamily Lutjaninae. *L. kasmira* is distributed throughout the Indo-Pacific region; from East Africa to the Line and Marquesas Islands, from Australia to Japan (Allen 1985, Druzhinin 1970). It also occurs in waters around Hawaii where it was introduced in 1955 and 1961 by the Hawaii Department of Land and Natural Resources (Uchida 1986). There are concerns among fishermen that *L. kasmira* may compete with native species of commercially important bottomfish, but available data does not support this claim (Oda and Parrish 1981).

L. kasmira is found on outer reef slopes at depths of up to 265 m and in shallow inshore waters and lagoons (Myers 1991; Amesbury and Myers 1982). Myers (1991) observes that, during the day, the species commonly forms large aggregations near high relief bottom features such as prominent coral heads, ledges, caves, wrecks and patch reefs, and at night, disperses to forage on benthic organisms, primarily crustaceans and fish.

Lutjanids are dioecious (Allen 1985). *L. kasmira* reaches maturity at 12 ■25 cm. Suzuki and Hioka (1979) note that group spawning has been observed in *L. kasmira* in the evening and at night. Males initiate courtship by rubbing and pecking against the body of the female. As other males congregate, they begin an upward spiral ascent, culminating with the release of the gametes near the surface, the authors state. Mizenko (1984) found that spawning events occur with a lunar periodicity coinciding with full and new moon events over an extended spawning period. In Western Samoa, peak spawning occurs during the autumn and winter months, the author adds.

Egg and Larval Distribution

Very little is known about this species♣s early life history. Suzuki and Hioka describe the eggs as 0.78■0.85 mm, noting that fertilized eggs are buoyant and spherical and contain, a single oil globule. They hatch in approximately 18 hours at 22 to 25^{E} C under controled conditions, the authors add.

Newly hatched lutjanid eggs are typical of other pelagic larvae. They are subject to advection by ocean currents (Munro 1987). Suzuki and Hioka say newly hatched *L. kasmira* larvae measure 1.83 mm in total length and possess a large ellipsoid yolk. Leis (1987) estimates the pelagic larval phase of lutjanids at 25■47 days. It is thought that the pelagic phase of *Lutjanus* spp. is shorter than that of the eteline lutjanids, and size may be a more important factor than age in determining when larval settlement occurs, Leis notes.

Juvenile

Juveniles of this species are known to utilize shallow water habitats such as seaward reefs and sea-grass beds as nursery habitat (Myers 1991; Amesbury and Myers 1982).

Adult

L. kasmira is found widely distributed in the Indo-Pacific region, occurring in a variety of habitat types and depths. Mizenko (1984) found that except during spawning events the *L. kasmira* was segregated by sex, with males dominating the deeper waters of the outer reef slope.

L. kasmira is a nocturnal predator that preys primarily on fish and crustaceans (Parrish 1987, Oda and Parrish 1981, Van der Elst 1981). Rangarajan (1972) reports that the chief prey items of *L. kasmira*, in order of abundance, include teleost fish, crabs, megalopa and prawns. Rangarajan concludes that there is no significant difference in the diets of young and adult fish of this species.

L. kasmira is frequently sold in local markets. In American Samoa it accounts for approximately 11% of the total reported bottomfish landings (WPRFMC 1997). In Hawaii, it is one of the principal species taken in the deep slope handline fishery (Allen 1985). The bulk of the taape landed are taken in state waters (Ralston 1979). In Guam, taape accounted for a little over 3% of the total reported bottomfish landed (WPRFMC 1997). Catch data are not available for this species for in the Northern Mariana Islands. *L. kasmira* is taken primarily by means of handlines, gill nets and traps (Allen 1985).

Essential Fish Habitat: Shallow water bottomfish complex (0■100 m).

L. kasmira is found in a wide range of habitats. It is often found in shallow, near-shore habitats and is commonly found in association with coral reef habitats.

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3.5.11 Habitat description for *Pristipomoides auricilla* (yellowtail snapper, yellowtail kalekale), *P. flavipinnis* (yelloweye snapper, yelloweye opakapaka) and *P. zonatus* (snapper, gindai)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

These three *Pristipomoides,* or snappers, are part of the fish assemblage associated with the rocky deeper reef slopes in the Indo-Pacific region beyond the areas of hermatypic corals. All three species are found in depths ranging from 80 to 300 m, although *P. auricilla* and *P. flavipinnis* are most abundant in the depth range 180■270 m, and *P. zonatus*, between 100 and 200 m. *P. auricilla* and *P. zonatus* are found throughout the western Pacific region, while *P. flavipinnis* is absent from Hawaii.

These three species do not comprise major fractions of bottomfish catches in Hawaii, but *P. zonatus* and *P. auricilla* form about 6% and 20% respectively of commercial bottomfish catches in Guam.

Egg and Larval Distribution

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. Lutjanids eggs typically are less than 0.85mm in size (Leis 1987). They hatch in 17■36 h depending on water temperature.

Clarke (1991), in a larval fish survey conducted off Oahu in the MHI, found eteline snapper larvae were rarely collected, comprising less than 0.5% of the 5,200 fish larvae identified. In this study, eteline snapper larvae were collected exclusively during the late summer and fall.

Very little is known about this species larval life history stage. Newly hatched lutjanid eggs are typical of other pelagic larvae. They have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. Snapper larvae are subject to advection by ocean currents (Munro 1987). Leis (1987) estimated the duration of the pelagic phase of lutjanids at 25■ 47 days. It is thought that the pelagic phase of eteline lutjanids, such as *P. seiboldii*, is longer than that of *Lutjanus* spp, and size may be a more important factor than age in determining when larval settlement occurs in Lutjanids, Leis notes.

Juvenile

Very little is known about the distribution and habitat requirements of this species.

Adult

See ■Life History and General Description• above.

Essential Fish Habitat: Deep-water species complex (100-400). The EFH for *P. auricilla, P. flavipinnis* and *P. zonatus* is shown in Table 15.

Table 21. Habitat description for *Pristipomoides auricilla*, *P. flavipinnis* and *P. zonatus*

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17▪36 h 18 hours	The pelagic larval phase of lutjanids life history last for 25▪-47 days and that size may be a more important factor than age in determining when settlement occurs.	No information available	No information available
Diet	N/A	No information available	No information available	Cconsists primarily of fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods
Distribution: General and Seasonal	Not well documented, widely distributed.	Eteline snapper larvae are more abundant in slope and oceanic waters than over the continental shelf	Very little is known about the distribution and habitat utilization patterns of this species.	All three species are found in depths ranging from 80 to 300 m, although *P. auricilla* and *P. flavipinnis* are most abundant in the depth range 180▪270 m, and *P. zonatus*, between 100 and 200 m. *P. auricilla* and *P. zonatus* are found throughout the western Pacific region, while *P. flavipinnis* is absent from Hawaii.
Water Column	Pelagic	Lutjanid larvae are known to avoid the surface layer during the day. At night, snapper larvae are found more evenly distributed throughout the surface waters.	Demersal	Demersal
Bottom Type	N/A	N/A	No information available	Found over rocky bottoms at depths of 80-300 m
Oceanic Features	Lutjanid eggs are subject to advection by ocean currents	Lutjanid larvae are subject to advection by ocean currents	No information available	No information available

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3.5.12 *Pristipomoides filamentosus* (pink snapper, opakapaka)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Pristipomoides filamentosus is an eteline snapper in the family Lutjanidae. It known by the English common name of pink snapper; in Hawaii, it is known as opakapaka. *P. filamentosus,* is widely distributed throughout the Indo-west Pacific region (Mees 1993, Druzhinin 1970). It is a deepwater species of snapper with a depth distribution of 30▪360 m (Kami 1973, Moffitt 1993). It is a long-lived, slow-growing species, capable of reaching a length of 31.5 inches and an age of 18 years (Moffitt 1993, Waas 1994).

P. filamentosus is one of the most important demersal species of fish managed by the Western Pacific Regional Fishery Management Council (the Council). The Council♣s *1996 Annual Report for the Bottomfish and Seamount Groundfish Fisheries* reports landings for the species were 137,755 lb from the MHI and an additional 76,860 lb from the NWHI●approximately 32% of the total reported BMUS landings in the Hawaiian Islands. The species also commanded the second highest price per pound of any BMUS in Hawaii, the report adds.

While less prevalent, *P. filamentosus* is still an important species in the American Samoa, Guam and the Northern Mariana Islands bottomfish fishery. In Guam, it comprises roughly 3% of the total bottomfish landed, and in terms of price per pound, it is one of the most valuable bottomfish species landed, the 1996 annual report notes. In the Northern Mariana Islands, it comprises an estimated 10% of the total reported bottomfish landings, while in American Samoa, it accounts for less than 1% of the total BMUS species landed.

According to Ralston and Polovina (1982), most of the fishing effort for deepwater bottomfish species occurs in the steep drop-off zone that surrounds the islands and banks of the Hawaiian archipelago; these researchers use the 100-fathom isobath that surrounds an island or bank to estimate the total amount of bottomfish habitat. Uchiyama and Tagami (1983) found that *P. filamentosus* dominated the catch at Necker Island, French Frigate Shoals and Brooks Banks.

Egg and Larval Distribution

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. According to Leis (1987), lutjanids eggs typically are less than 0.85mm in size. They hatch in 17▪36 h depending on water temperature. Pink snapper eggs are small, spherical and pelagic.

Little is known about the larval life of *P. filamentosus*. But the eggs of newly hatched lutjanid, such as *P. filamentosus,* are typical of other pelagic larvae. They have a large yolk-sac, no mouth, unpigmented eyes and limited swimming capabilities. Leis (1987) estimates that the duration of the pelagic phase of lutjanids to range from 25 to 47 days. The pelagic phase of eteline lutjanids is longer than that of *Lutjanus* spp., he notes. Size may be a more important factor than age in determining when larval settlement occurs in lutjanids, Leis adds. Snapper larvae are subject to advection by ocean currents (Munro 1987).

<u>Juvenile</u>

Little is known about the life history and habitat requirements of juvenile *P. filamentosus*. A dense aggregation of juvenile of this species has been found offshore of Kaneohe Bay on the island of Oahu in an area of very low relief, at depths of 65■100 m. This flat, featureless habitat is very different from the high relief areas preferred by adults of the species. While sampling for juvenile snapper was extended beyond the 60■100 target depth, no juveniles were taken outside of this depth range (Moffitt and Parrish 1996). These data demonstrate that at this specific location, juvenile *P. filamentosus* has a strong affinity for a relatively narrow depth range. It is thought that this habitat may provide them the advantage of reduced predation pressure and lessen interspecific competition.

Parrish et al. (1997) suggest that areas of uniform sediment type are an important substrate feature for juvenile *P. filamentosus*. They found a significant correlation between their abundance and clay-silt substrate; they also found significantly lower abundance of these juvenille in areas surrounded by escarpment-type relief than in areas of uniform sediment bottom. The same research found a similar pattern of significantly lower abundance of juveniles in areas of exposed hard substrate.

Juvenile *P. filamentosus* first appear at Kaneohe Bay at a size of about 7■10 cm FL (Moffitt and Parrish 1996). They stay in this habitat for less than a year before moving into deeper waters (150■190 m) as they mature (Parrish et al. 1996). When the juveniles move into deeper water, they are 18■20 cm FL (Moffitt and Parrish 1996). Age-length studies for species indicate a body length of 18 cm length would be obtained by age 1 (DeMartini et al. 1994).

A fishing survey of the MHI has identified only one other area with an aggregation of juvenile *P. filamentosus* similar to the Kaneohe Bay site. Parrish et al. (1997) identified the second site in 1993 off the southwest coast of Molokai. Snapper abundance at this site was found not to be correlated with substrate type. However, there was a significant correlation between juvenile snapper abundance and sources of coastal drainage. At the Kaneohe site, an internal, semi-diurnal tide provides an influx of cold water to the juvenile snapper nursery grounds during high tide (Moffitt and Parrish 1996). Parrish et al. postulate that distribution of juvenile snapper within their preferred habitat type may be more closely related to water flow than sediment particle size. They hypothesize that water flow may enhance the food supplies in these areas. Parrish (1989) reports the diet of juvenile *P. filamentosus* comprises primarily small crustaceans. Other prey items include juvenile fish, cephalopods, gelatinous plankton and fish scale.

The results of a tagging study found that juvenile *P. filamentosus* migrate between deeper daytime locations and shallow nighttime positions (Moffitt and Parrish 1996). This movement, which displayed a crepuscular periodicity, was unrelated to water temperature. The results of this study demonstrated that these juvenile pink snapper were more active during the day than night.

Based on video abundance data, Parrish et al. (1997) calculated a mean estimated density of 6.6 km^2 for ■non-premium• habitat. They applied this number to all of the available habitat at the 60■90 m depth range in the MHI (2,600 km^2) and came up with an estimate of 17,200 individuals. This estimate is only 15% of the 115,600■189,200 juvenile snappers, back-calculated from commercial catch data, needed to sustain the current level of landings in the MHI for this species of pink snapper, the authors note.

It is not known how widespread the preferred habitat of juvenile *P. filamentosus* is in the waters of Hawaii. Surveys suggest that it represents only a small fraction of the total habitat at the appropriate depths (Parrish et al. 1997). Areas of flat featureless bottom have typically been thought of as providing low value fishery habitat. The discovery of dense juvenile snapper aggregations in areas of very low relief provides substantial evidence to the contrary. This fact has important management implications for the conservation and protection of this critical and limited habitat type. More research is needed to help identify, map and study nursery habitat for juvenile *P. filamentosus*.

Adult

Adult *P. filamentosus* are found on the steep slopes and deepwater banks of Pacific islands. They aggregate near areas of high bottom relief (Parrish 1987). Large mixed groups of snappers (50■100), including *P. filamentosus*, have been observed aggregating 2■10 m above high relief structures on Penguin Bank (Haight 1989). Moffitt (1993) reports that some species of deepwater snappers, such as *P. filamentosus*, are not be restricted to high relief, deep-slope habitat. During the day, individuals of this species are found in areas of high relief at depths of 100■200 m; during the night, these individuals migrate into shallower flat, shelf areas, where they are found at depths of 30■80 m, Moffitt observes. Areas of high relief form localized zones of turbulent vertical water movement that increase the availability of prey items (Haight et al. 1993). Ralston et al. (1986) found higher densities of *P. filamentosus* on the up-current side vs. the down-current side of Johnston Atoll.

Haight (1989) studied the trophic relationships, density and habitat associations of deepwater snappers (Lutjanidae) on Penguin Bank. Based on the observations of the manned submersible and ROV surveys, maximum densities were calculated of 1.37 fish/m^2 and 1.24 fish/m^2 for snapper (Haight 1989). During the manned submersible dives, a mean encounter rate of 0.035 fish/m^2 was observed .*P. filamentosus* occur in progressively shallower waters (103 m) in the more northern reaches of the NWHI (Humphreys 1986).

The diets of deepwater snappers, such as *P. filamentosus*, are poorly understood. Parrish (1987) includes pelagic tunicates, fish, shrimp, cephalopods, gastropods, planktonic urochordates and crabs as prey items and reports that snappers feed mostly at night and forage over a wide area. Haight (198(9) characterizes *P. filamentosus* as a crepuscular feeder, displaying two peak foraging periods, shortly before dawn and shortly after sunset; he also found the species to display a seasonal variation in its diet.

The depths at which snappers feed are not well documented. According to Parrish (1987), *P. filamentosus* feed primarily at depths of greater than 100 m and stay within several m of the bottom, but little is known about the type of substrate where they feed. Haight (1989) found the greatest catch per unit effort (CPUE) for *P. filamentosus* on Penguin Bank at depths of between 100 and 150 m. Moffitt (1993) observed a diurnal migration from areas of high relief at depths of 100■200 m during the day to shallow flat shelf areas at depths of 30■80 m at night.

Female of this species reach maturity at a length of 42.7 cm and have a protracted spawning period of seven months (June■December) that peaks in August (Kikkawa 1983).

<u>Essential Fish Habitat</u>: Deep-water species complex (100-400)

Table 22. Habitat Description for *Pristipomoides filamentosus* (pink snapper, opakapaka)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17-36 h. incubation time depending on species and water temperature (Leis, 1987)	Leis (1987) reports pelagic phase of lutjanids life history last for 25-47 days. Size may be a more important factor than age in determining when settlement occurs (Leis 1987). Size at settlement varies widely among species and ranges from 10▪50 mm	10 months of age (7▪10 cm FL) -- 17 month (18▪25 cm FL) (Haight et al. 1997).	17 months▪18 years (need to confirm) Haight et al. (1993) reports the age of entry into the fishery as 2 to 3 years after settlement
Diet	N/A	No information available	Small crustaceans, juvenile fish, cephalopods gelantinous plankton, fish scale	Prey items include: pelagic tunicates, fish, shrimp, cephalopods gastropods, planktonic urochordates, crabs
Distribution General and Seasonal	***P. filamentosus*** spawn from June to December.	In Hawaii Pristipimoides larvae were found in August▪October. Most species of lutjanid larvae are less abundant in winter	Juvenile opakapaka appear during fall and early winter months (Haight et al. 1993).	*P. filamentosus* migrate diurnally from areas of high relief during the day at depths of 100▪200 m, to shallow (30▪-80 m) flat shelf areas at night (Moffitt 1993)
Location	Lutjanids are generally more abundant over the continental shelf waters	Eteline snapper larvae are more abundant in slope and oceanic waters than over the continental shelf (Leis 1987)	Bottom; 65▪100 m	Bottom; 30▪343 m.
Water Column	N/A	Pelagic: lutjanids larvae display diurnal vertical migrations in water column (Leis 1987); lutjanids larvae▴s abundance has been shown to increase with depth during the day (Leis 1987).	Demersal	
Bottom Type		N/A	Low relief , current flow, clay silt	Areas of high relief, (e.g., steep slope and pinnacles)
Oceanic Features		Snapper larvae are subject to advection by ocean currents (Munro 1987)	It is thought that distribution of juvenile snapper within its preferred habitat type may be closely related to water flow.	Areas of high relief form localized zones of turbulent vertical water movement. Higher densities of *P. filamentosus* have been found on the up-current side of Johnston Atoll

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3.5.13 Habitat description for *Pristipomoides sieboldii* (pink snapper, kalekale)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Pristipomoides sieboldii is a member of the family Lutjanidae. Within the family Lutjanidae there are four subfamilies including the Etelinae, in the which the genus *Pristipomoides* is found. The English common name of this species is pink snapper. In Hawaii it is known as kalekale while in Guam and the Northern Mariana Islands it is called guihan boninas.

There are 15 known species in the genus *Pristipomoides* in the Indo-Pacific region. According to Allen (1985), individuals of this genus are typically found singularly or in small groups, and members of *P. seiboldii* are found over rocky bottoms at depths of 180 to 360 m throughout the tropical Indo-Pacific region from East Africa to Hawaii and as far north as southern Japan.

P. sieboldii is taken primarily with handlines and bottom longlines (Allen 1985). According to the *1996 Annual Report of Bottomfish andSeamount Groundfish in the Western Pacific,* the species is commonly taken in the MHI offshore handline fishery. Most of the fishing effort for deepwater bottomfish species occurs in the steep drop-off zone that surrounds the islands and banks of the Hawaiian archipelago (Ralston and Polovina 1982). However, as noted in the bottomfish FMP, *P. sieboldii* is infrequently taken in American Samoa, Guam and the Northern Mariana Islands, based on the available landing data.

Egg and Larval Distribution

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. Lutjanids eggs typically are less than 0.85mm in size (Leis 1987). They hatch in 17▪36 h depending on water temperature.

In a larval fish survey conducted off Oahu in the MHI, Clarke (1991) found eteline snapper larvae were rarely collected, comprising less than 0.5% of the 5,200 fish larvae identified. In this study, eteline snapper larvae were collected exclusively during the late summer and fall.
Very little is known about this species♣s larval life history stage. Newly hatched lutjanid eggs are typical of other pelagic larvae. They have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. Leis (1987) estimates the duration of the pelagic phase of lutjanids at 25▪47 days and believes that the pelagic phase of eteline lutjanids, such as *P. sieboldii,* is longer than that of *Lutjanus* spp. However, he notes that size may be a more important factor than age in determining when larval

settlement occurs in lutjanids. Munro (1987) says snapper larvae are subject to advection by ocean currents.

Juvenile

Very little is known about the distribution and habitat requirements of this species. In the Hawaiian Islands, schools of several hundred juvenile *P. sieboldii* have been observed along the Oahu♣s north shore (Kelley C. 1998. pers. comm).

No information concerning the diet of juvenile *P. sieboldii* is available. Parrish (1989) found the diet of juvenile *P. filamentosus*, another eteline snapper, to consist primarily of small crustaceans. Other prey items included juvenile fish, cephalopods, gelatinous plankton and fish scales.

Adult

P. sieboldii♣s maximum size is commonly about 40 cm but can reach to approximately 60 cm (Allen 1985).

The diets of deepwater snappers, such as kalekale, are poorly understood (Parrish 1987). The diet of adult *P. sieboldii* consists primarily of fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods (Allen 1985). The depths at which snappers feed are not well documented. Parrish (1987) reports that snappers feed mostly at night and forage over a wide area.

Essential Fish Habitat: Deep-water species complex (100-400 m). The EFH for *P. seiboldii* is shown in Table 23.

Table 23. **Habitat description for *Pristipomoides sieboldii* (pink snapper, kalekale)**

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17▪36 h depending on water temperature	25▪47 days, the pelagic phase of eteline lutjanids, such as *P. sieboldii*, is longer than that of *Lutjanus* spp. Size may be a more important factor than age in determining when larval settlement occurs in lutjanids.	No information available	No information available
Diet	N/A	No information available	No information concerning the diet of juvenile *P. sieboldii* is available	The diet of adult *P. sieboldii* consists primarily of fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods
Distribution: General and Seasonal	Widely distributed throughout range	Widely distributed throughout range	No information	*P. seiboldii* are found over rocky bottoms at depths of 180 to 360 m throughout the tropical Indo-Pacific region from East Africa to Hawaii and as far north as southern Japan.
Water Column	pelagic	pelagic	demersal	demersal
Bottom Type	N/A	N/A	No information available	rocky bottoms at depths of 180 to 360 m throughout the tropical Indo-Pacific region
Oceanic Features	Eggs are subject to advection by ocean currents	Snapper larvae are subject to advection by ocean currents	No information available	No information available

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3.5.14 Habitat description for *Variola louti* (lunartail grouper)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Variola louti is a member of the family Serranidae, the groupers. *V. louti* is one of only two species of the genus *Variola.* It is the more common of the two genuses (Heemstra and Randall 1993). The English common name of this species is the lunartail grouper. In American Samoa it is known as papa. In Guam and the Northern Mariana Islands it is known as bueli.

Heemstra and Randall (1993) describes *V. louti*♣s distribution as being throughout the tropical Indo-Pacific region from the Red Sea to South Africa to the Pitcairn Islands. In the western Pacific, it ranges southern Japan to New South Wales, Australia, and is found at most of the islands of the west central Pacific, the authors continue. *Variola louti* is absent from the Hawaiian Islands.

According to Heemstra and Randall, the lunartial grouper is commonly found on coral reefs at depths of 4 to 200 m. The species seems to prefer clear water areas typical of offshore reefs and islands and is normally found swimming up in the water column well above the reef, the authors note.

V. louti are reported to reach maturity between 81 cm and 100 cm in length (Van der Elst 1981, Heemstra and Randall 1993) and 12 kg in weight (Postel et al. 1963).

Very little is known about the spawning behavior of this species. One study found mature females at 33 cm standard length (Morgans 1982). Research has documented spawning activity between December and February (Heemstra and Randall 1993).

According to Heemstra and Randall, lunartail grouper is an important food fish in artisanal fisheries throughout the Indo-Pacific region, even though it is known to often be the cause of ciguatera poisoning.

Egg and Larval Distribution

Heemstra and Randall describe the fertilized eggs as pelagic, spherical and transparent and 0.70▪1.20 mm in diameter with a single oil globule 0.13▪0.22 mm in diameter. Based on the available data the length of the pelagic larval stage of groupers is 25▪60 days. The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase, the authors note.

Heemstra and Randall calculate that the transformation of pelagic serranid into benthic larvae takes place between 25 mm and 31 mm TL. The serranid larvae are distinguishable by their ■kite-shaped• bodies and highly developed head spination, the authors point out.

Juvenile

The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools. There is no specific information available for the habitat utilization patterns of juvenile *V. louti*

Adult

Heemstra and Randall describe goupers as typically ambush predators, hiding in crevices and among coral and rocks in wait for prey. *V. louti* feeds primarily on fishes (particularly coral-reef species), crabs, shrimps and stomatopods, with adults reportedly feeding during both daylight and nighttime hours, the authors add.

Essential Fish Habitat: Shallow-water species complex (0-100). The EFH for *V. louti* is shown in Table 24.

Table 24. Habitat description for *Variola louti* (lunartail grouper)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Serranid eggs incubate in 20-35 days	The pelagic larval stage of groupers is 25▪60 days	*V. louti* are reported to reach maturity between 81 cm and 100 cm in length	No information available
Diet	N/A	N/A	No information available	*V. louti* feeds primarily on fishes (particularly coral-reef species), crabs, shrimps and stomatopods
Distribution: General and Seasonal		The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase	The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools. There is no specific information available for the habitat utilization patterns of juvenile *V. louti*	Distributed throughout the tropical Indo-Pacific region from the Red Sea to South Africa to the Pitcairn Islands. In the western Pacific, it ranges southern Japan to New South Wales, Australia, and is found at most of the islands of the west central Pacific. *Variola louti* is absent from the Hawaiian Islands.
Water Column	pelagic	pelagic	demersal	demersal
Bottom Type	N/A	N/A	No information available	Commonly found on coral reefs at depths of 4 to 200 m.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	No information available	No information available

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3.5.15 Habitat description for *Beryx splendens* (alfonsin)

Management Plan and Area: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

The alfonsins (Berycidae), typically bright red in coloration, are fairly large fish. The family consists of two genera, *Beryx and Centroberyx* (Mundy, 1990).

Alfonsin inhabit rocky bottom habitats at depths of several hundred meters (Seki and Tagami, 1986; Masuda et al., 1975). The distribution of the alfonsin is widespread in the tropical and subtropical waters of the Pacific, Indian and Atlantic oceans (Busakhin, 1982). In the Pacific northern hemisphere, alfonsin are found primarily in two areas, over the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts in the central Pacific and from Japan to Palau in the western Pacific. In the central Pacific, alfonsin are found over seamounts while in the western Pacific region they are also found over continental shelf areas (Humphreys et al., 1984). Over the SE-NHR seamounts their distribution overlaps with that of the pelagic armorhead (*Pseudopentaceros wheeleri*). Most of the available information about the biology and life history of alfonsin come from studies done in the South Pacific and a few Russian studies from the Atlantic. Alfonsin occupies a wide depth range from 10 to 1240 m (Lehodey and Grandperrin, 1995; Massey and Horn, 1990).

Based on examination of otoliths, Lehodey and Grandperrin (1996) calculated a maximum age of 16.8 years for a female of 56.7 cm (FL). The average size of alfonsin captured at the Hancock seamounts in the SE-NHR region ranges from 15.3 to 35.3 cm (FL) (Uchida, 1986).

In the South Pacific, females reportedly grow faster than males, the difference increasing with age (Lehodey and Grandperrin, 1994). At the Hancock seamounts, the sex ratio is nearly equal (Humphreys et al., 1983). In the South Pacific, Alfonsin reaches sexual maturity at 6 years of age for females and at 7 to 8 years for males; approximately 33 to 34 cm respectively for females and males (Lehodey and Grandperrin, 1996; Mundy, 1990). In the western Pacific, alfonsin reportedly reach sexual maturity by age three (Ikenuye, 1969). Alfonsin spawns between August and October in the Hancock seamount region (Mundy, 1990). The pelagic eggs hatch approximately 1 day after spawning (Uchida, 1986)

Tagging studies conducted by Japanese researchers indicate that alfonsins migrate form coastal to offshore waters as they mature. Alfonsins become demersal at one year of age or less (Uchida, 1986)

In the past, a large-scale foreign seamount groundfish fishery extended throughout the southeastern reaches of the northern Hawaiian Ridge. A collapse of the seamount groundfish stocks has resulted in a greatly reduced yield in recent years. Alfonsin are taken primarily by means of bottom trawls. While it is the second most abundant species taken in the seamount groundfish fishery it comprises only a small portion of the total catch (Seki and Tagami, 1986). Much of the demersal habitat on the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts is too steep and rough for bottom trawling. In the past, the principal gear used in the harvest of alfonsin by the Japanese was bottom longlines and handlines (Seki and Tagami, 1986).

Although a moratorium on the harvest of the seamount groundfish within the EEZ has been in place since 1986, no substantial recovery of the stocks has been observed. Historically, there has been no domestic seamount groundfish fishery.

Egg and larval distribution

Although alfonsin are commercially important species little is known about their early life history. As previously mentioned the eggs of the alfonsin are pelagic and hatch in about 1 day after spawning. The larvae are planktonic for the first 2 to 3 days of existence after which time they begin to swim (Uchida, 1986). The dispersal of eggs and larvae is determined by the prevailing currents (Humphreys et al., 1983).

Larvae

At the Hancock seamount *Beryx* larvae have been found almost exclusively in the upper 50 m of the water column. Larvae are nearly twice as abundant in the upper 25 m than between the 25 to 50 m (Mundy, 1990).

Juvenile distribution

Juveniles undergo a pelagic development phase that lasts several; months. Recruitment to benthic habitat takes place at approximately 1.5 years of age. (Lehodey and Grandperrin 1994). Juveniles inhabit shallower water than do adults, moving into progressively deeper waters as they grow and mature (Seki and Tagami, 1986).

Galaktionov (1984) studied the schooling behavior of juvenile alfonsin. He found that during midday juveniles were concentarted on the bottom. Between 1700 and 1800 hours school formation occurs relatively rapidly. The schooled juveniles move into shallower water at depths as shallow as 75 m around sunset.

Adult distribution

The alfonsin is a bentho-pelagic species, migrating to the surface at night to feed returning to the bottom during the day (Lehodey and Grandperrin, 1994). Galaktionov (1984) reports that adult alfonsin form dense schools from 1000 to 1100 hours and from 1600 to

1700 to hours. The fish school while at or near the bottom and slowly migrate upward through the water column.

Food habit studies indicate that small fish dominate this species diet. Other prey items include small crustaceans including decapods, euphausiids, krill and mysids (Uchida, 1986). Alfonsin are believed to prey primarily on bathypelagic organisms, with benthic prey contributing little to its diet (Lehodey and Grandperrin, 1994). In turn, alfonsin are preyed upon by large pelagic predators, including tuna.

In the western Pacific region, the abundance and distribution of alfonsin is dependent on the prevailing currents, particularly the Kuroshio (Uchida, 1986). Size increases with depth and latitude (Uchida, 1986). Sekli and Tagami (1986) report an optimum temperature range for this species of 6E to 18E C.

Essential Fish Habitat: Seamount groundfish complex. The EFH for *B. splendens* is shown in Table 25.

The EFH designation for the adult life stage of the seamount groundfish complex is all EEZ waters and bottom habitat bounded by latitude 29E-35EN and longitude 171EE-179EW between 80 to 600 m. EFH for eggs, larvae and juveniles is the epipelagic zone (~ 200 m) of all EEZ waters bounded by latitude 29E-35EN and Longitude 171EE-179EW.

Table 25. Habitat description for *Beryx splendens* (alfonsin)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Eggs hatch approximately 1 day after spawning	The larvae are planktonic for the first 2 to 3 days of existence after which time they begin to swim.	Alfonsin reaches sexual maturity at 6 years of age for females and at 7 to 8 years for males; approximately 33 to 34 cm respectively for females and males	16.8 years for a female of 56.7 cm
Diet	N/A	No information available	No information available	Small fish dominate this species diet. Other prey items include small crustaceans including decapods, euphausiids, krill and mysids
Distribution: General and Seasonal	No information available	No information available	Alfonsins migrate form coastal to offshore waters as they mature	The distribution of the alfonsin is widespread in the tropical and subtropical waters of the Pacific. In the Pacific northern hemisphere, alfonsin are found primarily in two areas, over the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts in the central Pacific and from Japan to Palau in the western Pacific.
Water Column	Pelagic	Pelagic, At the Hancock seamount *Beryx* larvae have been found almost exclusively in the upper 50 m of the water column. Larvae are nearly twice as abundant in the upper 25 m than between the 25 to 50 m	Pelagic, Juveniles undergo a pelagic development phase that lasts several; months. Recruitment to benthic habitat takes place at approximately 1.5 years of age. Juveniles inhabit shallower water than do adults, moving into progressively deeper waters as they grow and mature	Demersal, Alfonsin occupies a wide depth range from 10 to 1240 m
Bottom Type	N/A	N/A	N/A	Alfonsin inhabit rocky bottom habitats at depths of several hundred meters. In the central Pacific, alfonsin are found over seamounts while in the western Pacific region they are also found over continental shelf areas
Oceanic Features	The dispersal of eggs is determined by the prevailing currents	The dispersal of larvae is determined by the prevailing currents	The abundance and distribution of alfonsin is dependent on the prevailing currents, particularly the Kuroshio	The abundance and distribution of alfonsin is dependent on the prevailing currents, particularly the Kuroshio

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3.5.16 Habitat description for *Hyperoglyphe japonica* (ratfish, butterfish)

Management Plan and Area: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

There is no information available concerning the life history and basic biology of the ratfish. This species is infrequently taken as an incidental species in conjunction with the seamount groundfish fishery.

3.5.17 Habitat description for *Pseudopentaceros wheeleri* (armorhead)

Management Plan and Area: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Boehlert and Sasaki (1988) and Humphreys et al. (1983) were the primary sources used in the preparation of this species profile.

The pelagic armorhead (*Pseudopentaceros wheeleri*) is widely distributed throughout the North Pacific Ocean (Boehlert and Sasaki, 1988). Electrophoretic and meristic work suggests that a single stock of pelagic armorhead exists (Humphreys et al., 1983). Oceanographic conditions seem to be the primary factor regulating the armorhead♣s distribution. Zones of upwelling, produced by the prevailing currents, result in high biological productivity over the Southern Emperor-Northern Hawaiian Ridge (SE-NHR) seamounts (Pontekorvo, 1974 in Humphreys et al.,1983). The life histories and distributional patterns of the armorhead are poorly understood as is the effects of oceanographic variability on migration and recruitment of the armorhead.

The pelagic armorhead has two distinct life history phases that includes a pelagic juvenile phase and a demersal adult phase (Somerton and Kikkawa, 1992). Between 1.5 and 2.5 years of age, the pelagic armorhead inhabits the epipelagic zone of the subarctic-transitional waters of the North Pacific during a lengthy pre-recruit phase (Humphreys, 1995; Somerton and Kikkawa, 1992). During this time the fish remain nonreproductive. Subsequently, these fish recruit to demersal habitat on the SE-NHR seamounts. Humphreys et al. (1983) report that adults are found on the slopes of seamounts down to depths of 800 to 900 m. The commercial fishery for pelagic armorhead targets fish on the summits of seamounts at the 200 to 490 m depth range (Humphreys et al., 1983; Takahashi and Sasaki, 1977)

The smallest reported sizes for pelagic armorhead range from 5 to 20 mm and typically occurred south of 33 NE (Humphreys et al., 1984). Research indicates an age estimate of 3 years for 22 cm fork length (FL) and 6 years for 32 cm fork length (Humphreys et al., 1983). Based on length frequency data, it is believed that fish taken by the trawl fishery are typically 5 to 7 years of age (Chikuni, 1970 in Humphreys et al., 1983). Females are slightly larger than males.

Adult pelagic armorhead have three distinct morphological types: ■lean type•, ■intermediate type• and ■fat type•. While all three types are found over the SE-NHR seamounts, the lean and intermediate types predominate. The epipelagic phase of the armorhead life history is characterized by the accumulation of fat reserves and continuous somatic growth (Humphreys et al., 1989). The bluish mottled coloration of the open ocean fat type is indicative of its epipelagic existence. The open ocean fat type is nonreproductive. After recruitment to the summits of the SE-NWR seamounts, newly settled adults rapidly lose their mottled bluish coloration, ultimately assuming a brownish coloration. This transformation is fairly rapid and explains the relatively low abundance of fat type on the seamounts. Somatic growth ceases and the fat reserves are depleted as the fish become reproductively active. These physiological changes result in the intermediate morphological type and ultimately the lean type as the fat reserves are further depleted (Humphreys et al., 1989). The existence of these distinct morphological types are absent in juveniles. (Humphreys et al., 1983).

The main reproductive population is found on SE-NHR seamounts between latitude 29E and 35E N. (Boehlert and Sasaki, 1988). Spawning activity is benthic and is restricted to December to February at the SE-NHR seamounts.(Humphreys, 1995). Peak spawning activity occurs between January and February (Humphreys et al., 1983). Research indicates that armorhead reach sexual maturity at 1.5 to 2.5 years in age, ranging in size from 23.0 to 28.5 standard length (Boehlert and Sasaki, 1988). Spawning occurs at depths ranging from 200 to 500 m (Boehlert and Sasaki, 1988). It is thought that *P. wheeleri* is semelparous, spawning only once before dying.

Eggs, larvae and juveniles are pelagic and are found widely distributed in the North Pacific Ocean (Boehlert and Sasaki, 1988). Initially the larvae are found in the epipealgic waters in the vicinity of the SE-NHR seamounts (Humprheys et al., 1993). The larvae are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean (Humphreys et al., 1993). Boehlert and Sasaki (1973) report a 1.5 to 2.5 year time period between spawning and recruitment to the seamounts. The process by which these fish return and recruit to the seamounts is poorly understood (Humphreys et al., 1993). It is thought that recruitment occurs only during the late spring to midsummer months. The long pelagic phase combined with the variability of oceanic conditions play an important role in determining the strength of year-classes in this species (Boehlert and Sasaki, 1988). The size of individuals at recruitment is generally uniform, ranging from 25 to 33 cm (Humphreys et al., 1989).

In the past, a large-scale foreign seamount groundfish fishery extended throughout the southeastern reaches of the northern Hawaiian Ridge. The seamount groundfish complex consists of three species (pelagic armorhead•s, alfonsins, and ratfish). These species dwell at 200 to 600 m on the submarine slopes and summits of seamounts. A collapse of the seamount groundfish stocks has resulted in a greatly reduced yield in recent years. Although a moratorium on the harvest of the seamount groundfish within the EEZ has been in place since 1986, no substantial recovery of the stocks has been observed. Historically, there has been no domestic seamount groundfish fishery.

Egg and larval distribution

The egg, larval and juvenile stages of the pelagic armorhead all occur in the surface layers where they are subject to advection by the prevailing currents (Humphrey et al., 1984; Borets, 1979).

Larval and juvenile stages prey on zooplankton. Interannual variability in environment conditions affecting the abundance and availability of zooplankton may play an important role in the survival of these early life stages and thus year class strength (Boehlert and Sasaki, 1988).

Larvae of *P. wheeleri* are neustonic and are carried eastward by the prevailing wind driven surface flow in the SE-NHR seamount region (Boehlert and Sasaki, 1988). Through some unknown mechanism, fish move northeastward ultimately entering the subarctic waters of the Alaska gyre (Boehlert and Sasaki, 1988). The two available studies of larval distribution of armorhead conflict but suggest that the distribution of larvae varies from year to year (Boehlert and Sasaki, 1988).

Juvenile distribution

As stated, during the first 1.5 to 2.5 years of life, juveniles lead a pelagic existence, inhabiting the epipelagic zone of the subarctic-transitional waters of the North Pacific Ocean (Somerton and Kikkawa, 1992). Subsequently, a shift occurs from pelagic to demersal habitat. During the pelagic juvenile phase, armorhead acquire large reserves of fat before recruiting to SE-NHR seamounts. The largest influx of juvenile recruits to the Juveniles recruit to the SE-NHR seamounts occurs during spring between April and June (Humphreys, 1995). Recruits are characterized by their bluish to grey coloration and their fat reserves. After recruitment, the fish gradually assume a brownish coloration. The diet of juveniles is comprised primarily of small plankktonic prey items, particularly copepods (Borets, 1979).

Adult distribution

As stated, adults are found on the slopes of seamounts. *P. wheeleri* display crespuscular migrations through the water column. During daylight hours, they are found in the upper water column at depths between 80 to 100 m. As dusk approaches they descend to the summits of the seamounts. It is thought that these movements are related to foraging activity (Humphreys et al., 1983). At night, dense aggregations of armorhead are found on the summits of the seamounts (Somerton and Kikkawa, 1992).

The pelagic armorhead feeds during daylight hours, especially between the hours of 0800 and 1000. (Humphreys et al., 1983; Sakiura, 1972). Prey items include epipelagic crustaceans, copepods, amphipods, tunicates,eupausiids, pteropods, sergestids, myctophids, macrura and mesopelagic fish. Organisms of the deep scattering layer also comprise a portion of this species diet (Humphreys et al., 1983; Sakiura, 1972).

It is believed that the horizontal and vertical distribution of *P. wheeleri* is controlled by water temperature. The lower tolerance limit is approximately 5 CE while the upper limit is roughly 20 CE. It is thought that the preferred temperature range of this species is 8 to 15 CE (Humphreys et al., 1983; Chikuni, 1971). Pelagic armorhead are found year-round on the southern Emperor-Northern Hawaiian Ridge seamounts.

The life expectancy of the armorhead once it has recruited to demersal habitat ranges from 4 to 5 years.

<u>Essential Fish Habitat</u>: Seamount groundfish complex. The EFH for *Pseusopentaceros wheeleri* is shown in Table 26.

The EFH designation for the adult life stage of the seamount groundfish complex is all EEZ waters and bottom habitat bounded by latitude 29E-35EN and longitude 171EE-179EW between 80 to 600 m. EFH for eggs, larvae and juveniles is the epipelagic zone (~ 200 m) of all EEZ waters bounded by latitude 29E-35EN and Longitude 171EE-179EW.

Table 26. Habitat description for *Pseudopentaceros wheeleri* (armorhead)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	No information available	No information available	Fish recruit to demersal habitat Between 1.5 and 2.5 years of age	The life expectancy of the armorhead once it has recruited to demersal habitat ranges from 4 to 5 years
Diet	N/A	Larval stages prey on zooplankton	Juvenile stages prey on zooplankton	Prey items include epipelagic crustaceans, copepods, amphipods, tunicates,eupausiids, pteropods, sergestids, myctophids, macrura and mesopelagic fish.
Distribution: General and Seasonal	Eggs are found in the epipealgic waters in the vicinity of the SE-NHR seamounts	Initially the larvae are found in the epipealgic waters in the vicinity of the SE-NHR seamounts	The pelagic armorhead inhabits the epipelagic zone of the subarctic-transitional waters of the North Pacific during a lengthy pre-recruit phase	The pelagic armorhead (*Pseudopentaceros wheeleri*) is widely distributed throughout the North Pacific Ocean
Water Column	pelagic	pelagic	pelagic	Demersal, During daylight hours, they are found in the upper water column at depths between 80 to 100 m. At night, dense aggregations of armorhead are found on the summits of the seamounts
Bottom Type	N/A	N/A	N/A	Adults are found on the slopes of seamounts down to depths of 800 to 900 m
Oceanic Features	The eggs are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean	The larvae are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean	Oceanographic conditions seem to be the primary factor regulating the armorhead's distribution.	Oceanographic conditions seem to be the primary factor regulating the armorhead's distribution.

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4. CORAL REEF ECOSYSTEM MANAGEMENT UNIT SPECIES

4.1 Currently Harvested Coral Reef Taxa

4.1.1 Surgeonfish (Acanthuridae)

The surgeonfishes are one of the most prominent groups of reef-dwelling fishes in the tropical Indo-Pacific. They are important food fish on many Pacific islands, where they are typically caught by spearfishing or nets. In recent catch data (1991-1995) for Hawaii, 6 of the top 25 inshore species by weight were acanthurids (Friedlander 1996).[1] In American Samoa, Acanthuridae compose 28% of the reef fish catch (Dalzell et al. 1996), and over 40% of the catch composition by weight in the 1994 artisanal fishery was surgeonfishes. Some species are also sought after for the aquarium trade; those are discussed further as part of a separate management unit species assemblage.

There are no species of surgeonfish endemic to any of the management areas considered in this plan, although *A. triostegus sandvicensis* in Hawaii is recognized as an endemic subspecies. Also, *Zebrasoma flavescens* has a distribution from the North Pacific to southern Japan, but it is abundant only in Hawaii. Twenty-three species of surgeonfish are found in Hawaii (Randall 1996), 39 species in Micronesia (Myers 1991), and 32 species in Samoa .

Generally, acanthurids are diurnal herbivores or planktivores. All acanthurids shelter on the reef at night. *Acanthurus thompsoni, Naso annulatus, N. brevirostris, N. caesius, N. hexacanthus,* and *N. maculatus* feed primarily on zooplankton well above the bottom. *Naso lituratus* and *naso unicornis* browse mainly on leafy algae such as *Sargassum* (Randall 1996).

Surgeonfishes commonly defend territories that are primarily feeding territories; among three different species studied (*Acanthurus lineautus, A. leucosternon,*and *Zebrasoma scopas*), it was noted that each occupied characteristic depth zones and habitat types (Robertson et al. 1979).

Schooling behavior is common in acanthurids, particularly in association with spawning aggregations. Biologists have documented trains of surgeonfishes traveling along the reef to join thousands of other surgeonfish at spawning aggregation sites. Once there, the fish mingle near the substrate and slowly move upward as a group. Near dusk, small groups (6-15 individuals) of fish make spawning rushes to near the water surface and release gametes. Following spawning, fish return to the substrate, form trains, and return to their home reefs. Many species also form large single-species or mixed-species schools, apparently for overwhelming territorial reef fish to feed on the algal mats they are protecting. In *Acanthurus nigrofuscus*, for example, such schools may number in the thousands, and the

[1]*A . dussumieri*-32,407 lbs, *A. triostegus*-11,705 lbs, *Naso* spp.-9969 lbs, *A. xanthopterus*-5,234 lbs, *A. olivaceous*-4,813 lbs, and *Ctenochaetus strigosus*-3,776 lbs .

fishes may migrate as much as 500 to 600 m daily to reach the feeding grounds (Fishelson et al. 1987).

Acanthurid eggs are pelagic, spherical, and small, 0.66-0.70 mm in diameter with a single oil droplet to 0.165 mm for *Acanthurus triostegus sandvicensis* (Randall 1961). For that species, hatching occurred in about 26 hours. Watson and Leis (1974) found an egg size of 0.575 to 0.625 mm in diameter for an unidentified acanthurid from Hawaii. Like other coral reef fishes, surgeonfish larvae are typically less abundant in samples taken from the water column near the reef than they are in samples from offshore (Miller 1973). Surgeonfish larvae are primarily found well offshore at depths from 0-100m.

Although surgeonfish generally settle at a larger size than most reef fish, acanthurids are one of the families with juveniles that settle with larval characters still present (Leis & Rennis 1983). Late phase larvae actively swim inshore at night, seek shelter in the reef, and begin the transformation to juveniles (Clavijo 1974). Juvenile surgeonfish have been reported to shelter in tide pools in Hawaii (Randall 1961).

Adult surgeonfish are found in many coral reef habitat types, including mid-water, sand patch, subsurged reef, and seaward or surge zone reef. The largest number of surgeonfish species are typically found in the subsurge reef habitat, which are defined by Jones (1968) to be areas of moderate to dense coral growth corresponding to the subsurge portions of fringing reefs, deepwater reef patches, reef filled bays, and coral-rich parts of lagoons inside of atolls. These species are typically found between 0-30m depth, although surgeonfish do live in depths from 0-150m. Some species of *Naso* have been seen below 200m (Chave & Mundy 1994).

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Acanthurid assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section II. A.1.

Given the pelagic nature of the egg and larval phases of acanthurids, and their subsequent wide distribution, EFH for these life stages of this management unit is designated as extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm. For juvenile and adult acanthurids, because of their varied habitat preferences, EFH is designated as all bottom habitat and the adjacent water column from 0 to 50 fm.

4.1.2 Triggerfish (Balistidae)

The triggerfishes are named for an ability to lock their large, thickened first dorsal spine in an upright position, which can be released only by pressing down on the second dorsal spine (the trigger). When alarmed, or at night, they wedge themselves into a hole in the reef or rocks by erecting the first dorsal spine and pelvic girdle. During the day, most are carnivores of a wide variety or benthic animals including crustaceans, mollusks, sea urchins, other echinoderms, coral, tunicates, and fishes. Some feed largely on benthic algae and zooplankton, including *M. niger* and *M. vidua*, while *Xanthichthys auromarginatus* and *X. mento* feed mainly on zooplankton. Triggerfishes are usually solitary except when they form pairs at spawning time, although the black durgon, *Melichthys niger* may form large aggregations. Eleven species are known from the Hawaiian Islands. At least 20 species occur in Micronesia, and at least 16 species occur in Samoa. The range of the family is circumglobal, with some species (e.g., the clown triggerfish, *Balistoides conspicillum*) extending into temperate waters (to South Hokkaido, Japan [Myers 1991]).

The habitat preferences for the family are variable, and may include protected lagoons, high-energy surge zones, ledges and caves of steep dropoffs, sand bottoms, and rocky coral areas (Myers 1991). Preferences may vary from species to species, or may change within a given species depending on the life phase. Of the eleven known Hawaiian species, one (*Canthidermis maculatus*) is strictly pelagic (Randall 1996), rather than reef-associated (and is thus not considered as part of this management unit assemblage). Depth preferences are also variable. Some species frequent the shallow subtidal zone, while others are known only from fairly deep waters (e.g., *Xanthichthys caeruleolineatus*, 75-200 m; Myers 1991). Many species are collected for aquariums; the clown triggerfish *Balistoides conspicillum* is among the most highly prized aquarium fishes.

Balistids produce demersal eggs that may or may not be tended by a parent, usually the female. Unlike most other families of reef fishes, the balistids exhibit extensive maternal care of eggs. This could be related to a harem-based social structure that requires the male to vigorously defend his territory from other males. Balistid eggs are spherical, slightly over 0.5 mm in diameter, and translucent. Eggs are typically deposited in shallow pits excavated by the parents as an adhesive egg mass containing bits of sand and rubble. Triggerfish eggs hatch in as little as 12 hours and no more than 24 hours. The pelagic larval stage can last for quite a while, and some species reach a large size before settling to the bottom. Several species of *Melichthys* can reach as much as 144 mm before settling (Randall 1971, Randall & Klausewitz 1973). Prejuveniles are often associated with floating algae, and may be cryptically colored. Berry and Baldwin (1966) suggested that sexual maturity of *Sufflamen verres* and *Melichthys niger* occurs at approximately half maximum size, at an age of a year or more.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Balistidae assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.54.

For the pelagic larvae of balistids, EFH is designated to include the shoreline to the outer boundary of the EEZ to a depth of 50 fm. For eggs, EFH is designated as the water column and all rocky or gravelly bottom areas from 0■50 fm. For adults and juveniles, EFH is designated as all bottom habitats and the adjacent water column from 0 to 50 fm.

4.1.3 Big Eye Scad (*Selar crumenophthalmus)* and Mackerel Scad (*Decapterus macarellus*)

Members of the family Carangidae, the big eye scad (*Selar crumenophthalmus*) and mackerel scad (*Decapterus macarellus*) are regarded as important food fishes in many of the US Pacific Islands. Silvery-blue in color, *Selar spp. and Decapterus spp.* have round spindle shaped bodies and grow to a length of 8 to15 inches. There are six common species of scads that occur in Hawaii, Micronesia, and Samoa: *Decapterus macarellus, D. macrosoma, D. maruadsi, D. Pinnulatus, Selar crumenophthalmus and S. boops*, although *D. macarellus and S. crumenophthalmus* comprise most of the commercial catch. Juvenile big eye scad seasonally form large schools in shallow sandy lagoons, bays and channels during the day where they feed on small shrimps, benthic invertebrates and foraminifera, and may migrate offshore at night (Meyers 1999). Adults generally remain offshore. In Hawaii, the big eye scad (akule) fishery is one of the heathiest commercial fishery in the state. During the annual appearance of juvenile akule (hahalalu), commercial and recreational fishers use a variety of gear including hook and line, surround gill nets and purse seine nets to harvest schools. Similarly, mackerel scad (opelu) are also harvested in this manner.

Depending on species, the ovaries of the female may contain from 30,000 to 200,000 eggs. The eggs are spherical with a single oil globule, non-adhesive and free-floating (Yamaguchi 1953). The spawning of scad occurs in the pelagic environment, although very little information is available concerning the distribution of eggs or larvae of *Selar spp.* and *Decapterus spp.* (but presumably these stages are dispersed widely by ocean currents). Therefore EFH for this life stage is designated as the water column from the shoreline to the outer limits of the EEZ to a depth of 50 fm. Because adult and juvenile scads are reported to occur both in very shallow nearshore waters, and deeper waters offshore, EFH for this life stage is designated as all sandy bottoms and adjacent water column from 0 to 50 fm.

4.1.4 Gray Reef Shark (*Carcharhinus amblyrhynchos*; Carcharhinidae)

The Carcharinidae are one of the largest and most important families of sharks, with many common and wide-ranging species found in all warm and temperate seas. They are the dominant sharks in tropical waters in variety, abundance, and biomass. Most species inhabit tropical continental coastal and offshore waters, but several species prefer coral reefs and oceanic islands.

The gray reef shark (*Carcharhinus amblyrhynchos*) is distributed in tropical waters across the Indo-Pacific from the Red Sea eastward as far as Hawaii. It is often associated with coral reefs, and is one of the species most likely to be encountered by scuba divers. As with other sharks, the eggs of the gray reef shark develop internally. Thus there are no planktonic egg or larval phases. The gestation period for *C. amblyrhynchos* is about 12 months, with from 1-6 pups being produced in a litter. DeCrosta et al. (1984) reported maximum ages from a sample of 30-65 specimens to be 10 years, but Myers (1991) states that sexual maturity is only reached at around 7 years of age, and that the species may live up to 25 years.

Juvenile sharks frequently inhabit inshore areas such as bays, seagrass beds, and lagoon flats before moving into deeper water as they mature. Adult sharks prefer steep outer reef slopes and dropoffs, and the species has been reported from shallow waters to depths of 274 meters (Myers 1991). Adults may move back into shallow inshore areas during mating or birthing events. Some species forage in these shallow areas as well. Reef-associated sharks range widely and are found in a variety of coral reef habitats. Adult female *C. amblyrhynchos* have been reported to aggregate seasonally over shallow reef areas in the Northwestern Hawaiian Islands.

EFH for adult and juvenile *Carcharhinus amblyrhynchos* is designated as all bottom habitat and the adjacent water column from 0 to 50 fathoms. Since eggs and developing young are carried internally, no separate EFH designation for eggs or larvae is applicable.

4.1.5 Soldierfish/Squirrelfish (Holocentridae)

Holocentrids are spiny, deep-bodied, usually red fishes with large eyes and mouth, small teeth, large coarse scales, and stout dorsal and anal fin spines. The soldierfish genera *Myripristis, Plectrypops, Pristelepis, Ostichthys*, and the squirrelfish genera, *Neoniphon* and *Sargocentron,* are represented throughout the Indo-Pacific. Soldierfishes and squirrelfishes are nocturnal predators; soldierfish predominantly feed on large zooplankton in the water column, while squirrelfish prey mainly on benthic crustaceans, worms, and small fishes. Most holocentrids prefer low-light environments, and during the day hover along dropoffs, in or near caves and crevices, under rocky or coral overhangs, or among branching corals.

Depth ranges for the various holocentrid species are reported from shallow water down to an average of approximately 40 m, but with some species occurring as deep as 235m. About 17 holocentrid species inhabit Hawaiian waters. At least 13 species of soldierfishes and 16 species of squirrelfishes occur in Micronesia. At least 31 holocentrid species are found in Samoan waters. *Myripristis amaena* is particularly important in the recreational fishery at Johnston Atoll where it is the species caught in greatest abundance (Irons et al. 1990). It is common in reef fish catches throughout the Hawaiian archipelago.

Little is known about embryonic development and larval cycles in this group. After fertilization, pelagic eggs are distributed in the water column for an indeterminate period of time. Both eggs and larvae are subject to advection by ocean currents. The larval stage is believed to last for several weeks, at the end of which the larvae settle down in refugia on the reef.

Holocentrids are slow growing, late maturing, and fairly long lived. A study (Dee and Parrish 1993) on the reproductive and trophic ecology of *Myripristis amaena* found that sexual maturity for both sexes was reached between 145 and 160 mm SL at about 6 yrs of age. Longevity was determined to be at least 14 years. Fecundity was relatively low, fewer than 70,000 eggs in the most fecund specimen, and increased sharply with body weight. Spawning peaked from early April to early May, with a secondary peak in September. The diet of *M. amaena* was mainly meroplankton, especially brachyuran crab megalops, hermit crab larvae, and shrimps, but also a variety of benthic invertebrates and fishes.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Holocentridae assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.9.

In light of the uncertainties about distribution of eggs and larvae of the Holocentridae, EFH for these stages is designated under the Coral Reef Ecosystem FMP as the water column extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm. EFH for holocentrids in the juvenile and adult stages is designated as all rocky and coral areas and the adjacent water column from 0 to 50 fm. Because caves, crevices and overhangs serve as the primary sheltering habitat for all species of the family Holocentridae, these areas are particularly important habitat.

4.1.6 Flag-tails (Kuhliidae)

The flagtail family is comprised of the single genus *Kuhlia*, distributed throughout the Indo-Pacific region. The flagtails are ordinary-looking silvery fishes, usually with banded tails. The Hawaiian flagtail, or ʻaholehole (*Kuhlia sanvicensis*), is an endemic species that is much prized as a food fish. ʻAholehole form dense schools by day, often in areas of heavy surge, where they are safe from predators; at night the schools disperse to feed on plankton. Young ʻaholehole are often found in tidepools. ʻAholehole may enter brackish and even fresh water areas (Hoover 1993).

Kuhlia marginata is found on Johnston Island and in Micronesia., while *K. mugil* has a wide Indo-Pacific distribution (Myers 1991). *K. rupestris* is a brackish-water species from Guam (Randall 1996).

No information on the egg and larval stages of this species is available so a conservative designation for EFH for these stages was made, from 0-50 fm from the shoreline to the limits of the EEZ. Because adult and juvenile flagtails are generally found in very shallow waters, EFH for this management unit is designated as all bottom habitat and the adjacent water column from 0 to 25 fm.

4.1.7 Rudderfishes (Kyphosidae)

Rudderfishes, or sea chubs, are shore fishes that occur over rocky bottoms or associated with coral reefs along exposed coasts. They are distributed throughout the tropical and sub-tropical Indo-Pacific from Easter Island westward to the Red Sea. Adults of species in the genus *Kyphosus* typically swim in schools several meters above the bottom, and are reported to feed on a variety of algae including filamentous Rhodophyta and coarse Phaeophyta such as *Sargassum* (Myers 1991). Three species occur in Hawaii, Micronesia, and Samoa: *Kyphosus bigibbus, K. cinerascens*, and *K. vaigiensis*. Another species, *Sectator ocyurus* has been reported in Hawaii, but is rare and may be a waif from the tropical eastern Pacific. *K. cinerascens* may occur at least to 24 m depth.

Very little is known about reproduction in the kyphosids. The eggs are spherical, pelagic, and 1.0-1.1 mm in diameter (Watson and Leis 1974). The larvae hatch at 2.4■2.9 mm. Eggs and larvae are both subject to advection by ocean currents. The largest pelagic specimen, a juvenile, examined by Leis and Rennis (1983) was 56 mm. Juvenile individuals may be carnivorous for a while before becoming herbivorous (Rimmer 1986). Juveniles often occur far out at sea beneath floating debris.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Kyphosidae assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.33.

The scant information available for the developmental life history for eggs, larvae and juveniles for this family indicates that these stages usually occur in the upper layer of pelagic waters. EFH for these stages is designated to extend from the shoreline to the outer boundary of the EEZ to a depth of 50 fm. Because adults are almost always found in very shallow inshore waters, EFH is designated all rocky and coral bottom habitat and the adjacent water column from 0 to 15 fm.

4.1.8 Wrasses (Labridae)

The Labridae comprise a large family, second only to the Gobiidae for number of species in the Western Pacific. It is a very diverse family in size and body shape, with adult sizes ranging from less than 5 cm in *Wetmorella albofasciata* to greater than 229cm in the Napoleon, *Cheilinus undulatus*.

Labrids are shallow-water fishes closely associated with coral reefs or rocky substrate, though some species of *Bodianus* occur deeper than 200 m (Smith 1986, Chave & Mundy 1994), and the razorfishes, *Xyrichtys* and *Cymolutes* spp., occur on sand flats (though densities of these two genera tend to decline with distance from coral reefs;). Labrids are diurnal, and at night many bury themselves in the sand, seek refuge in holes and cracks of the reef, or lie motionless on the bottom. During the day, labrids keep close to coral or rocky cover, darting into refugia in the reef or burying themselves in the sand when danger approaches. Labrids can be found in virtually all coral reef habitats, including rubble, sand, algae, seaweeds, rocks, flats, tidepools, crevices, caves, fringing reefs, patch reefs, lagoons and reef slopes (Myers 1991, Randall 1993, Green 1996). Schooling behavior and excursions away from the reef into the water column are usually associated with reproduction (Thresher 1984). The degree of association with reef habitat varies for different species; many members of the family have large home ranges encompassing a wide variety of habitats (Green 1996). In general, many of the smaller species stay confined to very small areas of the reef, while larger species have bigger home ranges (Green 1996). However, even very large species such as *Cheilinus undulatus* return to favored holes or crevices to spend the night or to escape danger (Myers 1991).

The geographic range of the family as a whole includes shallow tropical and temperate seas of the Atlantic, Pacific, and Indian Oceans. Labrids are found throughout shallow areas in the Western Pacific, and include 96 known species in Micronesia (Myers 1991), and 43 species in Hawaii. Fourteen species of wrasses are endemic to Hawaii: *Anampses chrysocephalus*, *Anampses cuvier*, *Bodianus sanguineus*, *Cirrhilabrus jordani*, *Coris ballieui*, *Coris flavovittata*, *Coris venusta*, *Cymolutes lecluse*, *Labroides phthirophagus*, *Macropharyngodon geoffroy*, *Stethojulis balteata*, *Thalassoma ballieui*, *Thalassoma duperrey*, and *Xyrichtys umbrilatus* (Randall 1996). The Hawaiian population of another species, *Bodianus bilunulatus albotaeniatus*, is recognized as a subspecies (Randall 1996). No wrasse species are reported to be endemic to American Samoa. There are no important species of introduced wrasses to the Western Pacific.

There is generally a dearth of information on the life history parameters of age, growth, and mortality of many coral reef fishes, including labrids, and what information exists for some species cannot realistically be applied to the whole family.

Many species migrate to prominent coral or rock outcrops for spawning, including species of *Thalassoma*, *Halichoeres*, *Choereodon*, *Bodianus*, and *Hemigymnus* (Thresher 1984). Sandy areas are necessary for the sand-dwelling labrids, *Xyrichtys spp.* and *Cymolutes spp.* Labrid eggs are pelagic, spherical, 0.45 to 1.2 mm in diameter, lightly pigmented if at all, and usually contain a single oil droplet (Leis & Rennis 1983, Thresher 1984, Colin & Bell 1991). Larvae hatch at 1.5-2.7 mm and have a large yolk sac, unformed mouth, and unpigmented eyes (Leis & Rennis 1983). Both eggs and larvae are dispersed by ocean currents. Victor (1986) measured the duration of the larval phase of twenty four species of wrasses in Hawaii and found a range of 29.5 days (*Anampses chrysocephalus*) to 89.2 days (*Thalassoma duperrey*), although he noted substantial variability within species, up to a standard deviation of 11 days for some wrasses. Victor (1986) and other authors (Miller 1973, Leis & Miller 1976) have noted that despite their abundance as adults in the nearshore fauna of coral reef habitats, labrid larvae are conspicuously absent from nearshore samples, and common in offshore samples. Some labrid larvae are routinely found in the open ocean (Leis & Rennis 1983).

Like adult wrasses, juvenile labrids inhabit a wide variety of habitats from shallow lagoon flats to deep reef slopes. Green (1996) reported that *Labroides dimidiatus* and *Thalassoma lunare* use deeper reef slope and reef base habitats as recruits, and shallower habitats as adults. Examples of ontogenetic shifts in habitat use are not widely reported for the family, although relatively few studies have examined the topic.

Labrids have some importance as a minor component of the catch of commercial fishermen in Hawaii, according to Division of Aquatic Resources catch statistics from 1991-1995. Two species are present in the top 25 inshore fish species by weight ■ 4159 lbs of *Bodianus bilunulatus* and 3955 lbs of *Xyrichthys pavo* (Table 15 in Friedlander 1996). Some wrasse species are caught for the aquarium trade, including *Pseudocheilinus octotaenia, Cirrhilabrus jordani, Thalassoma* spp., *Anampses chrysocephalus, Macropharyngodon* *geoffroy*, and *Novaculichthys taeniourus*, but wrasses are a small portion of the trade in numbers and value (Pyle, pers. comm). In American Samoa, labrids comprise less than 3% of the reef fish catch (Dalzell et al. 1996), while in Guam, Labridae made up 7.3 percent of total landings by weight of the small-boat based spearfishing landings between 1985-1991 (Table 63 in Green 1997). Dalzell et al. (1996) reported that labrids composed approximately 4% of the reef fish catch in Guam. Data on labrids from other sites in the region are either too general to be useful, or lacking.

4.1.9 Napoleon Wrasse (*Cheilinus undulatus*)

Within the Labridae, the Napoleon wrasse, *Cheilinus undulatus*, merits special consideration because of its importance as a target species and because its populations, under pressure through overfishing have been declining rapidly. Once an economically important species on Guam, *C. undulatus* is now rarely seen on the reefs, much less reported on the inshore survey catch results (Hensley and Sherwood 1993). Similar declines in the number of sightings are reported from Saipan (Green 1997). Spearfishing, particularly at night when wrasses are more exposed and vulnerable, has significantly decreased the numbers of this very large reef fish. They are sought after despite accounts of ciguatera poisoning (Myers 1991). A description for the species as it occurs in Micronesia follows (Myers 1991):

The humphead is among the largest of reef fishes. Adults develop a prominent bulbous hump on the forehead and amazingly thick fleshy lips. Adults occur along steep outer reef slopes, channel slopes, and occasionally on lagoon reefs, at depths of 2 to at least 60m. They often have a ▪home• cave or crevice within which they sleep or enter when pursued. Juveniles occur in coral-rich areas of lagoon reefs, particularly among thickets of staghorn *Acropora* corals. The Napoleon is usually solitary, but occasionally occurs in pairs. It feeds primarily on mollusks and a wide variety of other well-armored invertebrates including crustaceans, echinoids, brittle stars, and starfish, as well as on fishes. It is one of the few predators of toxic animals such as the crown-of-thorns starfish, boxfishes, and sea hares. The thick fleshy lips appear to absorb sea urchin spines, and the pharyngeal teeth easily crush heavy-shelled gastropods like *Trochus* and *Turbo*. Much of its prey comes from sand or rubble.

Cheilinus undulatus ranges across the Indo-Pacific from the Red Sea to the Tuamotus, as far north as the Ryukyus, and south to New Caledonia. Though rare, the species can be found throughout Micronesia, and also in American Samoa.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Labridae assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.41.

As indicated above, eggs and larvae of labrids are subject to wide dispersal by ocean currents. Similarly, adult labrids may occur over and utilize a wide range of habitat types that extend beyond the physical boundaries of coral reefs. Thus, EFH for all life stages in the

Labridae is designated as the water column and all bottom habitat extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.

In light of the continued extreme vulnerability of the Napoleon to overharvesting, it is critical that its preferred habitats are protected so that there may be some opportunity for populations of the species to recover to healthier levels. Thus, cave environments that are known (past or present) habitat for adult napoleon wrasse, and *Acropora* beds that may provide suitable habitat for juvenile napoleon wrasse, are particular valuable habitat for this species.

4.1.10 Goatfish (Mullidae)

Goatfishes are important commercial fishes that are highly esteemed as food. All have a characteristic pair of long barbels at the front of the chin housing chemosensory organs, and the barbels are used to probe holes in the reef or nearby open sandy areas for benthic invertebrates or small fishes. Some species are primarily nocturnal, others are diurnal, and a few are active by day or night. Nocturnal species tend to hover in stationary aggregations or rest on coral ledges by day. In general, goatfishes are found in shallow waters, to depths of around 10m, but some species are reported from deeper waters (e.g., *Mulloides pfluegeri* at 110m [Myers 1991]; *P. porphyreus* at 140m [Randall 1996]).

There are 10 native species of goatfish known from Hawaiian waters, and one accidentally-introduced species from the Marquesas, *Upeneus vittatus*. Two species, *Parupeneus porphyreus* and *P. chrysonemus,* are endemic to Hawaii. Fifteen species are recorded from Micronesia. Thirteen species are recorded from Samoa.

Holland et al. (1993) conducted a study of the movements, distribution, and growth rates of *Mulloidichthys flavolineatus* by using tagging data. *M. flavolineatus* and *M. vanicolensis* were the most abundant mullids found in Hanalei Bay, Kauai (Friedlander et al. 1997). *M. flavolineatus* ranked second in overall mean biomass at 211g/100m^2, with an overall mean numerical density of 1.1 individuals/100m^2. *M. vanicolensis* had higher numbers in patch reef habitat, but the larger fish were present in reef slope habitat, indicating partitioning of habitat by size. *Parupeneus cyclostomus* was the rarest and most mobile of the mullids found in Hanalei Bay, with an overall mean density of 0.01 individuals/100m^2 or 2.02 g/100m^2. The largest individuals were seen in deeper reef slope habitat.

Schooling is common among the mullids, and group spawning and pair spawning have been documented for the family. An aggregation of 300 to 400 individuals was observed spawning at 21m depth off the coast of the U.S. Virgin Islands (Colin & Clavijo 1978). Groups of fish made spawning rushes about 2 meters above the bottom before releasing gametes.

Goatfish have pelagic eggs which are spherical, transparent, and non-adhesive with a single oil droplet. Egg diameters range from 0.63 to 0.93 mm and hatch within 3 days. Large size of larvae at settlement, and wide distribution, suggest that goatfish in general have a larval development period that lasts several weeks. Pelagic eggs and larvae are subject to advection by ocean currents. After settlement, juveniles take approximately one year to reach sexual maturity. Munro (1976) suggested that few live more than 3 years. In *P. porphyreus*, peak spawning occurs somewhere between December and July. Counts of nuclear rings on otoliths indicate a larval period of approximately 40-60 days. The juvenile phase involves rapid color changes, a lengthening of the gut, and an external change in shape. Fishes can mature sexually by about 1.25 years of age. Fecundity was estimated as 11,000 to 26,000 eggs per spawn. Adults in this species may live 6 years or longer (Moffitt 1979).

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Mullidae assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat.

For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.32. EFH for the egg and larval stages of the mullids is designated as the water column extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm. EFH for the juvenile and adult stages is designated as all rocky/coral and sand-bottom habitat and adjacent water column from 0 to 50 fm.

4.1.11 Mullets (Mugilidae)

The Mugilidae, or mullet family, includes silver-sided fishes that generally favor shallow nearshore waters. They can tolerate a wide range of salinities, are often found in brackish water, and occasionally even venture into fresh water. Traditionally, mullets have been an important food resource for people throughout the Western Pacific. Mullets generally feed over the reef or over sandy or mud bottoms. Three species of mullet occur in Hawaii: the common Striped mullet or ♣ama♣ama (*Mugil cephalus*), the Acute-jawed mullet or uouoa (*Neomyxus leuciscus*), and *Moolgarda engeli*, an introduced species that is proliferating at the expense of the more important striped mullet. At least 8 species in 5 genera are reported from Micronesia (Myers 1991). By weight, the striped mullet is ranked tenth among fish species caught inshore in Hawaii (DAR data in Green 1997), while acute-jawed mullet is the fourth most-important species caught at Johnston Atoll (1989-1990 data, Green1997).

<u>Striped Mullet (*Mugil cephalus*)</u>: This species feeds over sandy or muddy bottoms in shallow water, filtering out fine algae and organic detritus material through the gills. Although reported to have circumglobal distribution in subtropical seas, there are no verifiable records in the literature of the occurrence of the species in Micronesia (Myers 1991), and it is possible that other species or subspecies may account for the reportedly wide distribution (Randall 1996).

Very little information is available concerning the distribution of eggs or larvae of mullets. (but presumably these stages are dispersed widely by ocean currents). Therefore EFH is designated as the water column from the shoreline to the outter limits of the EEZ to a depth of 50 fm. Because adult and juvenile mullets are reported to occur almost exclusively in very shallow nearshore waters, EFH for the species is designated as all sand and mud bottoms and the adjacent water column from 0 to 25 fm.

4.1.12 Moray Eels (Muraenidae)

Members of Muraenidae, the morays, lack pectoral fins and scales and have a large mouth. Most species have long, fang-like teeth, but some do not. Species with long canines feed mainly on reef fishes, occasionally on crustaceans and octopuses. Species of Echidna and Gymnomuraena with mainly nodular or molariform teeth feed more on crustaceans, especially crabs. Morays have a lengthy pelagic leptocephalus larval stage that has resulted in a very wide distribution. In the Pacific Islands, morays are hunted for food in many locations, even though large individuals may be ciguatoxic. Morays typically remain hidden within the framework of the reef, and many are more active at night than during the day. There are 38 species of morays in Hawaii, second only to the wrasses for number of species. *Gymnothorax steindachneri* is endemic to Hawaii. At least 53 species are known from Micronesia. At least 47 species are known from Samoa.

Eel eggs are pelagic and spherical with a wide periviteline space, usually no oil droplets and in some species a densely reticulated yolk. The eggs are relatively large, ranging from 1.8 to 4.0 mm. Watson and Leis (1974) collected 145 eels eggs off Hawaii that ranged from 2.4 to 3.8 mm. Brock (1972) found 200,000 to 300,000 ripe eggs in each of four 5.0 to 6.8 kg *Gymnothorax javanicus*. Hatching of an unidentified 1.8 mm muraenid egg took approximately 100 hours (Bensam 1966).

Eels have a characteristic leptocephalus larval stage: a long, transparent, feather-shaped larva that starts out at 5-10 mm and grows up to 200 mm before settlement and metamorphosis. The duration of the planktonic stage is on the order of 3▪5 months for moringuids (Castle 1979), 6▪10 months for muraenids (Eldred 1969, Castle 1965) and about 10 months for some congrids (Castle and Robertson 1974).

Both juvenile and adult eels inhabit cryptic locations in the framework of the reef or in sand plains for some species. Some species remain so hidden within the reef that they have never been seen alive; their existence is known only from samples taken with the use of poisons.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Muraenidae assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS, see Section 4.2.1.4.

Because moray eels eggs and larvae have a pelagic phase, EFH for this life phase is designated as the water column from the shoreline to the outer limits of the EEZ to a depth of 50 fm. The EFH for the adult and juvenile phase is defined to include all coral, rocky and sand-bottom areas from 0 to 50 fm.

4.1.13 Octopuses (Octopodidae)

The octopods are mollusks of the class Cephalopoda. Several octopod species are found in the region, and at least two (*Octopus cyanea* and *O. ornatus*) are of some economic importance. While some octopods are known from at least 1,000 meters depth, these deep-water species are not reef-associated. Reef-inhabiting octopods generally occur from the shallowest parts of the reef down to depths of around 50 m. They are bottom-dwelling species that usually occupy holes and crevices in rocks or coral areas; while they can swim rapidly if necessary (especially in escape swimming), octopuses usually avoid swimming in mid-water. In sandy areas, they may dig burrows or construct shelters built from scattered rocks. Octopods venture out of their dens in search of food, and may swim and crawl over the bottom to distances more than 100m from their holes. In Hawaii, *Octopus cyanea* forages during the day, and is known as ■day squid•, while *O. ornatus,* the ■night squid•, forages after dark (Kay 1979).

Octopods lay demersal eggs that are attached in clusters within rocky recesses on the reef. Some (e.g., large specimens of *Octopus cyanea*) may lay up to 700,000 eggs (Van Heukelem 1983). Embryonic development is considered ■direct,• that is, there is no larval phase. However, the degree of development at hatching may be related to the size of the egg. In those species with smaller eggs (<4mm), hatchlings are less-developed, and first go through a planktonic ■paralarval• phase, before settling down to a benthic existence (Young and Harman 1989). Those species with larger eggs (around 17mm range) are typically more developed, and hatch immediately to a benthic stage. In *Octopus cyanea*, eggs are about 3mm in diameter. Newly-hatched juveniles are about 3mm long, and enter a planktonic stage, believed to last around 30-40 days. Similarly, *Octopus ornatus* has a juvenile, planktonic paralarval stage that measures less than 4mm in mantle length (Young and Harman 1989).

The following octopod species are known from Hawaiian waters: *Octopus cyanea, O. ornatus, Berrya hoylei* and *Scaeurgus patagiatus*. An additional three unnamed species are believed present (Young and Harman 1989). *Octopus hawiiensis,* an endemic species originally described in 1837, was only recently observed again in the islands (Hoover 1998). Octopus are a component of the incidental catch of the lobster-trap fishery in the Northwest Hawaiian Islands (WPRFMC 25 May 99). An unnamed species of octopus is known from Waianae, Oahu. It occupies burrows in sandy areas. The burrows have openings about the diameter of a thumb. It is not known whether the octopus digs the burrow, or simply occupies a burrow already dug by another animal (e.g., mantis shrimp). This octopus emerges from its burrow and mimics a flatfish (B. Carlson, pers. omm.. 27 Aug 99).

On Tutuila Island, American Samoa, it was reported that octopus accounted for approximately five percent of the catch composition for the shoreline subsistence fishery (Craig et al. 1993). Octopus (*Octopus cyanea* and *O. ornatus*) are reef-associated species commonly taken as food in the Marianas (Myers 1997 in Green October 1997). *Octopus cyanea* was identified as a species found on the reef slope at Rota, and targeted for capture in the local fishery (Smith et al 1989). Octopus are considered a preferred catch item in Saipan

(Micronesian Environmental Services, March 1997). Octopus, mainly *Octopus cyanea,* are considered the most sought-after unshelled mollusk.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Octopods assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat.

Because some species of octopus have a pelagic paralarval phase that is subject to advection by ocean currents, EFH for this life phase is designated as the water column from the shoreline to the outer limits of the EEZ to a depth of 50 fm. The EFH for the adult and juvenile phase and for the demersal eggs of the octopods, is defined to include all coral, rocky and sand-bottom areas from 0 to 50 fm.

4.1.14 Threadfins (Polynemidae)

Threadfins are relatives of the mullets, named for their thread-like lower pectoral rays that are used as feelers which become relatively shorter with growth. Threadfins typically occur over shallow sandy to muddy bottoms, occasionally in fresh or brackish water. One species, *Polydactylus sexfilis,* or moi, occurs in Hawaii, where it is highly valued as a food fish. In Hawaii, it has become rare as a result of intense fishing pressure, and is currently being propagated in hatcheries for use in stock enhancement projects. The same species occurs in Micronesia. Two species occur in Samoa, *P. sexfilis* and *P. plebeius*. The family Polynemidae is distributed throughout the tropical waters of the Atlantic and Indo-Pacific Oceans.

P. sexfilis is a fast-growing species that inhabits turbid waters, and can be found in large schools in sandy holes along rocky shoals and high energy surf zones. In Kaneohe Bay, adults may be found on reef faces, in the depths of the inner bay and in shallow (2-4 m) areas with muddy sand bottoms (Lowell 1971). When moi were more abundant in Hawaii, airplane spotters used to locate large schools and direct net fishermen to the catch. Threadfins are also reported to prefer sandy and mud bottom habitats in Micronesia (Myers 1991).

Spawning takes place for 3-6 days per month and has been observed in Hawaii from June to September, with a peak in July and August (Ostrowski and Molnar 1997). Spawning may be year-round in very warm locations. Spawning occurs inshore and eggs hatch offshore within 14-24 hours depending on water temperature (May 1979). Eggs are small, averaging 0.75 mm in diameter with a large oil globule. Both eggs and larvae are subject to advection by ocean currents. Larvae are pelagic, but after metamorphosis they enter nearshore habitats such as surf zones, reefs, and stream mouths (Ostrowski and Molnar 1997). Young moi, from 150-250 mm long, are found from shoreline breakers to 100 m depth (Lowell 1971). Fishing for juvenile *P. sexfilis*, or moilii, has historically been an important recreational and subsistence seasonal fishery in Hawaii.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Polynemidae assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.44.

EFH for the egg and larval stages of the polynemids is designated as the water column extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm. EFH for the juvenile and adult stages is designated as all rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 50 fm.

4.1.15 Bigeyes (Priacanthidae)

Priacanthids are nocturnal zooplanktivores that feed on larger zooplankton such as the larvae of crabs, fishes, polychaete worms and cephalopods. The family is distributed circumtropically and in temperate seas, but some species are limited to the Indo-Pacific or the Hawaiian islands. In Hawaiian waters, 4 species have been recorded: *Heteropriacanthus cruentatus*, the endemic *Priacanthus meeki*, and two deep-water species. In Micronesian waters, *H. cruentatus*, *P. hamrur*, and a deep species from over 200 m depth have been recorded. The shallow-water species are limited to 100 m or less. Five species are recorded from Samoan waters.

The glasseye, *H. cruentatus*, inhabits lagoon or seaward reefs from below the surge zone to a depth of at least 20m. During the day it is usually solitary or in small groups but may gather in large numbers at dusk prior to ascending into the water column for feeding.

Spawning by priacanthids has not been observed, but Colin and Clavijo (1978) reported seeing an aggregation of more than 200 individuals at a reef where many other species were spawning. The eggs of *Pristigenys niphonium* and *Priacanthus macracanthus* are pelagic, spherical, and 0.75 mm in diameter (Suzuki et al. 1980, Renzhai and Suifen 1982). The larvae hatch at 1.4 mm (Renzhai and Suifen 1982). The size of the largest examined pelagic larval specimen was 48 mm (Leis and Rennis 1983). Eggs and larvae are subject to advection by ocean currents. Caldwell (1962) reported a size at settlement for the deepwater subtropical species *Pristigenys alta* of 65mm.

Habits and habitat preferences for the family are similar to those of the holocentrids, in that these fishes prefer shaded overhangs, caves, and crevices on the reef during the daytime. At night, fishes may move out into the water column to feed, and some types are reported to feed over soft-bottom areas.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Priacanthid assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.23.

Because the distribution of eggs and larvae of the Priacanthidae have not been thoroughly studied, a precautionary approach is required in establishing EFH for these stages. Therefore, EFH for priacanthid eggs and larvae is designated as the water column extending from the shoreline to the outer boundary of the EEZ to a depth of 50 fm. EFH for priacanthids in the juvenile and adult stages is designated as all rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 50 fm.

4.1.16 Parrotfishes (Scaridae)

Scarids inhabit a wide variety of coral reef habitats including seagrass beds, coral-rich areas, sand patches, rubble or pavement fields, lagoons, reef flats, and upper reef slopes (Myers 1991). They are prominent members in numbers and biomass of shallow reef environments. Scarids are chiefly distributed in tropical regions of the Indian, Atlantic, and Pacific Oceans.

Parrotfishes often occur in large, mixed-species schools which rove long distances while feeding on reefs. A few species are territorial, but the majority are roving herbivores, with the size of the home range increasing with the size of the fish. Choat and Robertson (1975) found that smaller, less mobile scarids are usually associated with cover such as *Acropora* growth. Open areas with large amounts of grazing surface harbor larger, more mobile, and school-forming scarids. Schooling behavior is common among the scarids, both for feeding and spawning.

Species endemic to Hawaii are: *Calotomus zonarchus, Chlorurus per spicillatus,* and *Scarus dubius*. Seven species of scarids can be found in Hawaii, 33 species in Micronesia, and 23 species in Samoa.

Scarids spawn in both pairs and groups. Group spawning frequently occurs on the outer slope of the reef in areas with high current speeds. Pair spawnings are frequently observed at the reef crest or reef slope at peak or falling tide. Scarids have been observed to undergo spawning migrations within lagoons and to the outer reef slope (Randall and Randall 1963, Yogo et al. 1980, Johannes 1981, Choat and Randall 1986, Colin and Bell 1991). Some species are diandric, forming schools and spawning in groups often after migration to specific sites, while others are monandric, at times being strongly site-attached with haremic, pair spawning (Choat and Randall 1986). The pelagic eggs and larvae of scarids are subject to dispersal by ocean currents.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Scarid assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.42.

4.1.17 Bumphead Parrotfish (*Bolbometopon muricatum*)

The Bumphead parrotfish, *Bulbometopon muricatum*, merits special consideration because of its importance as a target species and because its populations, under pressure through overfishing, have been declining rapidly over much of its range. The Bumphead is a very large parrotfish (to 120cm and 75kg) that typically occurs in schools on clear outer lagoon and seaward reefs at depths from 1-30m. They are often located on reef crests and fronts. In unfished areas they may enter outer reef flats at low tide. The Bumphead is very wary in the daytime but sleeps in groups on the reef surface at night, making it an easy target for spearfishermen. As a result, it has nearly disappeared from most of Guam's reefs. Johannes (1981) cites an example of Bumpheads changing the location of their sleeping site away from the shallow reef flat to the deeper reef slope in Palau in response to increasing nighttime spearfishing. Their range is Indo-Pacific, although they are not found in the Hawaiian Islands. On the Great Barrier Reef, fish of less than 400mm are thought to have different habitat requirements from larger fish, since these smaller fishes are not seen on outer reefs (H. Choat, personal communication).

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Scarid assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual MUS see Section 4.2.1.42.

As indicated above, eggs and larvae of scarids are subject to dispersal by ocean currents. Similarly, adult scarids may occur over and utilize a wide range of coral and other shallow-water habitat types. Thus, EFH for all life stages in the Scaridae is designated as the water column and all bottom habitats from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.

In light of the continued vulnerability of the Bumphead parrotfish to overharvesting, it is critical that its preferred habitats be protected so that there may be some opportunity for populations of the species to recover to healthier levels over time. At present, little information is available regarding the specific habitat requirements of this species. Further research is thus needed to better understand the habitat requirements of the Bumphead parrotfish so that appropriate Habitat Areas of Special Concern can be designated, and other management measures initiated, to better protect this species.

4.1.18 Rabbitfish (Siganidae)

Siganids are small (from 20 -50 cm), essentially marine tropical Indo-West Pacific fishes. They have venomous dorsal, anal and pelvic spines. With a single row of flattened, close-set teeth, rabbitfishes feed primarily on algae and seagrasses, although some may occasionally feed on tunicates or sponges. Because of their herbivorous diet, most species live at depths less than 15 m, but some are trawled from as deep as 50m. Half the species live as pairs on coral reefs, the others usually gather in small schools. One species, *Siganus vermiculatus*, is almost exclusively estuarine; the rest move between estuaries, coral reefs, rocky shores, and other habitats. Rabbitfishes generally spawn on a lunar cycle with peak activity during the spring and early summer. Spawning occurs in pairs or groups on outgoing tides either at night or early in the morning. Juveniles of some species are estuarine. Rabbitfishes are highly esteemed foodfishes. Some of the colorful ones are popular aquarium fishes. None are found in Hawaii. Approximately 16 species are found in Micronesia, and at least 4 species in Samoa.

Spawning by rabbitfishes is typically preceded by a migration to specific and traditional spawning sites. The location varies from near mangrove stands (*S. lineatus*, Drew 1971), to shallow reef flats (*S. canaliculatus*, Manacop 1937, Johannes 1981), the outer reef crest (several spp. at Palau, McVey 1972; Johannes 1978), and even the deeper reef (*S. lineatus*, Johannes 1981). Sites are usually characterized by easy access to the ocean via channels, and large areas of sea grass flats nearby.

Reproduction in the schooling species has been studied in some detail, and in general the eggs are adhesive and demersal (with a few exceptions such as the pelagic eggs of *S. argenteus*); hatching occurs within 1-3 days and yolk sac absorption is completed in about 3 or 4 days (Lam 1974). Fecundity is high: 250,000-500,000 eggs per spawning season (Lam 1974, Gunderman et al. 1983). Larvae are pelagic and feed on phytoplankton and zooplankton. The duration of the larval stage is about 3 weeks in *S. fuscescens* (Hasse et al. 1977) and 3-4 weeks in *S. vermiculatus* (Gunderman et al. 1983). Popper et al. (1976) reported that siganid larvae follow a lunar rhythm in appearing on the reef, typically arriving inshore 3-5 days after a new moon. Fish are 15-20 cm long and sexually mature after one year. Judging by maximum size, some species survive from 2-4 years. *S. argenteus* is unique amongst the Siganidae in having a prejuvenile stage which is distinct from the larval and juvenile stages and is specially adapted for a pelagic life (Hubbs 1958). They can reach sizes of 6-8 cm SL before settling. Not surprisingly, *S. argenteus* has the widest distribution of all rabbitfishes.

The rabbitfishes vary widely in their habitat uses. The schooling species typically move between a wide range of habitats, whereas the pairing species tend to lead a sedentary existence among the branches of hard corals. Rabbitfishes are common on reef flats, around scattered small coral heads, and near grass flats. Gundermann et al. (1983) divided the siganids into two groups on the basis of habitat, behavioral characteristics and coloraton. One group includes species (*S. corallinus*, *S. puellus*, and *Lo vulpinnus*) that live in pairs, have limited home-ranges on reefs and are brightly colored. The remaining group, including *S. rivulatus* and *S. canaliculatus*, form schools at some stage of their life cycle, may undertake substantial migrations, and assume coloration similar to their preferred habitat.

Schools of juvenile *S. rostratus* and *S. spinus* swarm on the reef flats of Guam each year during April and May, and occasionally during June and October. Tsuda et al. (1976) studied the feeding and habitat requirements for these fish to determine the likelihood of mariculture of the rabbitfishes, which are highly esteemed for gastronomic and cultural reasons in Guam.

Very little information is available concerning the distribution of eggs or larvae of rabbitfish. Therefore EFH for this life stage is designated as the water column from the shoreline to the outter limits of the EEZ to a depth of 50 fm. Because adult and juvenile rabbitfish are reported to occur almost exclusively in very shallow nearshore waters, EFH for this life stage is designated as all benthic habitats and the adjacent water column from 0 to 25 fm.

4.1.19 Barracudas (Sphyraenidae)

The barracudas, all in the single genus *Sphyraena*, are top-level carnivorous fishes that feed mainly on other fishes. Some species are primarily diurnal, while others are nocturnal. Species such as *Sphyraena helleri* school in large groups during the day but disperse at night to feed. *Sphyraena barracuda* is typically a solitary diurnal predator. In Hawaiian waters, these are the only two species positively recorded. In Micronesian waters, at least 6 species occur. In Samoan waters, at least five species occur.

Juvenile *S. barracuda* occur among mangroves and in shallow sheltered inner reef areas. Adults occur in a wide range of habitats ranging from murky inner harbors to the open sea. *S. forsteri, S. acutipinnis, S. novaehollandiae*, and *S. obtusata* are all schooling barracudas that occur over lagoon and seaward reefs. *S. forsteri* is reported to occur on outer reef slopes to a depth of 300m (Myers 1991). *S. genie* is a larger schooling barracuda that frequently schools within defined territories on submarine terraces and is most often caught at night by trollers in Micronesia. In general, barracudas may be found in almost any tropical marine habitat, including within lagoons and mangrove areas, over coral reefs or sand or mud bottoms, or off of deep outer reef slopes.

Barracudas migrate to specific spawning areas, often in very large numbers at reef edges or in deeper water. The eggs are pelagic, spherical, and range in diameter from 0.7-1.5 mm with a single clear or yellow oil droplet. Eggs hatch within 24-30 hours. Both eggs and larvae may be carried for long distances by ocean currents. Larvae begin to feed within 3 days on small copepods. Larger larvae voraciously feed on zooplankton and other fish larvae. Settlement typically occurs at a length of 18 mm, but *S. barracuda* larvae occasionally drift in the ocean for an indefinite period of time, usually associated with floating debris or algae, developing all the characteristics of juveniles and sometimes attaining large sizes before being delivered inshore. Newly settled juveniles are piscivorous.

Because eggs and larvae of barracudas are subject to wide dispersal by currents, and since the adults may occur over virtually any bottom type, EFH for all life stages in the Sphyraenidae is designated to extend from the shoreline to the outer boundary of the EEZ to a depth of 50 fm.

4.1.20 Turban Shells/Green Snail (Turbinidae)

Turban shells are a gastropod belonging to the family Turbinidae which are distributed throughout the Indo-Pacific region extending into the South Pacific. In Micronesia and the South Pacific, several varieties of turban shells are harvested mainly for food but the shells of certain species are also highly prized for lacquerware and jewelry. The main species of turban shells harvested are the green snail (*Turbo marmoratus*), the rough turban (*T. Setosus*), and the silver-mouth turban (*T. Argyrostomus*)**.**

Green snails share similar habitat with other gastropod species like the trochiids and are generally found in healthy coral reef habitats which receive constant flow of oceanic water. Juveniles are often found on shallow reef crests while adults prefer deeper habitats with well developed reef and abundant coral growth. Very little information is available on the reproduction of green snails as none have been observed spawning in the wild. Lab studies conducted by (Yamaguchi 1988) indicate that ovaries of a well developed female may contain up to 7 million eggs which are then ejaculated and fertilized by male sperm. Although the eggs are heavier than saltwater, they are easily dispersed with slight agitation.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for Turbinidae assemblages pursuant to Section 600.805(b) of 62 FR 66551. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat.

Because eggs and larvae are subject to advection by ocean currents, EFH for these stages is designated as the water column from the shoreline to the outer limit of the EEZ to a depth of 50 fm. For adults and juveniles, EFH is designated as all bottom habitat and the adjacent water column from 0 to 50 fm.

4.1.21 Aquarium Taxa/Species Habitat

Within the jurisdictional waters of the WPRFMC, Hawaii is the main site where commercial collection and sale of coral reef fishes and invertebrates for the aquarium trade is occurring. On Guam, commercial collection at present is quite limited (only one commercial operation is involved in the export of live aquarium fish). On American Samoa, commercial collection of aquarium fishes is allowed by permit, but presently there are no commercial aquarium fish operators. In CNMI, the commercial export of live aquarium fishes is prohibited. No aquarium fish collecting occurs on other U.S. Pacific islands, since these islands are either National Wildlife Refuges or are in use by the military (Green 1997).

Because Hawaii is the area where most commercial harvesting of aquarium species occurs, the aquarium MUS complex is based primarily on those species known from Hawaiian waters. While the descriptions that follow give general information about the distribution of aquarium taxa across the region, EFH is defined primarily on the basis of the occurrence of taxa in Hawaii.

The ▪Aquarium Species/Taxa•grouping, does not represent a taxonomically related cluster of species. Nonetheless, the species contained in this MUS form a natural assemblage from the ecological standpoint, since most are found in similar habitat, primarily being closely associated with shallow coral areas.[2]

4.1.21.1 Surgeonfishes (Acanthuridae)

Surgeonfishes are among the most common families found on Indo-Pacific coral reefs. They are primarily herbivores and planktivores. The larval period is long, up to around 2.5 months (Randall 1961). Surgeonfish larvae are primarily found well offshore at depths from 0-100m. Like other common adult members of the coral reef fish community, surgeonfish larvae are typically less abundant in samples of the water column near the reef than they are in samples from offshore (Miller 1973). Presumably, the prolonged pelagic larval period contributes to the wide distribution of species in this family. Although surgeonfish larvae generally settle at a larger size than most other reef fish, acanthurids are one of the families wherein juveniles settle with larval characters still present (Leis & Rennis 1983). Late-phase larvae actively swim inshore at night, and seek shelter on the reef. Surgeonfishes have relatively long life spans, up to as much as 40 years (Dalzell et al. 1996).

Yellow tang (*Zebrasoma flavescens*): Although widely distributed in the Indo-Pacific, this species is only abundant in Hawaii. The yellow tang is a popular aquarium fish that represents more than 75% of all aquarium animals caught statewide (Clark and Gulko 1999). They occur singly or in loose groups on coral-rich areas of lagoon and seaward reefs from below the surge zone to at least 46 m depth. Juveniles tend to hide among branches of finger coral, while adults graze near the shore in calm areas.

Z. flavescens tends to prefer the leeward sides of islands, particularly areas of dense coral growth of *Pocillopora damicornis* and *Porites compressa*. It feeds on algae growing exposed on basalt and dead coral heads, as well as in crevices and interstices of the reef that it can reach with its long, thin snout (Jones 1968).

Yellow-eyed surgeon fish (*Ctenochaetus strigosus*): Like the yellow tang, the yellow-eyed surgeon is distributed across the tropical Indo-Pacific, but is only common in Hawaii. Individuals are observed in coral-rich areas of deep lagoon and seaward reefs. In addition to its importance as an aquarium species, it is also a popular food fish.

Achilles tang (*Acanthurus achilles*): This fish is distributed only in the Pacific Islands. It is common in Hawaii and Polynesia, but rare in Micronesia. It is a territorial species that feeds on filamentous and fleshy algae. The Achilles tang is primarily found in the surge zone to a depth of 4 m.

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[3] One exception is the feather-duster worm, a sessile benthic invertebrate that occupies sandy or rubble bottom areas. The species is nonetheless included as part of the aquarium assemblage because of its commercial importance as a harvested aquarium species.

4.1.21.2 Moorish Idol (*Zanclus cornutus;* Zancildae)

The Moorish idol, sole member of this monotypic family, is ubiquitous in areas of hard substrate, from waters less than 1 m deep in turbid inner harbors and reef flats, to clear seaward reefs as deep as 182 m. It is often found in small groups but may sometimes occur in schools of as many as 100 or more individuals. The species has a long larval stage and settles at a large size, >6cm SL for some individuals. As a result, they are ubiquitous wherever hard substrate is found, from turbid inner harbors to clear seaward reefs. They feed mainly on sponges, but will also take other invertebrates and algae. Their range is the Indo-Pacific and tropical eastern Pacific, and they are found throughout the jurisdiction. They are a popular aquarium fish.

4.1.21.3 Angelfishes (Pomacanthidae)

Angelfishes are indisputably among the most beautiful and popular of all aquarium fishes, in many cases commanding very high prices. Six species are found in Hawaiian waters, and four of them are endemic: *Centropyge fisheri*, *Centropyge potteri*, *Desmoholacanthus arcuatus*, and *Genicanthus personatus*. At least 26 species occur in Micronesia, and at least 11 species occur in Samoa.

Pomacanthid eggs are small, spherical, nearly transparent, and contain from one to several oil droplets. Hatching occurs within 24 hours after release (Thresher 1984). Feeding by the larvae begins within 2-3 days and settlement to the bottom occurs between 17-39 days (Allen et al. 1998).

Adult angelfishes require suitable shelter in the form of boulders, caves, and coral crevices. Most species occur from 2 to 30 m depth, but a few such as *Centropyge narcosis* are found in waters over 100m deep. Angelfishes are territorial, and males frequently maintain a harem of 2-5 females and defend a territory ranging from a few square meters for some smaller species (e.g., *Centropyge*) to well over 1 sq km for some larger species (e.g, *Pomacanthus*).

<u>Angelfish (*Centropyge shepardi and C. flavissimus*)</u>: These are two of the prime target species for the aquarium trade, and are found on Guam. Shepard♣s angelfish (*C. shepardi*) is usually observed on outer reef slopes at depths between 18-56 m. The lemonpeel angelfish (*C. flavissumus*) inhabits areas of rich coral growth in shallow lagoons or on exposed seaward reefs to depths of 25 m or more.

4.1.21.4 Dragon Moray (*Enchelycore pardalis*; Muraenidae)

Morays, in the family Muraenidae, occur mostly in waters less than 30 m deep. There are 38 species of morays in Hawaii, second only to the wrasses for number of species. *Gymnothorax steindachneri* is endemic to Hawaii. At least 53 species are known from Micronesia. At least 47 species are known from Samoa.

Eel eggs are pelagic, spherical, and relatively large, ranging from 1.8 to 4.0mm. Watson and Leis (1974) collected 145 eel eggs off Hawaii which ranged from 2.4 to 3.8mm. Brock

(1972) found 200,000 to 300,000 ripe eggs in each of four 5.0 to 6.8kg *Gymnothorax javanicus*. Hatching of an unidentified 1.8mm muraenid egg took approximately 100 hours (Bensam 1966).

Eels have a characteristic leptocephalus larval stage: a long, transparent, feather-shaped larva that starts out at 5-10 mm and grows up to 200mm before settlement and metamorphosis. The duration of the planktonic stage is on the order of 6-10 months for muraenids (Eldred 1969, Castle 1965).

Both juvenile and adult eels inhabit cryptic locations in the framework of the reef, or in sand plains for some species. Some species remain so hidden within the reef that they have never been seen alive; their existence is known only from samples taken with the use of poisons. Many species emerge to feed and some may even slither over rocks and enter shallow tidepools. *Enchelycore pardalis*, the dragon moray, is a striking fish that is popular with aquarists, and may attain a length of around 1 m. It is distributed throughout the Indo-Pacific. Known in Hawaii as puhi kauila, it is more common in the NWHI than in the MHI.

4.1.21.5 Hawkfishes (Cirrhitidae)

Hawkfishes are small grouper-like fishes in the family Cirrhitidae. In Hawaii, there are 6 species recorded. At least 10 species occur in Micronesia, and at least 8 species occur in Samoa. The colorful species are popular aquarium fishes.

Eggs are pelagic, spherical, and approximately 0.5 mm in diameter. The development at hatching is unknown. A lengthy pelagic larval stage, probably lasting a few to several weeks (Randall 1963) is suggested by the widespread distribution and limited geographic variation of some species.

Adults typically inhabit rock, coral, or rubble of the surge zone, seaward reefs, lagoons, channels, rocky shorelines, and submarine terraces. Some are typically found on heads of small branching corals.

<u>Longnose hawkfish (*Oxycirrhites typus*)</u>: The longnose hawkfish, *Oxycirrhites typus*, is a popular aquarium species that feeds mainly on zooplankton, and is usually seen perched on black coral or gorgonians at depths greater than 30 m. The fish is distributed throughout the Indo-Pacific from East Africa to the Americas. The fish is found and collected in Hawaii.

<u>Flame hawkfish (*Neocirrhitus armatus*)</u>: This spectacular hawkfish is commonly found along surge-swept reef fronts and marine terraces to a depth of about 11m. It inhabits coral heads of various species, including *Stylophora mordax*, *Pocillopora elegans*, *P. edouxi*, and *P. verrucosa.* The species is distributed in the islands and coastlines of the Pacific plate, and is collected in Guam.

4.1.21.6 Butterflyfishes (Chaetodontidae)

Butterflyfishes are among the most colorful and conspicuous fishes on the coral reef. Many species are corallivores that feed on polyps of corals and other coelenterates. The corallivores tend to be territorial and limited to the shallower depth ranges of the corals that they feed upon (e.g., *Pocillopora meandrina*). Others feed heavily on benthic algae and small benthic invertebrates. Some species, including those of *Hemitaurichthys*, are primarily zooplanktivores which often occur in mid-water aggregations and range into relatively deep water.

Butterflyfish eggs are planktonic and hatch within two days. The duration of the planktonic stage is not well studied, but Burgess (1978) suggested it is likely to be at least several months. Settlement occurs at night and juveniles tend to occupy shallower, more sheltered habitats than adults. The family is represented in Hawaiian waters by 24 species; *Chaetodon fremblii, C. miliaris*, and *C multicinctus* are endemic to Hawaii, and *C. tinkeri* is found only in Hawaii and the Marshall Islands. The family is represented in Micronesian waters by at least 40 species and in Samoan waters by 30 species. The yellow-crowned butterflyfish *C. flavocoronatus* is listed as a vulnerable species in Guam on the 1996 IUCN Red List.

Threadfin butterflyfish (*Chaetodon auriga*): This species is one of the most common butterflyfishes of areas of mixed sand, rubble, and coral, and typically occurs in shallow waters to a depth of 30m. It is distributed from the Red Sea eastward to Hawaii, and is taken as an aquarium fish in Hawaii and Guam.

Raccoon butterflyfish (*Chaetodon lunula*): This is a nocturnal species (possibly the only nocturnal butterflyfish) that inhabits lagoon and seaward reefs to depths in excess of 30m. It prefers rocky areas with high relief. Juveniles occur in shallows and idepools. The species is distributed from East Africa to Hawaii, and is captured for use as an aquarium fish in Hawaii and Guam.

Black-backed butterflyfish (*Chaetodon melannotus*): This species occurs in areas where corals grow luxuriantly, and can be found in shallow waters to depths of over 15 m. The black-backed butterflyfish is found from the Red Sea to American Samoa; it is absent in Hawaii. It has some importance as an aquarium species in Guam.

Saddled butterflyfish (*Chaetodon ephippium*): The saddled butterflyfish is a relatively common inhabitant of lagoon and seaward reefs to a depth oaf around 30m. It prefers areas of rich coral growth and clear water. The species is distributed throughout the Central and Western Pacific, but is uncommon in Hawaii. It is captured for aquarium use in Hawaii and Guam.

4.1.21.7 Damselfishes (Pomacentridae)

The damselfishes are among the most abundant fishes on coral reefs. Most damselfishes occur in shallow water on coral or rock substrata, wherever there is shelter. The species of *Chromis, Dascyllus, Lepidozygus, Amblyglyphidodon, Neopomacentrus*, and *Pomachromis* are aggregating planktivores that often form large schools in the water column. Most members of *Abudefduf*, *Chrysiptera*, and *Pomacentrus* are omnivores that feed on benthic algae, small invertebrates, or zooplankton. *Plectroglyphidodon johnstonianus* feeds on coral polyps. Other members of *Plectroglyphidodon*, as well as members of *Stegastes*, are aggressively territorial herbivores. Algal feeders frequently cultivate algal mats which they weed of undesirable algae and aggressively defend from other reef inhabitants. The anemonefishes, subfamily *Amphiprioninae*, live in a symbiotic relationship with large sea anemones. No anemonefish are found in Hawaii both because of the absence of host anemones, and the short larval duration, which has apparently prevented distribution of viable larvae to such an isolated location.

Pomacentrid eggs are demersal, elliptical, and adhesive by means of a cluster of fine threads at one end of the egg. Eggs are kept in nests and aggressively guarded by the males. Egg diameters range from 0.49 - 2.3mm. Hatching occurs in 2-4 days for most species, but up to 2 weeks for anemonefish eggs. The planktonic larval stage typically lasts 2-3 weeks but may be longer. Thresher, Colin and Bell (1989) found larval durations for the following genera: *Amphiprion* and *Premnas*: 7-14 days, *Chromis* and *Dascyllus*: 17-47 days with most between 20-30 days, and genera in the subfamily *Pomacentrinae*: 13-42 days. Size at settlement ranges from 7 to 15mm, and several studies suggest that settlement occurs mainly at dusk and at night (Williams 1980, Nolan 1975).

Many damselfishes are suitable for use in aquaria. Three of the species taken in the greatest numbers on Guam are further described below.
<u>Blue-green chromis (*Chromis viridis*)</u>: Huge aggregations of this brightly colored chromis may be seen above thickets of branching corals in protected areas. They occur on subtidal reef flats and in lagoons to depths of around 12 m. The species has a wide distribution throughout the Indo-Pacific, from the Red Sea to Line Islands and throughout Micronesia.

<u>Humbug dascyllus (*Dascyllus aruanus*)</u>: This damselfish occurs in large aggregations in shallow water, above branching *Acropora* heads. The fishes are strongly associated with their home coral heads. They are a shallow-water species, and are distributed from the Red Sea to the Line Islands, Lord Howe Island, and Micronesia.

<u>Three-spot dascyllus (*Dascyllus trimaculatus*)</u>: This popular aquarium species occurs in waters from 1-55m depth. Juveniles shelter among sea anemone tentacles, and adults are found around prominent coral mounds or large rocks. The species has an Indo-Pacific distribution from the Red Sea to the Line Islands, Lord Howe Island, and Micronesia.

4.1.21.8 Turkeyfishes (Scorpaenidae)

The Scorpaenidae, variously known as lionfishes, turkeyfishes, or scorpionfishes, possess venomous dorsal, anal, and pelvic fins in many species. They are stout-bodied, benthic carnivores that typically have fleshy flaps, a mottled coloring, and small tentacles on the head and body. These camouflage features help them to hide and effectively ambush small fishes and crustaceans. Lionfishes and turkeyfishes may swim well above the bottom, whereas small cryptic species of the subfamily Scorpaeninae tend to remain on the bottom and may be quite common in shallow rubbly areas. Fishes in the family are often observed by divers in shallow waters (around 10 m) but may also occur deeper (to at least 50m). In Hawaiian waters, around 25 species in the family are known (Hoover 1993) and 3 are endemic: *Dendrochirus barberi*, *Pterois sphex*, and *Scorpaenopsis cacopsis*. At least 30 species are known from Micronesia, and at least 22 species are recorded from Samoa.

Most reef scorpaenids (*Scorpaena, Pterois, Dendrochirus*) have 0.7-1.2mm spherical to slightly ovoid eggs embedded in a large, pelagic, sac-like gelatinous matrix (Leis & Rennis 1983). Eggs hatch in 58-72 hours. The duration of the planktonic larval stage is not known.

4.1.21.9 Feather-duster Worms (Sabellidae)

Feather-duster worms are attached benthic invertebrates in the Phylum Annelida, Class Polychaeta. The most conspicuous part of these animals is the large fan, or crown. The body is enclosed in a leathery tube that is mostly embedded in the substrate of the reef, often in sandy or rubble-bottom areas. Feather-duster worms generally prefer shallow, turbid waters, and can be found inhabiting harbors, bays, and similar sheltered areas. Occasionally, they are also found in clearer waters, down to depths of 30m or more.

Collectively, the aquarium fish unit comprises a diverse array of organisms that favor a wide variety of substrates, depths, and habitats. However, in general the group is characterized by a close association with the shallow coral reef environment, and most collecting of the species in the group occurs within a narrowly-defined range, i.e., from near-surface waters to depths usually no greater than about 50 m. The EFH for the juvenile and adult phase of this management unit is therefore designated as all coral, rubble, or other hard-bottom features and the adjacent water column from 0-50 fm. EFH for eggs and larvae of the group (though some eggs are demersal, e.g. in damselfishes) is described to include waters from 0-50 fm from the shoreline to the limits of the EEZ.

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4.2 Potentially Harvested Coral Reef Management Unit Species

Introduction

This report presents a compilation of information that will be used to help to define essential fish habitat (EFH) as part of a Coral Reef Ecosystem (CRE) Fisheries Management Plan (FMP) for the Western Pacific Region pursuant to Sections 303(a) and (b) of the Magnuson-Stevens Act. The development of a CRE FMP is also in keeping with the spirit and intent of Executive Order No. 13089 on Coral Reef Protection, issued by the President on June 11, 1998.

The report presents data for selected fish, invertebrate, and sessile taxa, termed Management Units Species (MUS), occurring within the geographical fishery management units (FMUs) under the jurisdiction of the Western Pacific Regional Fishery Management Council (WPRFMC). Information was gathered through review of available literature, and communication with authorities in the field. For each taxon, an effort was made to locate those data that will be helpful in defining EFHs, including descriptions of the habitat and ecological requirements for each life phase of the organisms under consideration.

For the purpose of this investigation, the taxa included were limited to those known or believed to occur on or in association with coral reefs, at least during some phase of the life cycle. In general therefore, pelagic taxa are excluded from this report. Similarly, those species occurring exclusively in zones deeper than the typical depth for coral reefs (as defined by the lower limits of the photic zone, i.e., 100 m depth), are not included.

4.2.1 EFH for Management Unit Species ▪ Fish

4.2.1.1 Acanthuridae (surgeonfishes)

The acanthurids typically have ovate to elongate compressed bodies, a small terminal mouth with a single row of close-set teeth, eyes high on the head, continuous unnotched dorsal and anal fins, and a tough skin with very small ctenoid scales. The common name surgeonfish stems from the presence of one or more pairs of sharp spines on the caudal peduncle which may be used to slash other fish or unwary human handlers. In species of the genera *Acanthurus*, *Ctenochaetus*, and *Zebrasoma*, the single lancet-like spine folds into a groove, while species of *Naso* have 2 fixed, keel-like spines. Some *Naso* species have a horn-like projection on the forehead, and as a result all members of the genus are commonly called unicornfishes. Generally, acanthurids are diurnal herbivores or planktivores. Species of *Ctenochaetus* and some of *Acanthurus* have a thick-walled gizzard-like stomach and often ingest sand with their diet of benthic algae. Some species of *Acanthurus* and many *Naso* spp. feed mainly on zooplankton in the water column. All acanthurids shelter on the reef at night. Reproduction typically occurs on a lunar cycle with greater activity in winter or early spring, but with some activity throughout the year. Spawning events are more frequent at dusk and involve groups, pairs, or both. The larval stage is long by reef fish standards, and size at settlement is larger than most. Surgeonfishes are important foodfishes on most Pacific islands. This description was composed from Myers (1991) and Randall (1996).

Habitat utilization - Jones (1968) divided the acanthurids from Hawaii and Johnston Island into 4 major habitat types: mid-water (*Acanthurus thompsoni*, *Naso hexacanthus)*, sand patch (*A. dussumieri*, *A. mata*, *A. olivaceous*, *A. xanthopterus*), subsurge reef (*A. nigrofuscus, A. nigroris, A. sandvicensis, Ctenochaetus hawaiiensis, C. strigosus, Naso brevirostris, N. lituratus, N. unicornis*, *Zebrasoma flavescens*, *Z. veliferum*), and seaward reef or surge zone (*A. achilles, A. glaucopareius*, *A. guttatus*, *A. leucopareius*) dwellers. The same paper gives extensive descriptions of feeding habits and each species use of the habitat features.

Life history - The biology and life history of surgeonfish have been studied in a number of Western Pacific locations, including *Acanthurus triostegus* in Hawaii (Randall 1961), *Naso brevirostris* in French Polynesia (Caillart 1988), and *Acanthurus nigricauda* and *A. xanthopterus* in Papua New Guinea (Dalzell 1989). Age and growth has been described by a combination of oberving captive specimens, otolith microstructure, length frequency data, and tagging. Lou and Moltschanowskyj (1992) validated daily growth increment formation on otoliths of several juvenile surgeonfish species, and Lou (1993) plotted growth curves for juvenile *Ctenochaetus binotatus* by measuring lapillus growth increments. Surgeonfishes have relatively long life spans. Randall (1961) reported *Naso unicornis* and *Acanthurus xanthopterus* living 15-20 years in captivity. Surgeonfish on the Great Barrier reef have shown an average maximum life span of over 20 years, and 40 years in one instance (Dalzell et al. 1996). Both of these situations involve no mortality from fishing. Hart & Russ (1996) measured *A. nigrofuscus* ages and found a mean age at different reefs on the Great Barrier reef ranging from 5.4 to 9.5 years, with the oldest specimen being 25 years old. Choat and Axe (1996) aged 10 species of acanthurids from the Great Barrier Reef through the use of otoliths and found life spans of 30-45 years in which growth was very rapid in the first 3-4 years of life. In American Samoa, Craig et al. (1997) found *A. lineatus* to grow very rapidly during the first year, 70-80% of total growth, followed by slower growth and a long life, up to 18 years.

Permanent sexual dimorphism is uncommon in the family. There are usually few differences between males and females, though in some species there are size differences, usually larger males. Males of the genus *Naso* frequently have a larger horn than females. Sexual dichromatism only exists during times of spawning, the rest of the time the sexes are similarly colored. Spawning is frequently timed with the lunar cycle, either during a new moon, a full moon, or both. Many surgeonfishes spawn in large aggregations, and others spawn strictly in pairs. Pair spawners may spawn throughout the lunar month (Robertson et al. 1979). The act of reproduction for all surgeonfishes involves a quick upward rush of the participants and a release of gametes into the water column. Spawning rushes typically occur in low light conditions, usually at or near dusk.

Detailed descriptions of spawning behavior and spawning cycles of eight Indo-Pacific surgeonfish species are given in Robertson (1983).

Acanthurids appear to have a peak in spawning activity in late winter and early spring. Spawning of *Acanthurus triostegus* in Hawaii occurs primarily from December to June

(Thresher 1984). Watson and Leis (1974) identified peak spawning from March to May, and another peak in October, for many reef fish in Hawaii, including acanthurids. There are instances of year-round spawning, and Randall (1961) suggested that seasonal variations in spawning may be less obvious in the deep tropics where variations in seawater temperature are less pronounced. Large aggregations of acanthurids do occur during spawning events, often near the mouths of channels in the reef and in areas with strong offshore currents (Randall 1961, Johannes 1981).

There are no species of surgeonfish endemic to any of the management areas in this plan, although *A. triostegus sandvicensis* in Hawaii is recognized as a subspecies. Also, *Zebrasoma flavescens* has a distribution from the North Pacific to southern Japan, but it is abundant only in Hawaii. Twenty three species of surgeonfish are found in Hawaii (Randall 1996), 39 species in Micronesia (Myers 1991), and 32 species in Samoa (Wass 1984).

Schooling behavior is common in acanthurids, particularly in association with spawning aggregations. Biologists have documented trains of surgeonfishes traveling along the reef to join thousands of other surgeonfish at spawning aggregation sites. Once there, the fish mingle near the substrate and slowly move upward as a group. Near dusk, small groups (6-15 individuals) of fish make spawning rushes to near the water surface and release gametes. Following spawning, fish return to the substrate, form trains, and return to their home reefs. Many species also form large single-species or mixed-species schools, apparently for overwhelming territorial reef fish to feed on the algal mats they are protecting.

<u>Trophic ecology</u> - Although acanthurids are predominantly herbivores, they are diverse and delicate feeders harvesting a variety of plants and organic materials which are processed in a gut environment characterized by a complex microflora (Choat 1991). Species of *Ctenochaetus* feed on detritus and algal fragments by whisking them from the substrate with comb-like teeth. *Acanthurus thompsoni*, *Naso annulatus, N. brevirostris, N. caesius, N. hexacanthus*, and *N. maculatus* feed primarily on zooplankton well above the bottom. *Naso lituratus* and *naso unicornis* browse mainly on leafy algae such as *Sargassum* (Randall 1996).

Surgeonfishes commonly defend territories that are primarily feeding territories (Robertson et al. 1979). In a study of the behavioral ecology of *Acanthurus lineautus, A. leucosternon*, and *Zebrasoma scopas*, Robertson et al. (1979) described the morphology, feeding strategies, and social and mating systems of three territorial species that occupied characteristic depth zones and habitat types.

Jones (1968) identified *Acanthurus thompsoni* and *Naso hexacanthus* as zooplankton feeders on copepods, crustacean larvae, and pelagic eggs; *A. dussumieri, A. mata, A. olivaceus, Ctenochaetus hawaiiensis*, and *C. strigosus* as grazers on a calcareus substratum rich in diatoms and detritus; and *A. achilles, A. glaucopareius, A. guttatus, A. leucopareius, A. nigrofuscus, A. nigroris, A. sandvicensis, Zebrasoma flavescens, Z. veliferum, Naso brevirostris, N. lituratus*, and *N. unicornis* as browsers on multicellular benthic algae.

Pacific fisheries- Surgeonfishes are important food fish on many Pacific islands, where they are typically caught by spearfishing or nets. Some species are also sought after for the aquarium trade.

Main Hawaiian Islands - Less than 12% of the catch of inshore fishes reported in DAR commercial statistics from 1991-1995 came from federal waters (Friedlander 1996). For catches reported to DAR between 0-200nm, six of the top 25 inshore species by weight are acanthurids: *A. dussumieri*-32,407 lbs, *A. triostegus*-11,705 lbs, *Naso* spp.-9969 lbs, *A. xanthopterus*-5,234 lbs, *A. olivaceous*-4,813 lbs, and *Ctenochaetus strigosus*-3,776 lbs (Friedlander 1996).

Northwestern Hawaiian Islands - No data is available on catches of surgeonfish in this area, where inshore fisheries are fairly unexploited (see Green 1997).

American Samoa - Craig et al. (1993) reported that no major commercial fishery operates in federal waters in American Samoa. Closer to shore, *Acanthuridae* compose 28% of the reef fish catch (Dalzell et al. 1996). Over 40% of the catch composition by weight in the 1994 artisanal fishery was surgeonfishes (in Craig et al. 1995). In 1994, *A. lineatus* ranked second among all species harvested in both the artisanal and substience fisheries, accounting for 10 % of the total catch of 295 metric tons (Craig et al. 1997). The artisanal fishery captured 28 t of *A. lineatus* by spearfishing. A much smaller amount of that species, only 1-3% of the catch, was taken in the subsistence fishery by use of gill nets, throw nets, rod-and-reels, and handlines.

Guam - At this time, much less than 20% of the total coral reef resources harvested in Guam are taken from federal waters (Myers 1997). Acanthuridae composed 9.12 % of the reef fish catch in Guam (Dalzell et al. 1996). Small-boat based spearfish landings from FY85-91 were 19.0% surgeonfishes by weight (Myers 1996). Further discussion of reef fish catches in Guam can be found in Green (1997).

CNMI - Most reef fish landed in the Northern Mariana Islands are reported as mixed reef fish. Only 1.11% of the catch was assigned to surgeonfishes (Dalzell et al. 1996).

Egg and larval distribution - Acanthurid eggs are pelagic, spherical, and small - 0.66-0.70 mm in diameter with a single oil droplet to 0.165 mm for *Acanthurus triostegus sandvicensis* (Randall 1961). For that species, hatching occurred in about 26 hours. Watson and Leis (1974) found an egg size of 0.575 to 0.625 mm in diameter for an unidentified acanthurid from Hawaii.

Acanthurid larvae are typically diamond-shaped and strongly laterally compressed, with a prominent serrated dorsal spine, two large and serrated pelvic fin spines, and a single smoother spine near the anal fin (Thresher 1984). Late larval stages, roughly 20-25 mm, are orbicular, transparent except for a silvery abdomen and gut, with small scales in narrow vertical ridges on the body (Randall 1996). Spines on the larvae serve to enhance protection from predation, and may be venomous. Lou (1993) reported that *Ctaenochaetus binotatus* larvae fed on various zooplankton for a larval period ranging from 47-74 days. Similarly, Randall (1961) reported a zooplankton diet and a larval duration of 2.5 months for *Acanthurus triostegus sandvicensis*.

Surgeonfish larvae are primarily found well offshore at depths from 0-100m. Like other common adult members of the coral reef fish community, surgeonfish larvae are typically less abundant in samples of the water column near the reef than they are in samples from offshore (Miller 1973).

Although surgeonfish generally settle at a larger size than most reef fish, acanthurids are one of the families with juveniles that settle with larval characters still present (Leis & Rennis 1983). Late phase larvae actively swim inshore at night, seek shelter in the reef, and begin growing scales and intestines to complete the transformation to juveniles (Clavijo 1974). Lengthening of the alimentary track to accommodate an herbivorous diet happens fairly quickly. Juvenile surgeonfish have been reported to shelter in tide pools in Hawaii (Randall 1961). Hart and Russ (1996) found an age-at-maturity for *Acanthurus nigrofuscus* of 2 years. Choat (1991) reported a range of 12-18 months to maturity for acanthurids. Juveniles frequently differ in coloration and behavior from adults.

Adult surgeonfish are found in many coral reef habitat types, including mid-water, sand patch, subsurge reef, and seaward or surge zone reef. The largest number of surgeonfish species are typically found in the subsurge reef habitat, which are defined by Jones (1968) to be areas of moderate to dense coral growth corresponding to the subsurge portions of fringing reefs, deepwater reef patches, reef filled bays, and coral-rich parts of lagoons inside of atolls. These species are typically found between 0-30m depth, although surgeonfish do live in depths from 0-150m. Some species of *Naso* have been seen below 200m (Chave & Mundy 1994).

Acanthurids were the dominant family of fishes in Hanalei Bay in both numbers and biomass (Friedlander 1997). There were high numbers of surgeonfish in shallow, complex backreef habitat. Biomass for the depth stratum 4.3-7.2m was dominated by three surgeonfish species, *A. Tristegus, A. leucopareis,* and *Ctenochaetus strigosus*. *C. strigosus* and *A. nigrofuscus* were common in the shallow complex backreef as well as in the deep slope and spur and groove habitat types (Friedlander and Parrish 1998).

As an example for the family, *Acanthurus nigrofuscus* form schools that migrate 500 to 600m daily to intertidal feeding areas of algal turf communities. In the summer, the main food items are brown and red algae, while in the winter, it is green algae. Spawning occurs in large schools of 2000 to 2500 fish on selected sites at dusk (Fishelson et al. 1987).

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Table 27. Management Unit Species: Acanthuridae (surgeonfishes)

	Egg	Larvae	Juvenile	Adult
Duration	26 hours for *A. triostegus sandvicensis*	47-74 days for *C. Binotatus*, 2.5 months for *A. triostegus sandvicensis*	1-2 years	25 yrs for *A. Nigrofuscus* (Hart & Russ 1996), over 40 yrs for *Naso* spp. (Choat & Axe 1996)
Diet	N/A	various zooplankters (Randall 1961)	mostly herbivorous although some may feed on zooplankton	*Acanthurus* & *Zebrasoma* - algal turfs, *Ctenochaetus* - detritus and sediment, *Naso* & *Paracanthurus* - mostly zooplankton
Distribution, general and seasonal	some species spawn year-round, but generally there appears to be a peak in spring and early summer; many species show lunar spawning periodicity	year-round distribution, with perhaps more settlement in late summer or fall	coral reef habitats throughout the Western Pacific	coral reef habitats throughout the Western Pacific, spawning aggregations at prominent outcroppings, some species are fairly stationary and territorial while others travel long distances for feeding
Location	water column from the surface to 100m	0-100m, larvae typically are more common in offshore waters than in water over reefs	tide pools, refugia on the reef	bottom and water-column; most between 0-100m but some deeper than 200m
Water column	N/A	pelagic	demersal and mid-water	demersal and mid-water
Bottom type	N/A	N/A	coral, rock, sand, mud, rubble, pavement	coral, rock, sand, rubble, pavement
Oceanic features	subject to ocean currents	subject to ocean currents		spawning aggregations may occur at channels just before or during outgoing tide

4.2.1.2 Carcharhinidae, Sphyrnidae, *Triaenodon obesus* (sharks)

Carcharinidae is one of the largest and most important families of sharks, with many common and wide-ranging species found in all warm and temperate seas. They are the dominant sharks in tropical waters in variety, abundance and biomass. Most species inhabit tropical continental coastal and offshore waters, but several species prefer coral reefs and oceanic islands. All members of *Carcharhinidae* have a circular eye, nictitating eyelids, a first dorsal fin positioned well ahead of the pelvic fins, precaudal pits and well developed lower caudal lobe.

Sharks differ from bony fishes in their cartilagenous skeleton, 5 to 7 gill openings on each side of the head, the frequent presence of a spiracle behind or below the eye, a rough skin composed of small, close-set dermal denticles, the absence of a swimbladder and the presence of a very large liver with large amounts of oil. Many sharks are apex predators in the food chain, feeding on bony fishes, octopuses, squids, shrimps, sea birds, other sharks and rays, sea turtles and marine mammals. Many sharks, including members of *Carcharhinidae* and *Sphyrnidae*, make seasonal migrations to warmer waters in the winter and cooler waters in the summer.

DeCrosta et al. (1984) reported on age determination, growth and energetics of the gray reef shark, the Galapagos shark and the tiger shark in the Northwestern Hawaiian Islands (NWHI). They found maximum ages from a sample of 30▪65 specimens of each species to be 10, 15 and 22 years, respectively. The gray reef shark was the most highly piscivorous species with 51% of its diet composed of perciform fish, as well as >12% eels and >22% cephalopods. The Galapagos shark ate primarily cephalopods (43%), tetraodontiform fish (21%), eels (14%) and parrotfish (7 %). The tiger shark was a very opportunistic feeder, with seabirds in 75% of the specimen stomachs, but also sea turtles (33%), lobsters (30%), cephalopods (22%) and tetraodontiform fish (15%).

Sphyrnidae is a small but common family of wide-ranging, warm-temperate and tropical sharks found in continental and insular waters. Depths range from the surface to at least 275 m depth. Hammerheads are very active swimmers, ranging from the surface to the bottom. They are versatile feeders on bony fishes, elasmobranchs, cephalopods, crustaceans and other prey, although some may specialize on other elasmobranchs (Compagno 1984). Sphyrnids are similar to carcharhinids with one obvious exception, a blade-like lateral extension of the head. The head shape serves to spread the eyes and olfactory organs farther apart and may increase electroreception, vision and smell; increases lift and maneuverability; and may be used to pin prey such as rays to the bottom.

Sharks reproduce by internal fertilization. Male sharks can be identified by the presence of a pair of claspers along the medial edge of the pelvic fin. The tiger shark, *Galeocerdo cuvier*, and most sharks are ovoviviparous, developing eggs within the uterus. The sharks of *Sphyrnidae* and *Carcharinidae* except the tiger shark, are viviparous, nourishing embryos by a placenta-like organ in the female. Some species such as *Nebrius concolor* and *Sphyrna lewini* move into shallow water to give birth. Calm, protected bays such as Kaneohe Bay are important nursery areas for sharks such as *S. lewini*.

Forty species of sharks are known from Hawaiian waters, but 20 of them occur only in deep water. Sharks likely to be associated with coral reefs in Hawaii include the gray reef shark *Carcharhinus amblyrhynchos*, the Galapagos shark *C. galapagensis*, the tiger shark *Galeocordo cuvier*, the blacktip reef shark *Carcharhinus melanopterus*, the sandbar shark *C. plumbeus*, the whitetip reef shark *Triaenodon obesus* and the scalloped hammerhead *S. lewini*. Ten species of carcharhinid sharks and two sphyrnid species, *S. lewini* and *S. mokorran*, are described for Micronesia in Myers (1991). Twelve carcharhinid and two sphyrnids are recorded for American Samoa.

Schooling is well documented for many shark species, especially the hammerheads. These species make long migrations in large groups for the purpose of spawning.

<u>Trophic ecology</u> - Sharks are apex predators on many coral reefs, where their presence may be a good indication of large stocks of fishes upon which they feed. All sharks are carnivorous, feeding on a wide variety of fishes, elasmobranchs and invertebrates including eagle rays, other sharks, reef fish, cephalopods, crustaceans, tuna, baitfishes and mahimahi. Larger species such as tiger sharks and great white sharks feed on those animals as well as porpoises, whales, sea turtles, sea birds, domestic animals, humans occasionally and marine debris, such as tin cans and plastic cups. Many sharks are nocturnal feeders, as sensory organs such as ampullae of Lorenzini are used to detect electomagnetic fields of prey fishes. The same sensory systems, including exceptional smell and a highly developed lateralis system, allow sharks to detect injured prey from considerable distance and lead to opportunistic feeding during the day as well.

<u>Reproductive ecology</u> - Egg and larval distribution are not applicable to sharks because they develop eggs internally. Sharks typically have a gestation period within the female of about 12 months. The gestation period and number of offspring per litter of common Western Pacific Region reef-associated sharks are *Triaenodon obesus* - 13 mths, 1–5 pups; *Carcharhinus albimarginatus* - 12 mths, 1–11 pups; *C. amblyrhynchos* - about 12 mths, 1–6 pups; *C. falciformis* - 2–14 pups; *C. galapagensis* - 6–16 pups; *C. melanopterus* - 8–9 mths, 2–4 pups; *Galeocerdo cuvier* - 12–13 mths, 10–82 pups; *C. plumbeus* - 8–12 mths, 1–14 pups, *Negaprion acutidens* - 1–11 pups; *Sphyrna lewini* - 15–31 pups; and *S. mokorran* - 13–42 pups.

Juvenile sharks frequently inhabit inshore areas such as bays, seagrass beds and lagoon flats before moving into deeper water as they mature. For example, *S. lewini* has well-documented nursery areas in shallow, turbid coastal areas such as Guam's inner Apra Harbor and Kaneohe Bay and Keehi lagoon on Oahu in Hawaii. The southern part of Kaneohe Bay is a major breeding and pupping ground for this species. Pups tend to avoid light, preferring more turbid water. They school in a core refuge area during the day and then disperse at night, foraging along the base of patch reefs (Clarke 1971, Holland et al. 1993). Schools of young hammerheads forage near the bottom within these bays before moving to deeper outer reef waters as adults.

Size at maturity for reef-associated sharks within the management area are *T. obesus* - 101 cm for females and 82 cm for males, *C. galapagensis* - 205■239 cm for males and 215■245 cm for females, *C. melanopterus* - 131■178 cm for males and 144■183 cm for females, *G. cuvier* - 226■290 cm for males and 250■350 cm for females, C. plumbeus - 131■178 cm for males and 144■183 cm for females, *S. lewini* - 140■165 cm for males and about 212 cm for females, and *S. zygaena* - about 210■240 cm for males and females.

Adult sharks can be found in shallow inshore areas during mating or birthing events. Some species forage in these shallow areas as well. Reef-associated sharks are found in a wide variety of coral reef habitats, and because of their wide-ranging nature, no particular coral reef habitat except the inshore areas important for mating and birthing holds significantly higher numbers of sharks than other habitats. The larger species, such as *Galeocerdo cuvier*, are more often found on outer reef slopes near deep dropoffs. Randall et al. (1993) noted the presence of tiger sharks in lagoon waters of Midway Island during June■August when they prey upon fledgling Laysan albatross. Adult female gray reef sharks *C. amblyrhynchos* aggregate seasonally over shallow reef areas in the NHWI.

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Table 28. Management Unit Species: Carcharhinidae, Sphyrnidae (sharks)

	Gestation	Juvenile	Adult
Duration	about 12 months	to 5▪10 years or more	to 20 years or more
Diet	N/A	carnivorous - fish, elasmobranchs, squid, crustaceans, molluscs, may feed more intensively on crustaceans in inshore nursery areas	carnivorous - fish, elasmobranchs, squid, crustaceans, molluscs
Distribution, general and seasonal	Sphyrnids and some Carcharhinids have inshore nursery grounds	variable among species, *S. lewini* and *Negaprion acutidens* inhabit inshore nursery grounds	Carcharinidae: variable among the family from Indo-Pacific, circumglobal, and circumtropical Sphyrnidae: circumtropical
Location	variable	highly variable, *S. lewini* and *Negaprion acutidens* inhabit inshore nursery grounds	Carcharinidae: highly variable among the family Sphyrnidae: primarily pelagic but use inshore areas for reproduction
Water column	N/A	inshore benthic, neritic to epipelagic, 1▪275 m	inshore benthic, neritic to epipelagic, mesopelagic. 1▪275 m
Bottom type	N/A	highly variable due to wide-ranging nature of most species	highly variable due to wide-ranging nature of most species
Oceanic features	N/A	unknown	unknown

4.2.1.3 Dasyatididae, Myliobatidae, Mobulidae (rays)

The rays are characterized by a flattened form, a lack of dorsal fins, a distinct tail which has one or more venomous barbs in some families and a small mouth with close-set pavement-like teeth. Water is taken in through a spiracle behind the eye and expelled through gill slits on the underside of the ray. Rays often bury into the sand with only the eyes and spiracle showing. Most rays are carnivorous on shellfish, worms and small burrowing fishes, except the members of Mobulidae that feed on zooplankton in the water column. Rays are ovoviviparous, giving birth to fully developed young that are nourished from vascular filaments within the uterus during gestation.

<u>Dasyatidae</u> - There are 3 species in Hawaii - *Dasyatis violacea*, *D. brevis* and *D. latus*; 4 species in Micronesia - *D. kuhlii, Hymantura uarnak, Taeniura melanospilos* and *Urogymnus asperrimus*; and 2 species in Samoa - *D. kuhlii* and *Hymantura fai*. Sting rays feed on sand-dwelling and reef-dwelling invertebrates and fishes, often excavating large burrows in sand bottoms to capture subsurface mollusks and worms.

<u>Myliobatidae</u> - One species, the spotted eagle ray *Aetobatis narinari*, represents the family in Hawaiian, Micronesian and Samoan waters. Eagle rays feed mainly on hard-shelled mollusks and crustaceans, using their snout to probe through sand and powerful jaws to crush the shells. An average of 4 pups is born per litter after a gestation period of about 12 months. They have a depth range from the intertidal to 24 m. Groups move from reef channels and the reef face during flood tide to feed. Schools of up to 200 individuals have been observed.

<u>Mobulidae</u> - One species of manta ray, *Manta birostris* (which recently has come to include other synonyms, including *M. alfredi*) represents the family in Hawaiian and Micronesian waters. Mantas are the largest of all rays and may attain a width of 6.7 m and a weight of 1,400 kg. They occur singly or in small groups in surface or mid-waters of lagoons and seaward reefs, particularly near channels. They strain zooplankton from the water using cephalic flaps to direct the plankton into the mouth. They occur in all tropical and subtropical seas. Mating and birthing occur in shallow water, and juveniles often remain in these areas before heading into deeper water as adults. During winter, mantas may migrate to warmer areas or deeper water or disperse offshore.

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Table 29. Management Unit Species: Dasyatididae, Myliobatidae, Mobulidae (rays)

	Gestation	Juvenile	Adult
Duration	about 12 months for Myliobatidae, avg of 4 pups	little information	little information on longevity
Diet	N/A	small fish, crustaceans, mollusks, worms, zooplankton for Mobulidae, may be a greater emphasis on shellfish for juveniles in shallow water habitats	fish, crustaceans, mollusks, worms, zooplankton for Mobulidae
Distribution, general and seasonal	N/A	*Dasyatis latus* range includes Hawaii and Taiwan, *D. kuhlii* and *Hymantura uarnak* range through the Indo-west-Pacific, *Taeniura melanospilos* and *Urogymnus asperrimus* range the Indo-Pacific, the spotted eagle ray and manta ray are circumtropical	*Dasyatis latus* range includes Hawaii and Taiwan, *D. kuhlii* and *Hymantura uarnak* range through the Indo-west-Pacific, *Taeniura melanospilos* and *Urogymnus asperrimus* range the Indo-Pacific, the spotted eagle ray and manta ray are circumtropical
Location	variable	wide variety of habitats from shallow lagoons to outer reef slopes, nursery areas in seagrass beds, mangroves, and shallow flats are important for many species	wide variety of habitats from shallow lagoons to outer reef slopes, generally located from 0-100m but have been found much deeper
Water column	N/A	demersal and in the water column	demersal and in the water column
Bottom type	N/A	soft (sand and mud), coral reef, pavement	soft (sand and mud), coral reef, pavement
Oceanic features	N/A	unknown	unknown

4.2.1.4 Chlopsidae, Congridae, Moringuidae, Ophichthidae (eels)

There are 15 families of true eels, and these are some of the important ones on Western Pacific Region coral reefs. The eels are characterized by very elongate bodies, lack of pelvic fins, very small gill openings and a caudal fin that, if present, is joined with the dorsal and anal fins.

Members of Muraenidae, the morays, lack pectoral fins and scales and have a large mouth. Most species have long, fang-like teeth, but some do not. Species with long canines feed mainly on reef fishes, occasionally on crustaceans and octopuses. Species of *Echidna* and *Gymnomuraena* with mainly nodular or molariform teeth feed more on crustaceans, especially crabs. Morays have a lengthy pelagic leptocephalus larval stage that has resulted in a very wide distribution. Morays are hunted for food in many locations, even though large individuals may be ciguatoxic. Morays typically remain hidden within the framework of the reef, and many are more active at night than during the day. There are 38 species of morays in Hawaii, second only to the wrasses for number of species. *Gymnothorax steindachneri* is endemic to Hawaii. At least 53 species are known from Micronesia. At least 47 species are known from Samoa.

Members of Chlopsidae, the false morays, resemble morays but have pectoral fins and posterior nostrils open to the margin of the upper lip. Males are typically smaller with larger teeth, which may be used for grasping females during courtship. They probably migrate off the reef to spawn but otherwise stay well hidden within the reef framework. Five species are recorded from Samoa.

Members of Congridae include the conger eels and garden eels. Conger eels have well-developed pectoral fins. Garden eels are smaller, extremely elongate burrowing forms with reduced or absent pectoral fins. They occur in large colonies on sand plains or slopes at depths of 7–53 m with strong currents. They are diurnal planktivores that extend from their burrows to feed on plankton in the current. The large-eye conger, *Ariosoma marginatum*, and the Hawaiian garden eel, *Gorgasia hawaiiensis,* are endemic to Hawaii. Five species are recorded in Samoan waters.

Members of Moringuidae, the spaghetti eels, have extremely elongate bodies with the anus located about two thirds of the way back. They change morphology radically as they mature. Immature spaghetti eels are orange-brown with small eyes and reduced fins. Mature eels have large eyes and a distinct caudal fin and are dark above and silvery below. Females burrow in shallow sandy areas but migrate to the surface to spawn with males, which are pelagic. Six species are recorded from Samoan waters.

Members of Ophichthidae, the snake eels, have elongate, nearly cylindrical bodies with median fins and small pectoral fins. Most species of snake eels are indwellers that stay buried in the sand but a few will occasionally come out and swim across sand, rubble or seagrass habitats. They appear to be nocturnal, and some species, if not all, come to the surface to spawn at night. Sixteen species are reported from the Hawaiian Islands. The freckled snake eel, *Callechelys lutea,* is endemic to Hawaii, and the magnificent snake eel, *Myrichthys magnificus,* is endemic to the Hawaiian Islands and Johnston Island. At least 26 species are known from Micronesia. Five species are recorded from Samoan waters.

Sexual characteristics of eels vary widely among the different families. Spawning migrations are a general, though not universal, characteristic of eel reproduction. Eel species that migrate for spawning, including members of the congrids, moringuids and ophichthids, tend to be sexually dimorphic, with moringuids displaying the greatest morphological difference between males and females. Nonmigratory eels such as morays and garden eels typically have no definitive external sexual dimorphism. Hermaphroditism has been documented for some species, including some morays, but is not a widespread characteristic of eels. Group spawning of eels has been documented, with large numbers of adults congregating at the water surface at night.

Eel eggs are pelagic and spherical with a wide periviteline space, usually no oil droplets and in some species a densely reticulated yolk. The eggs are relatively large, ranging from 1.8 to 4.0 mm. Watson and Leis (1974) collected 145 eels eggs off Hawaii that ranged from 2.4 to 3.8 mm. Brock (1972) found 200,000 to 300,000 ripe eggs in each of four 5.0 to 6.8 kg *Gymnothorax javanicus*. Hatching of an unidentified 1.8 mm muraenid egg took approximately 100 hours (Bensam 1966).

Eels have a characteristic leptocephalus larval stage: a long, transparent, feather-shaped larva that starts out at 5-10 mm and grows up to 200 mm before settlement and metamorphosis. The duration of the planktonic stage is on the order of 3■5 months for moringuids (Castle 1979), 6■10 months for muraenids (Eldred 1969, Castle 1965) and about 10 months for some congrids (Castle and Robertson 1974).

Both juvenile and adult eels inhabit cryptic locations in the framework of the reef or in sand plains for some species. Some species remain so hidden within the reef that they have never been seen alive; their existence is known only from samples taken with the use of poisons.

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Table 30. Muraenidae, Chlopsidae, Congridae, Moringuidae, Ophichthidae (eels)

	Egg	Larvae	Juvenile	Adult
Duration	100 hours or more	3–10 months		
Diet	N/A	zooplankton	most are benthic carnivores on fish, octopus, crustaceans; frequently nocturnal garden eels are diurnal planktivores	most are nocturnal benthic carnivores on fish, octopus, crustaceans; the morays of Gymnomuraena, Enchelycore and Sideria feed mainly on crustaceans; garden eels are diurnal planktivores
Distribution, general and seasonal	eggs frequently released near the surface; some are pelagic spawners, others spawn on reefs	predominantly offshore	worldwide in tropical and temperate seas; *Callechelys lutea*, *Ariosoma marginatum*, *Gorgasia hawaiiensis* and *Gymnothorax steindachneri* are endemic to the Hawaiian islands; *Myrichthys magnificus* is endemic to the Hawaiian Islands and Johnston Island	worldwide in tropical and temperate seas; *Callechelys lutea*, *Ariosoma marginatum*, *Gorgasia hawaiiensis* and *Gymnothorax steindachneri* are endemic to the Hawaiian Islands; *Myrichthys magnificus* is endemic to the Hawaiian Islands and Johnston Island
Location	near reefs and offshore	predominantly offshore	coral reefs and soft-bottom habitats	coral reefs and soft-bottom habitats
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef crevices, holes; sand, mud, rubble	coral reef crevices, holes; sand, mud, rubble
Oceanic features				

4.2.1.5 Engraulidae (anchovies)

The anchovies are a large family of small, silvery schooling fishes that are common baitfish for pole-and-line tuna fisheries. They share many of the characteristics of the clupeids but can be distinguished by their rounded overhanging snout and slender lower jaw. Most species also have a brilliant silver mid-lateral band. Anchovies typically inhabit estuaries and turbid coastal waters. However, but some occur over inner protected reefs, and, at least one, *Encrasicholina punctifer*, is found in the open sea. Anchovies occur in dense schools and feed by opening their mouths to strain plankton from the water with their numerous gill rakers. Two species are known from Hawaiian waters: the endemic Hawaiian anchovy *Encrasicholina purpurea* and the offshore species *E. punctifer*. Seven species are known from Micronesian waters. Four species are known from Samoan waters.

Anchovy eggs are pelagic. In *Coilia, Setipinna* and *Thryssa* they are spherical and of small to moderate size (0.8■1.6 mm). Eggs of *Encrasicholina*, *Engraulis* and *Stolephorus* are ovate to elliptical and vary from small to large (0.8■2.3 x 0.5■0.8 mm) (Zhang et al 1982, Fukuhara 1983, McGowan and Berry 1984, Ikeda and Mito 1988). Larvae hatch at 2.5■3.7 mm. The size of the largest pelagic specimen examined by Leis and Trnski (1989) was 23■27 mm.

Thryssa baelama occurs in large schools in turbid waters of river mouths and inner bays. The oceanic or buccaneer anchovy *E. punctifer* is mostly pelagic, but it can be found in large atoll lagoons or deep, clear bays. The blue anchovy *E. heterolobus* occurs primarily in deep bays under oceanic influence. Other anchovies occur in estuaries and coastal bays.

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Table 31. Management Unit Species: Engraulidae (anchovies)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	plankton	plankton	plankton
Distribution, general and seasonal			same as adults	Two species in Hawaiian waters: the endemic Hawaiian anchovy *Encrasicholina purpurea* and the offshore species *E. punctifer*. Seven Micronesian species. Four Samoan species.
Location			schools in inshore waters	estuaries and turbid coastal waters but some occur over inner protected reefs and at least one, *Encrasicholina punctifer*, is found in the open sea
Water column	pelagic	pelagic	frequently near the surface	frequently near the surface
Bottom type	N/A	N/A	same as adults	sand, coral reef, rock, mud
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.6 Clupeidae (herrings)

Herrings, sardines and sprats are small planktivorous silvery fishes with a single short dorsal fin near the middle of the body, no spines, no lateral line and a forked caudal tail. They are schooling fishes that are important for food and bait. Round herrings include several species that inhabit coral reefs as well as coastal waters. Sardines typically inhabit coastal waters of large land masses or high islands. In Hawaiian waters, 4 species occur. Two were introduced: the goldspot sardine *Herklotsichthys quadrimaculatus* unintentionally from the Marshall Islands in 1972 and the Marquesan sardine *Sardinella marquensis* intentionally from the Marquesas between 1955 and 1959, but it never became abundant. The other two Hawaiian species are the delicate roundherrring *Spratelloides delicatulus*, which is an inshore species that occurs in small schools over coral reefs and the red-eye roundherring *Etrumeus teres*, although it is rare. In Micronesian waters, there are at least 6 species of Clupeidae. In Samoan waters, 9 species have been recorded.

Clupeid eggs are spherical and vary among species from small to large (0.8■2.1 mm). They are thought to be pelagic in all tropical taxa except *Spratelloides*, which has demersal eggs (McGowan and Berry 1984, Jiang and Lim 1986). Clupeid larvae range from 1.6 to 4.7 mm long at the time of hatching. The size of the largest pelagic specimens examined by Leis and Trnski (1989) ranged from 21 to 33 mm.

The gold spot sardine, or herring, is an important food fish in many areas. It schools near mangroves and above sandy shallows of coastal bays and lagoons during the day and moves into deeper water at night to feed. In Belau, it migrates to tidal creeks to spawn from November to April (Myers 1991). The blue sprat *Spratelloides delicatulus* generally schools near the surface of clear coastal waters, lagoons and reef margins where it feeds on plankton.

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Table 32. Management Unit Species: Clupeidae (herrings, sprats and sardines)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	plankton	plankton	plankton
Distribution, general and seasonal			same as adults	Four species in Hawaiian waters; two introduced: *Herklotsichthys quadrimaculatus* and *Sardinella marquensis*, and two others: *Spratelloides delicatulus* and *Etrumeus teres.* At least 6 species occur in Micronesian waters, and at least 9 species occur in Samoa.
Location			schools in inshore waters	estuaries and turbid coastal waters but some occur over inner protected reefs
Water column	pelagic	pelagic	frequently near the surface	frequently near the surface; 0▪20 m
Bottom type	N/A	N/A	same as adults	sand, coral reef, rock, mud
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		most species tend to accumulate in relatively clear coastal, lagoon, and seaward reef waters

4.2.1.7 Antennariidae (frogfishes)

Frogfishes have bulbous bodies, jointed elbow-like pectoral fins that are used like arms, small holes behind the pectorals for gill openings and large upturned mouths. The first dorsal spine is modified to a lure consisting of the slender ilicium tipped with the esca (bait), which is used to attract prey. The frogfishes are very well camouflaged piscivores with cryptically colored prickly skin and fleshy or filamentous appendages. They are able to lure prey by waving the esca above their head, then striking quickly with a large mouth. They are able to swallow prey longer than themselves because of a highly distensible body. At intervals of 3 to 4 days, reproductive females lay thousands of tiny eggs embedded in a large, sometimes scroll-shaped gelatinous mass. Habitats where frogfish are found include bottoms of seagrass, algae, sponge, rock or corals from tidepools to lagoon and seaward reefs. In Hawaiian waters, 6 species are found, with one endemic: the Hawaiian freckled frogfish *Antennarius drombus*. At least 12 species occur in Micronesia, and at least 7 species in Samoa. Frogfishes are rare on most coral reefs and are present only in low numbers if at all.

Spawning by anglerfishes involves the production of a large, jelly-like egg mass. Frogfishes appear to be sexually monomorphic, with the only difference between sexes being the expanded size of the female prior to releasing eggs. For those species that have been observed spawning●*Histrio histrio* (Mosher 1954, Fujita and Uchida 1959), *Antennarius nummifer* (Ray 1961) and *A. zebrinus* (Burgess 1976)●spawning occurred in pairs after a quick spawning rush to the surface. Egg masses, or ■rafts,• or ■scrolls,• vary in size from species to species but are usually quite large. That of *H. histrio* is about 9 cm long (Mosher 1954, Fujita and Uchida 1959); that of *A. multiocellatus, A. tigrinus* and *A. zebrinus* is slightly larger (Mosher 1954, Burgess 1976); and that of *A. nummifer* is about 5 cm across and about 7 cm high (Ray 1961). Some species have immense egg rafts, including a raft produced by *A. hispidus* in an aquarium that was 2.9 m by 15.9 cm (Hornell 1922). Since rafts can be produced at 3-to 4-day intervals for many species, fecundity is extremely high for the frogfishes. Eggs hatch within 2■5 days. For *H. histrio*, growth and development is extremely fast, and an entire generation can take as little as 21 days (Adams 1960). Other species likely have much longer development and life spans.

A different spawning mode has been documented for members of at least two genera, *Lophiocharon* and *Histiophryne*, which brood eggs attached to the body of the male. The eggs are much larger (3.2■4.2mm) and more advanced at hatching than for pelagic spawners (Pietsch and Grobecker 1987).

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Table 33. Management Unit Species: Antennariidae (frogfishes)

	Egg	Larvae	Juvenile	Adult
Duration	2■5 days	days for *H. histrio*, but likely weeks for other species		*H. histrio* may only live a month or so; little information on others but likely to live much longer
Diet	N/A	likely zooplankton	similar to adult	ambush small fish which they lure close by waving an esca that resembles food
Distribution, general and seasonal				shallow tropical and temperate seas worldwide; 6 species in Hawaii with one endemic: the Hawaiian freckled frogfish *Antennarius drombus*. At least 12 species in Micronesia, and at least 7 species in Samoa.
Location	large egg ■raft• released at the surface after a fast spawning rush			from tidepools to lagoon and seaward reefs
Water column	pelagic	pelagic	demersal	demersal; 1■130 m, but most at less than 30 m
Bottom type	N/A	N/A	seagrass, algae, sponge, rock or corals	seagrass, algae, sponge, rock or corals
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.8 Anomalopidae (flashlightfish)

Flashlightfish are small, dark fishes with luminous organs under each eye, blunt snouts, large mouths and a forked tail. The lime-green light is produced biochemically by bacteria within the light organ. The light may be used to attract zooplankton prey, to communicate to other flashlightfish or to confuse predators. They are usually at depths from 30 to 400 m but may be found much shallower in some locations. They remain hidden during the day and venture out at night to feed, tending to occur shallower on dark, moonless nights. Flashlightfish do not occur in the Hawaiian Islands, but two species occur in Micronesian waters: *Anomalops katoptron* and *Photoblepheron palpebratus*. *A. katoptron* also occurs in Samoan waters.

The eggs of *A. katoptron* and *P. palpebratus* are of moderate size (1.0■1.3 mm) with a mucous sheath. They are positively buoyant (Meyer-Rochow 1976). The larvae of *A. katoptron* hatch at 2.6■3.3 mm.

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Table 34. Management Unit Species: Anomalopidae (flashlightfishes)

	Egg	Larvae	Juvenile	Adult
Duration		hatch at a size of 2.6■3.3 mm		
Diet	N/A	zooplankton	zooplankton	zooplankton
Distribution, general and seasonal				none found in Hawaiian Islands; 2 species in Micronesia, *Anomalops katoptron* and *Photoblepheron palpebratus*
Location			same as adult	hidden in caves or crevices by day; active in the water column by night
Water column	pelagic	pelagic	same as adult	demersal by day, and in the water column by night; 5■400 m
Bottom type		N/A	coral reef	coral reef
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.9 Holocentridae (soldierfishes/squirrelfishes)

Holocentrids are spiny, deep bodied, usually red fishes with large eyes and mouth, small teeth, large coarse scales and stout dorsal and anal fin spines. The family is divided into two subfamilies: the Myripristinae (soldierfishes of the genus *Myripristis*, *Plectrypops*, *Pristelepis* and *Ostichthys* are found in the Indo-Pacific; the latter two occur in deep water) and the Holocentrinae (squirrelfishes of the genus *Neoniphon* and *Sargocentron*). Soldierfishes lack a well-developed preopercular spine and a pointed snout, both of which are present in squirelfishes. The spine on the preopercle of squirrelfish may be venomous. Soldierfishes and squirrelfishes are both nocturnal predators, but soldierfish predominantly feed on large zooplankton in the water column while squirrelfish prey mainly on benthic crustaceans, worms and small fishes. During the day, most holocentrids hover in or near caves and crevices or among branching corals.

About 17 holocentrid species inhabit Hawaiian waters, some of them in very deep water. At least 13 species of soldierfishes and 16 species of squirrelfishes occur in Micronesia. At least 31 holocentrid species are found in Samoan waters.

Holocentrids are slow growing, late maturing and fairly long lived. A study (Dee and Parrish 1993) on the reproductive and trophic ecology of *Myripristis amaena* found that sexual maturity for both sexes was reached between 145 and 160 mm SL at about 6 years of age. Longevity was determined to be at least 14 years. Fecundity was relatively low, fewer than 70,000 eggs in the most fecund specimen, and increased sharply with body weight. Spawning peaked from early April to early May, with a secondary peak in September. The diet of *M. amaena* was mainly meroplankton, especially brachyuran crab megalops, hermit crab larvae and shrimps but also a variety of benthic invertebrates and fishes.

M. amaena is particularly important in the recreational fishery at Johnston Atoll where it is the species caught in greatest abundance (Irons et al. 1990). It is common in reef fish catches throughout the Hawaiian archipelago.

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Table 35. Management Unit Species: Holocentridae (soldierfishes/squirrelfishes)

	Egg	Larvae	Juvenile	Adult
Duration		probably several weeks, settle at large size (up to 30 mm or more)	6 years for *M. amaena*	at least 14 years (Dee and Radtke 1989)
Diet	N/A	zooplankton	diet similar to adults	Myropristis spp.: mostly meroplankton, especially brachyuran crab megalops, hermit crab larvae and shrimps, but also a variety of benthic invertebrates and fishes, Holocentrinae: feed mainly on benthic crustaceans
Distribution, general and seasonal	spawning peak in April▪May and another in Sept. for *M. amaena* at Johnston Atoll	generally, a recruitment peak in June-July and another in Feb.▪March, but a lot of variation	tropical Atlantic, Indian, and Pacific Oceans	tropical Atlantic, Indian, and Pacific Oceans
Location				
Water column	pelagic	pelagic	demersal in caves and crevices during the day; demersal and in the water column at night	demersal in caves and crevices during the day ; demersal and in the water column at night
Bottom type	N/A	settle in refugia on the reef	coral reef caves and crevices, also within the branches of branching corals	coral reef caves and crevices, also within the branches of branching corals
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.10 Aulostomidae (trumpetfishes)

Trumpetfishes are very elongate with a compressed body, a small mouth, a long tubular snout, small teeth and a small barbel on the chin. The one Indo-Pacific species occurs in three color patterns: uniformly brown to green, mottled brown to green and uniformly yellow. They feed on fishes and shrimps by slowly moving close to the prey, often in a vertical stance, and then darting forward to suck the prey in through its snout. Trumpetfishes inhabit rocky and coral habitats of protected and seaward reefs from below the surge zone to a depth of 122 m. They have an ability to blend in with a background of coral branches or seagrasses by hanging vertically in order to sneak up on unwary prey. They also camouflage themselves by traveling with schools of surgeonfishes or large individual fish to sneak up on prey. There are three species in the world, but only one in the Indo-Pacific, *Aulostomus chinensis*. It is found in Hawaii, Micronesia and Samoa.

Spawning by *A. chinensis* has been observed off One Tree Island, Great Barrier Reef. At dusk, a male and female made a spawning ascent of 5■8 m to release gametes before returning to the bottom (in Thresher 1984). The pelagic eggs of *A. chinensis* are spherical, smooth and 1.3 to 1.4 mm in diameter. Larvae are approximately 4.8 mm at hatching (Watson and Leis 1974).

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Table 36. Management Unit Species: Aulostomidae (trumpetfish)

	Egg	Larvae	Juvenile	Adult
Duration	approximately 4 days	4.8 mm at hatching		
Diet	N/A	likely small zooplankton	similar to adults	ambush predators of small fishes and crustaceans
Distribution, general and seasonal			similar to adults	one Indo-Pacific species, *Aulostomus chinensis*
Location	pelagic	pelagic	similar to adults	protected and seaward reefs from below the surge zone to 122 m
Water column	pelagic	pelagic	similar to adults	reef-associated; 1■122 m
Bottom type	N/A	N/A	similar to adults	coral reef and rock
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.11 Fistularidae (cornetfish)

Cornetfishes have a very elongate body like the trumpetfish but differ in the body being vertically flattened rather than laterally compressed and by having a forked caudal fin with a long median filament. Like the trumpetfish, cornetfish feed by sucking small fishes and crustaceans into their long tubular snout. They are seen in virtually all reef habitats except areas of heavy surge. They are usually seen in open sandy areas and may occur in schools of similarly sized individuals. One species, *Fistularia commersonii*, is seen on Hawaiian, Micronesian and Samoan coral reefs, and another species is seen only in deep water.

Fistularid eggs are pelagic and large, with a diameter of 1.5▪2.1 mm (Mito 1961). The larvae hatch at 6▪7 mm (Mito 1961). Hatching occured in about 7 days for *Fistularia petimba* (Mito 1966). The size of the largest examined pelagic fistularid specimen examined by Leis and Rennis (1983) was 145 mm.

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Table 37. Management Unit Species: Fistularidae (cornetfish)

	Egg	Larvae	Juvenile	Adult
Duration	4 ■7 days	6 mm at hatching		
Diet	N/A	likely small zooplankton	similar to adults	ambush predators of small fishes and crustaceans
Distribution, general and seasonal			similar to adults	two Indo-Pacific species: *Fistularia commersonii* and one deepwater species
Location	pelagic	pelagic	similar to adults	virtually all coral reef habitats except areas of high surge; most common in sandy areas where it may form schools of similarly sized fish
Water column	pelagic	pelagic	similar to adults	reef-associated; 1■128 m
Bottom type	N/A	N/A	similar to adults	sand, coral reef, rock
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.12 Syngnathidae (pipefishes/seahorses)

Pipefishes and seahorses have a long tubular snout with a very small mouth, which they use to feed in a pipette-like manner on small free-living crustaceans such as copepods. Some species clean other fishes. Many species are small and generally inconspicuous bottom dwellers that feed on minute benthic and planktonic animals. The syngnathids have very unique parental care in which the female deposits eggs into a ventral pouch on the male, which carries the eggs until hatching. Most species are rarely seen on reefs in the management area, partly because of their small size and inconspicuous nature. They occur in a wide variety of shallow habitats from estuaries and shallow sheltered reefs to seaward reef slopes, though they are generally limited to water shallower than 50 m. There are 8 species reported from Hawaiian waters, where the redstripe pipefish *Dunckerocampus baldwini* is endemic. At least 37 species occur in Micronesian waters, and at least 17 species occur in Samoa.

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Table 38. Syngnathidae (pipefishes/seahorses)

	Egg	Larvae	Juvenile	Adult
Duration		likely weeks to months		
Diet	N/A		similar to adults	small free-living crustaceans such as copepods; minute benthic and planktonic invertebrates
Distribution, general and seasonal				circumtropical and temperate; 8 spp. reported from Hawaiian waters, where the redstripe pipefish *Dunckerocampus baldwini* is endemic. At least 37 species in Micronesian waters, and at least 17 in Samoa
Location	male carries eggs in a ventral pouch	offshore waters	occasionally found in the open sea in association with floating debris	wide variety of shallow habitats from estuaries and shallow sheltered reefs to seaward reef slopes
Water column	male carries eggs in a ventral pouch	pelagic	similar to adults	benthic and free-swimming
Bottom type	N/A	N/A	similar to adults	coral, rock, mud, seagrass, algae
Oceanic features		subject to advection by ocean currents		

4.2.1.13 Caracanthidae (coral crouchers)

The coral crouchers consist of one genus, *Caracanthus*, and 4 small species. They are small, deep-bodied, ovoid fishes with venomous dorsal spines and small tubercles covering the body. They are found exclusively among the branches of certain *Stylophora*, *Pocillopora* and *Acropora* corals, where they feed on alpheid shrimps and other small crustaceans. The name coral crouchers comes from their tendency to tightly wedge themselves into the coral branches when threatened. One species, the Hawaiian orbicular velvetfish *Caracanthus typicus*, is found in Hawaiian waters and is endemic. Two species are found in Micronesian and Samoan waters: the spotted coral croucher *C. maculatus* and the pigmy coral croucher *C. unipinna*. *C. maculatus* is common among the long branches of large pocilloporid corals such as *Pocillopora eydouxi*, *Stylophora mordax* and ramose species of *Acropora*. *C. unipinna* is found in *S. mordax* and ramose species of *Acropora*.

The spawning mode and development at hatching of coral crouchers is not known. Caracanthid larvae are very similar to Scorpaenid larvae. The size of the largest examined pelagic specimen was 16.5 mm (Leis and Trnski 1989).

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Table 39. Management Unit Species: Caracanthidae (coral crouchers)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	zooplankton		alpheid shrimps and other small crustaceans
Distribution, general and seasonal			same as adults	Indian and Pacific Ocean; one endemic species in Hawaii - *Caracanthus typicus*, two species in Micronesia
Location			same as adults	exclusively among the branches of certain *Stylophora, Pocillopora*, and *Acropora* corals
Water column	probably pelagic; gelatinous egg masses float	pelagic; 0■100m depth	demersal	demersal
Bottom type	N/A	N/A	*Stylophora*, *Pocillopora*, and *Acropora* corals	*Stylophora, Pocillopora* and *Acropora* corals
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.14 Tetrarogidae (waspfish)

Waspfishes are closely related to scorpionfishes but have dorsal fins that originate over or in front of the eyes, typically do not have scales and tend to be more compressed. They have extremely venomous spines. They feed on small fishes and crustaceans. No species are found in Hawaiian waters, and only one species is found in Micronesia: the mangrove waspfish *Tetraroge barbata*, which inhabits muddy inshore waters of mangrove swamps and may also move into freshwater rivers.

There is little information on waspfish reproduction, but it is likely to be very similar to that for Scorpaenidae. They likely produce small to medium eggs embedded in a large, pelagic, sac-like gelatinous matrix.

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Table 40. Management Unit Species: Tetrarogidae (waspfishes)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	zooplankton	ambush small fishes and crustaceanss	ambush small fishes and crustaceans
Distribution, general and seasonal	no information on spawning in the wild			Indo-West Pacific; little seasonal difference in distribution
Location				estuarine or freshwater habitats; mangroves or rivers
Water column	probably pelagic; gelatinous egg masses float	pelagic; 0▪100m depth	demersal	demersal
Bottom type	N/A	N/A		mangroves, rock, rubble, mud
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.15 Scorpaenidae (scorpionfishes)

Scorpionfishes are so named for the venomous dorsal, anal and pelvic fins of many species. They are stout-bodied, benthic carnivores that typically have fleshy flaps, a mottled coloring and small tentacles on the head and body. These camouflage features help them to ambush small fishes and crustaceans. Scorpionfish lie on the reef and wait for unwary prey to come near, when they pounce on the prey with a large mouth full of small viliform teeth. Many feed mainly at dusk or during the night. Lionfishes and turkeyfishes of the subfamily Pteroinae have greatly enlarged pectoral fins, elongate dorsal fin spines and bright colorations. The lionfish and turkeyfish species may swim well above the bottom, whereas small cryptic species of the subfamily Scorpaeninae tend to remain on the bottom and may be quite common in shallow rubbly areas. In Hawaiian waters, 13 species are known and 3 are endemic: *Dendrochirus barberi*, *Pterois sphex* and *Scorpaenopsis cacopsis*. At least 30 species are known from Micronesia. At least 22 species are recorded from Samoa.

Most reef scorpaenids (*Scorpaena, Pterois, Dendrochirus*) have 0.7■1.2 m spherical to slightly ovoid eggs embedded in a large, pelagic, sac-like gelatinous matrix (Leis and Rennis 1983). Eggs hatch in 58■72 hours. The duration of the planktonic larval stage is not known. Older larval stages are described by Miller, Watson and Leis (1979).

Harmelin-Vivien and Bouchon (1976), analyzing the stomach contents of 17 species of scorpionfish from Tuléar, Madagascar, find that crustaceans generally were a dominant component of their diet. Only one species, *S. gibbosa*, fed exclusively upon fishes, while others fed on a mixture of fish and crustaceans. Seven species fed mainly on crustaceans such as brachyurans, shrimps and polychaetes. Their diets were supplemented with small amounts of galatheids and amphipods. Feeding tended to be heavier at night than during the day, but feeding was apparent for both night and day for all species.

Several biologists and aquarium collectors have noted reduced numbers of the endemic Hawaiian turkeyfish, *Pterois sphex*. Sightings of this previously more abundant species have become very infrequent. Its numbers may have been reduced by collecting efforts driven by its popularity as an aquarium fish. Randall et al. (1993) lists it as occasional in caves or ledges inside and outside the lagoon at Midway Atoll, but it is now very rare in the main Hawaiian Islands.

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Table 41. Management Unit Species: Scorpaenidae (scorpionfishes)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	little information, but 58–72 hrs for *Scorpaena guttata* (David 1939)		2–3 yrs for 2 Mediterranean species	
Diet	N/A	zooplankton	ambush small fishes and invertebrates	ambush fish and invertebrates; *Scorpaenopsis diabolus* feeds exclusively on fishes (Harmelin-Vivien et al. 1976)
Distribution, general and seasonal	little information on spawning in the wild		worldwide in tropical and temperate seas; little seasonal information, but probably recruitment peak in summer or fall	worldwide in tropical and temperate seas; small home ranges; little seasonal difference in distribution
Location			reef and hard-bottom associated	reef and hard-bottom associated
Water column	pelagic; gelatinous egg masses float	pelagic; 0–100m depth	demersal	demersal
Bottom type	N/A	N/A	coral reef, rock, rubble	coral reef, rock, rubble
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.16 Serranidae (groupers)

Egg and Larvae

Serranid fertilized eggs are spherical, transparent and range in size from 0.70 to 1.20 mm in diameter. Each egg contains a single oil globule 0.13 to 0.22 mm in diameter. Based on the available data, the length of the pelagic larval stage of groupers is 25-60 days (Kendall 1984, Leis 1987). The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase. Serranid larvae are distinguishable by their kite-shaped bodies and highly developed head spination (Heemstra and Randall 1993).

Juvenile

Very little is known about the distribution and habitat utilization patterns of juvenile serranids. Research has found that transformation of pelagic serranids into benthic larvae takes place between 25 mm to 31 mm TL (Heemstra and Randall, 1993). The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools.

Adult

Serranids inhabit coral reefs and rocky bottom substrates from the shore to depths of at least 400 m. Serranids typically are long-lived and have relatively slow growth rates. Based on the available data, groupers appear to be protogynous hermaphrodites. After spawning for one or more years the female undergoes sexual transformation, becoming male. Some species of serranids spawn in large aggregations, others in pairs. Individual males may spawn several times during the breeding season. Some species of groupers are known to undergo small, localized migrations, of several km to spawn. Except for occasional spawning aggregations, most species of groupers are solitary fishes with a limited home range (Heemstra and Randall, 1993). Based on the results of tagging studies, it has been found that serranids are resident to specific sites, often residing on a particular reef for years .

Groupers are typically ambush predators, hiding in crevices and among coral and rocks in wait for prey (Heemstra and Randall 1993). Adults reportedly feed during both the day and night. The diet of adult serranids includes brachyuran crabs, fishes, shrimps, galatheid crabs, octopus, stomatopods, fishes and ophiurids (Heemstra and Randall, 1993, Morgan 1982, Randall and Ben-Tuvia 1983, Harmelin-Vivien and Bouchon 1976)

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Table 42.Management Unit: Serranidae (groupers)

	Egg	**Larvae**	**Juvenile**	Adult
Duration	Incubate in 20-35 days	Pelagic duration : 25-60 days	Metamorphosis to demersal habitat at ~25-31 mm TL	Long-lived, slow growing
Diet	N/A	No information available	No information available	Primarily feed in demersal habitat. Diet includes crabs, shrimp, octopus and fish.
Distribution	Serranid eggs have a relatively long pelagic phase that results in wide distribution	Serranid larvae have a relatively long pelagic phase that results in wide distribution	Throughout Indo-Pacific. Juveniles of some species Inhabit shallow reef areas (sea-grass beds and tide pools).	Throughout Indo-Pacific. Inhabit shallow coastal coral reef areas to deep slope rocky habitats (0-400 m)
Water Column	Pelagic	Pelagic	Demersal	Demersal
Bottom Type	N/A	N/A	Wide variety of shallow-water reef and estuarine habitats	Primary forage habitat is shallow to deep reef and rocky substrate.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

4.2.1.17 Grammistidae (soapfish)

The soapfishes are small, grouper-like fishes that emit a toxic slime to deter predation by larger fishes. They are secretive fish that occur on reef flats, shallow lagoon and seaward reefs, often in small caves, under ledges or in holes at depths up to 150 m. They are nocturnal predators on fishes, crustaceans and a variety of invertebrates. They are represented in Hawaii by three species of the genus *Liopropoma* and two species of *Pseudogramma*. At least one species, *L. aurora,* is endemic. There are 6 species of soapfishes in Micronesia and 4 species in Samoan waters. The taxonomy of the soapfish is frequently under debate, and it has been placed in at least 4 other families. Randall (1996) treats Grammistinae as a subfamily of the Serranidae.

The grammistids, like the serranids, are generally hermaphroditic, although Smith (1971) reported that members of *Liopropoma* appeared to be secondary gonochorists, with separate sexes but clearly derived from hermaphroditic ancestors. Smith and Atz (1966) reports that members of *Pseudogramma* are hermaphroditic. All are typically solitary and territorial. *Diploprion* and *Liopropoma* appear to have pelagic eggs, while P*seudogramma* has large, bright red eggs that are probably demersal. The duration of the planktonic phase is not known, but the size of the largest examined pelagic specimen was 12.6■14.5 mm (Leis and Rennis 1983).

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Table 43. Management Unit Species: Grammistidae (soapfishes)

	Egg	Larvae	Juvenile	Adult
Duration				
Diet	N/A	zooplankton	similar to adult	small fishes, crustaceans and other invertebrates
Distribution, general and seasonal			similar to adult	Atlantic, Pacific, and Indian Oceans; 5 species in Hawaii with at least one endemic; at least 6 species in Micronesia
Location	pelagic; possibly demersal for *Pseudogramma* spp.	predominantly offshore		outer reef slopes, reef flats, lagoons, wave-washed seaward reefs
Water column	pelagic; possibly demersal for *Pseudogramma* spp.	pelagic	demersal; 1-150 m	demersal; 1▪150 m
Bottom type		N/A	similar to adults	secretive inhabitants of caves, crevices on coral reefs and rocky substrate
Oceanic features		subject to advection by ocean currents		

4.2.1.18 Plesiopidae (prettyfins)

Prettyfins, or longfins, are characterized by a disjunct lateral line, preopercle with a double border and long pelvic fins. They are nocturnal predators on small crustaceans, fishes and gastropods. They are secretive during the day. No species are recorded for the Hawaiian Islands and 3 species are recorded for Micronesian waters. Three species are recorded in Samoan waters. The comet *Calloplesiops altivelis* is a popular aquarium fish that is relatively uncommon in Micronesia. The red-tipped longfin *Plesiops caeruleolineatus* is a common, but seldom seen, fish on exposed outer reef flats and outer reef slopes to a depth of 23 m. The bluegill longfin *P. corallicola* is relatively common on reef flats under rocks or in crevices.

Prettyfin reproduction is similar to the closely related dottybacks. They are demersal spawners in which the male tends the egg mass. Mito (1955) reported that *P. semeion* eggs are 0.9 by 0.6 mm, and are deposited in a single layer on the underside of a rock.

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Table 44. Management Unit Species: Plesiopidae (prettyfins)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	15 days by a mouth-brooding species in an aquarium (Debelius and Baensch 1994)	3 months for a related basslet	3 years for a related basslet	
Diet	N/A	zooplankton	probably similar to adult	small crustaceans, fishes, and gastropods
Distribution, general and seasonal				3 species recorded for Micronesian waters; none in Hawaiian waters
Location	near adult territory; often in caves or crevices	primarily offshore	similar to adults	outer reef slopes and flats
Water column	demersal; or carried in the mouth of the male	pelagic	demersal; 3-45 m	demersal; 3▪45 m
Bottom type	cleared patch of rock or coral	N/A	same as adults	holes and crevices on coral reefs; also sand and rock
Oceanic features		subject to advection by ocean currents		

4.2.1.19 Pseudochromidae (dottybacks)

Dottybacks are small (<65mm) elongate fishes with a long continuous dorsal fin. Two genera are present in Micronesian waters: *Pseudochromis* has a disjunct lateral line, whereas *Pseudoplesiops* lacks one. Members of *Pseudoplesiops* typically remain hidden within the reef framework and are rarely seen except when an ichthyocide is used. Some members of *Pseudochromis* are brightly colored and are sought after for the aquarium trade. The dottybacks are carnivores of small crustaceans, polychaete worms and zooplankton. The dottybacks are demersal spawners, and some may brood eggs in the mouth of the male. Females of *Pseudochromis* produce a spherical mass of eggs that is guarded by the male. Dottybacks are not present in Hawaiian waters, while 10 species are present in Micronesian waters. Five species are recorded for Samoan waters.

Dottybacks are hermaphrodites. Males are typically larger than females. Some species are obviously sexually dichromatic, while others are not. Pseudochromoid egg balls range in diameter from 7 mm with about 60 eggs in *Assessor macneilli* (Thresher 1984) to 5■8 cm with 8,200 to 17, 500 eggs for *Acanthoclinus quadridactylus* (Jillet 1968). Individual *Pseudochromis fuscus* eggs are 1.25 mm in diameter, slightly elongate spheroids attached by several adhesive threads. Incubation periods range from 3 to 5 days at approximately 29EC. Hatching typically occurs at night, shortly after sunset. Newly hatched larvae of *P. fuscus* are 2.5 mm, and feeding typically begins on the first day after hatching (Lubbock 1975). Jillett (1968) estimates a planktonic larval stage of 3 months for *A. quadridactylus*, which reaches sexual maturity in approximately 3 years.

Pseudochromis cyanotaenia is sexually dichromatic, relatively common near holes and crevices of exposed outer reef flats and reef margins to a depth of 4 m, often occurs in pairs and feeds on small crabs, isopods and copepods. *P. fuscus* is common near small patches of branching corals on shallow sandy subtidal reef flats and lagoons.

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Table 45. Management Unit Species: Pseudochromidae (dottybacks)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	3■5 days for *Pseudochromis fuscus* (Thresher 1984)	3 months	3 years for an Australian species *Acanthoclinus quadridactylus*	
Diet	N/A	zooplankton	probably similar to adult	small crustaceans, polychaete worms, and zooplankton
Distribution, general and seasonal				10 species recorded for Micronesian waters; none in Hawaiian waters
Location	near adult territory; often in caves or crevices	primarily offshore	similar to adults	exposed outer reef flats and reef margins; also near small patches of branching corals on shallow sandy subtidal reef flats and lagoons
Water column	demersal; or carried in the mouth of the male	pelagic	demersal; 0■100m	demersal; 0■100m
Bottom type	cleared patch of rock or coral	N/A	same as adults	holes and crevices on coral reefs; also sand
Oceanic features		subject to advection by ocean currents		

4.2.1.20 Acanthoclinidae (spiny basslets)

Acanthoclinids are closely related to the pseudochromids but differ in having more dorsal and anal fin spines and 1or 2 instead of 3 to 5 pelvic rays. Basslets in general produce demersal eggs and have a tendency towards oral incubation. Eggs are typically tended by the male or brooded by them in the case of brooders. Other basslets have eggs that hatch within 3–16 days and larvae that have a planktonic stage of up to 3 months. The basslets are fairly secretive inhabitants of coral reefs, but some species are conspicuous as they hover near shelter. They are often collected for aquariums. There are 10 known species, but only 3 occur in the Indo-Pacific, with none in Hawaii and one species in Micronesia. Hiatt's basslet *Acanthoplesiops hiatti* is a tiny species (to 21 mm) that has been collected from shallow-washed seaward reefs in Micronesia.

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Table 46. Management Unit Species: Acanthoclinidae (spiny basslets)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	3■16 days	months		
Diet	N/A		similar to adults	small crustaceans, polychaete worms, and zooplankton
Distribution, general and seasonal				West-central Pacific; one species *Acanthopesiops hiatti* found in Micronesia
Location		offshore waters	shallow wave-washed seaward reefs	shallow wave-washed seaward reefs
Water column	demersal	pelagic	reef-associated; 1■65 m	reef-associated; 1■65 m
Bottom type			coral or rock shelter	coral or rock shelter
Oceanic features		subject to advection by ocean currents		

4.2.1.21 Cirrhitidae (hawkfish)

Hawkfishes are small grouper-like fishes characterized by projecting cirri on the tips of the dorsal spines. The common name comes from their tendency to perch themselves on the outermost branches of coral heads or other prominences. They use enlarged lower pectoral rays to support their body or to wedge themselves in place. All are carnivores of small benthic crustaceans and fishes. The species thus far studied are protogynous hermaphrodites, and the males are territorial and defend a harem of females. Courtship and spawning occur at dusk or early night throughout the year in the tropics. Spawning occurs at the apex of a short, rapid paired ascent. The pelagic larval stage probably lasts a few to several weeks (Randall 1963). In Hawaii, there are 6 species recorded. At least 10 species occur in Micronesia, and at least 8 species occur in Samoa. The colorful species are popular aquarium fishes.

Hawkfishes range in size at maturity from less than 10 cm to almost a meter. Most species are sexually monomorphic. Pair spawning occurs with the male making quick ascents with each of the members of his harem in rapid succession. Eggs are pelagic, spherical and approximately 0.5 mm in diameter. The development at hatching is unknown. A lengthy pelagic stage is suggested by the widespread distribution and limited geographic variation of some species. The smallest specimen examined by Leis and Rennis (1983) was 2.7 mm, and the largest pelagic specimen examined was 33.0–37.9 mm. Juveniles of most species resemble the adults.

Adults typically inhabit rock, coral or rubble of the surge zone, seaward reefs, lagoons, channels, rocky shorelines and submarine terraces. Some are typically found on heads of small branching corals. The longnose hawkfish *Oxycirrhites typus* is a popular aquarium fish that feeds mainly on zooplankton and is usually seen perched on black coral or gorgonians at depths greater than 30 m.

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Table 47. Management Unit Species: Cirrhitidae (hawkfishes)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration		weeks to months		
Diet	N/A		similar to adults	carnivores of small benthic crustaceans and fishes; the longnose hawkfish *Oxycirrhites typus* feeds heavily on zooplankton
Distribution, general and seasonal				most are Indo-West Pacific; 6 species in Hawaii, at least 10 species in Micronesia, and at least 8 species in Samoa
Location	near adult territory	generally offshore	similar to adults	the surge zone, seaward reefs, lagoons, channels, rocky shorelines and submarine terraces. Some are typically found on heads of small branching corals
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	rock, coral, or rubble	rock, coral, or rubble
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.22 Apogonidae (cardinalfishes)

The cardinalfishes are named for the red color of some of the species, although most are fairly drab and many are striped. They are characterized by two dorsal fins, large eyes, a large mouth and double-edged preopercles. Most species are small, less than 12 cm. They are typically nocturnal, remaining hidden under ledges or in holes in the reef during the day. Most prey mainly on large zooplankton, but some feed primarily on small benthic crustaceans. A few species form dense aggregations immediately above mounds of branching corals. As far as is known, all species are brood spawners in which the male carries the eggs in his mouth until they hatch. Ten species occur in Hawaii, and at least 58 species occur in Micronesia. *Apogon erythrinus*, *A. maculiferus*, and *A. menesemus* are endemic to the Hawaiian Islands. At least 36 species occur in Samoa.

External sexual dimorphism is slight or nonexistent in the cardinalfishes, except for females that are noticeably swollen with eggs prior to spawning. Temporary color differences during courtship and spawning occur in a few species. Apogonid species display a variety of different seasonal spawning patterns, from year-round spawning to spring and fall peaks. Spawning may also be tied to the phases of the moon.

Schooling behavior is important in some species of cardinalfishes. The fragile cardinalfish *A. fragilis* occurs in large aggregations above branching corals. Despite these aggregations, courtship and spawning in cardinalfishes are always paired rather than group activities. The female often initiates courtship, which involves prolonged tight side-by-side swimming until spawning occurs and the female releases a ball of eggs which the male quickly circles back to and inhales. The male broods the eggs in the mouth for anywhere from 2 to 8 days. The eggs, up to 22,000 of them, are bound together by threads that originate from one pole of the egg and, in some species, a fine mucous membrane. Upon hatching, the eggs become planktonic larvae ranging in size from 1.0■3.3 mm. The planktonic larval stage lasts approximately 60 days, until larvae settle out at a size ranging from 10 to 25 mm.

Cardinalfish are found in water depths from 1 to 80 m. Members of the genera *Apogonichthys*, *Foa* and *Fowleria* are typically secretive, cryptic inhabitants of seagrasses, algal beds or rubble of sheltered reefs and reef flats. The bay cardinalfish *Foa brachygramma* is usually found around dead coral, sponge or heavy plant growth in shallow bays such as Kaneohe Bay, Oahu, and Tumon Bay, Guam.

Chave (1978) detailed the ecology of 6 species of Hawaiian cardinalfishes, all of which remain in holes and caves in the daytime and emerge at night to feed on zooplankton and benthic invertebrates. The habitat requirements of each species were distinct. Some species remain near the substrate at night (*A. snyderi* and *A. erythrinus*), while others occur in midwater (*A. menesemus*, *A. maculiferus* and *A. waikiki*), and *Foa brachygramma* occurs in both locations. *A. snyderi* eats mostly sand dwelling invertebrates in sandy, bright, flat substrate, *A. maculiferous* eats mostly midwater zooplankton near dawn, and *A. erythrinus* eats crustaceans only (Chave 1978).

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Table 48. Management Unit Species: Apogonidae (Cardinalfishes)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	2–8 days	approximately 60 days		
Diet	N/A	zooplankton; tintinnids (Watson 1974)	feed on plankton at night; some species eat primarily small benthic crustaceans	feed on plankton at night; some species eat primarily small benthic crustaceans
Distribution, general and seasonal	throughout the year, spring and fall peaks for some species	throughout the year, spring and fall peaks for some species	Atlantic, Pacific, and Indian Ocean	Atlantic, Pacific, and Indian Ocean
Location	within the father's mouth	predominantly offshore	coral reefs	coral reefs
Water column	within the father's mouth	pelagic	demersal and mid-water at night for feeding on zooplankton; 1-80m depth	demersal and mid-water at night for feeding on zooplankton; 1–80 m depth
Bottom type	N/A	N/A	coral reef ledges, holes, flats, rubble, within the branches of branching corals	coral reef ledges, holes, flats, rubble, within the branches of branching corals
Oceanic features				

4.2.1.23 Priacanthidae (bigeyes)

Priacanthids have very large eyes, moderately deep compressed bodies, oblique mouths with a projecting lower jaw, small conical teeth in a narrow band in each jaw, an opercle with 2 flat spines and a serrate preopercle with a broad spine at the corner. They are usually red but are able to change quickly to silver or blotches of silver and red. They are nocturnal zooplanktivores on larger zooplankton, such as the larvae of crabs, fishes, polychaete worms and cephalopods. The family is distributed circumtropically and in temperate seas, but some species are limited to the Indo-Pacific or the Hawaiian Islands. In Hawaiian waters, 4 species have been recorded: *Heteropriacanthus cruentatus*, the endemic *Priacanthus meeki* and two deep-water species. In Micronesian waters, *H. cruentatus*, *P. hamrur* and a deep species from below 200 m depth have been recorded. The shallow-water species are limited to 100 m or less. Five species are recorded from Samoan waters.

The glasseye *H. cruentatus* inhabits lagoon or seaward reefs from below the surge zone to a depth of at least 20 m. During the day it is usually solitary or in small groups but may gather in large numbers at dusk prior to ascending into the water column for feeding.

Spawning by priacanthids has not been observed, but Colin and Clavijo (1978) reports seeing an aggregation of more than 200 individuals at a reef where many other species were spawning. The eggs of *Pristigenys niphonium* and *Priacanthus macracanthus* are pelagic, spherical and 0.75 mm in diameter (Suzuki et al. 1980, Renzhai and Suifen 1982). The larvae hatch at 1.4 mm (Renzhai and Suifen 1982). The size of the largest examined pelagic larval specimen was 48 mm (Leis and Rennis 1983). Caldwell (1962) reports a size at settlement for the deep-water subtropical species *Pristigenys alta* of 65 mm.

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Table 49. Management Unit Species: Priacanthidae (bigeyes)

	Egg	Larvae	Juvenile	Adult
Duration		from 10 mm to about 60 mm		
Diet	N/A	various zooplankton	similar to adults	larger zooplankton such as the larvae of crabs, fishes, polychaete worms and cephalopods; also crustaceans and soft-bodied invertebrates
Distribution, general and seasonal				worldwide in tropical and temperate seas, but 3 Indo-Pacific genera, 1 Hawaiian endemic
Location				lagoon or seaward reefs from below the surge zone to a depth of at least 80 m
Water column	pelagic	pelagic	demersal and mid-water column	demersal and mid-water column; some species very deep
Bottom type	N/A	N/A		coral reef crevices or overhangs during the day; may feed over soft substrate at night
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.24 Malacanthidae (tilefishes)

The tilefishes have elongate bodies with one sharp opercular spine and a long continuous dorsal fin. They have viliform and canine teeth for taking a variety of benthic animals along with substantial amounts of plankton. They usually occur in pairs on sandy and rubbly areas of outer reef slopes. They frequently build a burrow into which they retreat when threatened, often piling rubble on top. They can be found in depths from 6 to 115 m in mud, sand, rubble or talus areas of barren seaward slopes. The family is distributed worldwide in tropical and temperate seas. The family is represented in Hawaiian waters by a single species, *Malacanthus brevirostris*, and in Micronesian waters by the same species plus four more: *Hoplolatilus cuniculus, H. fronticinctus, H. starcki* and *M. latovittatus*. Two species are present in Samoan waters: *M. brevirostris* and *M. latovittatus*.

Accounts of spawning are few, but pairs typically make a short spawning ascent to release pelagic, spheroid eggs, about 0.7 mm in diameter with a single oil globule. After a larval phase of undetermined duration, *Malacanthus* settle to the bottom at a size of about 6 cm and immediately construct burrows under rocks in shallow water (Araga 1969).

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Table 50. Management Unit Species: Malacanthidae (Tilefishes)

	Egg	Larvae	Juvenile	Adult
Duration		weeks or months	settlement at a size of about 6 cm	
Diet	N/A		benthic invertebrates and plankton	benthic invertebrates and plankton
Distribution, general and seasonal				3 Indo-Pacific genera
Location			shallow sheltered habitats	outer reef slopes
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	sand, mud, rubble	sandy and rubbly areas
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.25 Echineididae (remoras)

Remoras have a broad flat head uniquely modified for suction that allows them to attach to other marine animals. Some species are host specific while others use a variety of hosts such as sharks, rays, large bony fishes, sea turtles or marine mammals. Some species are free swimming. The two species of *Echeneis* are not host-specific and are free-living part of the time. Remoras are circumglobal in their distribution. In Hawaii and in Micronesia, the sharksucker *E. naucrates* is the most common, although *Remora remora* may be found on large sharks and *Remorina albescens* on mantas. Five species are recorded from Samoan waters, including *E. naucrates, R. remora,* and *Phtheirichthys lineatus,* which was attached to a hawksbill turtle. *Remoropsis pallidus* and *Rhombochirus osteochir* were found attached to marlin.

Johnson (1984) reports that eggs of *E. naucrates* and *R. remora* are large (1.4■2.6 mm), pelagic and spherical, although Nakajima et al. (1987) reports *E. naucrates* eggs are negatively buoyant. Newly hatched eggs are 4.7■7.5 mm long. The size of the largest examined pelagic larval stage was 14.5■22 mm (Leis and Trnski 1989).

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Table 51. Management Unit Species: Echineididae (remoras)

	Egg	Larvae	Juvenile	Adult
Duration		size at hatching ranges from 3.7 to 7.5 mm		
Diet	N/A	zooplankton	similar to adults	zooplankton such as copepods and isopods; zoobenthos such as small crustaceans; detritus, and small fishes (Randall 1967)
Distribution, general and seasonal	little information on seasonal patterns		circumglobal	circumglobal
Location			coastal and pelagic waters	coastal and pelagic waters; often attached to sharks, rays, large bony fishes, sea turtles, or marine mammals
Water column	pelagic	pelagic	same as adults	pelagic; either free swimming or attached to large reef-associated inhabitants
Bottom type	N/A	N/A	N/A	N/A
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.26 Carangidae (jacks, *papio, ulua*)

Eggs and larvae

There are few extant studies of the distribution of carangid eggs and larvae. Carangid eggs are planktonic, spherical and 0.70-1.3mm in diameter (Laroche et al. 1984, Miller et al. 1979). The eggs usually contain one to several oil globules. The eggs hatch 24-48 hours after spawning in water temperatures from 18 to 30 CE (Laroche et al. 1984). The larvae are relatively small (1 - 2 mm) at hatching and contain a relatively large yolk sac. The larvae are moderately deep bodied and large headed with well developed preopercular spines (Miller et al. 1979). According to Miller et al. (1979) carangid larvae are common in nearshore waters surrounding the Hawaiian Archipelago.

Juvenile

Juvenile carangids are often found in nearshore and estuarine waters and may form small schools over sandy inshore reef flats (Lewis et al. 1983, Meyers 1991). Available diet studies suggest that juvenile carangids are planktivorous and feed on fish larvae and planktonic crustaceans

Adult

The carangids are distributed throughout tropical and subtropical waters in the Indo-Pacific. They are widely distributed in shallow coastal waters, estuaries, shallow reefs, deep reef slope, banks and seamounts (Sudekum et al. 1991). Juvenile and adult carangids are an important component of shallow reef and lagoon fish catches throughout the management area. Adult carangids are large highly-mobile predators that range widely through the reef and deep slope habitat from depths of 0- 250m. A single species (*Seriola dumerili*) has been documented to forage at depths of up to 355 m (Myers 1991, Ralston et al. 1986). Although most of the large jacks utilize the complete water column in their habitat range they are associated primarily with demersal habitat.

In general adult carangids are piscivourous, they also prey on crustaceans, gastropods, and cephalopods. *Caranx ignobilis*, one of the most abundant species of jacks found in Hawaii is primarily piscivourous, preying primarily on reef-associated fish. The most recent study of the feeding habits of *C. ignobilis* concludes that the predominance of reef fishes in its diet indicates that shallow-water reef areas are important foraging habitat for these fish. The occurrence of small pelagic fish and squid in the diet of C. ignobilis indicates that part of its foraging also occurs in the water-column (Sudekum at al. 1991).

Reproductive information is sparse for most species. In Hawaii the sex ratio for *C. ignobilis* is slightly skewed toward females 1:1.39 (Sudekum et al. 1991). Peak spawning occurs between May and August, although gravid fish are present in the Northwestern Hawaiian Islands (NWHI) between April and November. Spawning occurs in pairs within larger aggregations during the new and full moon (Johannes 1981), on offshore banks and shallow nearshore reefs (Myers 1991).

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Table 52. Management Unit: Carangidae (jacks)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	24 - 48 hours after spawning	Poorly known, larvae thought to be more common offshore than inshore	Sexual maturity attained at 1-3.5 years depending on species	One species (*C. ignobilis*) life span exceeds 15 years
Diet	N/A	No information available	Generally switch from planktivory to piscivory with increase in age	Predominantly piscivorous utilizing shallow-water reefs. The water-column is also utilized .
Distribution	Pelagic	Pelagic, more common in summer	Near-shore and estuarine waters	Throughout Indo-Pacific. Inhabit shallow coastal areas to deep slope (0-350m)
Water Column	Pelagic	Pelagic	Bentho-pelagic	Bentho-pelagic, utilize entire water-column but primarily associated with demersal habitat
Bottom Type	N/A	N/A	Wide variety of shallow-water reef and estuarine	Primary forage habitat is shallow to deep reef
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

4.2.1.27 Decapterus/Selar (scads, *opelu*, *akule*)

Egg and Larvae

The spawning of scads occurs in the pelagic environment. Depending on the species the ovaries of the female may contain from 30,000 to 200,000 eggs. The spawned eggs are spherical with a single oil globule, non-adhesive, and free floating (Yamaguchi 1953).

Juvenile

After hatching the larvae and juvenile fish remain in the pelagic environment where they frequently form large aggregating schools. Reports from fishermen have identified aggregations of juvenile scads as far as 80 nmi. offshore (Yamaguchi 1953). Juveniles enter the nearshore coastal waters in late fall and winter, where they grow rapidly over the next few months, usually attaining sexual maturity during the first year of life.

Larval and juvenile fish remain in offshore pelagic waters for the first several months of their life, after which they migrate to the nearshore adult habitat (0-100m).

Adults

Adults spawn in pelagic waters usually in proximity to their coastal habitat. Spawning appears to be seasonal from March through August, reaching a peak from May to July. These species feed in the water column and are mainly planktivorous, preying on zooplankton. Their diet consists of amphipods, crab megalops, fish larvae, pteropods, and copepods, however some species also feed on small fishes such as anchovies and holocentrids (Yamaguchi 1953). Adult opelu and akule inhabit nearshore waters around islands from shoreline depths to 100m.

Table 53. Management Unit: Decapturus/Selar (scads)

	Egg	Larvae	Juvenile	Adult
Duration	No information	No information	migrate to nearshore waters ~ Six months after hatching	Relatively fast growing and short lived. Sexual maturity usually in first year of life
Diet	N/A	planktivorous	zooplanktivorous	primarily zooplanktivorous, with some piscivory
Distribution	circumtropical pelagic	circumtropical pelagic	circumtropical nearshore	circumtropical nearshore
Water Column	pelagic	pelagic	pelagic and nearshore reef in water column	nearshore reef in water column (neritic)
Bottom Type	N/A	N/A	N/A	N/A
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	offshore pelagic, migrate to nearshore waters in first year	nearshore waters

4.2.1.28 Caesionidae (fusiliers)

Fusiliers are planktivorous, schooling fishes. They have an elongate, fusiform body, a small terminal mouth with a very protrusible upper jaw, small conical teeth and a deeply forked tail. During the day, fusiliers swim actively in midwater around or near reefs in synchronomous formation, changing the formation to feed on zooplankton. They are particularly abundant along steep outer reef slopes and around deep lagoon pinnacles. They are often observed around cleaner stations, where some members of the aggregations pause to be cleaned by cleaner wrasses. They are not found in Hawaii. At least 10 species occur in Micronesia, and at least 5 species occur in Samoa.

The reproductive biology of caesionids has been examined in only a few species. They appear to be typified by early sexual maturity and high fecundity. They have a prolonged spawning season, but recruitment peaks once or twice a year. Fusiliers are dioecious and gonochoristic, with no significant difference in sex ratio. Spawning has been observed for *Caesio teres* (Bell and Colin 1986) and *Pterocaesio digramma* (Thresher 1984). These caesionids spawn in large groups around the full moon. They migrate to select areas on the reef at dusk and initiate spawning during slack water. In *C. teres*, spawning is preceded by periodic mass vertical ascents and descents to within about 1 m of the surface. During spawning they stay near the surface and subgroups within the mass swirl rapidly in circles and release gametes (Carpenter 1988).

During initial recruitment to a reef, juvenile caesionids generally remain close to the substrate and dart around coral heads and rocks to escape. At night, fusiliers shelter in crevices and under coral heads. Fusiliers often school in mixed species aggregations. They are primarily reef inhabitants, although they often range over soft bottoms in between reefs.

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Table 54. Management Unit Species: Caesionidae (fusiliers)

	Egg	Larvae	Juvenile	Adult
Duration		weeks to months	reach maturity early	
Diet	N/A	various plankton	planktivores	planktivores
Distribution, general and seasonal	prolonged spawning season but tends to peak once or twice a year			tropical Indo-Pacific; None in Hawaii, at least 10 spp. in Micronesia, and 5 in Samoa
Location	spawning occurs at specific sites on a reef (Bell and Colin 1986)	offshore	similar to adults	abundant along steep outer reef slopes and around deep lagoon pinnacles
Water column	pelagic	pelagic	reef-associated; typically remain close to shelter	pelagic
Bottom type	N/A	N/A	coral or rock	coral, rock, but range over sand in travels from reef to reef
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.29 Haemulidae (sweetlips)

Haemulids are very similar to lutjanids but differ by having smaller mouths a bit lower on the head with small conical teeth and thickened lips, by having pharyngeal teeth and by lacking canine and palatine teeth. Some members of the sweetlip family are commonly called grunts because of the sound they can make by grinding the pharyngeal teeth and amplifying the noise with their gas bladder. Haemulids are primarily nocturnal feeders on benthic invertebrates. During the day they typically school under or near overhangs or tabular corals. Their general lethargy during the day and their schooling tendencies makes them easy targets for spearfishers. As a result, they have become scarce in waters near population centers such as Guam. Most species of *Plectorhinchus* change color dramatically with group. The striped juveniles of many species are similar and difficult to distinguish from other haemulid juveniles. Eleven species are recorded from Micronesian waters. None are recorded for the Hawaiian Islands. Three species are recorded from Samoan waters.

There is little information on haemulid reproduction, particularly in Indo-Pacific locations. Given their similarity to other roving benthic predators, such as groupers or snappers, the haemulids probably migrate to spawning sites on the outer reef slope for group spawning at dusk. Eggs are pelagic with a single oil droplet, and hatching time is approximately 24 hours. Duration of the planktonic stage for *Haemulon flavolineatum* is approximately 15 days, when the larvae settle to the bottom at a length of approximately 6 mm (McFarland 1980, Brothers and McFarland 1981). Juvenile grunts are commonly found in small groups on grass flats, near mangroves and in other inshore areas. Cummings et al. (1966) report sexual maturity of *H. album* at approximately 37.5 cm. Gaut and Munro (1983) found mean lengths at maturity for the Caribbean species *H. plumieri, H. flavolineatum, H. sciurus* and *H. album* of 22 cm FL, 12 cm FL or less, 15.5 cm FL 22 cm FL and 24 cm FL respectively.

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Table 55. Management Unit Species: Haemulidae (sweetlips and grunts)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	approximately 24 hrs	15 days to months	from 6 mm until 12–24 mm FL	
Diet	N/A	copepods, nauplii (Houde and Lovdal 1984)	similar to adult	nocturnal predators on benthic invertebrates, including crustaceans, mollusks, and fishes
Distribution, general and seasonal	likely spring spawning peak		similar to adult	no species recorded for Hawaii; tropical and temperate seas in marine and brackish waters worldwide; 11 Micronesian species
Location	probably outcroppings on outer reef slopes	offshore	sheltered inshore areas in lagoons, estuaries, mangroves as well as adult locations	close to patch reefs, lagoons,inshore and seaward reefs, channels, outer reef slopes
Water column	pelagic	pelagic	demersal and reef or mangrove-associated	demersal and reef-associated; 1–100m
Bottom type	N/A	N/A	sandy to muddy bottoms, coral, rocky ledges or table corals	sandy to muddy bottoms, coral, rocky ledges or table corals
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.30 Lethrinidae (emperors)

Egg and Larvae

Lethrinid eggs are pelagic, spherical ,colorless, and range in size from 0.63 to 0.83 mm. The eggs hatch within 21 to 40 hours after fertilization (Carpenter and Allen 1989). The larvae when hatched range in size from 1.3 to 1.7mm. Larval characteristics include unpigmented eyes, large yolk sac, variable body pigmentation and extensively developed head spination.

Juveniles and Adults

Juvenile and adult lethridids are found throughout the Indo-Pacific in tropical and sub-tropical waters. They are fairly long-lived ranging 7-27 years (Carpenter and Allen 1989). Although little is known of the biology of these species, they are known to inhabit the deeper waters of coral reefs and adjacent sandy areas. Some species also occur in shallow water habitats around coral reefs, sand flats, sea-grass beds and mangrove swamps (Carpenter and Allen 1985). Lethrinids appear to be carnivorous bottom-feeders. Their diet includes: crabs, sea-urchins, bivalves, gastropods, and fish (Walker 1978).

Based on the available data, lethrinids appear to be protogynous hermaphrodites (Young and Martin 1982). Spawning occurs throughout the year, and is preceded by localized migrations during crepuscular periods. Peak spawning occurs on or near the new moon. Spawning may occur at near the surface as well as near the bottom of reef slopes. Lethrinids may reach a maximum length of 70 cm. Males tend to attain a larger size than females.

Table 56. Management Unit: Lethrinidae (emperors)

	Egg	Larvae	Juvenile	Adult
Duration	hatch 21 - 40 hours after spawning	No information	No information	7-27 Years
Diet	N/A	No information	No information	Carnivorous bottom-feeders
Distribution	Pelagic	Pelagic	Nearshore areas and shallow seamounts	Throughout Indo-Pacific. Inhabit shallow coastal areas to deep slope (0-350m)
Water Column	Pelagic	Pelagic	Benthic	Benthic
Bottom Type	N/A	N/A	Demersal Reef	Primary forage habitat shallow to deep reef feeding on the bottom
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

4.2.1.31 Lutjanidae (snappers)

Egg and Larvae

Lutjanid eggs are pelagic, spherical and 0.65-1.02 mm in diameter. Each egg contains a single oil globule which provides buoyancy during the pelagic phase. Incubation is between 17-27 hours depending on species and temperature. Newly hatched larvae of lutjanids in general are typical of those from fish with small pelagic eggs; the larvae have a large yolk sac, unpigmented eyes and no mouth. The yolk sac typically lasts 3-4 days, after which the mouth is fully formed and the eyes become pigmented (Leis 1987). The larvae are absent from surface waters during the day and migrate upward at night. Snapper larvae are thought to be planktonic and subject to advection by ocean current systems until benthic habitat suitable for metamorphosis is encountered (Munro 1987). The duration of the pelagic phase is thought to be at least 25 days (Leis 1987) and may be as long as 45 days.

Juveniles

Little information currently exists on larval development, settlement or early juvenile life history of deepwater snappers in Hawaii (Haight et al. 1993a). Little is known about the ecology of juveniles from time of settlement to their appearance in the adult fishery. Age at entry to the fishery for the principle fishery species in Hawaii is thought to be 2 to 3 years after settlement (Moffitt and Parrish 1996). In a three year study of fish settlement on artificial reefs adjacent to adult snapper habitat in Hawaii, no recruitment of juvenile snappers to the reefs was observed, although adults aggregated at times around the reef structures (Moffitt et al. 1989).

Studies on juveniles of one snapper species in Hawaii indicated juvenile *Pristipomoides filamentosus* first appear in the relatively shallow (60 - 100 m) nearshore areas at about 10 months of age (7 - 10 cm FL) during the fall and early winter months. The young fish remain in this habitat for the next 7 months until they reach 18 - 24 cm FL (Moffitt and Parrish 1996, Ellis et al 1992). *In situ* scuba observations of the juvenile habitat found it to be a relatively flat, soft sediment substrate devoid of relief (Parrish 1989).

Adults

Tropical snappers in general are slow growing, long lived and have low rates of natural mortality. Maximum ages exceed 10 years and von Bertalanffy growth coefficients (K) are usually in the range of 0.10 to 0.25 per year (Manooch 1987). Most ageing studies of tropical snappers have depended on the enumeration of regularly formed marks on calcareous structures. In Hawaii, Ralston and Miyamoto (1983) used daily growth increments deposited on the otoliths of immature *P. filamentosus* to determine its growth rate. The estimated growth coefficient of opakapaka is 0.145 per year, and asymptotic upper boundary on growth (L4) was 78 cm FL, which occurred at over 18 years of age.

Ralston (1987), in a comprehensive review of published reports on snapper growth and natural mortality, determined that for the 10 species studied, mortality and growth rates were highly correlated, with a mean M/K ratio of 2.0. Thus, if a value of K is available for a given species, its natural mortality rate can be estimated. Using an age-length probability matrix for opakapaka applied to length frequency samples, Ralston (1981) estimated the natural mortality rate for opakapaka in Hawaii to be 0.25, which when compared to the estimated K value for this species (0.145) is close to the value predicted by the M/K relationship derived for snappers in general.

Size at sexual maturity for lutjanids on average occurs at about 43 to 51% of L_4 (Allen 1985). Size at maturity has been estimated for only two species in the MHI and two species in the NWHI. In the MHI, uku reaches sexual maturity at 47 cm fork length (FL), which is 46% of maximum size (L_4). Onaga reaches sexual maturity at 61 cm FL (62% L_4) (Everson et al. 1989). In the NWHI, ehu reaches maturity at about 30 cm FL (46% L_4) and opakapaka reaches maturity at around 43 cm FL (48% L_4) (Everson 1984, Kikkawa 1984, Grimes 1987).

Gonadal studies on four of the species in Hawaii indicate that spawning may occur serially over a protracted period but is at a maximum during the summer months, and peaks from July to September (Everson et al. 1989, Uchida and Uchiyama 1986). Estimated annual fecundity is 0.5 to 1.5 million eggs. The eggs are released into the water column.

Although snappers throughout the world are generally thought of as top level carnivores, several snapper species in the Pacific are known to incorporate significant amounts of zooplankton, often gelatinous urochordates, in their diets (Parrish 1987). Haight et al. (1993b) found zooplankton to be an important prey item in four of the commercially important snappers in Hawaii. The same study found that the six snapper species studied were either primarily zooplanktivorous or primarily piscivorous, with little overlap in diet composition between trophic guilds. A contributing factor in the distribution pattern of zooplanktivores may be that currents striking deepwater areas of high relief form localized zones of turbulent vertical water movement, increasing the availability of planktonic prey items (e.g. Brock and Chamberlain 1968). In an ecological study of the bottomfish resources of Johnston Atoll, Ralston et al. (1986) found *P. filamentosus* in much higher densities on the upcurrent versus downcurrent side of the atoll, and postulated that this was related to increased availability of allochthonous planktonic prey in the neritic upcurrent areas due to oceanic currents impacting the atoll.

Table 57. Management Unit Lutjanidae (snappers)

	Egg	Larvae	Juvenile	Adult
Duration	Incubate 17-36 hours	Pelagic duration : 25-47 days	Reach sexual maturity in 2-3 years	Long-lived, slow growing. Age at entry to fishery at 2-3 years
Diet	N/A	No information available	Diet of one species includes crustaceans, cephalopods and small fish	Primarily demersal carnivores although some species are zooplanktivorous
Distribution	Widely distributed throughout management area	Widely distributed throughout management area	Throughout Indo-Pacific. Juveniles of some species Inhabit shallow reef areas not utilized by adults	Throughout Indo-Pacific. Inhabit shallow coastal coral reef areas to deep slope rocky habitats (0-400 m)
Water Column	Pelagic	Pelagic	Demersal	Demersal
Bottom Type	N/A	N/A	Wide variety of shallow-water reef and estuarine habitats	Primary forage habitat is shallow to deep reef and rocky substrate.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

4.2.1.32 Mullidae (goatfishes)

Goatfish are important commercial fish that are highly esteemed as food. All have a characteristic pair of long barbels at the front of the chin, a moderately elongate body, two well-separated dorsal fins, a small mouth with a slightly protruding upper jaw and a forked tail. Goatfish use the barbels, which contain chemosensory organs, to probe sand or holes in the reef for benthic invertebrates or small fishes. The barbels are tucked between the lower portion of the gill covers when not in use. Some species are primarily nocturnal, others are diurnal and a few are active by day or night. Nocturnal species tend to hover in stationary aggregations or rest on coral ledges by day.

There are 10 native species of goatfish known from Hawaiian waters, and one accidental introduced species from the Marquesas, *Upeneus vittatus*. Two species, *Parupeneus porphyreus* and *P. chrysonemus*, are endemic to Hawaii. Fifteen species are recorded from Micronesia. Thirteen species are recorded from Samoa.

Goatfish have pelagic eggs, which are spherical, transparent and non-adhesive with a single oil droplet. Egg diameters range from 0.63 to 0.93 mm and hatch within 3 days. Goatfish in general have a long larval development. After settlement, juveniles take approximately 1 year to reach sexual maturity. Munro (1976) suggests that few live more than 3 years.

Schooling is common among the mullids. Group spawning and pair spawning have been documented for goatfishes. An aggregation of 300 to 400 individuals was observed spawning at 21 m depth off the coast of the US Virgin Islands (Colin and Clavijo 1978). Groups of fish made spawning rushes about 2 meters above the bottom before releasing gametes.

Holland et al. (1993) conducted a study of the movements, distribution and growth rates of *Mulloidichthys flavolineatus*by using tagging data. *M. flavolineatus* and *M. vanicolensis* were the most abundant mullids found in Hanalei Bay (Friedlander et al. 1997). *M. flavolineatus* ranked second in overall mean biomass at 211g/100m^2, with an overall mean numerical density of 1.1 individuals/100m^2. *M. vanicolensis* had higher numbers in patch reef habitat, but the larger fish were present in reef slope habitat, indicating partitioning of habitat by size. *Parupeneus cyclostomus* was the rarest and most mobile of the mullids found in Hanalei Bay, with an overall mean density of 0.01 individuals/100m^2 or 2.02 g/100m^2. The largest individuals were seen in deeper reef slope habitat. *P. cyclostomus* has a diet strongly dominated by fish, particularly fish that are diurnally active over reef and other hard substrata. It also eats lesser quantities of crabs, shrimps and stomatopods and trace amounts of other invertebrates. It typically probes sand or reef crevices to flush out small fish with its barbels. *P. cyclostomus* is inactive at night.

The diet of the Hawaiian endemic *P. porphyreus* encompasses a wide variety of benthic invertebrates such as crabs, shrimps, isopods, amphipods, ostracods, stomatopods, planktonic crab megalops larvae and copepods, gastropods, foraminiferans and fish in order of decreasing importance. *P. porphyreus* shelters in areas of high relief and feeds over hard substrate and sandy areas nearby (Friedlander et al. 1997).

The breeding season for *P. porphyreus* shows peak spawning somewhere between December and July. Counts of nuclear rings on otoliths indicate a larval period of approximately 40■60 days. The juvenile phase involves rapid color changes, a lengthening of the gut and an external change in shape. Juveniles can sexually mature as early as 1.25 years. Fecundity was estimated as 11,000 to 26,00 eggs per spawn. Adults live 6 years or longer (Moffitt 1979).

Five goatfish species at Midway Island were generalized feeders, eating mostly small crustaceans, polychaetes and bivalve and opisthobranch molluscs (Sorden 1982). Sorden (1982) discusses similarities and differences among feeding preferences of the goatfish fauna at Midway.

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Table 58. Management Unit Species: Mullidae (goatfishes)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	3 days	relatively long, months?	approximately one year	3 years (Munro 1976)
Diet	N/A	planktivorous	benthic invertebrates such as crabs, shrimps, isopods, amphipods, ostracods, stomatopods, planktonic crab megalops larvae and copepods, gastropods, and foraminiferans; some species eat small fish	benthic invertebrates such as crabs, shrimps, isopods, amphipods, ostracods, stomatopods, planktonic crab megalops larvae and copepods, gastropods, and foraminiferans; some species eat small fish
Distribution, general and seasonal	spawning peaks in late spring and fall	most abundant in the open ocean, though still <25km from reefs	Atlantic, Indian and Pacific oceans, rarely in brackish waters	Atlantic, Indian and Pacific oceans, rarely in brackish waters; may have seasonal spawning aggregations at prominent reef features
Location	released several meters from the bottom	most abundant in the open ocean, though still <25km from reefs	pelagic for some species (Caldwell 1962), but coral reef and sand flat otherwise	coral reef or soft-bottom habitat
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef, rock, sand, mud, crevices, ledges	coral reef, rock, sand, mud, crevices, ledges
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents	unknown	spawning aggregations near channels with heavy tidal flow

4.2.1.33 Kyphosidae (rudderfishes)

Rudderfishes, or sea chubs, are shore fishes of rocky bottoms or coral reefs of exposed coasts. They have deep oval bodies, a continuous dorsal fin, a forked caudal fin and a small mouth with close-set incisiform teeth. They are benthic herbivores and the species of *Kyphosus* often occur in large groups that may overwhelm the defenses of territorial herbivorous fish, such as damselfishes and surgeonfishes. Juveniles often occur far out at sea beneath floating debris. Adults typically swim in schools several meters above the bottom, where they may feed on planktonic algae. Three species occur in Hawaii, Micronesia and Samoa: *Kyphosus bigibbus, K. cinerascens* and *K. vaigiensis*. Another species *Sectator ocyurus* has been reported in Hawaii but is rare and may be a waif from the tropical eastern Pacific.

Very little is known about reproduction in the kyphosids. The eggs are spherical, pelagic and 1.0■1.1 mm in diameter (Watson and Leis 1974). The larvae hatch at 2.4■2.9 mm. The largest pelagic specimen, a juvenile, examined by Leis and Rennis (1983) was 56 mm. Juvenile individuals may be carnivorous for a while before becoming herbivorous (Rimmer 1986).

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Table 59. Management Unit Species: Kyphosidae (rudderfishes)

	Egg	Larvae	Juvenile	Adult
Duration		prejuveniles commonly collected far out at sea under floating debris		
Diet	N/A	zooplankton	may be carnivorous for a while, such as *Kyphosus cornelii* (Rimmer 1986)	herbivorous on benthic and planktonic algae
Distribution, general and seasonal				circumtropical; 3 species in Hawaii, Micronesia, and Samoa: *Kyphosus bigibbus*, *K. cinerascens*, and *K. vaigiensis*
Location			exposed seaward reefs	exposed seaward reefs
Water column	pelagic	pelagic	same as adults	benthic and pelagic, may school in the water column
Bottom type	N/A	N/A	rocky bottoms or coral reefs	rocky bottoms or coral reefs
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.34 Monodactylidae (monos)

Monos are a small family of highly compressed silvery fishes with small oblique mouths, brush-like teeth in the jaws, viliform teeth on the vomer and palatines, vestigial pelvic fins and a continuous unnotched dorsal fin. They occur primarily in estuarine habitats and can live in freshwater. No monos are recorded for the Hawaiian Islands. The family occurs off West Africa and in the Indo-Pacific, and one species, *Monadactylus argenteus*, occurs in Micronesia and Samoa. It is an active schooling fish that occurs primarily in estuaries but may venture over silty coastal reefs. It is valued as an aquarium fish.

M. argenteus spawns demersal, adhesive eggs, at least in freshwater (Breder and Rosen 1966). The eggs of *Psettus sebae*, a tropical Atlantic species, are small (0.6■0.7 mm), spherical and pelagic in seawater but demersal in freshwater (Akatsu et al. 1977). Larvae of *P. sebae* hatch at 1.8 mm. The largest size of a pelagic larval specimen of *M. argenteus* was 14.5 mm (Leis and Trnski 1989).

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Table 60. Management Unit Species: Monodactylidae (monos)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration		from <1 mm to 14.5 mm		
Diet	N/A		probably similar to adults	small benthic and planktonic invertebrates
Distribution, general and seasonal	spring or summer spawning peak likely		similar to adults	West Africa and Indo-Pacific; not in Hawaii, *Monadactylus argenteus* only species in Micronesia
Location			similar to adults	primarily in estuaries, but may venture over silty coastal reefs
Water column	pelagic in seawater, demersal in freshwater	pelagic in seawater, demersal in freshwater	pelagic	pelagic
Bottom type			silt, mud, sand, coral	silt, mud, sand, coral
Oceanic features	pelagic larvae subject to dispersal by ocean currents	pelagic larvae subject to dispersal by ocean currents		

4.2.1.35 Ephippidae (batfishes, spadefishes)

Batfishes have deep, highly compressed bodies, a small terminal mouth with brushlike teeth, a continuous dorsal fin and small ctenoid scales extending to the basal portions of the median fins. They are schooling, semi-pelagic fishes often associated with reefs. Juveniles have very deep bodies and greatly elevated dorsal, anal and pelvic fins that shorten with age. Juveniles occur singly or in small groups among mangroves and in inner sheltered lagoons or reefs. Adults migrate to deeper channels and lagoons where they aggregate in small schools, although larger adults may be solitary. They are omnivores that feed on algae, invertebrates and small fishes. In Micronesian waters, 3 species occur: *Platax orbicularis, P. pinnatus* and *P. teira*. In Samoan waters, 2 species have been recorded.

There is little information on the spawning or egg characteristics of Indo-Pacific ephippidids, but there is some information for the Atlantic genus *Chaetodipterus*, which has pelagic eggs of about 1 mm diameter (Johnson 1984). Spawning for *C. faber* was observed near floating objects about 40 m offshore. Two small schools were present, but spawning occured between pairs (Chapman 1978). This observation suggests that ephippids migrate offshore to spawn. Spadefish larvae hatch in 24 hours and are about 2.5 mm long. By a length of 10 mm, the larvae are recognizable as spadefish and are ready to settle.

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Table 61. Management Unit Species: Ephippidae (batfishes, spadefishes)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	24 hrs	hatch at 2.5 mm, ready to settle at 10 mm		
Diet	N/A		similar to adults	algae, invertebrates, small fishes
Distribution, general and seasonal	spring or summer spawning (Munro et al. 1973)		similar to adults	the family is found in tropical and temperate seas worldwide; the genus *Platax* is found in Micronesia, not in Hawaii
Location	offshore	offshore	mangroves, sheltered lagoons and reefs	deeper channels, lagoons, seaward reefs
Water column	pelagic	pelagic	semi-pelagic	semi-pelagic
Bottom type	N/A	N/A	sand, mud, silt, and coral reefs	reef-associated, but also mud and sand bottoms in mangroves and lagoons
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.36 Chaetodontidae (butterflyfishes)

Butterflyfishes are colorful, conspicuous fishes with deep, highly compressed, ovate bodies, small mouths and a band of brush-like teeth in the jaws. They have a single continuous dorsal fin with anterior interspinous membranes deeply incised and a caudal fin varying from slightly rounded to slightly emarginate. They are diurnal predators with diets that vary significantly between species. Many specialize on polyps of corals and other coelenterates. The corallivores tend to be territorial and limited to the shallower depth ranges of the corals, such as *Pocillopora meandrina*, upon which they feed. Others feed heavily on benthic algae and small benthic invertebrates. Some species, including those of *Hemitaurichthys*, are primarily zooplanktivores. The zooplankton feeders often occur in mid-water aggregations and range into relatively deep water. Most butterflyfishes are solitary or occur in pairs, but a few form aggregations. Butterflyfishes appear to be gonochorists, with sex remaining the same throughout life, and often form heterosexual pairs that stay together for many years and possibly their whole life.

Spawning generally occurs in pairs at the top of an ascent in which the male nudges the abdomen of the female. Eggs are planktonic and hatch within 2 days. The larval stage lasts from several weeks to a few months, with a distinctive late larval stage called the tholichthys larva when large bony plates cover the head and front of the body. Settlement occurs at night, and juveniles tend to occur in shallower, more sheltered habitats than adults. Coloration typically changes little with growth, although butterflyfish do exhibit slightly different, more subdued color patterns at night when they shelter in the reef. Because of their specialized feeding habits, butterflyfishes do not tend to do well in aquariums, although some of the generalists and planktivores are collected for the aquarium trade. The family is represented in Hawaiian waters by 24 species; *Chaetodon fremblii*, *C. miliaris*, and *C multicinctus* are endemic to Hawaii; and *C. tinkeri* is found only in Hawaii and the Marshall Islands. The family is represented in Micronesian waters by at least 40 species. It is represented in Samoan waters by 30 species. The yellow-crowned butterflyfish *C. flavocoronatus* is listed as a vulnerable species in Guam on the 1996 IUCN Red List.

Chaetodontid eggs are buoyant, transparent and spherical. They typically range from 0.6 to 0.74 mm in diameter and contain a single oil droplet. The eggs hatch in 1▪2 days. The larvae typically have a preopercular spine and a bony sheath around the head. The tholichthys stage of development is unique to the butterflyfishes and is characterized by a series of thin transparent bony plates that completely encase the head of the larva and extend dorsally and ventrally to form bony spines. The plates remain until after the fish have settled on the bottom. The duration of the planktonic stage is not well studied, but Burgess (1978) suggests it is likely to be at least several months.

The Hawaiian endemic *C. miliaris* reaches reproductive maturity at a size of about 90 mm SL, or about 1 year old (Ralston 1976). Spawning occurs between December and April but peaks around the end of February or the beginning of March.

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Table 62. Management Unit Species: Chaetodontidae (butterflyfishes)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	2 days	several weeks to a few months	1–2 yrs; approximately one year for *C. miliaris* (Ralston 1976), two years for *C. rainfordi* (Fowler 1991); size at settlement for *Hemitaurichthys polylepis* is 60 mm (Burgess 1978)	10–25 yrs in captivity (Allen et al. 1998)
Diet	N/A	zooplankton	some are obligate corallivores (*C. trifascialis* and *C. trifasciatus*); some are planktivores; others consumea variety of benthic algae, small benthic invertebrates, fish eggs, coelenterate tentacles or polyps	some are obligate corallivores (*C. trifascialis* and *C. trifasciatus*); some are planktivores; others consumea variety of benthic algae, small benthic invertebrates, fish eggs, coelenterate tentacles or polyps
Distribution, general and seasonal	spawning peaks in late winter through early summer •January to March for *C. miliaris* in Hawaii (Ralston 1981), with another smaller peak in early fall for some species	typically more abundant in offshore waters in the summer months in Hawaii	primarily Indo-West-Pacific, but also tropical to temperate Atlantic, Pacific, and Indian Oceans; settlement of juvenile *C. lunula* and *C. multicinctus* peaked in Hawaii in May-July (Walsh 1987)	primarily Indo-West-Pacific, but also tropical to temperate Atlantic, Pacific, and Indian Oceans
Location	waters above coral reefs and nearshore waters	offshore waters	coral reef ecosystems	coral reef ecosystems
Water column	eggs released at the height of spawning rushes	pelagic	demersal and mid-water column; 1–100 m, as deep as 172 m	demersal and mid-water column; 1–100 m, as deep as 172 m
Bottom type	N/A	N/A	coral reef; obligate corallivores may be restricted to distributions of corals they feed upon- *C. trifascialis* and *Acropora* for example (Reese 1981)	coral reef; obligate corallivores may be restricted to distributions of corals they feed upon–*C. trifascialis* and *Acropora*, for example (Reese 1981)
Oceanic features	subject to dispersal by currents	subject to dispersal by currents		

4.2.1.37 Pomacanthidae (angelfishes)

Angelfishes are similar to butterflyfishes and at one time were grouped in the same family. They differ mainly in having a strong spine on the cheek at the corner of the preopercle, in the presence of strongly ctenoid scales and in lacking the distinctive chaetodontid tholichthys larval stage. They are diurnal, spectacularly colored and territorial. Many of the large species, including those of *Pomacanthus,* are primarily spongivores with a small amount of feeding on other soft-bodied invertebrates, algae and fish eggs. Smaller species such as those of *Centropyge* feed on benthic algae and detritus. Species of *Genicanthus* feed primarily on zooplankton but also a little on benthic invertebrates and algae. Juveniles of some species are cleaners of external parasites from larger fishes.

Most, and possibly all, of the angelfishes are protogynous hermaphrodites that change from male to female and frequently have different color patterns depending on their sexual development. Males frequently maintain a harem of 2▪5 females and defend a territory ranging from a few square meters for some species of *Centropyge* to well over 1 km for some *Pomacanthus* species. Angelfish spawn in pairs, typically near dusk, at the apex of a spawning rush after courtship and nuzzling by the male. Eggs hatch within 24 hours and undergo a pelagic larval stage of 3▪4 weeks. They are popular aquarium fish. Six species are found in Hawaiian waters, and 4 of them are endemic: *Centropyge fisheri, C. potteri*, *Desmoholacanthus arcuatus* and *Genicanthus personatus* At least 26 species occur in Micronesia. At least 11 species occur in Samoa.

Pomacanthid eggs are small, spherical and nearly transparent and contain from one to several oil droplets. Egg diameter ranges from 0.6 to 1.05 mm depending on the species. Hatching occurs from 15 to 23 hours after release (Thresher 1984). Feeding by the larva begins within 2▪3 days and settlement to the bottom occurs between 17 and days (Moe 1977, Allen et al. 1998). Juveniles seek shelter in reef crevices. Juveniles frequently exhibit dramatically different color patterns from adults and may inhabit shallower habitats. Juveniles of *Pomacanthus* may maintain cleaning stations on or near the reef (Brockmann and Hailman 1976). There is little information on the age at sexual maturity, but most angelfishes probably become mature at between 1 and 2 years of age (Allen et al. 1998).

Adult angelfishes require suitable shelter in the form of boulders, caves and coral crevices. Most species occur from 2 to 30 m depth, but a few, such as *C. narcosis*, are found over 100 m deep. Adults forage throughout territories that vary in size with the size of the species. Generally *Pomacanthus* are spongivores; *Genicanthus* are zooplanktivores, especially on pelagic tunicates; and *Centropyge* are herbivores. Small amounts of zoantharians, tunicates, gorgonians, fish and invertebrate eggs, hydroids and seagrasses may supplement the diet of any of the angelfish species. Hybridization is common amongst the angelfish species (Pyle and Randall 1994).

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Table 63. Management Unit Species: Pomacanthidae (angelfishes)

	Egg	Larvae	Juvenile	Adult
Duration	12▪24 hrs	17▪39 days	1▪2 yrs	10▪26 yrs in captivity
Diet	N/A	plankton	diet similar to adults, although some species may be cleaners as juveniles	*Pomacanthus*-sponges; *Genicanthus* - zooplankton, especially pelagic tunicates; *Centropyge* - benthic algae; all may take small amounts of zoantharians, tunicates, gorgonians, fish and invertebrate eggs, hydroids, algae and seagrasses
Distribution, general and seasonal	spawning peak for *C. miliaris* in Hawaii from Jan. to Mar. (Ralston 1981)	more abundant in offshore samples	circumtropical, with greatest number of species in Indo-Pacific; seasonal peak of recruitment for Hawaii in the summer (Walsh 1987)	circumtropical, with greatest number of species in Indo-Pacific
Location	eggs released at apex of spawning rush of 3▪9 m above the bottom	more abuundant in offshore samples	coral reef ecosystems	coral reef ecosystems
Water column	pelagic	pelagic	demersal and mid-water column, mostly 2▪30 m but some species over 100 m deep	demersal and mid-water column, mostly 2▪30 m but some species over 100 m deep
Bottom type	N/A	N/A	refugia on the reef such as cracks, crevices, boulders	home ranges encompass a wide variety of bottom types on coral reefs and flats; rubble/coral
Oceanic features	subject to advection by currents	subject to advection by currents		

4.2.1.38 *Genicanthus personatus* (masked angelfish)

The masked angelfish is endemic to the Hawaiian Islands and is highly valued for the aquarium trade, despite doing very poorly in captivity. They are typically found on seaward reef slopes below 23 m deep. In the main Hawaiian Islands, they are seldom seen within safe diving depth limits, but, in the Northwestern Hawaiian Islands, they are more common in shallower water. The population starts at Necker Island and increases in density toward Midway, where it is common at diveable depths and probably extends into undiveable depths (Pyle, pers. comm.). They are often found near ledges and dropoffs and on bottoms or walls of coral reef, rock or sand and rubble.

First collected in 1972, the females of the species were described in Randall (1975) from 3 specimens collected off Oahu and one off the Kona coast of Hawaii. Almost all the specimens from the main Hawaiian Islands have been females, including individuals seen from submersibles greater than 100 m deep (Chave and Mundy 1994). Soon after the original description, 2 males were trawled from a depth of 51 m near Nihoa Island and described by Randall (1976). The stomach of one of the males was full of the green alga *Codium*, as well as planktonic organisms and fish eggs. Though members of *Genicanthus* are generally zooplanktivores, the guts of several *G. personatus* contained a majority of algae but also copepods, diatoms, fish eggs and sponge spicules (Howe 1993). Howe (1193) notes that the presence of oesophageal papillae may allow for a different feeding mode from other pomacanthids.

Like other members of the genus, *G. personatus* is sexually dichromatic. It most likely forms harems and is hermaphroditic. Like other angelfish species, it releases pelagic eggs at the end of a short spawning ascent, with eggs hatching within 12■24 hours and larvae remaining adrift for 17■39 days before settlement (Allen et al. 1998). In a study of the reproductive behaviour of another endemic Hawaiian angelfish, *Centropyge potteri*, Lobel (1978) found a peak in spawning from January to April and a peak in juvenile recruitment from May to July. Juvenile and adult angelfishes are highly dependent on the availability of shelter in the form of boulders, caves and coral crevices.

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Table 64. Management Unit Species: *Genicanthus personatus* (masked angelfish)

	Egg	Larvae	Juvenile	Adult
Duration	angelfish in general: 12■24 hrs (Allen et al. 1998)	angelfish in general: 17■39 days (Allen et al. 1998)	angelfish in general: likely 1■2 yrs (Allen et al. 1998)	
Diet	N/A	likely small zooplankton	no information that it is different from adult	the genus is considered zooplanktivorous, but gut samples of *G. personatus* show a majority of algae, with some copepods, diatoms, fish eggs, and sponge spicules (Howe 1993, Randall 1976)
Distribution, general and seasonal	Lobel (1978) found a spawning peak from Jan to April for another endemic Hawaiian angelfish, *Centropyge potteri*		Lobel (1978) found a recruitment peak from May through July for another endemic Hawaiian angelfish, *Centropyge potteri*	endemic to Hawaii; rare in main Hawaiian Islands within diving depths, but more common shallower in Northwestern Hawaiian Islands
Location	typically released 3■9 m from the bottom after a spawning ascent	offshore waters	no information that it is different from adult	seaward reef slope, often near vertical discontinuities
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef, rock, sand and rubble	coral reef, rock, sand and rubble
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents	N/A	N/A

4.2.1.39 Pomacentridae (damselfishes)

The damselfishes are one of the most abundant fishes on coral reefs. They are seldom larger than 10■15 cm and are moderately deep-bodied, with a small mouth and conical or incisiform teeth. They have a continuous dorsal fin and a caudal fin that varies from truncate to lunate but is usually forked. Juveniles frequently have very different and brighter colors than adults. Males tend to have a distinct, darker color pattern during spawning times. Most damselfishes occur in shallow water on coral reefs or rocky substrata, wherever there is shelter. The species of *Chromis*, *Dascyllus, Lepidozygus, Amblyglyphidodon, Neopomacentrus* and *Pomachromis* are aggregating planktivores, which often form large schools in the water column.

Most members of *Abudefduf*, *Chrysiptera* and *Pomacentrus* are omnivores that feed on benthic algae, small invertebrates or zooplankton. *Plectroglyphidodon johnstonianus* feeds on coral polyps. Other members of *Plectroglyphidodon*, as well as members of *Stegastes*, are aggressively territorial herbivores. Algal feeders frequently cultivate algal mats, which they weed of undesirable algae and aggressively defend from other reef inhabitants. Spawning for damselfishes usually occurs in the morning. The eggs, are elliptical and demersal and are guarded by the male until hatching. Predators on the eggs such as wrasses and butterflyfishes, quickly consume the eggs if the male is removed from the nest. In Hawaiian waters, there are 17 species of pomacentrids; 6 are endemic: *Abudefduf abdominalis, Chromis hanui, C. ovalis, C. verater, Dascyllus albisella* and *Plectroglyphidodon sindonis*. At least 89 species occur in Micronesian waters. At least 47 species occur in Samoan waters.

The anemonefishes, subfamily Amphiprioninae, live in a symbiotic relationship with large sea anemones. They are protandrous hermaphrodites; all females start out as males before sex reversal. *Amphiprion* and *Premnas* are unique among the damselfishes in forming permanent pair bonds (Fautin and Allen 1992). Spawning typically occurs near the time of a full moon most often during morning hours and involves the laying of several hundred adhesive eggs on a hard surface near the base of the anemone. Within the tropics, spawning occurs throughout the year although there may be seasonal peaks of activity. The male guards the eggs until hatching after about a week. A short planktonic larval stage lasts from 8 to16 days before settlement. New recruits must locate a suitable anemone, as anemonefish do not survive without a host. No anemonefish are found in Hawaii because of both the absence of host anemones and the short larval duration. Anemonefishes feed primarily on copepods, larval tunicates and filamentous algae. They have been recorded to live at least 6■10 years in nature (Fautin and Allen 1992).

Pomacentrid eggs are demersal, elliptical and adhesive by means of a cluster of fine threads at one end of the egg. Egg diameters range from 0.49 to 2.3 mm. Hatching occurs in 2■4 days for most species but up to 2 weeks for anemonefish eggs. The planktonic larval stage typically lasts 2■3 weeks but may be longer. Thresher, Colin and Bell (1989) found larval durations for the following families: *Amphiprion* and *Premnas*: 7■14 days; *Chromis* and *Dascyllus*: 17■47 days with most between 20 and 30 days; and genera in the subfamily Pomacentrinae: 13■42 days. Size at settlement ranges from 7 to 15 mm, and several studies suggest that settlement occurs mainly at dusk and at night (Williams 1980, Nolan 1975).

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Table 65. Management Unit Species: Pomacentridae (damselfishes)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	2■4 days for most species, but up to 14 days for anemonefish	2■3 weeks for most species, but ranging from 7-47 days	1■2 years	6■8 years, but up to 10 years or more
Diet	N/A	zooplankton	planktivores: *Chromis, Dascyllus, Lepidozygus, Amblyglyphidodon, Neopomacentrus* and *Pomachromis*; omnivores: *Abudefduf, Chrysiptera* and *Pomacentrus*; herbivores: *Stegastes* and *Plectroglyphidodon*, except *P. johnstonianus* that feeds on corals	planktivores: *Chromis, Dascyllus, Lepidozygus, Amblyglyphidodon, Neopomacentrus* and *Pomachromis*; omnivores: *Abudefduf, Chrysiptera* and *Pomacentrus*; herbivores: *Stegastes* and *Plectroglyphidodon*, except *P. johnstonianus* that feeds on corals
Distribution, general and seasonal	peak spawning in Mar./Ap. and another in Sept./Oct. (Watson and Leis 1974)	more abundant in offshore waters	circumtropical and warm temperate with 84% of species in the Indo-West Pacific; peak in recruitment in spring or summer (Walsh 1987)	circumtropical and warm temperate with 84% of species in the Indo-West Pacific
Location	on hard substrate cleared and protected by the male	more abundant in offshore waters	coral reef-associated	coral reef-associated
Water column	demersal	pelagic	demersal and mid-water column, most within 0■20 m, but some deeper than 100 m	demersal and mid-water column, most within 0■20 m, but some deeper than 100 m
Bottom type	cleared surface of rock or coral	N/A	all hard substrate in coral reef habitats	all hard substrate in coral reef habitats
Oceanic features	N/A	subject to advection by ocean currents		

4.2.1.40 Labridae (wrasses)

Labridae is a large family, second only to Gobiidae for number of species in the Western Pacific. It is a very diverse family in size and body shape, with adult sizes ranging from less than 5 cm in *Wetmorella albofasciata* to greater than 229 cm in the humphead wrasse, *Cheilinus undulatus* (this species is rare and heavily fished in Guam and is treated as a separate management unit). Labrid body shapes vary from elongate and cigar-shaped in many species to deep and compressed in others (Myers 1991). Most wrasses are brilliantly and complexly colored, with juveniles frequently having a different color pattern from adults. Color changes may also be associated with protogynous hermaphroditism, sex reversal from female to male that has been described for many labrids and may be true for all species in the family (Randall 1996). Wrasses swim mainly with their pectoral fins, using their tail only when quick bursts are necessary. They have a terminal mouth usually with thick lips, protruding front canine teeth and nodular to molariform pharyngeal teeth. Scales are cycloid. Important summary documents are Randall (1996) and Myers (1991).

The wide variety of color phases in the labrids has created significant taxonomic confusion. Some new species have proven to be a different color phase of an existing species, resulting in a general shrinking of the number of species listed in the family. Still, the family has over 600 species (Hoover 1993). There are 96 known species of labrids in Micronesia (Myers 1991), 43 species in Hawaii (Randall 1996) and 68 species in American Samoa (Wass 1984).

Labrids are shallow-water fishes closely associated with coral reefs or rocky substrate, though some species of *Bodianus* occur deeper than 200 m (Smith 1986, Chave and Mundy 1994), and the razorfishes *Xyrichtys* and *Cymolutes* spp. occur on sand flats. Labrids are diurnal, and at night many bury into the sand, seek refuge in holes and cracks of the reef or lie motionless on the bottom. During the day, labrids keep close to coral or rocky cover, darting into refugia in the reef or burying themselves in the sand when danger approaches. Labrids can be found in virtually all coral reef habitats from inner lagoons and subtidal reef flats to deep seaward reefs (Myers 1991, Green 1996).

Schooling behavior and excursions away from the reef into the water column are usually associated with reproduction (Thresher 1984). Many labrid species are solitary inhabitants of the reef, though many members of the family have large home ranges encompassing a wide variety of habitats (Green 1996). The geographic range of *Labridae* as a family is shallow, tropical and temperate seas of the Atlantic, Pacific and Indian Oceans. Labrids are found throughout shallow areas in the Western Pacific Region, including 96 known species in Micronesia (Myers 1991), and 43 species in Hawaii, 14 of them endemic (Randall 1996).

There is generally a dearth of information on the life history parameters of age, growth and mortality of many coral reef fishes, including labrids, and what information exists cannot realistically be applied to the whole family. Reef fish guides for Pacific coral reef fishes (Myers 1991, Hoover 1993, Randall 1996) include maximum sizes in the species description. Few correlations have been made between size and age for wrasses.
Sexual dimorphism is a characteristic of all labrids. Every species studied thus far has proven to be a protogynous hermaphrodite (Myers 1991, Randall 1996). Most species have a drab initial phase consisting of all females or a combination of females and non-sex-reversing

males and a gaudier terminal phase consisting of males that were formerly females. Species vary as to the ratio of initial phase and terminal phase fishes (Thresher 1984).

Spawning usually occurs along the outer edge of a patch reef or along the outer slope of more extensive reefs. Two types of spawning are characteristics of the labrids: aggregate spawning of large groups of a dozen to several hundred initial-phase males and females and pair spawning of a terminal-phase male and an initial-phase female (Thresher 1984). Both types of spawning involve a sudden upward rush of the participants 0.1 to 2 m into the water column, where milt and eggs are released before the fish return to the bottom. The entire sequence often takes less than a second (Thresher 1984). Colin and Bell (1991) described polygonous haremic, lek-like and promiscuous mating systems for labrids in the Marshall Islands. Spawning season for many tropical wrasses is year-round, and some species perform spawning rituals daily. In Hawaii, the saddle wrasse *Thalassoma duperrey* had a peak in spawning from November to February (Ross 1983) and a peak in juvenile recruitment from January to March (Walsh 1987). Many species migrate to prominent coral or rock outcrops for spawning, including species of *Thalassoma*, *Halichoeres*, *Choereodon*, *Bodianus* and *Hemigymnus* (various references in Thresher 1984).

Fourteen species of wrasses are endemic to Hawaii: *Anampses chrysocephalus*, *A. cuvier*, *Bodianus sanguineus*, *Cirrhilabrus jordani*, *Coris ballieui*, *Coris flavovittata*, *Coris venusta*, *Cymolutes lecluse*, *Labroides phthirophagus*, *Macropharyngodon geoffroy*, *Stethojulis balteata*, *Thalassoma ballieui*, *T. duperrey* and *Xyrichtys umbrilatus* (Randall 1996). The Hawaiian population of another species, *Bodianus bilunulatus albotaeniatus*, is recognized as a subspecies (Randall 1996). No wrasse species are reported to be endemic to American Samoa (Wass 1984). There are no important species of introduced wrasses to the Western Pacific Region.

Schooling behavior is common among the wrasses, particularly group spawning aggregations and haremic systems of certain wrasse species. Aggregations of spawning labrids sampled by Robertson and Choat (1974) consisted of mostly males, although initial-phase females typically outnumber initial-phase males in the general population (Thresher 1984).

The majority of labrids are benthic carnivores, feeding on a wide variety of invertebrates or fishes, although some are planktivores, corallivores or cleaners.

The following carnivores feed on benthic invertebrates, including molluscs, crustaceans, polychaetes, sea urchins, brittle stars, tunicates and foraminiferans. Many species also feed on fishes or fish eggs.

Bodianus spp.
Pseudodax moluccanus
Wetmorella spp.
Cymolutes spp.
Xyrichtys spp.
Pterogogus spp.
Cheilio inermis
Choerodon anchorago
Cheilinus spp.
Epibulis insidiator
Novaculichthys spp.
Pseudocheilinus spp.
Anampses spp.
Coris spp.

Gomphosus varius
Halichoeres spp.
Hemigymnus spp.
Hologymnosus spp.
Macropharyngdon spp.
Pseudojuloides spp.
Stethojulis spp.
Thalassoma spp. (except *T. amblycephalum*)

The following small planktivore (usually < 100 mm) feed on zooplankton such as copepods, fish eggs, and larval fish and invertebrates in the water column.

Cirrhilabrus spp.
Paracheilinus spp.
Pseudocoris yamashiroi
Thalassoma amblycephalum

The following corallivores feed on live coral polyps.

Labropsis xanthonata (adults)
Labrichthys unilineatus
Diproctacanthus xanthurus (plus cleaning)

The following cleaners feed on external parasites or damaged tissue of other fishes. They are frequently territorial around a cleaning station, although some species roam larger areas to find fishes to clean. Larger fishes often travel long distances seeking the services of a cleaner, and removal of cleaners has led to abandonment of the area by larger fishes.

Labroides spp.
Labropsis micronesica
Labropsis xanthonata (juvenile)
Diproctacanthus xanthurus

Labrids are found in large numbers in a wide variety of habitats associated with reefs in the Western Pacific Region. Green (1996) measured the density of the 10 most abundant fish families in each of 5 coral reef habitat types in American Samoa. Labridae were the third most abundant fish family in the reef flat, shallow lagoon, reef crest and reef front at 20 m depth, with densities ranging from 719 to 1,123 fish per hectare. Wrasses were the fourth most abundant family on the reef front at 10 m depth with 858 fish per hectare (Table 11 in Green 1997). The great majority of Labridae are found in depths from 1 to 100 m of water, in close association with coral or rocky substrate, although species of *Bodianus, Polylepion* and *Suezichthys* were seen well below 150 m during submersible cruises on seamounts near Hawaii (Chave and Mundy 1994). Prominent outcroppings of rock or coral are important as sites for spawning aggregation in some species (Thresher 1984). Sandy areas are necessary for the sand-dwelling labrids, *Xyrichtys* spp. and *Cymolutes* spp.

Migration patterns have not been documented for the labrids. Many of the smaller species stay confined to very small areas of the reef, while larger species have bigger home ranges (Green 1996). Even very large species, such as *Cheilinus undulatus,* return to a favored hole or crevice to spend the night or to escape danger (Myers 1991).

In the main Hawaiian Islands, wrasses are a minor portion of the commercial catch, according to Division of Aquatic Resources catch statistics from 1991 to 1995. Two species are present in the top 25 inshore fish species by weight●4,159 lbs of *Bodianus bilunulatus* and

3,955 lbs of *Xyrichthys pavo* (Table 15 in Friedlander 1996). Some wrasse species are caught for the aquarium trade, including *Pseudocheilinus octotaenia*, *Cirrhilabrus jordani*, *Thalassoma* spp., *Anampses chrysocephalus*, *Macropharyngodon geoffroy* and *Novaculichthys taeniourus*, but wrasses are a small portion of the trade in numbers and value (Pyle, pers. comm). A report on commercial collection of aquarium fish by Forum Fisheries Agency countries—which did not include Hawaii, Guam or the Philippines but did include exporters from Belau, Christmas Island, Fiji, Kwajalein, Majuro, Pohnpei, Rarotonga, Tarawa and Australia—indicate that wrasses made up 7% of the catch by number of fish and 12% by value of catch, with an approximate selling price between US $3 and $15 per fish (Pyle 1993).

No fisheries target wrasses in the Northwestern Hawaiian Islands. Labrids do form a substantial component of coral reef systems in these areas (Hobson 1983, Parrish 1989, Randall et al. 1993, Demartini et al. 1994).

The coral reef fishery in American Samoa has two components: the shoreline subsistence and the boat-based artisanal fishery (Green 1997). Labrids comprise less than 3% of the reef fish catch throughout American Samoa (Dalzell et al. 1996) and were not listed in the catch composition of the shoreline fishery on Tutuila Island in 1991 (from Craig et al. 1993 in Green 1997). Green (1997) reports no commercial aquarium trade in American Samoa.

There is little information on the biological resources of the coral reefs in the federal waters surrounding Guam. Fisheries data is limited to unprocessed catch reports and anecdotal collection data (Myers 1996). Inshore, Labridae made up 7.3% of total landings by weight of the small-boat based spearfishing landings on Guam between 1985 and 1991 (Table 63 in Green 1997). In a study by Katnik (1982), wrasses composed 4.4% of the total catch weight on heavily fished reefs and 4.0% of total catch weight on lightly fished reefs. Similarly, Dalzell et al. (1996) reported that labrids composed 4.31% of the reef fish catch in Guam. Studies detailing overfishing of reefs near Guam are discussed in Green (1997).

There is very little information on the catch of wrasses in the Northern Marianas. For example, data collection in Saipan from 1992 to 1994 assigned 87–91% of annual landings to an unidentified reef fish category (Gourley 1997). Hamm et al. (1994, 1995, 1996) reported catches of 44, 346 and 206 lbs of wrasses in NMI reef-associated commercial fisheries in 1992, 1993 and 1994, respectively. As of 1997, NMI Division of Fish and Wildlife regulations prohibited the commercial export of live fish for the aquarium trade (Gourley 1997).

Labrid eggs are pelagic, spherical, 0.45 to 1.2 mm in diameter and lightly pigmented if at all and usually contain a single oil droplet (Leis and Rennis 1983, Thresher 1984, Colin and Bell 1991). Colin and Bell (1991) measured oil globule diameter for 21 species of labrids in Enewetak Atoll and found a range of 0.10 to 0.24 mm. Colin and Bell documented spawning mostly on a reef bisecting a main channel with strong tidal currents but also on lagoon reefs and in *Halimeda* beds. Most labrids spawned at or slightly after high tide (Colins and Bell 1991), which is in agreement with similar findings for Indo-Pacific labrids (Ross 1983).

Larvae hatch at 1.5■2.7 mm and have a large yolk sac, unformed mouth and unpigmented eyes (Leis and Rennis 1983). Victor (1986) measured the duration of the larval phase of 24 species of wrasses in Hawaii and found a range of 29.5 days (*Anampses chrysocephalus*) to 89.2 days (*Thalassoma duperrey*), although he noted substantial variability within species, up to a standard deviation of 11 days for some wrasses. Victor (1986) and other authors (Miller 1973, Leis and Miller 1976) have noted that despite their abundance as adults in the nearshore fauna of coral reef habitats, labrid larvae are conspicuosly absent from nearshore samples and common in offshore samples. Some labrid larvae are routinely found in the open ocean (Leis and Rennis 1983).

Like adult wrasses, juvenile labrids inhabit a wide variety of habitats from shallow lagoon flats to deep reef slopes. Green (1996) reported that *Labroides dimidiatus* and *Thalassoma lunare* use deeper reef slope and reef base habitats as recruits and shallower habitats as adults. Examples of ontogenetic shifts in habitat use are not widely reported for the family, although relatively few studies have examined the topic.

Labrids are found in most any habitat associated with a coral reef, including rubble, sand, algae, seaweeds, rocks, flats, tidepools, crevices, caves, fringing reefs, patch reefs, lagoons and reef slopes (Myers 1991, Randall 1993). Most species of Labridae show similar patterns of habitat use as adults and recruits, aside from 2 species reported by Green (1996). Spatial and temporal patterns of habitat use by labrids, including descriptions of labrid assemblages distinct to each depth zone, are further reported in Green (1996).

A study of the fish population of Hanalei Bay, Kauai, found *Thalassoma duperrey* was the most numerous species in all habitat types except the deep slope (Friedlander et al. 1997). In the same study, 3 labrid species, *Bodianus biulunulatus, Coris flavovittata* and *Thalassoma ballieui*, were present in a creel survey of fishers in the bay. Sand-dwelling species, such as the razorfish *Xyrichtys pavo*, live in and forage over open sandy areas on crabs, shrimp and benthic molluscs (Friedlander et al. 1997). Their densities tend to decline with distance from the reef (Friedlander et al. 1997).

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Table 66. Management Unit Species: Labridae (wrasses)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	approximately 24 hours	29.5 to 89.2 days for 24 species in Hawaii (Victor 1986)		
Diet	N/A	likely small zooplankton	some species have ontogenetic shifts ●*Labropsis xanthonata* from cleaner to corallivore, for example●but most have similar diets as adults	1) most are carnivores of benthic invertebrates and fishes; some are 2)corallivores, 3)planktivores, and 4)cleaners●see text for species list
Distribution, general and seasonal	year-round spawning common, although Miller (1973) and others have documented spring and fall peaks in spawning; *Thalassoma duperrey* has a winter spawning peak (Ross 1983)	more abundant in offshore samples	coral reef habitats throughout the Western Pacific; seasonal peak in recruitment for *T. duperrey* from January to May (Walsh 1987)	coral reef habitats throughout the Western Pacific
Location	released from <1 up to 5 m from the bottom	more abundant in offshore samples (Miller 1973, Leis and Miller 1976)	closely associated with reef substrate or sand flats; 1-200m	closely associated with reef substrate or sand flats; 1▪200 m
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	wide variety from shallow lagoon sand flats to deep reef slopes (Green 1996)	wide variety from shallow lagoon sand flats to deep reef slopes (Green 1996)
Oceanic features	subject to ocean currents	subject to ocean currents		prominent points or outcroppings are important for spawning aggregations; gyres associated with these points may serve to take larvae temporarily away from reef predators (Johannes 1978)

4.2.1.41 *Cheilinus undulatus* (humphead wrasse)

Cheilinus undulatus is treated as a separate management unit because spear fishing has brought the species to very low population levels, particularly around Guam (Dalzell et al. 1996). Because the species is not present in Hawaii, a description follows from Micronesia (Myers 1991).

The humphead wrasse is among the largest of reef fishes. Adults develop a prominent bulbous hump on the forehead and amazingly thick fleshy lips. Adults occur along steep outer reef slopes, channel slopes, and occasionally on lagoon reefs, at depths of 2 to at least 60 m. They often have a home cave or crevice within which they sleep or enter when pursued. Juveniles occur in coral-rich areas of lagoon reefs, particularly among thickets of staghorn *Acropora* corals. The humphead wrasse is usually solitary, but occasionally occurs in pairs. It feeds primarily on mollusks and a wide variety of other well-armored invertebrates including crustaceans, echinoids, brittle stars, and starfish, as well as on fishes. It is one of the few predators of toxic animals such as the crown-of-thorns starfish, boxfishes, and sea hares. The thick fleshy lips appear to absorb sea urchin spines, and the pharyngeal teeth easily crush heavy-shelled gastropods like *Trochus* and *Turbo*. Much of its prey comes from sand or rubble.

The range of *Cheilinus undulatus* is Indo-Pacific: Red Sea to the Tuamotus, north to the Ryukyus, south to New Caledonia. Though rare, they can be found throughout Micronesia and also in American Samoa.

Humphead, or Napoleon, wrasse reach sizes of 229 cm TL and weights of 191 kg. Kitalong and Dalzell (1994) estimate growth and mortality parameters from length frequency data for humpheads in Belau. Studies of humphead wrasse otoliths from the Great Barrier Reef indicate an expected life span of about 25 years (in Dalzell et al. 1996). New research on the life history of *C. undulatus* indicates that it may grow and mature much faster than previously thought (C. Birkeland, pers. comm.).

Once an economically important species in Guam, *C. undulatus* is now rarely seen on the reefs, much less reported on the inshore survey catch results (Hensley and Sherwood 1993). Similar declines in the number of sightings are reported from Saipan (Green 1997). Spearfishing, particularly at night when wrasses are inactive near the reef surface or in caves, has significantly decreased the numbers of this very large reef fish. They are sought after despite accounts of ciguaterra poisoning (Myers 1991).

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Table 67. Management Unit Species: *Cheilinus undulatus* (humphead wrasse)

	Egg	Larvae	Juvenile	Adult
Duration			research underway by Dr. Howard Choat	at least 25 years (in Dalzell et al. 1996)
Diet	N/A		likely to be similar to adult	carnivore; primarily on mollusks and a wide variety of well-armored invertebrates including crustaceans, echinoids, brittle stars, and starfish, as well as on fishes; also eats toxic animals such as crown-of-thorns starfish, boxfishes, and sea hares
Distribution, general and seasonal				Indo-Pacific, though not found in Hawaii
Location			coral-rich areas of lagoon reefs; among thickets of staghorn *Acropora* corals	steep outer reef slopes, channel slopes, and occasionally on lagoon reefs
Water column	pelagic	pelagic	demersal	demersal; 2 to at least 60 m depth
Bottom type	N/A	N/A	coral, sand, rubble	coral, sand, rubble
Oceanic features	subject to ocean currents	subject to ocean currents		

4.2.1.42 Scaridae (parrotfishes)

Parrotfishes get their name from the beak-like dentition and brightly colored appearance of mature adults. Like the wrasses from which they evolved, scarids are protogynous hermaphrodites that change color in relation to changes in growth and sex. Unlike wrasses, parrotfishes have a characteristic pharyngeal dentition, a digestive system lacking a true stomach but with a very long intestine, and a diet of mostly algae with some ingestion of live coral. Most scarids feed by scraping algae and bits of coral from the surface of coral rock, grinding the material with their pharyngeal mill into a slurry of calcium carbonate and algae, digesting the slurry and excreting grains of calcium carbonate ■sand• that make up a large portion of the sediment on most coral reefs. A few species feed heavily on live coral, on large leafy algae or seagrasses or on sand to extract algae from between the grains.

Parrotfishes are diurnal, sleeping under ledges or wedged against coral or rock at night, often surrounded by a mucus cocoon that may serve to mask their scent from detection by nocturnal predators. Small juveniles are frequently drab with white stripes. Some species are diandric, with both male and female juveniles, while others are monandric, with only females in the initial phase. Terminal males, usually formed from sex-reversal of a female, frequently maintain a harem of females, though they perform pair-spawning with each female individually. Initial phase males spawn in groups. Parrotfishes often occur in large, mixed-species schools which rove long distances while feeding on reefs. Some species are territorial and occur in small groups. Important summary documents are Myers (1991) and Randall (1996).

Scarids inhabit a wide variety of coral reef habitats including seagrass beds, coral-rich areas, sand patches, rubble or pavement fields, lagoons, reef flats and upper reef slopes (Myers 1991). They are prominent members in numbers and biomass of shallow reef environments. Scarids are chiefly distributed in tropical regions of the Indian, Atlantic and Pacific Oceans.

Among scarid species, adult sizes range from 110 to 1,000 mm SL, but most are between 200 to 500 mm. Warner and Downs (1977) suggested a maximum age of 6 years for *Scarus iserti*. Choat et al. (1996) found life spans ranging from 5 years (*S. psittacus*) to 20 years (*S. frenatus)*. Coutures (1994) used annular marks on scales to age *Bolbometopon muricatum* and found a life span of about 25 years.

Parrotfishes generally have complex socio-sexual systems based on protogynous hermaphroditism, drab initial phase coloration, gaudy terminal phase color patterns and dualistic reproduction. Males can either be primary, in which they are born male, or secondarily derived from females. Most species of *Scarus* are diandric. The relative proportion of primary males, terminal males and females vary widely between and within species.

Scarids spawn in both pairs and groups. Group spawning frequently occurs on the outer slope of the reef in areas with high current speeds. Pair spawnings are frequently observed at the reef crest or reef slope at peak or falling tide. Scarids have been observed to undergo spawning migrations within lagoons and to the outer reef slope (Randall and Randall 1963, Yogo et al. 1980, Johannes 1981, Choat and Randall 1986, Colin and Bell 1991). Some species are diandric, forming schools and spawning in groups often after migration to specific sites, while others are monandric, at times being strongly site-attached with haremic, pair-spawning (Choat and Randall 1986).

A few species are territorial, but the most are roving herbivores, with the size of the home range increasing with the size of the fish. Choat and Robertson (1975) found that smaller, less mobile scarids are usually associated with cover such as *Acropora* growth. Open areas with large amounts of grazing surface harbour larger, more mobile and school-forming scarids. Schooling behavior is common among the scarids, both for feeding and spawning.

Species endemic to Hawaii are *Calotomus zonarchus*, *Chlorurus perspicillatus*, *Scarus dubius*. Seven species of scarids can typically be found in Hawaii, 33 species in Micronesia, and 23 species in Samoa.

Most scarids are herbivores, although a few feed on live coral (most notably *Bolbometopon muricatum*) and a few have been reported to feed on newly exposed cryptic sponges (Bakus 1964, Dunlap and Pawlik 1996). The majority graze turf algae from hard substrata, some ingest algal filaments with sand grains, and some feed on seagrasses and leafy algae, such as *Padina*. Friedlander et al. (1997) found high counts of scarids in back reef and reef slope habitats of Hanalei Bay.

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Table 68. Management Unit Species: Scaridae (parrotfishes)

	Egg	Larvae	Juvenile	Adult
Duration	25 hours	30■50 days	3■5 years (Sale 1991)	average as a family is 8■12 years, medium size-6■9 years, large size-20■25+years
Diet	N/A	copepods, nauplii, bivalve larvae (Houde and Lovdal 1984)	carniverous for 1 month, gradually becoming herbivorous (Horn 1989, Bellwood 1988)	algae●usually thin algal film on coral or rock, but some feed on seagrasses, macroalgae, or graze over sand; a few species feed on live coral
Distribution, general and seasonal	year round, but peak spawning may occur in the summer	higher concentrations in offshore water samples	abundant year round in many coral reef systems	abundant year round in many coral reef systems
Location	spawning aggregation sites frequently on the outer edge of the reef	0■100 m; peak density between 40■80 m in the Caribbean (Hess et al. 1986)	all coral reef habitats, plus seagrass beds, mangroves, lagoons	all coral reef habitats, plus seagrass beds, mangroves, lagoons
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef, sand patches, rubble, pavement	coral reef, sand patches, rubble, pavement
Oceanic features	advection by ocean currents	advection by ocean currents	seagrass beds and mangroves may be important nursery areas	channels with high relief habitat nearby are important spawning aggregation sites

4.2.1.43 *Bolbometopon muricatum* (bumphead parrotfish)

The bumphead is a very large parrotfish (to 120 cm and 75 kg) with a vertical head profile, a uniform dark green color except for the front of the head which is often light green to pink and a nodular outer surface to its beak. It typically occurs in schools on clear outer lagoon and seaward reefs at depths from 1 to 30 m. They are often located on reef crests and fronts. In unfished areas it may enter outer reef flats at low tide. In addition to algae, it feeds substantially on live coral, using its large foreheads to ram coral and break it into smaller pieces for ingestion. It is very wary in the daytime but sleeps in groups on the reef surface at night, making it an easy target for spearfishers. As a result, it has nearly disappeared from most of Guam♣s reefs and is rapidly declining in Belau. Johannes (1981) cites an example of bumpheads changing the location of their sleeping site away from the shallow reef flat to the deeper reef slope in Belau in response to increasing nighttime spearfishing. Its range is Indo-Pacific, although it is not found in the Hawaiian Islands.

B. muricatum on the Great Barrier Reef exhibits a gradual approach to the asymptotic length. On the Northern Great Barrier Reef, most schools are composed of fish 12▪20 years old. The oldest bumphead *maximum age* identified is a 3- year-old fish with a standard length of 770 mm (Howard Choat, pers. comm.). Younger fishes appear to have different habitat requirements, as fish of SL less than 400 mm are not seen on outer reefs.

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Table 69. Management Unit Species: *Bolbometopon muricatum* (bumphead parrotfish)

	Egg	Larvae	Juvenile	Adult
Duration	25 hours	30▪50 days		20▪25+years, up to 34 years
Diet	N/A		herbivore/coralivore	herbivore/ coralivore; eats a substantial amount of live coral; in Palau, stomachs were often full of sea urchins (Johannes 1981)
Distribution, general and seasonal	Spawning aggregations reported in barrier reef channels of Palau on the 8th and 9th days of the lunar month (Johannes 1981)			Indo-Pacific; not found in Hawaii
Location			fish < 400 mm not seen on outer reefs of the Great Barrier Reef	typically occurs in schools on clear outer lagoon and seaward reefs at depths of 1 to at least 30 m; may enter outer reef flats at low tide in unfished areas
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	coral reef, rubble, pavement	coral reef, rubble, pavement
Oceanic features	advection by ocean currents	advection by ocean currents		

4.2.1.44 Polynemidae (threadfins)

Threadfins are relatives of the mullets with silvery bodies, an inferior mouth with villiform teeth, two widely-spaced dorsal fins, a deeply forked caudal fin and moderately large scales. Thread-like lower pectoral rays are used as feelers and become relatively shorter with growth. Threadfins typically occur over shallow sandy to muddy bottoms, occasionally in fresh or brackish water. One species, *Polydactylus sexfilis,* occurs in Hawaii where it is highly valued as a food fish. The species, called *moi* in Hawaii, was historically reserved for royal people, or *alii*. It has become rare as a result of intense fishing pressure, and is currently being propagated in hatcheries for use in stock enhancement projects. The same species occurs in Micronesia. Two species occur in Samoa, *P. sexfilis* and *P. plebeius*. The family Polynemidae is distributed throughout the tropical Atlantic and Indo-Pacific Ocean.

P. sexfilis is a fast-growing species that inhabits turbid waters and can be found in large schools in sandy holes along rocky shoals and high energy surf zones. Spawning takes place for 3▪6 days per month and has been observed in Hawaii from June to September, with a peak in July and August (Ostrowski and Molnar 1997). Spawning may be year-round in very warm locations. Spawning occurs inshore and eggs hatch offshore within 14▪24 hours depending on water temperature (May 1979). Eggs are small, averaging 0.75 mm in diameter with a large oil globule.

Larvae are pelagic, but after metamorphosis they enter nearshore habitats such as surf zones, reefs and stream entrances (Ostrowski and Molnar 1997). Larvae and pre-settlement juveniles feed on zooplankton in the water column, mainly mysids, euphausiids, crab zoeae and amphipods.

Inshore juveniles have distinct dark vertical bars and feed on benthic crustaceans, mostly penaeid and caridean shrimps, as well as zooplankton. Young moi, from 150 to 250 mm long, are found from shoreline breakers to 100 m depth (Lowell 1971). Fishing for juvenile *P. sexfilis*, or *moilii*, has historically been an important recreational and subsistence seasonal fishery in Hawaii.

P. sexfilis is a protandrous hermaphrodite, with individuals first maturing as males within 5▪7 months at a fork length of 20▪29 cm. After mating at least once as a male, fish have a hermaphroditic stage of about 8 months when they have both male and female characteristics. By an age of about 1.5 years and a fork length of 30▪40 cm, fish become mature females. The sexes are monomorphic.

Adults feed throughout the day on benthic crustaceans as well as fish. In Kaneohe Bay, adults could be found on reef faces, in the depths of the inner bay and in shallow (2▪4 m) areas with muddy sand bottoms (Lowell 1971). When *moi* were more abundant in Hawaii, airplane spotters used to locate large schools and direct net fishers to the catch.

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Table 70. Management Unit Species: Polynemidae (threadfins)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	14–24 hours depending on the temperature	weeks to months	5–7 months	
Diet	N/A	zooplankton, mainly mysids, uphausiids, crab zoeae, and amphipods	benthic crustaceans (mainly penaeid and caridean shrimps) and zooplankton	benthic crustaceans (mainly penaeid and caridean shrimps) and fish
Distribution, general and seasonal	spawning 3–6 days per month from June to September in Hawaii, with a peak in July/August; may be year-round in very warm locations	largest numbers in late summer	largest numbers in late summer and fall in Hawaii	*Polydactylus sexfilis* only species in Hawaii, also found in Micronesia and Samoa; *P. plebeius* recorded in Samoa
Location	inshore	offshore	from shoreline breakers to offshore reefs; also near stream entrances in sheltered bays	sandy holes along rocky shoals and high energy surf zones
Water column	pelagic	pelagic	0–100 m depth	0–100 m depth
Bottom type	N/A	N/A	sand, mud, rock, coral reef	sand, mud, rock, coral reef
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.45 Sphyraenidae (barracudas)

The barracudas are a single genus of top-level carnivorous fishes that feed mainly on other fishes. They have a very elongate body, a large mouth with protruding pointed lower jaw, very large compressed teeth and two widely separated dorsal fins. They have small cycloid scales and a well-developed lateral line. Some species are primarily diurnal, while others are nocturnal. Species such as *Sphyraena helleri* school in large groups during the day but disperse at night to feed. *S. barracuda* is typically a solitary diurnal predator. In Hawaiian waters, these are the only 2 species positively recorded. In Micronesian waters, at least 6 species occur. In Samoan waters, at least 5 species occur.

Juvenile *S. barracuda* occur among mangroves and in shallow sheltered inner reef areas. Adults occur in a wide range of habitats ranging from murky inner harbors to the open sea. Ciguaterra is widely reported for large *S. barracuda*, and has caused deaths in the West Indies where it is now banned from sale. *S. forsteri, S. acutipinnis, S. novaehollandiae* and *S. obtusata* are all schooling barracudas that occur over lagoon and seaward reefs. *S. genie* is a larger schooling barracuda that frequently schools at the same sites on submarine terraces and is most often caught at night by trollers in Micronesia.

There is no evident external sexual dimorphism among sphyraenids, although males reach sexual maturity at a smaller size than females. Male *S. barracuda* reach maturity in 2 years, but females take about 4 years. Barracudas migrate to specific spawning areas, often in very large numbers at reef edges or in deeper water. Spawning typically takes place in warmer months, and may last extended periods of time in which individual females spawn repeatedly.

The eggs are pelagic, spherical, and range in diameter from 0.7■1.5 mm with a single clear or yellow oil droplet. Eggs hatch within 24■30 hours. Larvae begin to feed within 3 days on small copepods. Larger larvae voraciously feed on zooplankton and other fish larvae. Settlement typically occurs at a length of 18 mm but may be larger. *S. barracuda* larvae occasionally drift in the ocean for an indefinite period of time, usually associated with floating debris or algae, developing all the characteristics of juveniles and sometimes attaining large sizes before being delivered inshore. Newly settled juveniles are piscivorous.

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Table 71. Management Unit Species: Sphyraenidae (barracudas)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	24■30 hours for *S. pinguis*	the time it takes to grow from 1■2 mm to 18 mm	2 years for male *S. barracuda*, 4 years for females	
Diet	N/A	zooplankton, copepods, fish eggs	mostly fish	mostly fish
Distribution, general and seasonal	spring spawning aggregation sites may be important for some species	typically more abundant in offshore waters	circumtropical and subtropical	circumtropical and subtropical; seasonal spawning aggregations may be important for some species
Location	reef edge or interface of pelagic and coastal currents	coastal offshore waters	mangroves, shallow lagoons, estuaries	from shallow turbid inner harbors to reefs, as well as coastal offshore waters
Water column	pelagic	pelagic; within 0■100 m depth	from reef-associated to surface	from reef-associated to surface
Bottom type	N/A	N/A	mud, sand, reef	all bottom types
Oceanic features	subject to advection by currents	subject to advection by currents		

4.2.1.46 Pinguipedidae (sandperches)

The sandperches are represented in the Indo-Pacific by only one genus, *Parapercis*. The genus is characterized by an elongate, nearly cylindrical body, eyes on the top of the head and oriented upwards and a terminal protractile mouth. All are benthic carnivores of small invertebrates and fishes. They are usually found on rubble or sand bottoms near reefs, where they typically rest on the bottom by propping on well-separated pectoral fins. Adults are typically found in depths from 1 to 50 m, but some occur deeper. Most species are sexually dichromatic. Hermaphroditism has been demonstrated for some species and may be true for all. Males are territorial and haremic. Spawning occurs year round in the tropics, typically just before sunset. Eggs are pelagic and the larval period lasts for 1–2 months. In Hawaiian waters, 2 species occur. In Micronesia, 4 shallow water species occur. In Samoan waters, 3 species are recorded.

P. cylindrica males defend an area that includes 2–5 females who are defending smaller territories from each other. The male initiates courtship with one of the females about 40 minutes prior to sunset, and eventually the pair makes a short spawning ascent of 60–70 cm before releasing gametes. The eggs are spherical and pelagic, with a diameter ranging from 0.63 to 0.99 mm. Hatching occurs in 22–24 hours. Duration of the planktonic larval stage is estimated to be 1–2 months (Stroud 1981).

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Table 72. Management Unit Species: Pinguipedidae (sandperches)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	22■24 hours	1■2 months		
Diet	N/A	zooplankton	small invertebrates and fishes	small invertebrates and fishes
Distribution, general and seasonal	year-round spawning, but late spring/summer peak	year-round, with summer peak	one Indo-Pacific genus *Parapercis*	one Indo-Pacific genus *Parapercis*
Location	released near parents home; no evidence of spawning migrations	offshore of reefs and soft-bottom habitats	coral reefs and associated soft-bottom communities	coral reefs and associated soft-bottom communities
Water column	pelagic	pelagic, although Leis (1989) found them concentrated in the epibenthos over soft bottoms on the GBR	demersal; most within 1■50 m, but some deeper	demersal; most within 1■50 m, but some deeper
Bottom type	N/A	N/A	sand, mud, rubble and occasionally coral	sand, mud, rubble and occasionally coral
Oceanic features	subject to advection by ocean currents	subject to advection by ocean currents		

4.2.1.47 Blenniidae (blennies)

Blennies are small, elongate, agile, scaleless fishes with blunt heads and a long continuous dorsal fin. They are a large family of more than 300 species, most of which are bottom-dwelling territorial fishes that lay adhesive demersal eggs that are guarded by the male. The family may be divided into two subfamilies primarily based on dentition and diet. The sabretooth blennies, subfamily Salariinae, typically have small mouths and large fangs. They are carnivores and some feed on the scales, skin or mucus of larger fishes. Some species are mimics of cleaner wrasses or other blennies. They are active swimmers that rapidly approach larger fish, while other members of Salariinae are sedentary.

The combtooth blennies, subfamily Blenniinae, typically have wide mouths, feeble teeth and feed on benthic algae. An exception is the leopard blenny *Exalias brevis*, which feeds primarily on coral polyps of *Acropora*, *Pocillopora, Seriatopora*, *Porites* and *Millepora*. Most combtooth blennies are sedentary inhabitants of rocky shorelines, reef flats or shallow seaward reefs. In Hawaiian waters, 14 species of blennies have been recorded; 7 are endemic: *Cirripectes obscurus, C. vanderbilti, Entomacrodus marmoratus, E. strasburgi, Istiblennius zebra, Plagiotremus ewaensis* and *P. goslinei*. The mangrove blenny *Omobranchus rotundiceps obliquus* was introduced to the Hawaiian and Line Islands, and the tasseled blenny *Pablennius thysanius* was probably introduced to Hawaii by ballast water. At least 59 species occur in Micronesia. At least 47 species occur in Samoa.

The blennies have very complex color patterns and are often well camouflaged to the surrounding habitat. Blennies tend to shelter in small holes in the reef or sand by backing into them tail-first. Some blennies, including those of the genera *Istiblennius* and *Entomacrodus*, live inshore on rocky bottom exposed to surge. They are called rockskippers for their ability to leap from pool to pool.

In addition to their unique feeding strategy, *Exalias brevis* has unusual reproductive characteristics. Males prepare a nesting site by clearing a patch of coral near a crevice. Females make the rounds of up to 10 different male♠s nests, depositing bright yellow eggs in each of them. Nests may contain more than one female’s eggs, and both males and females occasionally cannibalize eggs. Spawning occurs throughout the year with a peak from January to April.

The reproductive biology of blennies has been studied extensively. There are many variations, but all appear to produce relatively large demersal eggs which are deposited in or near a shelter hole and defended by the male. Eggs are characteristically flattened ovals, usually brightly colored, and about 1.0 mm in the longest dimension. Hatching typically occurs in 9■11 days. In the Red Sea species *M. nigrolineatus*, the larvae develop juvenile colors in 20 days and settle to the bottom by 30 days.

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Table 73. Management Unit Species: Blenniidae (blennies)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	9–11 days	20–30 days		
Diet	N/A	copepods, nauplii, bivalve larvae (Watson 1974, Houde and Lovdal 1984)	most graze on benthic algae; some feed on zooplankton; some prey on minute invertebrates such as foraminiferans, ostracods, copepods and gastropods; fangblennies of *Plagiotremus* eat mucus and skin tissue from fishes; at least one species, *Exallias brevis*, feeds on coral polyps	most graze on benthic algae; some feed on zooplankton; some prey on minute invertebrates such as foraminiferans, ostracods, copepods and gastropods; fangblennies of *Plagiotremus* eat mucus and skin tissue from fishes; at least one species, *Exallias brevis*, feeds on coral polyps
Distribution, general and seasonal			worldwide in tropical and temperate seas	worldwide in tropical and temperate seas
Location	near the adults shelter hole		rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, lagoons	rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, lagoons
Water column	demersal	pelagic	demersal; a few feed on zooplankton in the water column, and many of the fangtooths are active swimmers that pursue larger fish; many found in very shallow depths, and some rockskippers found above sealevel	demersal; a few feed on zooplankton in the water column, and many of the fangtooths are active swimmers that pursue larger fish; many found in very shallow depths, and some rockskippers found above sealevel
Bottom type	coral or rock	N/A	rock, coral reef, sand	rock, coral reef, sand
Oceanic features		subject to advection by ocean currents		

4.2.1.48 Gobiidae (gobies)

The gobies are the largest family of marine fishes, with about 1000 Indo-Pacific species and at least 1900 marine and freshwater species worldwide. They are typically small, elongate, blunt-headed fishes with a relatively large mouth with conical teeth, pelvic fins close together and usually fused to form a sucking disk, and two dorsal fins. Gobies are primarily shallow-water species. All are carnivorous and bottom-dwelling, although a few swim a short distance above the bottom to feed on plankton (*Ioglossus*, *Nemateleotris*). They inhabit a variety of habitats such as coral reef, sand, mud, rubble or seagrass. The majority of gobies occur on coral reefs, where they typically have unsurpassed diversity and abundance, but many occur in adjacent coastal and estuarine waters.

Many live in close association with other animals such as sponges, gorgonians, and snapping shrimps. Several species have a symbiotic relationship with one or more species of Alpheid snapping shrimp in which the gobies share a burrow. The shrimp digs the burrow while one or more gobies keeps watch for predators. Nearly all gobies are gonochorists that lay a small mass of demersal eggs which are guarded by the male. A few have been shown to be protogynous hermaphrodites. There are 31 marine species of gobies in Hawaiian waters. Five of them are endemic to Hawaii: the noble goby *Priolepis eugenius*, the rimmed-scale goby *Priolepis limbatosquamis*, the Hawaiian shrimp goby *Psilogobius mainlandi*, plus two new species described recently in *Copeia*. In Micronesian waters, at least 159 species occur. At least 100 species are recorded for Samoan waters.

Most reef-associated gobies are sexually monomorphic, although gobies in other habitats do have color and size differences between the sexes. Protogynous hermaphroditism was documented for gobies of the genus *Paragobiodon*, in which the largest individual present was always male, the second largest was the functional female, and the smaller individuals were non-spawning females (Lassig 1977). In most cases gobies appear to spawn promiscuously with many individuals loosely organized into a social hierarchy or with individuals maintaining small contiguous territories, although pairing and apparent monogamy have been documented for a number of gobies, including Ioglossus spp. (Colin 1972), Gobodion spp. (Tyler 1971), and Valencienna spp. (Hiatt & Strasburg 1960), among others.

Gobies lay demersal adhesive eggs in a burrow, on the underside of a rock or shell, or in cavities within the body of a sponge. Males tend and guard the eggs, which are attached to the substrate by a tuft of adhesive filaments at one end. Most goby eggs are elongate, smoothly round-ended and range in length from 1.1 to 3.3 mm and in diameter from 0.5 to 1.0 mm, although the eggs of fresh water and anadramous species may be as large as 8 mm. Some species, such as those of *Elacatinus*, have distinctive protuberances from the eggs. Incubation typically lasts 5-6 days depending on temperature. The size at hatching ranges from less than 2 mm to 4mm. The majority of the gobies leave the plankton at a size less than 10 mm. The planktonic larval duration is known for a few species. Lassig (1976) estimated a duration of about 6 weeks for *Paragobiodon spp*. at Heron Island. Moe (1975) reported a planktonic larval duration of from 18-40 days for *Gobiosoma oceanops*. Colin (1975) reported metamorphosis at 26 days for neon gobies, which grew quickly to subadult size in 3 months and spawned as soon as 5 months. He suggested neon gobies were ■annual• fishes that mature quickly and may only live one or two years.

Species of *Amblyeleotris, Cryptocentroides, Cryptocentrus, Ctenogobiops, Vanderhorstia, Lotilia*, and *Mahidolia* live in burrows constructed by alpheid prawns. At least 20 species of gobies share burrows with at least 7 species of prawns in Micronesia. The gobies, either singly or in pairs, act as sentinels for the alpheid shrimps who maintain the burrows. The gobies benefit from the use of the burrow, and also from feeding on the invertebrates excavated by the shrimp. The shrimps benefit from having a wary sentinel with better eyesight to warn them of approaching danger.

Some gobies have specific habitat requirements. The gorgonian goby *Bryaninops amplus* is usually found on gorgonians. The whip coral goby *Bryaninops yongei* is usually found on the antipatharian seawhip *Cirrhipathes anguina*. The Hawaiian shrimp goby *Psilogobius mainlandi* lives in burrows built and maintained by the snapping shrimp *Alpheus rapax*. The translucent coral goby *Bryaninops erythrops* lives on certain branching forms of fire corals *Millepora* spp. and other branching or massive corals such as *Porites cylindrica* and *P. lutea*. The hovering goby *Bryaninops natans* occurs in groups that hover just above or within the branches of *Acropora* corals. Members of *Paragobiodon* and *Gobiodon* are obligate coral-dwellers. Mudskippers of the genus *Periophthalmus* are essentially amphibious and are typically found resting on mud, rocks, or mangrove roots.

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Table 74. Management Unit Species: Gobiidae (gobies)

	Egg	Larvae	Juvenile	Adult
Duration	5-6 days	18-42 days	as soon as 5 months for neon gobies (Colin 1975)	smaller gobies may only live 1-2 years; others much longer
Diet	N/A	copepods, nauplii, tintinnids, mollusc larvae (Watson 1974, Houde and Lovdal 1984)	similar to adults	most are carnivorous on a wide variety of benthic invertebrates (copepods, amphipods, ostracods, nematodes, foraminiferans), fishes, and fish eggs; some semi-pelagic species are planktivorous
Distribution, general and seasonal				worldwide in tropical and temperate seas; 28 marine species of gobies in Hawaiian waters, with 3 endemic; at least 159 Micronesian species and at least 100 species in Samoa
Location			rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, lagoons	rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, lagoons
Water column	demersal	pelagic	same as adults	demersal; species of *Ioglossus* and *Nemateleotris* are semi-pelagic, hovering a short distance above the reef
Bottom type	coral, rock, sponge	N/A	coral reef, sand, mud, rubble or seagrass	coral reef, sand, mud, rubble or seagrass
Oceanic features		subject to advection by ocean currents		

4.2.1.49 *Zebrasoma flavescens* (yellow tang)

The yellow tang is a popular aquarium fish that is the top marine fish export from Hawaii, representing more than 75% of all animals caught statewide (Clark and Gulko 1999). They occur singly or in loose groups on coral-rich areas of lagoon and seaward reefs from below the surge zone to at least 46 m. Juveniles tend to hide among branches of finger coral, while adults graze near the shore in calm areas. They are diurnal herbivores of filamentous algae from hard surfaces. The genus is characterized by an unusually deep body with tall dorsal and anal fins and an elongate tubular snout. The yellow tang is moderately common at some locations in the Marianas, but is most abundant in Hawaii.

Group spawning (Lobel 1978) as well as pair spawning by territorial males that court passing females (in Thresher 1984) has been observed. Spawning occurs a few meters above the bottom or the depth of the spawning aggregation, usually at dusk. Pelagic eggs likely hatch within 1 to 2 days, and a pelagic larval stage lasts for up to a few months.

Z. flavescens tends to prefer the leeward sides of islands (Brock 1954), particularly areas of dense coral growth of *Pocillopora damicornis* and *Porites compressa*. It feeds on algae growing exposed on basalt and dead coral heads, as well as in crevices and interstices of the reef that it can reach with its long, thin snout (Jones 1968). The majority of yellow tang in Hawaii are collected off West Hawai♣i, Kawaihae, Kona and Miloli♣i (Clark and Gulko 1999).

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Table 75. Management Unit Species: *Zebrasoma flavescens* (yellow tang)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	approximately 24 hours	up to a few months		
Diet	N/A	various zooplankters	similar to adults	herbivores on filamentous algae
Distribution, general and seasonal	late winter, spring peak in spawning		highest recruitment in the summer, May to August, in Hawaii (Walsh 1987)	Pacific Plate; abundant only in Hawaii, found uncommonly at some locations in the Marianas; not recorded from Samoa
Location	eggs released after short spawning ascent from the bottom or the depth of a spawning aggregation	0-100m, larvae typically are more common in offshore waters than in water over reefs	often hide within the branches of finger coral	coral-rich areas of lagoon and seaward reefs from below the surge zone to at least 46 m; adults may feed very near the shore in calm areas
Water column	pelagic	pelagic	demersal and mid-water	demersal and mid-water
Bottom type	N/A	N/A	coral, rock, rubble, pavement	coral, rock, rubble, pavement
Oceanic features	subject to ocean currents	subject to ocean currents		

4.2.1.50 Zanclidae (Moorish idol)

This family consists of one species, *Zanclus cornutus*. It has a strongly compressed discoid body, tubular snout with a small mouth and many bristle-like teeth, and dorsal spines elongated into a whip-like filament. Moorish idols have a long larval stage and settle at a large size, >6cm SL for some individuals. As a result, they are ubiquitous in areas of hard substrate from turbid inner harbors to clear seaward reefs. They feed mainly on sponges, but will also take other invertebrates and algae. They usually are found in small groups of 2-5 individuals but may occur in large schools of well over 100 individuals. Their range is Indo-Pacific and tropical eastern Pacific, and they are found throughout the management area. They are a popular aquarium fish.

There is little information on Moorish idol reproduction, but they have been observed to spawn in pairs at dusk on outer reef slopes, producing pelagic eggs that are capable of long planktonic existence. Their wide distribution and length at settlement as large as 7.5cm are good indicators of long larval stages. The larval phase is similar to acunthurid larval phases.

Moorish idols inhabit all types of hard substrate in the tropical Pacific. They are present in very shallow habitats < 1m deep and have also been sighted as deep as 180m. They are diurnal predators that feed mainly on sponges, but also on small benthic crustaceans and algal film on rocks and coral.

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Table 76. Management Unit Species: Zanclidae (Moorish idol)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	unknown	relatively long; several months, ranging in size from a few millimeters to 7.5 cm		
Diet	N/A	zooplankton	mostly sponges, some small benthic crustaceans and algae	mostly sponges, some small benthic crustaceans and algae
Distribution, general and seasonal	little known	predominantly offshore	Indo-Pacific and tropical Eastern Pacific	Indo-Pacific and tropical Eastern Pacific
Location	released near the surface on outer reef slope	predominantly offshore	from turbid inshore harbors to clear outer reef slopes	from turbid inshore harbors to clear outer reef slopes
Water column	pelagic	pelagic	demersal	demersal
Bottom type	N/A	N/A	all hard substrates, including coral reef, rocks, rubble, reef flats, wrecks	all hard substrates including coral reef, rocks, rubble, reef flats, wrecks
Oceanic features				

4.2.1.51 Siganidae (rabbitfishes)

Siganids are small (from 20 -50 cm), essentially marine tropical Indo-West Pacific fishes. They have venomous dorsal, anal and pelvic spines. With a single row of flattened, close-set teeth, rabbitfishes feed primarily on algae and seagrasses, although some may occasionally feed on tunicates or sponges. Because of their herbivorous diet, most species live at depths less than 15 m, but some are trawled from as deep as 50m. Half the species live as pairs on coral reefs, the others usually gather in small schools. One species, *Siganus vermiculatus*, is almost exclusively estuarine; the rest move between estuaries, coral reefs, rocky shores, and other habitats. Rabbitfishes generally spawn on a lunar cycle with peak activity during the spring and early summer. Spawning occurs in pairs or groups on outgoing tides either at night or early in the morning. Juveniles of some species are estuarine. Rabbitfishes are highly esteemed foodfishes. Some of the colorful ones are popular aquarium fishes. None are found in Hawaii. Approximately 16 species are found in Micronesia, and at least 4 species in Samoa.

Spawning by rabbitfishes is typically preceded by a migration to specific and traditional spawning sites. The location varies from near mangrove stands (*S. lineatus*, Drew 1971), to shallow reef flats (*S. canaliculatus*, Manacop 1937, Johannes 1981), the outer reef crest (several spp. at Palau, Mcvey 1972; Johannes 1978), and even the deeper reef (*S. lineatus*, Johannes 1981). Sites are usually characterized by easy access to the ocean via channels, and large areas of sea grass flats nearby.

Reproduction in the schooling species has been studied in some detail, and in general the eggs are adhesive and demersal (with a few exceptions such as the pelagic eggs of *S. argenteus*); hatching occurs within 1-3 days and yolk sac absorption is completed in about 3 or 4 days (Lam 1974). Fecundity is high: 250,000-500,000 eggs per spawning season (Lam 1974, Gunderman et al. 1983). Larvae are pelagic and feed on phytoplankton and zooplankton. The duration of the larval stage is about 3 weeks in *S. fuscescens* (Hasse et al. 1977) and 3-4 weeks in *S. vermiculatus* (Gunderman et al. 1983). Popper et al. (1976) reported that siganid larvae follow a lunar rhythm in appearing on the reef, typically arriving inshore 3-5 days after a new moon. Fish are 15-20 cm long and sexually mature after one year. Judging by maximum size, some species survive from 2-4 years. *S. argenteus* is unique amongst the Siganidae in having a prejuvenile stage which is distinct from the larval and juvenile stages and is specially adapted for a pelagic life (Hubbs 1958). They can reach sizes of 6-8 cm SL before settling. Not surprisingly, *S. argenteus* has the widest distribution of all rabbitfishes.

The rabbitfishes vary widely in their habitat uses. The schooling species typically move between a wide range of habitats, whereas the pairing species tend to lead a sedentary existence among the branches of hard corals. Rabbitfishes are common on reef flats, around scattered small coral heads, and near grass flats. Gundermann et al. (1983) divided the siganids into two groups on the basis of habitat, behavioral characteristics and coloraton. One group includes species (*S. corallinus, S. puellus*, and *Lo vulpinnus*) that live in pairs, have limited home-ranges on reefs and are brightly colored. The remaining group, including *S. rivulatus* and *S. canaliculatus*, form schools at some stage of their life cycle, may undertake substantial migrations, and assume coloration similar to their preferred habitat.

Schools of juvenile *S. rostratus* and *S. spinus* swarm on the reef flats of Guam each year during April and May, and occasionally during June and October. Tsuda et al. (1976) studied the feeding and habitat requirements for these fish to determine the likelihood of mariculture of the rabbitfishes, which are highly esteemed for gastronomic and cultural reasons in Guam.

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Table 77. Management Unit Species: Siganidae (rabbitfishes)

	Egg	Larvae	Juvenile	Adult
Duration	1-3 days	3-4 weeks	1 year	2-4 years
Diet	N/A	phytoplankton and zooplankton	herbivores	herbivores, though some may feed on tunicates and sponges; they will assume a carnivorous diet in captivity
Distribution, general and seasonal	spawning in Guam in April and May, and occasionally in June and October		some species estuarine as juveniles before moving offshore	throughout the shelf waters of the Indo-West Pacific, except for the Hawaiian and Easter Island provinces
Location	mangrove stands (*S. lineatus*, Drew 1971), to shallow reef flats (*S. canaliculatus*, Manacop 1937, Johannes 1981), the outer reef crest (several spp. at Palau, Mcvey 1972; Johannes 1978), and even the deeper reef (*S. lineatus*, Johannes 1981). Sites are usually characterized by easy access to the ocean via channels, and large areas of sea grass flats nearby	more abundant offshore	estuaries for some species	most wide-ranging over many habitats. *Siganus vermiculatus*, is almost exclusively estuarine; the rest tend to move between estuaries, seagrass beds, coral reefs, rocky shores
Water column	pelagic	pelagic	demersal or reef-associated	demersal or reef associated
Bottom type	N/A	N/A	silt, sand, and mud for estuarine species	some pair-forming species are sedentary in the branches of Acropora corals; most range over many bottom types
Oceanic features	ocean currents	ocean currents		

4.2.1.52 *Gymnosarda unicolor* (dogtooth tuna)

Very little is known about the biology of the dogtooth tuna (*Gymnosarda unicolor*), although it is widely distributed throughout much of the Indo-Pacific faunal region, from the Red Sea eastward to French Polynesia (Collette and Nauen 1983). This species is not found in the Hawaiian Islands, although fishermen do refer to catches of the meso-pelagic snake mackerel (Gempylidae) as ■dogtooths•.

G. unicolor is an epipelagic species, usually found individually or in small schools of 6 or less (Lewis et al. 1983). Dogtooth tuna are found in deep lagoons and passes, shallow pinnacles and off outer reef slopes (Collette and Nauen 1983). It occurs in mid-water, from the surface to depths of approximately 100m, and has a preference for water temperatures ranging from 20-28 degrees Celsius.

G. unicolor is one of the few tuna species found primarily in association with coral reefs (Amesbury and Myers 1982) and probably occupies a niche similar to other reef-associated pelagic predators such as Spanish mackerel (*Scomberomorus* spp.) and queenfish (*Scomberoides* spp). Like the Spanish mackerels, large dogtooths can become ciguatoxic from preying on coral reef herbivores, which themselves have become toxic through ingestion of the dinoflagellate, *Gambierdiscus toxicus* (Myers 1991).

A positive correlation between size and depth has been observed in the distribution of this species based on limited information from Tuvalu, with larger individuals being found at greater depths (Haight 1998). This species reportedly reaches a maximum size of 150cm FL and 80kg (Lewis et al. 1983).

Observations from Fiji suggest that dogtooth tuna obtain sexual maturity at approximately 65 cm (Lewis et al. 1983), while Silas (1963) reported a partially spent 68.5 cm male dogtooth tuna from the Andaman Islands. Females outnumbered males by nearly 2:1 in Fiji, and all fish larger than 100cm were females, suggesting sexual dimorphism in this species (Lewis et al. 1983). Lewis et al. (1983) suggest that the vulnerrability of female dogtooth tuna to trolling declines as the fish approach spawning condition.

In Fiji, spawning reportedly occurs during the summer months - between October and March (Lewis et al. 1983). Dunstan (1961) observed spawning dogtooth tuna in Papua New Guinea during March, August and December, and various other authors (Silas 1963) have provided some evidence of summer spawning for this species. Okiyama and Ueyangi (1977) note that the larvae of dogtooth tuna occur over a wide area of the tropical and subtropical Pacific Ocean, between 10EN and 20ES, with concentrations along the shallow coastal waters of islands, such as the Caroline Islands, Solomon Islands and Vanuatu. Dogtooth larvae were collected in surface and subsurface tows, with greater numbers in the sub-surface tows at depths between 20-30m. Older larvae appear to make diurnal vertical migrations, rising to the surface during the night. On the basis of larval occurrence throughout the year, Okiyama and Ueyangi (1977) postulate year round spawning in tropical areas.

There are no fisheries specifically directed at dogtooth tuna in the western Pacific region. The primary means of capture include pole and line, handlines and surface trolling

(Severance 1998, pers. comm; Collette and Nauen 1983). Dogtooth tuna have been sold in local markets in American Samoa and the Northern Mariana Islands, but currently have little market value (Severance 1998, pers. comm.).

Dogtooth tuna are voracious predators, feeding on a variety of squids, reef herbivores such as tangs and unicorn fish (Acanthuridae), and small schooling pelagic species including fusiliers (*Caesio* spp) and roundscads (*Decapterus*) (Myers 1989).

Dogtooth tuna are unique among the family Scombridae in having such a close association with coral reefs, although they are also found around rocky reefs in higher latitudes such as in Korea and Japan (Myers 1989). Within the western Pacific region, waters on and adjacent to coral reefs down to a depth of about 100m should be designated EFH for this specis.

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Table 78. Management Unit Species: Gymnosarda unicolor (dogtooth tuna)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration			sexually mature at approximately 65cm	unknown
Diet	N/A	unknown	unlikely to be different from adult	a variety of squids, reef herbivores such as tangs and unicornfish (Acanthuridae), and small schooling pelagic species such as fusiliers (*Caesio* spp)and roundscads (*Decapterus*)
Distribution, general and seasonal	unknown	tropical and subtropical Pacific Ocean between 10EN and 20ES, with greater concentrations along shallow coastal waters of islands such as the Caroline Isl., Solomon Isl. and Vanuatu	unlikely to be different from adult	widely distributed throughout much of Indo-Pacific, from the Red Sea eastward to French Polynesia. Not found in the Hawaiian islands
Location			unlikely to be different from adults	deep lagoons and passes, shallow pinnacles and off outer reef slopes
Water column	epipelagic	epipelagic; greater numbers in subsurface tows at depths between 20-30m	epipelagic	epipelagic; occurs in mid-water, from the surface to approximately 100m
Bottom type	N/A	N/A	N/A	N/A
Oceanic features	subject to advection by prevailing currents	subject to advection by prevailing currents	unknown	unknown

4.2.1.53 Bothidae/Soleidae/Pleuronectidae (flounder and soles)

Flatfishes have both eyes on one side of the body and a greatly compressed body suited for lying flat on the bottom. The eyes are situated on both sides of the head in the larvae, but migrate to one side as the larvae transforms into a benthic juvenile. The eyes migrate onto the left side for members of the family Bothidae, and onto the right side for members of the family Pleurnectidae and Soleidae. The side with no eyes settles on the bottom and remains unpigmented, while the top side can change color patterns to match the surrounding bottom.

They are ambush carnivores of small fishes and crustaceans that live on silt, sand or gravel bottoms. They are important foodfishes worldwide, where they inhabit continental shelves of tropical and temperate seas. A few species are found on shallow coral reefs: in Hawaiian waters, there are 13 species of Bothidae but only 2 common shallow species, 2 species of the genus *Samariscus* that formerly were considered a part of Pleuronectidae but now are in their own family Samaridae, and 2 species of Soleidae. In Micronesian waters, there are at least 3 species of Bothidae, one species of Pleuronectidae, and at least 5 species of Soleidae found on shallow reefs. Two sole species, *Aseraggodes borehami* and *Aseraggodes theres*, are recently described species found only in the Hawaiian Islands. Three species are recorded from Samoan waters.

Bothid eggs are pelagic, spherical, and small, with a diameter of 0.6-0.9mm. The larvae hatch at 1.6-2.6mm. Soleid eggs are pelagic, spherical and moderate in size, with a diameter of 0.9-18mm. The larvae range from 1.7 to 4.1mm at hatching. Larval pleuronectiform fish have symmetrical eyes, but many remain pelagic for some time after the eyes migrate. Some become quite large before settling, and often possess highly ornamented spines, elongate fin rays, or protruding guts as larval specializations (Leis & Trnski 1989). Larvae are found in the upper 100m of the water column.

Habitat for most flatfishes is soft bottoms such as sand, mud, or silt that are often found in association with coral reef habitats. Some species are found directly on the reef or within the reef framework. Many species are found in water deeper than 100m, but some are common in shallow habitats.

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Table 79. Management Unit Species: Bothidae/Soleidae/Pleurnectidae (flounder and soles)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration		1.6 to 4.1mm at hatching		
Diet	N/A	the sole *Achirus lineatus* eats copepods, mollusc larvae, rotifers, dinoflagellates (Houde & Lovdal 1984); other species eat larvaceans, chaetognaths and copepods (Liew 1983)	similar to adult	ambush carnivores of fishes and invertebrates
Distribution, general and seasonal			similar to adult	tropical and temperate continental shelves worldwide; some species associated with coral reefs in the Indo-Pacific
Location	spawning aggregations not recorded	offshore waters	lagoons, caves, flats, reefs	lagoons, caves, flats, reefs
Water column	pelagic	pelagic; from 0-100m depth	demersal	demersal
Bottom type	N/A	N/A	similar to adult	soft bottoms such as sand, gravel, mud, and silt; some species found on reef surface or within reef framework
Oceanic features				

4.2.1.54 Balistidae/Monocanthidae (triggerfishes/filefishes)

The triggerfishes are named for an ability to lock their large, thickened first dorsal spine in an upright position, which can be released only by pressing down on the second dorsal spine (the trigger). They are deep-bodied fish with eyes high on the head, a long snout, a small terminal mouth, and tough skin with armor-like non-overlapping scales. Triggerfishes are usually solitary except when they form pairs at spawning time, although the black durgon *Melichthys niger* may form large aggregations. When alarmed, or at night, they wedge themselves into a hole in the reef or rocks by erecting the first dorsal spine and pelvic girdle.

During the day, most are carnivores of a wide variety or benthic animals including crustaceans, mollusks, sea urchins, other echinoderms, coral, tunicates, and fishes. Some feed largely on benthic algae and zooplankton, including *M. niger* and *M. vidua*, while *Xanthichthys auromarginatus* and *X. mento* feed mainly on zooplankton. Eleven species are known from the Hawaiian Islands. At least 20 species occur in Micronesia. At least 16 species occur in Samoa. Many species are collected for aquariums. The clown triggerfish *Balistoides conspicillum* is among the most highly prized aquarium fishes, although like most triggerfishes it is very aggressive to other fish in a tank and tends to eat all the invertebrates.

The filefishes are closely related to the triggerfishes, differing by having more compressed bodies, a longer and thinner first dorsal spine, a more pointed snout, a very small or absent second dorsal spine, and no third dorsal spine. Unlike the triggerfishes, many filefish are able to change their coloration to match their surroundings, and are frequently secretive. Some filefishes are sexually dimorphic, not in coloration so much as the size of the spines or setae posteriorly on the body. Filefishes are mostly omnivorous, feeding on a wide variety of benthic plant and animal life. Some species eat noxious sponges and stinging coelenterates that most fish avoid. Eight species occur in Hawaii, at least 17 in Micronesia, and at least 7 species occur in Samoa. Three species are endemic to Hawaii: the squaretail filefish *Cantherhines sandwichiensis*, the shy filefish *C. verecundus*, and the fantail filefish *Pervagor spilosoma*.

Sexual dimorphism is widespread, though not universal, in the triggerfishes. The male is typically more brightly colored and larger, as in *X. auromarginatus, X. mento, B. undulatus, B. vetula, Odonus niger, Pseudobalistes fuscus, Hemibalistes chrysopterus*, and *M. niger* (Berry & Baldwin 1966, Randall et al. 1978, Matsuura 1976, Breder & Rosen 1966, Aiken 1975, Fricke 1980). Sexual dimorphism is less common in the filefishes, in which males and females tend to be drabber. There is some evidence of lunar spawning periodicity for balistids. At Belau, the yellowmargin triggerfish *Pseudobalistes flavimarginatus* spawns in nests in sand-bottom channels within a few days before both new and full moons during the months of November, December, March, April, and May, if not throughout the year (Myers 1989). Balistids produce demersal eggs that may or may not be tended by a parent, usually the female. They are one of the, if not the only, reef fish families that have extensive maternal care. This could be related to a harem-based social structure that requires the male to vigorously defend his territory from other males. Balistid eggs are spherical, slightly over 0.5 mm in diameter, and translucent. Eggs are typically deposited in shallow pits excavated by the parents as an adhesive egg mass containing bits of sand and rubble. Triggerfish eggs hatch in as little as 12 hours and no more than 24 hours. Filefish eggs may take longer to hatch, up to 58 hours. The pelagic larval stage can last for quite a while, and some species reach a large size before settling to the bottom. Several species of Melichthys can reach as much as 144 mm before settling (Randall 1971, Randall & Klausewitz 1973). Prejuveniles are often associated with floating algae, and may be cryptically colored. Berry and Baldwin (1966) suggested that sexual maturity of *Sufflamen verres* and *Melichthys niger* occurs at approximately half maximum size, at an age of a year or more. Smaller filefishes may mature within a few months after hatching.

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Table 80. Management Unit Species: Balistidae/Monacanthidae (triggerfishes/filefishes)

	Egg	Larvae	Juvenile	Adult
Duration	12-24 hours for triggerfish, up to 58 hours for filefish	several months, can grow up to 144 mm before settling (Randall & Klausewitz 1973)	one or more years	
Diet	N/A	various plankton	similar to adult	carnivores of a wide variety or benthic animals including crustaceans, mollusks, sea urchins, other echinoderms, coral, tunicates, and fishes. Some feed largely on benthic algae and zooplankton
Distribution, general and seasonal	At Belau, the yellowmargin triggerfish *Pseudobalistes flavimarginatus* spawns within a few days before both new and full moons during the months of November, December, March, April, and May, if not throughout the year (Myers 1989)		similar to adult	tropical and temperate seas worldwide; 11 species are known from the Hawaiian Islands. At least 20 species occur in Micronesia. At least 16 species occur in Samoa.
Location	many spawn on sand or other soft-bottom habitats		Juvenile *B. conspicillum* usually occur in or near ledges and caves of steep dropoffs below 20m (Myers 1989)	lagoon and seaward reefs; many prefer steeply sloping areas with high coral cover and a lot of caves and crevices; zooplanktivores spend day in the water column
Water column	demersal	pelagic	demersal and pelagic	some species in very shallow water, 2-20m while others as deeper than 100m
Bottom type	sand, mud, rubble	N/A	similar to adults	coral reef, rock, sand
Oceanic features		subject to advection by ocean currents		

4.2.1.55 Ostraciidae (trunkfish)

The trunkfishes, or boxfishes, possess a bony carapace of polygonal plates that encase the head and body. The bony shell may be triangular, quadrangular, pentagonal, hexagonal, or nearly round in cross-section. Some species have stout spines projecting from the rough surface of the plates. The mouth is small and low with thick lips and a row of conical to incisiform teeth with rounded tips. Trunkfishes are slow swimming diurnal predators that feed on a wide variety of small sessile invertebrates, especially tunicates and sponges, and algae. Some species, and perhaps all, secrete a skin toxin when under stress. Some species, and perhaps all, are protogynous hermaphrodites. Sexual dichromatism is common in the family. The species studied thus far are haremic with males defending a large territory with non-territorial females and subordinate males. Spawning in pairs occurs at dusk, usually above a conspicuous outcrop. In Hawaiian waters, 6 species are recorded and the spotted boxfish *Ostracion meleagris camurum* is recognized as a subspecies. In Micronesian waters, 6 species are recorded. In Samoan waters, 3 species are recorded.

Leis (1978) described the eggs of Hawaiian ostraciids as slightly oblong, with less than 10 oil droplets, and a patch of ■bumps• at one end. However, Mito (1962) described eggs from Japanese waters as 1.62-1.96mm in diameter with a single oil droplet. A western Atlantic species *Acanthostracion quadricornis* had spherical eggs, 1.4 to 1.6mm in diameter that hatched in about 48 hours at 27.5EC. About 114 hours after hatching, it reaches a distinctive square armor-plated postlarval stage. Postlarvae and juveniles are commonly collected in grassbeds and other shallow areas and are rarely seen on the reef (Thresher 1984). Juveniles of *Ostracion*, on the other hand, are commonly seen on shallow reefs, especially in late summer.

The longhorn cowfish, *Lactoria cornuta*, occurs over sand and rubble bottoms of subtidal reef flats, lagoons, and bays to a depth of 50m. It feeds on polychaetes and other benthic invertebrates, often ■blowing• sand off the bottom to expose the prey. The thornback cowfish *Lactoria fornasini* inhabits sandy areas with rubble, algae, or corals of clear outer lagoon and seaward reefs. The spotted trunkfish *Ostracion meleagris* occurs on clear lagoon and seaward reefs from the lower surge zone to 30m, where it feeds on didemnid tunicates as well as smaller amounts of polychaetes, algae, sponges, mollusks, and copepods. They are sexually dimorphic, with males taking a bright blue and yellow form upon sex-reversal from a female to male.

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Table 81. Management Unit Species: Ostraciidae (trunkfishes)

	Egg	Larvae	Juvenile	Adult
Duration	48 hrs for A. quadricornis (Thresher 1984)	fairly short in general; 114 hrs in A. quadricornis in the Caribbean (Thresher 1984), but Moyer (1980) reported much older pelagic larvae, up to 90mm long		
Diet	N/A		similar to adults	small sessile invertebrates, especially didemnid tunicates and sponges, but also polychaetes, algae, sponges, mollusks, and copepods; also algae
Distribution, general and seasonal				
Location		offshore	grassbeds and other shallow areas	coral reefs, lagoon and seaward reefs
Water column	pelagic	pelagic	demersal and mid-water column	demersal and mid-water column, well defended from predators
Bottom type	N/A	N/A	similar to adults;	sandy areas with rubble, algae, or corals
Oceanic features	subject to advection by prevailing currents	subject to advection by prevailing currents		

4.2.1.56 Tetradontidae/Diodontidae (puffers/porcupinefishes)

Puffers are named for their ability to enlarge their bodies by drawing water into a highly distensible ventral diverticulum of the stomach. That feature, prickly skin, and a powerful toxin concentrated in their viscera, gonads, and skin helps them deter predators. Toxicity varies greatly with species, area, and season. Puffers have the teeth in their jaws fused to beak-like dental plates with a median suture. Most are slow swimmers that feed on a wide variety of algae and benthic invertebrates, including fleshy, calcareous or coralline algae and detritus, sponges, mollusks, tunicates, corals, zoanthid anemones, crabs, hermit crabs, tube worms, sea urchins, brittle stars, starfishes, hydroids, bryozoans and foraminifera. All species known to date lay demersal eggs. At least one species of Canthigaster, *C. valentini*, is haremic with males controlling a territory containing 1-7 females. The males spawn at mid-morning with a different female each day, and the eggs are deposited in a tuft of algae. Most puffers are solitary but a few form small aggregations. In Hawaiian waters, there are 14 species recorded, with 2 endemics: *Canthigaster jactator* and *Torquigener randalli*. In Micronesian waters, there are at least 17 species. In Samoan waters, 18 species are recorded.

Much of the information on puffer reproduction has been completed in temperate locations, but some reasonable assumptions can made about tropical species. Puffers lay demersal adhesive eggs, although courtship is often observed near the surface. The eggs are typically on their own after being deposited, and take approximately 4 days to hatch in *C. valentini* (Gladstone 1985). Newly hatched larvae range in size from 1.9 to 2.4mm. Settlement to the bottom can occur in a little over 30 days, but some species have a much longer pelagic existence.

Porcupinefishes are similar to puffers in many ways, but differ primarily in having prominent spines on the head and body. They also have larger eyes, broader pectoral fins, and lack a median suture on the dental plates. Hard, beak-like jaws allow them to crush the hard shells of mollusks or crustaceans, or tests of sea urchins. They appear to be nocturnal. Spawning has been observed in *Diodon holacanthus*, which spawns at the surface at dawn or dusk as pairs or groups of males with a single female. In Hawaiian waters, 3 species have been recorded. In Micronesian waters, 3 species are known, although one, *Diodon eydouxii,* is entirely pelagic. The juveniles of *D. hystrix* and *D. liturosus* are pelagic as well.

Porcupinefish in Hawaii have a peak in spawning in the late spring, with some spawning from January to September (Leis 1978). Courtship and spawning by *Diodon holacanthus* has been observed in a large public aquarium (Sakamoto & Suzuki 1978) and in the Gulf of California (Thresher 1984). Diodontid eggs are spherical, 1.62 to 2.1 mm in diameter, and may be demersal or pelagic. Hatching occurs in 4-5 days. Leis (1987) reported metamorphosis at a length of 3 mm and an age of 3 weeks to a postlarval stage similar in appearance to the adult. The duration of the larval stage may be several months. Very large prejuveniles (up to 86 mm for *D. holacanthus* and 180 mm for *D. hystrix*) are common in plankton tows.

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Table 82. Management Unit Species: *Tetradontidae/Diodontidae* (Puffers/Porcupinefishes)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	4-5 days	several months or longer	size at settlement of 180-191mm (Leis 1987)	
Diet	N/A	various zooplankton	similar to adult	wide variety of algae and benthic invertebrates, including fleshy, calcareous or coralline algae and detritus, sponges, mollusks, tunicates, corals, zoanthid anemones, crabs, hermit crabs, tube worms, sea urchins, brittle stars, starfishes, hydroids, bryozoans and foraminifera
Distribution, general and seasonal			same as adults	worldwide throughout tropical and temperate seas
Location	pelagic or demersal depending on species	pelagic	estuaries, mangroves, lagoons, coral reefs	estuaries, mangroves, lagoons, coral reefs
Water column	puffers are demersal spawners, porcupinefish may spawn pelagic or demersal eggs	pelagic; 0-100m	reef-associated and pelagic	reef-associated and pelagic
Bottom type	reef, sand, or algae tufts	N/A	sand, silt, coral, rock	sand, silt, coral, rock
Oceanic features		subject to advection by ocean currents		

4.2.2 EFH for Management Unit Species ■ Invertebrates

4.2.2.1 Cephalopods

General Description of the Taxon[i]

The cephalopods (Class Cephalopoda of the Phylum Mollusca) comprise a relatively small group of organisms that includes squid, octopods, cuttlefish, and nautilus. Although certain members of the class (e.g., the octopods) are for the most part bottom-dwellers, the majority are adapted for a free-swimming lifestyle. The head projects into a circle of large prehensile tentacles or arms, which are homologous to the anterior of the foot of other mollusks. The tentacles are used for various functions, including seizing prey, grasping the substrate, and for copulation and fertilization. Most cephalopods swim by jet propulsion, rapidly expelling water from the mantle cavity through a ventral tubular funnel. The funnel is highly mobile and can be directed either anteriorly or posteriorly. The force of water leaving the funnel propels the animal in the opposite direction, enabling both backward and forward swimming.

Certain species of squid have attained the highest speed of movement through water observed for any marine invertebrate (up to 40 km per hour). (Barnes 1987; Nesis 1987). Within the class, only members of the genus *Nautilus* (in Subclass Nautiloidea) have a true external shell. All other cephalopods belong to the subclass Coleoidea, in which the shell is reduced and internal, or lacking altogether. In squids, for example, the shell is reduced to a long, flattened chitinous ■pen• or gladius, while in cuttlefish the internal shell, the sepion, is thicker and calcareous. In certain genera●*Nautilus*, *Spirula*, and *Sepia*●the gas-filled chambers of their shells allow for maintenance of neutral buoyancy within the water column. Many species exhibit diurnal vertical migration, moving upward to feed during the night and into deeper water during the day (Barnes 1987; Nesis 1987).

Reproduction and Life History

Cephalopods are dioecious, with a single gonad positioned at the posterior end of the body. Sperm are conducted through the vas deferens to a ciliated seminal vesicle, where the sperm are rolled together and encased in spermatophores. The spermatophores are then transported to a storage sac which opens into the mantle cavity. In females, the oviduct terminates in an oviductal gland. Octopods and some squid may have two oviducts.

Fertilization may occur within the mantle cavity or outside. One of the arms of the male is highly modified into a copulatory organ, the hectocotylus. During copulation, while the male grasps the female with the regular arms, the hectocotylus receives spermatophores from the funnel (opening of the vas deferens), or plucks them from the storage sac. The hectocotylus may be inserted into the mantle cavity, and spermatophores are deposited on the mantle wall of the female, near the openings of the oviducts. In *Octopus*, the hectocotylus is inserted into the genital duct. In some squid, the hectocotylus may be inserted into a seminal receptacle located in a fold beneath the mouth for deposition of spermatophores.

Eggs are discharged from the oviduct, then surrounded by a paired membrane or capsule. In some genera eggs may be surrounded by a gelatinous mass. In most cases, eggs are either attached by the female to a stable substrate, or shed into the seawater. Sepioids may attach the single eggs by means of a flexible threadlike stalk, which the female wraps around the blades of seagrasses or seaweeds (Pearse et al. 1987).

Embryonic development is considered ■direct,• that is, there is no trochophore or larval phase. However, newly-hatched cephalopods may remain planktonic for a time. In the octopods, those species in which hatchlings are less-developed may first go through a planktonic phase and then settle down to a benthic existence, while those species in which the newly-hatched offspring are well-developed may immediately take up a benthic lifestyle (Pearse et al. 1987). The degree of development at hatching may be related to the size of the egg, since Young and Harman (1989) noted that species with small eggs include a paralarval (planktonic) phase, while those with larger eggs, do not.

Most cephalopods are relatively short-lived (typically one- to two-year lifespan), dying after a single spawning, while certain members such as *Nautilus*, may live longer (up to twenty years; Barnes 1987).

Habitat and Ecological Requirements for Various Life History Stages

Substrate and Depth Preferences

Nautilus occur in waters down to 500 m depth, but generally occur at depths from 200-300m. The few observations made of nautiluses in the ocean suggest that they spend the day resting in coral crevices on deep reefs, attached by their tentacles, and swim out at night to feed (Pearse et al. 1987). They may rise to within 60-100m during nighttime (B. Carlson, Waikiki Aquarium, pers. comm., 27 Aug 99).

Cuttlefishes are generally found in shallow waters of seagrass beds and nearby reefs. Some species may bury themselves in the sand during the day, and emerge at night to hunt for the small fishes and crustaceans that are their preferred prey.

Octopods generally inhabit crevices in rocks or coral areas. In sandy areas, they may dig burrows or construct shelters built from scattered rocks.

Substrates utilized for the deposition of eggs may vary for different taxa, but it appears that there is some correlation with the habitats utilized for shelter by the species in question. Thus octopods may attach egg clusters within rocky recesses on the reef, while cuttlefish may attach their eggs to seaweeds or seagrasses.

The reef squid, *Sepioteuthis lessoniana*, uses corals and rocks of reef areas for egg-laying, and swims over the reef in shallow areas to feed. The reef cuttlefish, *Sepia latimanus*, deposits its eggs deep among the branches of heads of finger coral (B. Carlson, pers. comm. 27 Aug 99).

Feeding

Within the cephalopod group are found a range of feeding habits and food preferences. Free-swimming squids typically hunt for fish, crustaceans, and other squids in open water. Cuttlefish swim near the bottom in shallow water, stir up sand with jets from their siphons, and feed on benthic and infaunal invertebrates, including crustaceans such as shrimps and crabs. Octopods venture out of their dens in search of food, and may swim and crawl more than 100m from their holes. Octopods often hunt by jumping to ambush their prey, which include principally crabs and shrimps. In Hawaii, one of the most common species, *Octopus cyanea*, forages during the day (hence the name ■day squid•), while another *O. ornatus* (the ■night squid•), forages after dark (Kay 1979). Squid bite and tear prey organisms with their jaws; cuttlefish first immobilize prey by injecting salivary toxins, and then chew their prey; while octopods, which also first paralyze their prey with salivary toxins, release enzymes that start to digest the tissue of the target prey prior to ingestion. It is thought that nautiluses scavenge on such food items as crab and lobster molts; it is not known whether they also prey on live organisms (B. Carlson, pers. comm. 27 Aug 99).

Economic Importance and Utilization of the Resource

Within the region, cephalopods, especially squid, cuttlefish, and octopus, have some economic importance as food items in the subsistence fishery. Octopus are a component of the incidental catch of the lobster-trap fishery in the Northwest Hawaiian Islands (NWHI; WPRFMC 25 May 99). In addition, shells of *Nautilus* may be used for ornamental purposes on a small scale, either by utilizing the whole or cut shell, or processing for production of mother-of-pearl. The meat is also occasionally sold in markets (Roper et al. 1984). The internal shells (cuttlebones) of sepioids may also have limited commercial value for use in the pet supply industry.

<u>Occurrence of the Taxon Within WPRFMC Fishery Management Units (FMUs)</u>

The following is an account of those cephalopod species reported in the literature that may occur on reef areas within the jurisdictional waters of WPRFMC.

American Samoa

On Tutuila Island, it was reported that octopus accounted for approximately five percent of the catch composition for the shoreline subsistence fishery (Craig et al. 1993).

Nautilus pompilius is known to occur in American Samoa. This may represent the easternmost extension of its range (B. Carlson, pers. comm. 27 Aug 99).

Commonwealth of Northern Mariana Islands (CNMI)

Octopus (*Octopus cyanea* and *O. ornatus*), squid (*Sepioteuthis lessoniana*), and cuttlefish (*Sepia latimanus*) are reef-associated species[3] commonly taken as food in the Marianas (Myers 1997 in Green October 1997). *Octopus cyanea* was identified as a species found on the reef slope at Rota, and targeted for capture in the local fishery (Smith et al 1989).

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1 The octopods are well-known reef-dwellers. The common names for *Sepioteuthis lessoniana* and *Sepia latimanus*, bigfin reef squid and reef cuttlefish, respectively, reflect their assocation with reef areas (Allen and Steene 1996).

Guam

It is reported that on Guam, the octopus is the most sought-after unshelled mollusk, while squid and cuttlefish form a part of the incidental catch of the inshore fisheries (Hensley and Sherwood 1993). Octopus and squid are reported to contribute to the importance of mollusks as a food source (Amesbury et al. 1986 in Green October 1997). *Sepia latimanus* is reported from Guam (B. Carlson, pers. comm. 27 Aug 99). Presumably, other cephalopod species reported in the Northern Marianas (i.e., *Octopus cyanea, O. ornatus, Sepioteuthis lessoniana*) would be expected to occur in Guam, as well.

Hawaii (MHI and NWHI)

The following octopod species are known from Hawaiian waters: *Octopus cyanea, O. ornatus, Berrya hoylei* and *Scaeurgus patagiatus*. An additional three unnamed species are believed present (Young and Harman 1989). Octopus are a component of the incidental catch of the lobster-trap fishery in the Northwest Hawaiian Islands (WPRFMC 25 May 99). An unnamed species of octopus is known from Waianae, Oahu. It occupies burrows in sandy areas. The burrows have openings about the diameter of a thumb. It is not known whether the octopus digs the burrow, or simply occupies a burrow already dug by another animal (e.g., mantis shrimp). This octopus emerges from its burrow and mimics a flatfish (B. Carlson, pers. comm. 27 Aug 99).

While more than a dozen species of squids and cuttlefishes are recorded from Hawaiian waters (Matsumoto and Suzuki October 1988), most of these are pelagic. *Euprymna scolopes*, an endemic cuttlefish, is typically associated with a benthic existence in shallow-water areas. The species is common in the sand and mud flats of Kaneohe Bay, where it forages to feed on shrimp (*Leander debilis*) at depths of less than 0.5m (Kay 1979).

In Hawaii, *Sepioteuthis lessoniana,* the bigfin reef squid, was previously common, but may now be nearly extirpated. It had been known from Waianae, Oahu. A recent sighting of the species was made on Molokini Island, Maui (B. Carlson, pers. comm. 27 Aug 99).

Other Sites

No reports.

4.2.2.2 Tunicates

<u>General Description of the Taxon</u>

The tunicates, or sea squirts, are an unusual group of sessile marine organisms within the Phylum Chordata. While vertebrates comprise the most conspicuous and well-known species in the phylum, species in two subphyla (the Urochordata and Cephalochordata) lack backbones. Nonetheless, they possess the three traits diagnostic for chordates--presence of a notochord, a dorsal hollow nerve cord, and pharyngeal clefts at some point in the life cycle. The Urochordata, which comprise the tunicates, are further divided into three classes, the Ascidiacea, the Larvacea, and the Thaliacea, the latter two being specialized planktonic forms (Abbott et al. 1977). The discussion in this section therefore refers to members of the Class Ascidiacea.

The ascidians are common marine invertebrates worldwide. Most inhabit shallow waters, where they attach to rocks, shells, pilings, or ship bottoms, or grow epizoically on other sessile organisms. Some forms anchor in sand or mud, though the species inhabiting sediments occur more generally in deeper waters.

The tunicate animal is sheathed in an outer covering, the tunic that is distinctive for the group. The tunic in most cases contains cellulose, a rare instance of the substance being produced by an animal. Calcareous spicules may also be present. The consistency of the tunic varies from soft and gelatinous to fleshy, tough, leathery, cartilaginous, or fibrous. Tunicates are attached to the substrate at their proximal end, and have two openings at the opposite pole, the buccal and atrial siphons. The organisms filter plankton by drawing water into a pharyngeal "basket" through the buccal siphon (ICLARM 1998).

The pharyngeal basket is the most prominent internal organ in most tunicates. Rows of perforations in the basket, the stigmata, are fringed with beating cilia that circulate water through the basket, with plankton filtered out in the process. A single tunicate a few centimeters long can filter about 173 liters of seawater in a 24-hour period (Barnes 1987). The filtered water is ultimately discharged through the atrial siphon. In addition to obtaining nutrition through filter-feeding, some tunicates possess within their tissues (in the tunic or cloacal region) endosymbiotic algae of the genus *Prochloron.* In certain ascidians, another algal endosymbiont, *Synechocystis,* occurs. This alga imparts a pink or red color to the appearance of the tunicate Monniot et al. 1991). Presumably, excess photosynthate produced by *Prochloron* or *Synechocystis* cells provides an accessory food source for the tunicate host.

While some of the largest species are solitary (or simple) ascidians, many are colonial. Colonies may be organized along several different lines. In the simplest colonies (e.g., *Perophora*), the bodies of individual zooids are almost completely separated but are connected by a stolon. In other types, the stolons are short, and the individuals form tuftlike groups (e.g., *Clavelina*). In the most specialized colonial types (e.g., *Botryllus*), individual animals are minute, and completely embedded in a common tunic. The buccal siphons of each zooid open separately to the environment. The atrial siphons may also, but in many cases the apertures of the atrial siphons open into a common cloacal chamber, which has one large opening in the middle of the colony (Barnes 1987; Abbott et al. 1977).

<u>Reproduction and Life History</u>

Patterns of sexual reproduction vary from one family to another, and sometimes from one genus to another, within the class. For the most part, solitary and colonial ascidians are simultaneous hermaphrodites (Abbott et al. 1977). The degree to which self-fertilization occurs is not well known. Typically, solitary ascidians release both eggs and sperm into open water, where fertilization occurs. The embryo develops into a non-feeding, swimming larva, or "tadpole." It is in the tadpole phase (which superficially resembles a typical frog tadpole) that the notochord and dorsal nerve cord, which characterize these organisms as chordates, are present. However, these features are lost during metamorphosis, and are absent in the adult phase. Colonial forms are ovoviviparous: sperm are shed to the sea, but not eggs. Fertilization in these types occurs within the oviduct or peribranchial cavity of the female parent, and the tadpole larvae emerge swimming, following development inside the parent body (Monniot et al. 1991). The larvae are completely encased in a tunic, and the buccal and atrial siphons are not functional. Thus the larvae are unable to feed; their prime function is to quickly find a suitable substrate to settle on. Therefore, tadpole larvae may only swim for a few minutes to a few days (Pearse et al. 1987). Following settlement, metamorphosis to the adult phase generally entails resorption of the tail and other larval structures, 180-degree rotation of the body to its adult posture, opening of the siphons, development of the brancial sac, and formation of the adult nervous system (Monniot et al. 1991).

In addition to sexual reproduction, the tunicates can reproduce asexually by budding. Budding individuals, or blastozooids, originate in different parts of the ascidian body, depending on the species. Individuals produced by primary buds are eventually freed from the parent colony (Barnes 1987). In addition to budding, colonial forms may undergo continuous divisions into smaller units termed cormomeres. The division entails rapid and dynamic movement of the colonies over the substrate. In addition to accomplishing the actual physical separation of the colony fragments, it is thought that this form of division may serve some other purposes as well, including maximizing periphery to area (which may improve efficiency of feeding or growth), excluding competitors by the dynamic movement involved; and mingling clones to facilitate cross-fertilzation (Ryland et al., 1984).

Typically, tunicates may live for 1-3 years, but some colonies may have a somewhat longer life span (Barnes 1987).

<u>Habitat and Ecological Factors</u>

Finding a stable substrate is critical for the survival of settling tunicates. Thus, inert surfaces of rocks, corals or pilings may be preferable to the less durable surfaces of seaweeds, mangrove roots, or other sessile invertebrates (soft corals, sponges, other tunicates), though all of these may provide surfaces for tunicates to grow on. Many tunicates (especially the more delicate soft-bodied forms) also show a marked preference for growth in protected pockets or crevices, as opposed to exposed areas of the reef crest or face, where they would be subject to extreme variations in water movement, and possibly, greater predation by grazing animals. When they do occur in such places, tunicates are often covered by epibionts that may afford some camouflage and physical protection (Monniot et al. 1991).

Light and color of the substrate may be physical cues that influence larval settling, with darker, less illuminated surfaces being the preferred substrates. However, some forms, especially didemnids containing the endosymbiotic alga, *Prochloron,* can grow as high up as the intertidal zone, where light is most intense (Ryland et al. 1984). In addition, it is believed that certain chemicals may trigger initiation of various processes, including spawning, metamorphosis, larval attraction, and repulsion of predators or epibionts. For example, chemicals exuded by parent zooids may cause larvae to settle nearby, increasing the likelihood that larvae will find a suitable settlement substrate (Monniot et al. 1991).

As filter-feeders, tunicates are dependent upon the availability of adequate suspended food particles in the water column. Tunicate growth on outer reef slopes may be relatively more limited than within enclosed bays or lagoons, since phytoplankton may be less abundant there. Ovoviviparous colonial types are better suited to growth on outer slopes than are solitary forms, since larvae are protected during development and the free-swimming stage is very brief. By contrast, within lagoons, both solitary and colonial types are fairly abundant. Solitary forms seem to dominate in colonizing newly-available surfaces in disturbed areas (for example, in harbors), but typically species diversity in such settings is low (Monniot et al. 1991). Dominance of the solitary forms may be due to the fact that their larvae are released in greater numbers, and spend a longer time in the free-swimming phase, than larvae of colonial types.

Tunicates are not selective about the types of particles that are ingested in filter-feeding, and in waters with a high sediment load, silt and other mineral particles may accumulate in the pharyngeal basket and the digestive tract. If excessive, the silt may clog the pharynx and suffocate the animal.

Economic Importance

With minor exceptions,[4] ascidians are not presently utilized for any economic purposes. However, over the last twenty years or so, considerable research efforts have been directed at isolating and identifying compounds from tunicates that may have some cytotoxic activity, and thus some future medical value. For example, didemnines extracted from *Trididemnum solidum* are effective anti-cancer agents and may also have anti-viral properties (Monniot et al. 1991). Alkaloids and peptides, derivatives of amino acids, have also been isolated from tunicates. Some of these have antimicrobial properties (Lee et al., 1997; Zhao et al., 1997). Other proteinaceous compounds derived from tunicates may play a role in mediating responses in the immune system (Pancer et al., 1997; Pancer et al., 1993). *Lissoclinum bistratum*, a tunicate from New Caledonia that contains within its tissues endosymbiotic *Prochloron* algae, has been the source of polyethers that have strong effects on the nervous system. It remains to be determined whether the embedded *Prochloron* algal cells, rather than the tissues of the tunicate animal itself, are the source of these compounds (Monniot et al., 1991). It is speculated that in life, tunicates may utilize cytotoxic compounds to ward off predators or repel epibionts (Muller et al., 1994).

The ascidians are important members of the community of marine fouling organisms. The solitary tunicates seem to be especially opportunistic in colonizing freshly-exposed surfaces of pilings, docks, other harbor structures, and boat hulls. Ascidians and other fouling organisms interfere with boat operations and normal function such equipment as cooling water intakes. On hulls, fouling organisms cause additional drag of vessels as they move through the water. Significant effort and money are spent in developing effective means for deterring the growth of fouling organisms, and for eliminating them from boat hulls and other structures. Recently, great concern has developed about the transoceanic transport of tunicate species to areas where they are not indigenous, typically by attachment to boat hulls or being carried in bilge water. Introduction of exotic species transported in this manner can

[4] In some countries, certain larger species are consumed as a food item.

be disruptive of the balance of species in natural communities.[5] Among the Hawaiian species discussed by Abbott (1977), many are potential fouling organisms, with *Polyclinum constellatum, Diplosoma listerianum, Ciona intestinalis, Corella minuta, Ascidia sydneiensis Phallusia nigra, Symplegma oceania, Polyandrocarpa zorritensis, Styela canopus, Herdmania momus* being the most prevalent.

While ascidians typically will settle only on dead parts of coral, once established they may overgrow and smother adjacent living coral tissue (Monniot et al. 1991). The encrusting colonial tunicate, *Diplosoma similis,* has an extremely wide range in the tropical Western Pacific, and is known to overgrow large areas of living *Acropora* coral and the coralline alga, *Hydrolithon* (Littler and Littler 1995). This can cause indirect economic consequences, since such overgrowth of living coral areas can reduce the productivity of the reef, reducing the potential for fisheries.

Occurrence of the Taxon Within WPRFMC Fishery Management Units (FMUs)

Little information is available on occurrence of ascidians in the Pacific Islands. Data from the few citations located are presented here.

American Samoa

No reports.

Commonwealth of Northern Mariana Islands (CNMI)

Abbott et al. (1977) mention that *Polyclinum vasculosum*, has been reported widely in the Pacific, including from the Marianas.

Guam

The ascidian fauna of Guam is not well-known. As the result of some recent surveys, work is in progress to more accurately assess and describe the fauna (pers. comm. Gretchen Lambert, California State University, Fullerton 19 Aug 99).

Hawaii (MHI and NWHI)

Eldredge and Miller (1995) report a total of 45 species from Hawaii, but give no firm indications about how many might be endemic or introduced species. Abbott et al. (1977) report species from Hawaii in the following families: Polyclinidae (4 species); Polycitoridae (4); Didemnidae (11); Cionidae (1); Perophoridae (4); Corellidae (1); Ascidiidae (6); Styelidae (10); Pyuridae (3). All the growth forms discussed above are represented, and these taxa occupy a corresponding range of substrates. *Diplosoma similis,* the species that overgrows live reefs, is among the tunicates reported from Hawaii.

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[5] Biological Resources Division, US Geological Service, Nonindigenous Tunicate Information Website.

Other Sites

No reports.

4.2.2.3 Bryozoans

<u>General Description of the Taxon</u>

The Phylum Bryozoa is a taxonomically problematic group. While authorities have variously regarded them as including (Ehrenberg [1831]) or excluding (Hyman [1959]) the Entoprocta (a group of sessile organisms that superficially resemble hydroids), the Bryozoa as considered here refer only to the Ectoprocta. This group is comprised of colonial, sessile animals, with the vast majority occurring in marine environments. They have formed an important component of the fossil record since the Ordovician period. Though widespread on tropical reefs, bryozoans are often not recognized because they occur in mixed associations with algae, hydroids, sponges, and tunicates, especially on older portions of coral reefs (Soule et al. 1987).

The Bryozoa comprise the largest of four phyla of invertebrates that possess a lophophore. The lophophore is a fold of the body wall that encircles the mouth and bears numerous ciliated tentacles. Through the movement of the cilia, a water current is generated that drives plankton into the mouth of the bryozoan animal. The individual animals of the colony, or zooids, have a large coelom and a ■U•-shaped digestive tract, with the anus opening to the outside of the lophophore tentacle circle (hence, ■Ectoprocta•). Organs for gas exchange, circulation, and excretion are absent, probably owing mostly to the small size of the animals, which would allow for direct exchange of nutrients and wastes.

The phylum is divided into three classes, with Class Gymnolaemata containing most of the living marine species. Other marine types are contained within the order Cyclostomata in Class Stenolaemata (Ryland 1970). While some Bryozoa occur at great depths, the majority are found in shallower coastal waters, where they grow attached to rocks, corals, shells, other animals, wood (e.g., mangrove roots), or algae. Growth habit may be stoloniferous, foliose, branching, or encrusting. Large colonies may consist of more than two million individual zooids, and may reach up to 24 cm in height for erect species, and up to 50 cm diameter for encrusting forms (Barnes 1987). While various species are recognized on a gross level by their growth habit, to some degree, growth form is mediated by environmental conditions, so that within any given taxon, a range of variation in the form of the colony may occur (Soule et al. 1987).

The Gymnolaemata are divided into two distinct orders. The Ctenostomata, or ctenostomes, contain stoloniferous or compact colonies in which the exoskeleton is membranous, chitinous, or gelatinous. Usually, the terminal aperture of the zooid is open (i.e., lacks an operculum). In contrast, the Cheilostomata, or cheilostomes, have boxlike calcareous walls. A hinged, moveable operculum covers the aperture of the zooid in most cheilostome species. The operculum opens when the lophophore is extended for feeding, and shuts when the animal withdraws into the calcareous chamber of the zooecium (the colonial skeleton). Specially modified zooids are the avicularia, with movable jaw-like parts that serve to repel predators, and vibracula, with setae or bristles that are used to prevent accumulations of silt.

The marine Stenolaemata, the cyclostomes, are considered more primitive in organization than the Gymnolaemata (Ryland 1970). In the cyclostomes, the zooids are tubular and calcified, and the orifice is distally or anteriorly located, without an operculum (Barnes 1987).

<u>Reproduction and Life History</u>

The reproductive process in the Gymnolaemata is representative for the majority of marine species. Most marine bryozoans are hermaphroditic. However, the details of this arrangement may vary, with individual bryozoans being sequentially or simultaneously hermaphroditic, or unisexual. In some cases, permanently unisexual colonies may form (Soule et al. 1987). Sperm are shed through terminal pores of two or more tentacles of the lophophore, and released into seawater. Sperm are captured in the currents generated by the action of the lophophores of other nearby zooids. Fertilization between zooids of the same colony is probably common, but sufficient cross-fertilization likely occurs between colonies to assure outbreeding. In certain non-brooding species, fertilized eggs are shed directly into the seawater. Eggs of other species may be brooded in the coelomic cavity, or outside it. One specialized structure for brooding is a hood-like outgrowth of the body wall and coelom called the ovicell. In many species, the developing embryo receives its nutrition from a contained yolk, but in others, placenta-like connections to the ovicell from the mother zooid may provide food material.

For the Cyclostomata, specialized individuals, the gonozooids, may be modified for reproduction, or the colony may form a centralized chamber as a brooding structure (Soule 1987).

Bilateral cleavage leads to the development of a larva that has a locomotory ciliated girdle, or corona, an anterior tuft of long cilia, and a posterior adhesive sac. In certain genera of non-brooding bryozoans (e.g., *Membranipora*) a specialized feeding larva, the cyphonautes larva, develops. These are the only larvae that possess a functional digestive tract, and feed during the larval stage, a phase which may last several months. In brooding species, larvae are non-feeding, and the larval phase lasts only for a brief period before settlement.

During settling, the vibratile plume, a sensory tuft of cilia, is used in selecting a suitable site for attachment. The adhesive sac is everted and attaches the larva to the selected site. After settlement, the larva undergoes a marked metamorposis to form the ancestrula, the first zooid. Subsequent zooids in the colony are formed by asexual budding. The zooids formed by budding can themselves bud in various arrangements, giving rise to the form that characterizes each species (Meglitsch and Schram 1991).

<u>Habitat and Ecological Requirements for Various Life History Stages</u>

Preferences and Other Physical Parameters

Rather than being a primary structural reef-builder, bryozoans generally function as ■hidden encrusters• that grow on the undersides of coral heads, rock ledges, and rubble, and may also partially fill cavities deep within the reef (Cuffey 1972). In this capacity, to a limited degree, bryozoans may reinforce the structural strength and stability of the reef.

A correlation has been noted between growth form and the depth at which various types occur (Ryland 1970). Generally, encrusting forms may be associated with intertidal areas or other sites subject to strong waves. Such forms would also be more resistant to grazing by predators. Less sturdy types, including erect branching and foliose forms, are found in areas not subject to strong surge or heavy pressure from grazing predators. For example, reticulate to fenestrate reteporids are typically confined to deeper, more stable marine habitats (Dade and Honkalehto 1986).

On modern tropical reefs, encrusting cheilostomes are the most abundant and diversified bryozoans. Encrusting cheilostomes comprise from 50 to 70 percent of the colonies observed in various reef environments in Kaneohe Bay (Dade and Honkalehto 1986). It appears that in depths below 5 to 7 m, bryozoans become more abundant and more diverse than in shallower areas (Cuffey 1972). In surveys conducted to depths of approximately 20 m in Kaneohe Bay (Dade and Honkalehto 1986), a similar trend was observed toward conditions that appear to favor more abundant and diverse growth in deeper water. Among the possible contributing factors cited were environmental stability (e.g., less water movement, fewer grazers); availability of substrate (as competition with corals and encrusting algae decreases); and decrease in ambient light.

It is known that bryozoan larvae actively search for suitable substrates for settlement. It has been observed that bryozoan larvae are able to persist in the plankton for many days longer than expected when conditions are not favorable for settling (Soule et al. 1987). Different species settle variously on rocks, shells, corals, or algae. The length of time over which larvae settle for a given species within a given area is thought to be dependent on a number of environmental factors, including day length and temperature. Day length may be both a direct influencing factor, and an indirect influence, since phytoplankton, presumed to be the preferred food source for many bryozoans, would be available in larger quantities during days with longer daylight hours. In Hawaii, larvae of *Bugula neritina* settled almost year-round (March to December). This also may indicate that *B. neritina* has an extended spawning season in Hawaii (Ryland 1970).

In many species, larvae first exhibit a positive phototropic reaction, but then become negatively phototropic before metamorphosis, eventually settling in dark places on the reef, such as the undersides of stones or flat coral plates (Soule et al. 1987). Generally, high light intensity environments do not support the growth of bryozoans (Soule et al. 1987). Empirical observation suggests that heavily-silted environments generally deter successful settlement; few bryozoans are found growing in areas where rapid deposition of fine sediments occurs, or where water is frequently muddy or turbid (Soule et al. 1987).

Strong correlations were observed between various growth form groups and their position on the reef. So-called lagoon reef areas (fringing and patch reefs, 1-8m depth) were dominated by encrusting cheilostomes (*Celleporaria vagens, Rynchozoon* sp., *Coscinopsis fusca, Cleidochasma* sp.) and mat-like, tuft-like, and disk-like cheilostomes, as well as lichenoporid and tubuliporid cyclostomes. The barrier reef coral-algal flat breaker zone (1-2.5m depth) portion of the study site was dominated by the encrusting cheilostomes, *Thallamoporella* *stapifera* and *Rhynchozoon* sp. The ocean slope bench (15-20m depth) provided habitat for a wider variety of species, including encrusting cheilostomes (especially *Steginoporella magnilabris*, *Parasmittina parsevaliformis*, and *Schizoporella decorata*), as well as an assortment of reteporid cheilostomes, tuft-like cheilostomes, and lichenoporid and tubuliporid cyclostomes.

Idmidronea, a genus of highly-branched cyclostomatous bryozoans, is reported to occur on the surface of living corals and sponges in Hawaii (Gossliner et al. 1996).

Reteporellina and *Reteporella* sp. occur in areas with fairly strong currents at 10-20m depth (Gossliner et al. 1996).

Another interesting occurrence is the association of bryozoans with black corals (*Antipathes dichotoma*) growing at around 50m depth in the Auau Channel off Maui. About thirty species were found attached to the bases of the corals, and to mollusks attached to the lower coral branches. *Haloporella vaganas* and *Reteporellina denticulata* were the most common members of these assemblages (Soule et al. 1986).

In another study, encrusting and erect cheilostome bryozoans were found to grow on an artificial reef positioned in 20m of water in Kaneohe Bay, Oahu. Bryozoans grew rapidly on introduced substrates after two months. Two encrusting species, *Celloporaria vagans* and *Thalamoporella* spp., competed vigorously for space on an artificial substrate (Bailey-Brock 1987). In a similar manner, fouling organisms also appear to opportunistically colonize available surfaces. Thirteen species[6] were found to occur regularly on harbor and bay structures and boat hulls around Oahu (Soule et al. 1987).

Feeding

Bryozoans are suspension-feeders that capture plankton from the water. Gut contents show the presence of diatoms, detritus, bacteria, silicoflagellates, peridinians, coccolithophores, algal cysts, and flagellates. Unicellular algal cultures (*Dunaliella tertiolecta* and *Gymnodinium simplex)* have been used to successfully rear bryozoans in the laboratory (Soule et al. 1987).

While not an obvious food source for other animals, bryozoans are utilized by a variety of grazers, including echinoids, labrid fishes, and nudibranchs (Soule et al. 1987).

Economic Significance

Despite their widespread occurrence, bryozoans are generally not directly utilized for any applied purposes. However, they are being thoroughly investigated for the presence of biochemically active compounds that may ultimately prove useful for treatment of disease. Bryostatin 1, a compound isolated from a common marine bryozoan, is currently being tested

[6] *Aetea recta, Bowerbankia gracilis, B. imbricata, Bugula stolonifera, B. neritina, Hippopodina feegeensis, Savignyella lafonti, Schizoporella unicornis, Zoobotryon verticillatum, Scrupocellaria sinuosa, Cryptosula pallasiana, Tryptostega venusta,* and *Watersipora edmondsoni*.

as an anti-cancer drug.[7] Bryozoans are recognized for producing a range of other compounds, particularly alkaloids that may ultimately be shown to have pharmaceutical applications (Van Alstyne and Paul 1988).

Many bryozoan species also have economic importance because of their action as fouling organisms. Bryozoa, along with other common sessile invertebrates and algae, attach to boat hulls, making their movement in the water less efficient. Among the common bryozoan fouling species in warm-water areas are *Bugula neritina*, *Schizoporella errata, Watersipora subovoidea,* and *Zoobotryon verticillatum* (Ryland 1970). These and other species can also clog industrial water intakes and conduits. Significant effort and money are spent in developing effective means for deterring the growth of fouling organisms, and for eliminating them from boat hulls and other structures. The growth of fouling organisms, besides being of economic significance, also has ecological implications--species growing on ship hulls are readily transported great distances beyond their natural range, and may be introduced into new areas, thus having an impact on the natural balance of species in established ecosystems.

Occurrence of the Taxon Within WPRFMC Fishery Management Units (FMUs)

American Samoa

No reports.

Commonwealth of Northern Mariana Islands (CNMI)

No reports.

Guam

No reports.

Hawaii (MHI and NWHI)

Surveys in Kaneohe Bay (Dade and Honkalehto 1986) yielded a total of 57 species of ectoproct bryozoans, including 45 cheilostomes, 13 cyclostomes, and 1 ctenostome. Many of these are cosmopolitan, capable of being dispersed over great distances, often by rafting on algae, logs, or artificial substrates. However, owing to the isolation of the archipelago, significant speciation has occurred, with the result that of the species recorded in Kaneohe Bay, 23 percent were believed to be endemic to Hawaii. It is estimated that over 150 species of bryozoans occur in Hawaii; however the total number of endemic species for Hawaii is not known (Eldredge and Miller 1985).

Other Sites

With the exception of Hawaii, little published information is available for the other U.S. Pacific Islands. Because the shallow sublittoral bryozoan fauna for the Indo-Pacific is not

[7] U. of California, Berkeley: Bryozoan Internet website.

well known, it is difficult at present to establish with any certainty the degree of endemism of specific taxa within any given island or archipelago (Soule et al. 1987).

4.2.2.4 Crustaceans

<u>Introduction</u>

The arthropod subphylum Crustacea is one of the most diverse and widespread groups of invertebrates. Within the subphylum, the Class Malacostraca contains such familiar types as mantis shrimps, lobsters, crabs, and shrimp, as well as less conspicuous, but ecologically important organisms, the isopods and amphipods.

Crustaceans cannot grow as many other animals do, because the hard exoskeleton does not stretch. Therefore, they periodically shed the outer skeleton, grow rapidly for a period of time, then re-grow a new exoskelteton. The molting process involves many complex physiological changes, including reduction of the lime content in the exoskeleton to weaken it prior to molting; rapid absorption of water after molting to expand the body size; and redeposition of lime to again strengthen the exoskeleton (Tinker 1965). During molting, the animal is in a weakened and vulnerable condition, and must seek shelter to avoid being preyed upon by other animals. Thus the molting process strongly influences the habitat requirements of these animals.

The malacostracan body is typically composed of 14 segments, plus the telson, with the first 8 segments forming the thorax and the last 6, the abdomen. The thorax may or may not be covered by a carapace. All segments bear appendages, with the first antennae usually being biramous, the exopodite (outer branch) of the second antennae often in the form of a flattened scale, and the mandibles usually bearing palps. In the primitive condition, the thoracic appendages are similar, with the endopodite (inner branch) being more developed for use in crawling or grasping. In most species, the first one, two, or three pairs of thoracic legs have been turned forward and modified to form maxillipeds. The anterior abdominal legs are similar, and are called pleopods. They are used for swimming, burrowing, ventilating, gas exchange, and carrying eggs in females. In males, the first one or two pleopods are modified to form copulatory organs. The sixth abdominal appendages, or uropods, are flattened, and together with the telson, form a tail fan used in escape swimming.

The present discussion is confined to those larger forms that are of concern from a management standpoint. These belong to the order Stomatopoda (mantis shrimps), and order Decapoda (shrimps, lobsters, and crabs). As part of Amendment 10 to the *Crustacean Fisheries Management Plan,* (WPRFMC September 1998) background information has been presented, and EFH has already been defined, for certain economically-important decapod taxa (i.e., spiny lobsters, *Panulirus marginatus* and *P. penicillatus*, and kona crab, *Ranina ranina*) (Table 88). The present discussion will provide further information on other decapod taxa, and summarize the information contained in Amendment 10 on lobsters and Kona crab.

Stomatopoda (Mantis Shrimps)

Description

Several hundred marine species constitute the order Stomatopoda, the mantis shrimps. These organisms live in rock or coral crevices or in burrows excavated in sand. They are dorsoventrally flattened with a small, shield-like carapace and a large segmented abdomen that widens toward the posterior end. Characteristic of the group is the possession of a highly developed, powerful pair of second-segment raptorial appendages that are used either for spearing or smashing prey.

Reproduction and Life History

In stomatopods, as many as 50,000 eggs (e.g., genus *Squilla*) are joined together by an adhesive secretion to form a globular mass. The mass is held by the female in small subchelate appendages and constantly turned and cleaned. The female does not feed while brooding. Depending on the species, the egg mass may be left in the burrow, or the female may carry the egg mass with the thoracic legs (Meglitsch and Schram 1991). The eggs hatch into zoea larvae that have carapaces that are much larger than in the adult, relative to total body size. The larvae may appear in very large numbers in the plankton community in tropical waters. Two types of larvae are recognized, an erichthus and an alima. The larvae pass through a prolonged phase during which the last three thoracic somites have no appendages, a feature also observed in zoea larvae of decapods (Meglitsch and Schram 1991). The planktonic larval phase lasts for up to three months (Barnes 1987).

Habitat and Ecological Requirements for Various Life History Stages

Most stomatopods live in pockets or crevices on the reef, or in burrows in sand. They may dig their own burrows or occupy burrows excavated by other animals. A variety of mechanisms are used to close the burrow entrance for protection; the animal may plug the hole with its telson, or gather shells and other debris to close the entrance at night, and block it during the day with the raptorial appendages.

Mantis shrimps may leave the burrows to feed, either crawling or swimming over the bottom. Some types (■spearers,• e.g., *Lysiosquilla maculata*) are equipped with raptorial appendages that have sharp barbs that pierce soft-bodied prey animals, such as shrimps or fishes. In others (■smashers• such as *Gonodactylus* spp.) the raptorial appendages have a sharp, heavy heel that can crack the shells of crabs, snails, and clams.

Economic Importance

Mantis shrimps are part of the incidental catch of subsistence fisheries, and may be captured in crab nets that are placed near their burrows (Tinker 1965). Their use as a food source is generally limited. Some species, especially brightly-colored ones (e.g., *Gonodactylus* sp.), may have some minor value in the aquarium trade (?-confirm). Limited use is made of the ivory-like raptorial appendages of some species in the small-scale manufacture of jewelry (Tinker 1965).

Occurrence of the Taxon Within WPRFMC Fishery Management Units

American Samoa

No reports.

Commonwealth of Northern Mariana Islands (CNMI)

Two stomatopods found in the Northern Marianas, *Mesacturus dicrurus* and *Gonodactylus* sp., were reported by Hamano (1994). Both species, in the Gonodactylidae, occur in rocky intertidal areas.

Guam

Lysiosquilla spp. (Green October 1997) and *Mesacturus dicrurus* (Gonodactylidae; Hamano 1994) are known from Guam. *Mesacturus dicrurus* is associated with rocky intertidal environments (Hamano 1994).

Gossliner et al. (1996) report on the following species:

Gonodactylellus affinis (Stomatopodidae), a species that is highly polymorphic in color, occurs here, usually below 20m depth. By contrast, *Gonodactylus chiragra* is an inhabitant of shallow intertidal reef flats and rocky outcrops, and forages in low tide in a few centimeters of water. *Gonodactylaceus mutatus* occurs on reef flats to 5m depth, and also forages at extreme low tide. *Mesacturoides spinosocarinatus* may be found at depths ranging from 5 to 50 m. The animals stay close to their burrows, but dart about nearby. *Pseudosquilla ciliata* burrows in sand and gravel on reefs and sand flats, to 30m depth.

Hawaii (MHI and NWHI)

Eldredge and Miller (1995) list a total of approximately 17 stomatopods from Hawaii. Of these, 11 are considered endemic.

Lysiosquilla maculata and *Squilla (Oratosquilla) oratoria* are reported to occur in Hawaii. Both are found in mud-bottom areas suitable for burrows (Tinker 1965).

Gossliner et al. (1996) report the occurrence of the following Hawaiian species:

Odontodactylus brevirostris is found in burrows of small rubble pieces at 10-50m depth. *O. scyallarus* is a night-feeding carnivore that preys on crustaceans, worms, mollusks, fish. It is found on sand and rubble bottoms to 70m. *Oratosquilla oratoria*, another nocturnal species, is reported in muddy estuaries and on reefs, in U-shaped burrows up to 1m long. *Pseudosquilla ciliata* burrows in sand and gravel on reefs and sand flats, and is found to 30m depth.

Other Sites

A single specimen of *Pseudosquilla ciliata* was encountered at Palmyra Island (Edmondson 1923).

Decapoda: Shrimps, Lobsters, and Crabs

Introduction

With approximately 10,000 species, decapods represent about one fourth of all known crustaceans (Barnes 1987). They are among the most diverse and successful crustacean groups, having exploited virtually all available niches in the marine habitat, as well as having developed specialized strategies for nutrition and reproduction.

The generalized decapod life cycle is characterized by the nauplius and protozoea stages being passed inside the egg. However, some primitive forms (e.g., penaeids) pass the earlier developmental stages outside of the egg. Transition from protozoea to the next stage (zoea) involves the addition of thoracic limbs and dependence on the thoracic appendages for locomotion. The carapace fuses to the thorax, and pleopods and stalked eyes appear. The zoea is typically the stage at which the larva emerges from the egg. From the zoea phase, further transformations occur, making the postlarval or juvenile phase more closely resemble the adult (Meglitsch and Schram 1991).

In the adult phase, decapods are distinguished by having the first three pairs of thoracic appendages modified into maxillipeds. The remaining five pairs are the legs. The first or second pair of legs may be chelipeds (pincer-like claws) that are used for seizing prey or for defense (Barnes 1987).

Decapods exhibit a wide range of feeding behaviors, but most combine predation with scavenging, with large invertebrates being typical prey items (Barnes 1987). Others may be detritus or filter feeders. The form of the body, especially the appendages, is often modified for more effective functioning in acquiring food. Thus, box crabs such as *Calappa calappa* have powerful chelae used to crush mollusks; sand-burrowing mole crabs (e.g., *Emerita pacifica*) use long fringed antennae to filter plankton and detritus; and banded coral shrimp (*Stenopus hispidus*) use thin pincers to delicately pick ectoparasites from the scales of fishes♣ bodies (Gossliner et al. 1996).

Shrimps: Infraorders Penaeidea, Stenopodidea, Caridea

General Description and Morpohology

The shrimps are found in several different decapod infraorders, and this taxonomic disunity reflects the wide range of forms and lifestyles that are represented in this large but artificial grouping. The penaeids are considered the most primitive decapods, while other types, such as the alpheids and palaemonids, represent more advanced forms. The features that generally characterize shrimps are bodies that are laterally compressed or more or less cylindrical, with well-developed abdomens, and a cephalothorax that often has a keel-shaped, serrated rostrum. Legs are usually slender, and chelipeds may be present or absent. The exoskeleton is usually relatively thin and flexible (Barnes 1987).

Reproduction and Life History

In most shrimps, copulation takes place with the adults pair oriented at right angles to each other. The male uses the modified first and second pair of pleopods to transfer a spermatophore to a median receptacle between the thoracic legs of the female. The penaeids are the only decapod group in which eggs are shed directly into the water and hatch as naupliar or metanaupliar larvae. In all other decapods, females carry the eggs on the pleopods, and hatching takes place at the protozoea or zoea stage (Barnes 1987). The various larval schemes in decapods are summarized in Table 83.

Habitat and Ecological Requirements for Various Life History Stages

Most shrimps are bottom-dwellers. Thoracic appendages are used for crawling, while pleopods are used for swimming, and also to fan sediments during excavation of burrows. Many penaeids construct burrows in sand or other soft-bottom material, or simply bury themselves in sediment during daytime, emerging at night to feed (Gossliner et al. 1996). Other types, such as snapping or pistol shrimp (Alpheidae), live in holes and crevices beneath rocks and coral rubble, or may construct burrows. Certain alpheids are also closely associated with corals, especially in the genus *Pocillopora* (Hayashi et al. 1994; see notes in section IV.C.4.e, below) Other genera also may live inside or in close association with a variety of other living organisms, including sponges, tunicates, mollusks, corals, echinoderms, or anemones (Tables 84-87).

Many of the commensal associations between shrimps and other organisms are quite specialized. The ■cleaner shrimps,• an artificial grouping of species distributed among several families, play an important role in reef ecology by reducing ectoparasites on reef fishes. Through complex behavioral cues and signals, the fishes approach well-defined ■cleaning stations• on the reef and allow the shrimps to climb over their bodies and even insert their chelipeds into the gill region to pick off parasites. Anemone shrimps in the genus *Periclimenes* may also clean fish, and spend most of their time living among the stinging tentacles of sea anemones. Many snapping shrimps of the family Alpheidae typically share their burrows in a close relationship with fish of the family Gobiidae, presumably to the mutual benefit of both partners.

<u>Occurrence of the Taxon Within WPRFMC Fishery Management Units</u>

American Samoa

No reports.

Commonwealth of Northern Mariana Islands (CNMI)

Hayashi et al (1994) surveyed the crustacean fauna on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug (East, West and North), and Uracas. Their collections were made at depths ranging from 3-14 meters. The findings included reports of the following species of shrimps:

Stenopodidae:

Stenopus hispidus (found in the rocky subtidal zone; known from a wide geographic range where it occurs from the intertidal to depths of 210m); Rhyncocinetidae: *Rhyncocinetes* sp.; Palaemonidae: *Brachycarpus biunguiculatus, Harpiliopsis beaupresii* (on coral), *H.depressa, Ichnopontonia lophos, Jocaste japonica, Onycocaris quadratophthalma* (on *Pocillopora* coral), *Palaemonella spinulata*; Alpheidae: *Alpheopsis* sp., *Alpheus bidens, A.* cf. *crinitus, A. frontalis* (under boulders), *A. lottini* (in somewhat deeper water [14 m]on *Pocillopora*), *A. obesomanus, A. pacificus, A. pearcyi, Athanas areteformis* (on *Pocillopora*), *Automate dolicognatha, Metalpheus rostratipes* (on *Pocillopora*), *Racilius compressus, Syalpheus charon* (on *Pocillopora*), *S. paraneomeris* (on *Pocillopora*), *S. tumidomanus* (on *Pocillopora*); Hippolytidae: *Hippolyte edmondsoni* (on algae; known otherwise only from Oahu, Hawaii)

Guam

Several species of snapping shrimp (Alpheidae) were found in Guam. One species, *Alpheus obesomanus*, occupied extensive tunnels in *Millepora platyphylla* colonies; up to 95 percent of the colonies surveyed had shrimp tunnels. Another species, *A. idiocheles*, occupied sub-hemispherical pockets, called ■galleries,• in an intertidal erosion bench. Each gallery typically was inhabited by a male-female pair (Kropp 1987).

Hawaii (MHI and NWHI)

Eldredge and Miller (1995) indicate that there are approximately 200 species of marine shrimps in Hawaii; of these, 4 stenopodids are believed to be endemic. Endemism of other types has not been established with certainty.

Tinker (1965) reports the following species of interest: *Stenopus hispidus* (Stenopodidae), the banded cleaner shrimp, is or pan-tropical distribution. It is typically found in holes in the reef. The harlequin shrimp, *Hymenocera picta* (Gnathophyllidae), is found from Hawaii eastward to the Red Sea. This species, relatively uncommon in Hawaii, is occasionally found in quiet inshore waters on the reef.

Gossliner et al. (1996) report the following shrimps from Hawaii:

Stenopodidae:
Stenopus hispidus, S. pyrosonotus (cleaner shrimp found in crevices to 15 m depth; eggs are light blue color); Pontoniidae: *Periclimenes soror* (on sea stars), *P. imperator* (on nudibranch [*Hexabranchus*], holothurians [*Stichopus, Bohadschia, Synapta*], and sea star [*Gomophia*]), *Pontonides unciger* (mimics polyps of black coral [*Cirripathes*] on which it lives), *Stegopontonia commensalis* (on sea urchin spines); *Lysmata amboinensis* (cleaner shrimp); Hippolytidae: *Parhippolyte uveae* (in anchialine ponds), *Saron marmoratus*

(nocturnal in protected lagoons); Gnathophyllidae: *Gnathophylloides mineri* (on sea urchins), *Gnathophyllum americanum* (associated with echinoderms), *Hymenocera picta* (preys on sea stars); Rhinchocinetidae:*Rhinchocinetes rugulosus.*

Hayashi et al (1994) indicate that the following species are known from Hawaii:

Palaemonidae:
Brachycarpus biunguiculatus; Alpheidae: *Alpheus pearcyi, Metalpheus rostratipes, Syalpheus paraneomeris*; Hippolytidae: *Hippolyte edmondsoni* (on algae; known only from, Oahu, Hawaii and CNMI).

Other Sites

For each of the following families of shrimps, Edmondson (1923) lists the following number of species (in parentheses) represented at Palmyra Atoll and/or Fanning Island:[8] Alpheidae (10); Hippolytidae (1); Gnathophyllidae (2); Palaemonidae (5); Stenopodidae (1); Sergestidae (1).

<u>Lobsters, Spiny Lobsters, Slipper Lobsters: Infraorders Astacidea, Palinura</u>

General Description and Morpohology

Lobsters are heavy-bodied decapods that generally inhabit holes and crevices of rocky and coralline bottoms. They have extended abdomens that bear a full complement of appendages, and the carapace is always longer than it is broad. The infraorder Astacidea includes large-clawed lobsters, while the Palinura include the spiny lobsters (Palinuridae), slipper lobsters (Scyllaridae), and coral lobsters (Synaxidae)(Barnes 1987; Pitcher 1993). Spiny lobsters are non-clawed, decapod crustaceans with slender walking legs of roughly equal size (Uchida 1986, FAO 1991). In spiny lobsters, the carapace is large and spiny. Two horns and antennae project forward of the eyes and the abdomen terminates in a flexible tailfan (FAO 1991). The slipper lobster, while in many respects quite similar to the spiny lobster, has its second antennae modified into broad, platelike structures (Pearse et al.1987). The body is more flattened dorsiventally than the body of spiny lobsters. Large-clawed, or true lobsters are more widespread and abundant in temperate areas, but of limited occurrence in the tropical and sub-tropical Western Pacific. They differ from palinurids in having large, heavy chelipeds.

Reproduction and Life History

The developmental history of the spiny lobster is covered at length in Amendment 10 of the *Crustacean Fisheries Management Plan,* (WPRFMC September 1998). Key points are excerpted here.

[8] Family name nomenclature is updated.

Spiny lobsters (*Panulirus* sp.) are dioecious (Uchida 1986). Generally, the different species within the genus have the same reproductive behavior and life cycle (Pitcher 1993). The male spiny lobster deposits a spermatophore or sperm packet on the female's abdomen (WPRFMC 1983, Uchida 1986). The fertilization of the eggs occurs externally (Uchida 1986a). The female lobster scratches and breaks the mass, releasing the spermatozoa (WPRFMC 1983). Simultaneously, ova are released from the female's oviduct and are then fertilized and attached to the setae of the female's pleopods (WPRFMC 1983, Pitcher 1993). At this point the female lobster is ovigerous, or "berried" (WPRFMC 1983).

The fertilized eggs hatch into leaf-like zoea larvae (the phyllosoma larvae) after 30–40 days (MacDonald 1986, Uchida 1986), and enter a planktonic phase (WPRFMC 1983). The duration of this planktonic phase varies, depending on the species and geographic region, and may last from 6 months to 1 year from the time of hatching (WPRFMC 1983, MacDonald 1986). There are 11 dissimilar morphological stages of development that the phyllosoma larvae pass through before they transform into the postlarval puelurus phase (Johnson 1986, MacDonald 1986). The relatively long pelagic phase for palinurid larvae results in very wide dispersal; palinurid larvae are transported up to 2,000 miles by prevailing ocean currents (Johnston 1973, MacDonald 1986).

There is a lack of published data pertaining to the preferred depth distribution of phyllosoma larvae in Hawaii. However, the depth distribution of phyllosoma larvae of other species of *Panulirus* common in the Indo-Pacific region has been documented. Newly hatched larvae of the western rock lobster (*P. cygnus*) are typically found within 60 m of the surface. Later stages of the phyllosoma larvae are found at depths between 80–120 m. *P. cygnus* undergoes a diurnal vertical migration, ascending to the surface at night, descending to lower depths during the day, the authors add. Research has shown that early phyllosoma larvae display a photopositive reaction to dim light. In the Gulf of Mexico, the depth to which *Panulirus* larvae descend is restricted by the depth of the thermocline (Phillips and Sastry 1980).

The puelurus stage for spiny lobster lasts 6 months or less (WPRFMC 1983). The pueruli are free-swimming and actively return to shallow, nearshore waters in preparation for settlement (WPRFMC 1983, MacDonald 1986). MacDonald and Stimson (1980) found pueruli settlement to occur at approximately 1 cm in length.

MacDonald (1986) states that after settlement the pueruli molt and transform into post-pueruli, a transitional phase between the pelagic phyllosoma phase and the juvenile stage. Pitcher (1993) states that the post-pueruli of *Panulirus penicillatus* have been observed inhabiting the same "high-energy reef-front habitat" as adults of the species. Yoshimura and Yamakawa (1988) conclude that small holes in rocks, boulders and algae provide important habitat for the newly settled pueruli and juvenile lobsters.

The other palinuroids (coral and slipper lobsters) also have the unique phyllasoma larval phase (Pitcher 1993). Johnston (1973) reports that the phyllosoma phase of some species of slipper lobster (genus *Scyllarides)* is somewhat shorter than that of the spiny lobster.

Habitat and Ecological Requirements

Adult spiny lobsters are typically found on rocky substrate in well-protected areas, in crevices and under rocks (Pitcher 1993, FAO 1991), down to a depth of around 110m (Brock 1973). Unlike many other species of *Panulirus,* the juveniles and adults of *P. marginatus* are not found in separate habitat apart from one another (MacDonald and Stimson 1980, Pitcher 1993, Parrish and Polovina 1994). Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters (MacDonald and Stimson 1980, Parrish and Polovina 1994). Juvenile and adult *P. marginatus* do utilize shelter differently from one another (MacDonald and Stimson 1980). Similarly, juvenile and adult *P. pencillatus* also share the same habitat (Pitcher 1993).

In the NWHI, *P. marginatus* is found seaward of the reefs and within the lagoons and atolls of the islands (WPRFMC 1983). Uchida (1986) reports that *P. penicillatus* rarely occur in the commercial catches of the NWHI lobster fishery. In the NWHI, *P. pencillatus* is found inhabiting shallow waters (<18 m) (Uchida and Tagami 1984).

In the NWHI, the relative proportion of slipper lobsters to spiny lobsters varies between banks; several banks produce relatively higher catch rates of slipper lobster than total spiny lobster (Uchida 1986; Clarke et al. 1987, WPRFMC 1986). The slipper lobster is taken in deeper waters than the spiny lobster (Clarke et al., 1987, WPRFMC 1986). Uchida (1986) reports that the highest catch rates for slipper lobster in the NWHI occur between the depths of 20▪55 m.

Pitcher (1993) observes that, in the southwestern Pacific, spiny lobsters are typically found in association with coral reefs. Coral reefs provide shelter as well as a diverse and abundant supply of food items, he notes. Pitcher also states that in this region, *P. pencillatus* inhabits the rocky shelters in the windward surf zones of oceanic reefs, an observation also noted by Kanciruk (1980). Other species of *Panulirus* show more general patterns of habitat utilization, Pitcher continues. At night, *P. penicillatus* moves on to reef flat to forage, Pitcher continues. Spiny lobsters are nocturnal predators (FAO 1991).

P. marginatus is typically found on rocky substrate in well-protected areas such as crevices and under rocks (FAO 1991). During the day, spiny lobsters are found in dens or crevices in the company of one or more other lobsters (WPRFMC 1983). MacDonald and Stimson (1980), studying the population biology of spiny lobsters at Kure Atoll in the NWHI, found that 57% of the dens examined were inhabited by solitary lobsters. The remaining 43% were occupied by more than one lobster, with adult and juvenile lobsters of both sexes often found sharing the same dens. However, the authors note, adult and juvenile spiny lobsters exhibit distinctly different den occupancy patterns, with juveniles (less than 6 cm in carapace length) typically in multiple occupancy dens with other lobsters. Adult and juvenile spiny lobsters are not segregated by geographic area or habitat type at Kure Atoll, MacDonald and Stimson observe. They found that juvenile spiny lobsters do not utilize separate nursery habitats apart from the adult lobsters. The larval spiny lobster puerulus recruits directly to the adult habitat (Parrish and Polovina 1994). This is in contrast to the juveniles of other species of spiny lobsters that tend to reside in shallow water and migrate to deeper, offshore waters as they mature (MacDonald and Stimson 1980).

There are limited data available concerning growth rates, reproductive potentials and natural mortality rates at the various life history stages (WPRFMC 1983). The relationships between egg production, larval settlement, and stock recruitment are poorly understood (WPRFMC 1983).

Occurrence of the Taxon Within WPRFMC Fishery Management Units

American Samoa

The only species of *Panulirus* reported from American Samoa is *P. penicillatus* (Pitcher 1993).

Commonwealth of Northern Mariana Islands (CNMI)

P. penicillatus is the most common species of the genus encountered in the CNMI. *P. longipes* and *P. versicolor* are also found in significant numbers. Regulations prohibit capture of individuals less than 76 mm carapace length and of egg-bearing females (Pitcher 1993).

Guam

P. penicillatus is the most common species of spiny lobster on Guam, and is caught by islanders spearfishing at night. *P. longipes* and *P. ornatus* are also caught occasionally. Regulations are in effect that protect small (<0.45 kg) lobsters (Pitcher 1993).

Of the several hundred species of crustaceans that likely occur on Guam, lobsters of various types are among the most sought-after by local fishermen. They include spiny lobsters (*Panulirus longipes, P. ornatus, P. penicillatus,* and *P. versicolor*); a homarid; and a slipper lobster (*Scyllarus squamosus*)(Green October 1997).

Crabs (True Crabs and Hermit Crabs): Infraorders Brachyura and Anomura

Description

The Brachyura, the so-called true crabs, are one of the largest and most successful groups of decapods. The body form is short and wide, and the abdomen is flexed to fit tightly beneath the cephalothorax. Uropods are generally lacking. Pleopods are retained in females for brooding of eggs, and in males only the anterior two pairs of copulatory pleopods are present. The carapace is typically wider than long. The broad body form, while allowing for crawling in the forward direction, is better suited for sideways movement. Most crabs are poor swimmers, but in the Portunidae (swimming crabs), the last pair of legs are modified into broad paddles, enabling them to swim rapidly (Barnes 1987).

The Anomura contain the hermit crabs and several other interesting groups, such as the Porcellanidae (porcelain crabs). In the Anomura, the fifth pair of legs is reduced. However, the abdomen is not reduced (as in brachyurans) and uropods are generally present. The anomuran superfamily Pagurolidea, the hermit crabs, have adapted to living the majority of their adult life with their abdomens protected in abandoned shells of gastropods. In these types, the abdomen is modified to fit inside the spiral chamber of the gastrpopod shell. The porcelain crabs, often found in commensal relationships with sea anemones, resemble true crabs in having symmetrical, flexed abdomens, but the abdomens are longer than in typical brachyurans (Barnes 1987).

Reproduction and Life History

When brachyurans copulate, the female lies under the male facing in the same position or with ventral surfaces opposed. The male inserts the first pair of pleopods into the openings on the female's abdomen. Fertilization is internal. The abdomen, which is normally in a tightly flexed position, is lifted to a considerable degree to permit brooding. The egg mass, often orange in color is called a sponge. Eggs hatch out into a zoea larval stage, easily recognized by the presence of a long rostral spine, and sometimes a pair of lateral spines that project from the posterior of the carapace. The postlarval megalops is also quite distinctive, already possessing the flexed abdomen and the full complement of appendages found in the adult (Barnes 1987).

Hermit crabs partially emerge from their gastropod shell shelters to mate. The mating pair appress their ventral surfaces, and eggs and spermatophores are released simultaneously. Eggs hatch into a zoea larval phase, and metamorphose into glaucothoë postlarvae (Barnes 1987).

Habitat and Ecological Requirements

Crabs exhibit an astonishing array of structural and behavioral adaptations that enable them to occupy a wide range of niches within the coral reef habitat and associated environs. They may bury themselves in high littoral sands, occupy crevices or burrows among subtidal rocks and coral heads, or live on the surfaces of marine plants or other invertebrates. Their commensal associations include living in the mantle cavities of bivalves (pea crabs, Pinnotheridae); living among the tentacles of sea cucumbers (sea cucumber crab, Portunidae), attaching varied invertebrates to their carapaces for camouflage (sponge crabs, Dromiidae; decorator crabs, Majidae); or holding anemones in their chelipeds for defense (boxer crabs, genus *Lybia*). Additional ecological and habitat notes, where available, are provided in Section IV.C.4.e., below.

<u>Occurrence of the Taxon Within WPRFMC Fishery Management Units</u>

Commonwealth of Northern Mariana Islands (CNMI)

Asakura et al. (1994) collected 27 species of anomurans in the Northern Marianas. Among these was the coconut crab, *Birgus latro* (Coenobitidae). Its distribution includes most islands of the Marianas, including Guam, Saipan and Tinian.

Takeda et al. (1994) reported on the results of collections of crustaceans made during a survey of the remote islands of the Northern Marianas in 1992. The majority of the collections were from the rocky intertidal and high subtidal zones. Subtidal collections were from the 3m depth zone, usually on coral. The following families and genera of crabs, and number of species (in parentheses) were recorded:

Dromiidae: Cryptodromia (1); Dynomenidae: Dynomene (1); Majidae: Menaethius (1), Perinea (1), Tiarinia (1); Parthenopidae: Daira (1); Atelecyclidae: Kraussia (1); Portunidae: Charybdis (1), Thalamita (2); Xanthidae: Chlorodiaella (1), Forestia (1), Lachnopus (1), Leptodius (1), Liomera (1), Lophozozymus (1), Lybia (1), Macromedaeus (1), Paraxanthias (1), Phymodius (1), Pilodius (2), Pseudoliomera (4), Xanthias (2); Menippidae: Dacryopilumnus (1), Epixanthus (1), Eriphia (1), Lydia (1), Ozius (1), Pseudozius (1); Pilumnidae: Nanopilumnus (1), Parapilumnus (1); Trapeziidae: Domecia (2), Tetralia (2), Trapezia (9); Ocypodidae: Ocypode (2); Grapsidae: Grapsus (2), Geograpsus (3), Pachygrapsus (2), Cyclograpsus (1), Plagusia (1), Percnon (1); Gecarcinidae: Cardisoma (1).

Guam

Several crabs (*Carpilius maculatus*, *Etisus dentatus*, *E. utilis*, *Calappa calappa* and *C. hepatica*) are among the species of shellfish sought by local fishermen (Green October 1997).

Table 83. Summary of post-embryonic development and larval types in Decapoda.[9]

Group	Postembryonic Development	Larvae
Suborder Dendrobranchiata		
Family Penaeidae	slightly metamorphic	nauplius > protozoea > mysis (zoea) > mastigopus (postlarva)
Family Sergestidae	metamorphic	nauplius > elaphocaris (protozoea) > acanthosoma (zoea) >mastigopus (postlarva)
Suborder Pleocyemata		
Infraorder Caridea	metamorphic	protozoea > zoea > parva (postlarva)
Infraorder Stenopodidea	metamorphic	protozoea > zoea > parva (postlarva)
Infraorder Palinura	metamorphic	phyllosoma (zoea) > puerulus, nisto, or pseudibaccus (postlarva)
Infraorder Astacidea	slightly metamorphic	mysis (zoea) > postlarva
Infraorder Anomura	metamorphic	zoea > glaucothoë [in pagurids], or grimothea (postlarva)
Infraorder Brachyura	metamorphic	zoea > megalopa (postlarva)

[9] After Waterman and Chace (T. H. Waterman [ed.]: Physiology of Crustacea, Vol. 1) *in* Barnes 1987.

Table 84. Habitat description for Cephalopods (Class Cephalopoda).

	Egg	Larvae	Juvenile	Adult
Duration		N/A (no larval phase)	unknown	in many cases, cephalopods die shortly after spawning; 1-2 year life span is typical (e.g., 12-15 months after settling from planktonic juvenile phase in *Octopus cyanea*); *Nautilus* may live up to 10 years
Diet	yolk	N/A	in *Nautilus*, eggs hatch directly to juvenile phase; juveniles believed to start immediately scavenging and grazing	generally predators on fishes, shrimps, crabs and mollusks; *Nautilus* may scavenge upon crab and lobster molts
Distribution	*Nautilus* may have a single annual egg laying season, peaking around October; a few (10-15) large (mean 29mm) eggs are produced by each female *Euprymna scolopes* may have two reproductive periods per year in other taxa (e.g., *Octopus cyanea*) no seasonality noted	N/A	*Euprymna scolopes* goes through a short (<1 week) planktonic juvenile phase	nautiloids may migrate into deeper waters in daytime, rise to shallower reef flats at night to feed
Location	octopods attach eggs to rocky recesses on the reef reef cuttlefish deposits eggs among branches of finger coral; other cuttlefish may attach eggs to seagrasses; *Euprymna scolopes* attaches eggs to dead coral reef squid attach eggs to rocks and coral *Nautilus* attaches egg capsules to hard substrate	N/A		*Octopus* spp. in American Samoa, CNMI, Guam, NWHI, MHI *Nautilus pompilius* is found in American Samoa, perhaps the easternmnost extension of its range reef squid and cuttlefish in CNMI, Guam *Euprymna scolopes* cuttlefish endemic to Hawaii *Sepioteuthis lessoniana* believed nearly extirpated in Hawaii
Water Column		N/A	in octopod species with smaller, less developed eggs, juveniles may be planktonic and then settle to benthic existence; other octopod species may not have planktonic phase juveniles of other cephalopods generally have a planktonic phase	interidal, high subtidal (e.g., octopods, *Euprymna*); mesopelagic (squids, cuttlefishes); 60-500m (nautiloids) nautiloids may migrate into deeper waters in daytime, rise to shallower reef flats at night to feed
Bottom Type		N/A		octopods mostly in holes and crevices in rocky or coral areas, but some types in burrows in sand; squid and cuttlefish over reefs or seagrass areas; *Euprymna scolopes* burrows in sand on shallow sand and mud flats
Oceanic Features	N/A	N/A		some reef-associated squids semi-pelagic

Table 85. Habitat description for Tunicates (Class Ascideacea).

	Egg	Larvae	Juvenile	Adult
Duration	solitary forms release eggs to the water; in colonial forms, fertilization is internal and larvae, not eggs are released	▪tadpole• larvae are non-feeding, and thus short-lived; larval phase may last from several minutes to a few days	rapid transition from larval to adult zooid phase, with no marked juvenile phase	typically 1-3 year life span
Diet	N/A	nutrition derived from yolk sac; some forms have endosymbionts that may contribute photosynthate product to the ascidian host as a food source	N/A	adults filter-feed non-selectively on phytoplankton and other suspended food particles and nutrients
Distribution	egg production occurs year-round	in some species studied (e.g., *Diplosoma similis*), larvae are released year-round		wide range of species known from most locations in the region; many species dispersed as fouling organisms transported on boat hulls
Location	eggs may be found in peribranchial cavity during embryonic development; in solitary forms, fertilization and subsequent development occurs outside the parent body	in colonial forms, larvae are typically held in the peribranchial cavity, or may be in a brood pouch or the basal test	N/A	range from high-light and high-energy environments (especially those forms with photosynthetic endosymbionts), to protected deeper-water areas
Water Column	N/A	larvae generally in same depth range as adults, approx. 0-100 m (or deeper); larvae in *Diplosoma similis* first swim up to enter layers with faster current, then swim down to settle on substrate	N/A	intertidal to 120 m depth or greater
Bottom Type	N/A	attach to dead corals, seaweeds, mangrove roots, other sessile invertebrates; favor attachment to darker surfaces with lower illumination	N/A	dead corals, seaweeds, mangrove roots, other sessile invertebrates; may also overgrow live coral
Oceanic Features	N/A	larvae in *Diplosoma similis* first swim up to enter layers with faster current, then swim down to settle on substrate	N/A	N/A (sessile attached organisms)

Table 86. Habitat description for Bryozoans (Phylum Bryozoa or Ectoprocta).

	Egg	Larvae	Juvenile	Adult
Duration	approximately two weeks from fertilization to development and release of larva	two types: •non-feeding coronate larvae: planktonic for a few hours •feeding (cyphonautes) larvae develop in those forms that shed eggs directly to the sea (e.g., in *Membranipora*): cyphonautes may last several months	no distinct juvenile phase; following adhesion of larva to substrate, all larval organs undergo histolysis within approx. one hour from the onset of metamorphosis, forming ancestrula (first zooid of colony)	large colonies may add 2-4 cm growth annually and believed to live for ten years or more
Diet	in some species, developing embryo receives its nutrition from a contained yolk, but in others, placenta-like connections to the ovicell from the mother zooid may provide food material	cyphonautes larvae are planktotrophic; "non-feeding" types may take up dissolved organic nutrients (e.g., amino acids)		selective suspension-feeders that consume diatoms, bacteria, flagellates, and phytoplankton
Distribution				adult colonies may be transported as fouling organisms on ships' hulls; various species found throughout all sites in the region
Location	eggs may variously be: •small sized, fertilized at the time of discharge into seawater (e.g., *Membranipora*); •larger, brooded internally in coelomic cavity during embryonic development; •brooded in specialized ovicells	may develop internal or external to parent zooid		usually found on shaded surfaces (e.g., undersides of coral tables)
Water Column		larvae are initially positively phototropic, and move upward in water column; later become negatively phototropic and move toward shaded areas (e.g., under stones or coral plates) prior to settlement		benthic sessile organisms occurring from intertidal to abyssal depths, but majority associated with substrates at 20-80m depth; preference for clear water free of suspended silt and sediment
Bottom Type		larvae highly selective in choosing attachment site; usually settle on rock, dead coral, seaweeds or wood		adults attached to rock, dead coral, seaweeds or wood
Oceanic Features		January thermal boundaries (e.g. 27 degree C isotherm may act as filtering mechanisms that determine larval distribution		steady water currents essential for successful filter-feeding function; however, waves may be destructive of delicate erect, branching or foliose colonies

Table 87. Habitat description for Crustaceans (Class Malacostraca [in part]).[10]

	Egg	Larvae	Juvenile	Adult
Duration	30-40 days in lobster; 29 days in kona crab	⨳zoea larvae last up to 3 months in stomatopods ⨳in penaeids, eggs hatch to the nauplius or metanauplius stage, last for a few weeks ⨳in spiny lobster phyllosomae may last approx. 6 months to 1 year (shorter in other lobsters), metamorphose into pueruli which last 6 months, and after settling, post pueruli ⨳brachyurans and anomurans hatch to zoea phase, develop into megalops and glaucothöe postlarvae, respectively	up to six years (in coconut crab)	most species several years; up to 50 years in coconut crab
Diet	N/A	generally planktivorous		various, but typically carnivorous or omnivorous predators or scavengers, with preferred food items being mollusks, other crustaceans, and small fish; some taxa are specialized cleaners that feed on ectoparasites, while others are filter feeders
Distribution	in spiny lobster spawning continuous throughout the year, with individual females spawning up to 4 times each year, producing up to 0.5 million eggs each spawning; other species may have more defined spawning seasons			all major groups known or assumed to be well-represented at all locations in the region (e.g., around 2,000 species of crabs are known from the region)
Location	in penaeid shrimps, eggs are shed directly to the water; in other decapod groups and in stomatopods eggs carried on the pleopods of the female			
Water Column		in lobsters, newly-hatched larvae may occur in upper 60m, but later larval stages may occur in deeper water (80-120m)		⨳stomatopods are generally subtidal from 5-70m depth ⨳coral associated shrimps generally found in depths from 3-15m but may be found much deeper ⨳lobsters generally occur in depths between 20-55m, but may occur to at least 110m ⨳crabs may be terrestrial, intertidal, or subtidal to depths of at least 115m

	Egg	Larvae	Juvenile	Adult
Bottom Type			juvenile spiny lobsters occupy habitat similar to that of adults	×stomatopods typically in burrows, either in sand or rubble ×shrimp may stay buried in sand or live in pockets in coral or among rubble ×lobsters typically in subtidal holes or crevices on reefs ×crabs may occupy mud or sand bottom, corals, or rocky areas
Oceanic Features		palinurid larvae may be transported up to 2,000 miles by prevailing ocean currents		while some taxa are pelagic, these are generally not reef-associated

[8] The MUS as defined here includes mantis shrimp (Order Stomatopoda), as well as shrimps, lobsters, and crabs (various taxa within the Order Decapoda). The taxa not already addressed under Amendment 10 of the *Crustacean Fisheries Management Plan* (which covers spiny lobsters and kona crab) are the primary emphasis here.

Table 88. Economic importance of invertebrates.

FMU	Economic Importance				Distribution					
	Food	Ornamental	Bio-prospecting	Fouling Organism	AS	CNMI	GU	MHI	NWHI	Other
CEPHALOPODS:										
octopus	⚒	L			⚒	⚒	⚒	⚒ R	⚒ R	A
squid and cuttlefish	⚒				A	⚒	⚒	⚒	A	A
nautilus	L	⚒			⚒					
TUNICATES			⚒	⚒	A	⚒	⚒	⚒	⚒	⚒
BRYOZOANS			⚒	⚒	A	A	A	⚒	A	A
CRUSTACEANS:										
stomatopods	L	L			A	⚒ R[11]	⚒	⚒	A	⚒
shrimps	⚒	⚒			A	⚒ R[1]	⚒	⚒	⚒	⚒
lobsters	⚒	L			⚒	⚒ R	⚒R	⚒R	⚒R	⚒
crabs	⚒	L			⚒	⚒ R[1]	⚒ R[12]	⚒ R[13]	⚒ R	⚒

L = Limited Use

A = Assumed to be Present; R = Regulated

[11] all invertebrates regulated (for export)
[12] coconut crab
[13] blue crab, Samoan crab

4.2.2.5 Bibliography

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4.2.3 EFH for Management Unit Species ▪ Sessile Benthos

The concept of essential fish habitat (EFH) is of obvious value when used as a tool to protect individual fisheries. It is defined as that habitat necessary for their various stages of managed species life histories to perpetuate. To consider the sessile benthos (SB) as required by the Interim Final Rule (IFR) for EFH, the concept must be qualified. This is because it is applied to broad groups of organisms, many of which form the habitat upon which all other species depend. Due to the large numbers of species of coral, algae and other sessile benthos (450 spp algae; 99 Scleractinia and 150 spp. of the other groups considered in Hawaii (Eldredge and Miller, 1995) and a total of approximately 1200 spp of the combined groups in the total AFPI), the concept loses definition and becomes too generalized to be of value. The vast numbers of SB do not represent a managed fishery. This is particularly the case when considering the benthos of coral and algae. Tables 89 to 92 summarize the various aspects of EFH for algae in the Western Pacific Region.

The fauna and flora, generally, lack mobility in the adult stages with the intermediate stages are transported in the water column until settlement. Once they have settled they largely become habitat. They are instrumental in the ecosystems primary production and are largely responsible for supporting the higher trophic levels, many with predator-prey relationships. The high degree of symbiosis begins with the zooxanthellate associations and encompasses a wide degree of associations involving all groups of the fauna and flora. Much of the physical relief of the reef is the result of the living environment as is the deposition of the coral reef itself. An overly simplistic assessment of the habitat requirements for the sessile benthos includes suitable substrate, water quality and light. This, however, negates the history of the substrate development and the myriad of biological interactions, which qualify as a coral reef. Due to these considerations, the species and their fundamental roles in the ecosystem define the EFH as the coral reefs themselves. As such, all coral reefs in the AFPI should be designated EFH for the sessile benthos. This is because all of the coral reef associated fisheries for which the Magnuson-Stevens Fisheries Conservation and Management Act was designed to protect and conserve depend on the coral reef ecosystem.

As there is no fisheries extraction of the sessile benthos in the AFPI, the objective of the concept discussion shifts to the life history characteristics of the fauna and flora of the coral reef environment. It is the life history stages of the selected benthic groups that comprise the discussion of their importance in the EFH description. It is important in the consideration of the management unit species (MUS).

Life histories and habitat requirements rely on an understanding that the coral reef is a variable and dynamic entity. The composition of the reefs responds to environmental parameters such as temperature, dilution and sedimentation. Regionally, their composition varies in response to temperature by virtue of latitude, current regimes and events brought on by unique climatic events such as El Nino hot spots. Such major discontinuities in taxa occurrence such as the absence of the genus *Acropora* in Hawaii or reef cementing coralline alga in extra-tropical areas, require that we consider reefs on a regional basis, as well as, locally. The history of a particular area is as important as short-term community cycles and is often seen to be decadal in time frame, and most probably represents longer cycles. The fossil record of reefs shows a process of progressive change in the nature of reefs. Current

concern for global warming and the effects of some of the hotspots may require this to be added to the equation, when human induced impacts are considered.
The interconnectivity of the coral reef, in terms of potential recruitment, provide us with an understanding of the reef environment that is at once very robust and able to restore itself after the most destructive natural events. The coral reef is fragile, in that, if the composition of a reef is changed then the effect is likely to be manifest down current as well. A chronic change in the environmental parameters of an area is likely to result in a permanent change in the community composition. In summary, EFHs are not a useful concept for the numerous sessile benthos at the species level but rather a conformation of the importance of the many non-commercial species that comprise the coral reef ecosystem. In developing this as an operational framework, Conservation of these broad groups may be accomplished in two ways. 1) It may be appropriate to establish criteria for the amount of reef that is allowed to be affected by development, fishing practices or tourism. This quantity would be established in relation to the amount of area of unaffected reef, within the range of the ocean currents that would allow restoration or maintenance of this area through recruitment. 2) Equally useful is the concept of the *management unit species (MUS)* in making the description of the ecosystem more manageable with better resolution in its definition. Here generic assemblages or their interactions are considered entities, which allow a more categorical method of management.

The Management Unit Species (MUS): An Ecosystem Approach

The concept of the management unit species (MUS) is a useful concept when considering a resource composed of species or higher taxa who share the same habitat, have the same trophic ecology or respond to changing environmental variables in a predictable way. Coral reef zonation, as the result of an environmental regime, reflects a natural MUS organization. Whether through tolerance or requirement, benthos is sorted into a zonation with respect to the proximity to land, depth or wave action. Impacts which add nutrients, as the result of some human activity, to a naturally low-nutrient coral reef and the community changes from being micro-algal and coral dominated, to being macro-algal and with a great reduction in the hard coral component. In the case of increases in sediments and freshwater, there is a reduction in species numbers in both groups to those which are resistant to such effects. Tidal influences of periodic exposure, ponded waters or exposure to wave action have a dramatic effect in conditioning species compliments.

The MUS may be defined in relation to the environmental variables, be it natural or induced. With respect to this, taxonomic classification does not conform to groupings by environmental tolerances. As a result, a wide range of taxonomic groups is considered depending on the type of organism. This section describes these groups as general taxonomic entities. Depending on the availability of information or scale of consideration, in an operational sense, the appropriate taxonomic level should be used. As an example, *Porites/Favid* assemblages are characteristic of areas of periodic flooding. *Acropora* assemblages and a micro-algal assemblage are characteristic of normal seawater salinity with clear, flowing aerated water. Add wave action to this and the coral assemblages become reduced in diversity and morphology characterized by robust or encrusting forms. Coralline alga dominated. The dynamic potential inherent in coral reef communities becomes apparent with a change in the environment as the result of some change in a natural parameter resulting from development or terrestrial activity.

In conforming to the MUS approach, using the general taxonomic groupings of sessile benthos was considered for designations of the MUS. Within these groups species can be clumped based on selection by environmental parameters. Suggested divisions are the hard and soft coral and the micro and macro-alga. Other benthic groups of reef associated organisms (*Porifera*, *Actinaria, Hydroidea, Gorgonacea and Zooanthidea*), generally, are less dominate in reef communities and more liable to conform, in terms of abundance, to the dominance exhibited by the primary groupings. In terms of the reef community composition, these more minor groups are largely coral or algal associated with the type and abundance of coral or alga conditioning their occurrence. It is useful to consider the light limited environments of depth or caves where the groups such as the *Gorgonacea* and *Porifera* may be dominant.

It would be in error not to emphasize considering the regionality of such a framework. The Caribbean and Florida seaboard are very different than the Indo-Pacific. Within the Indo-Pacific, species occurrence, generally, winnows from west to east and is limited when approaching the temperate boundaries. As a result, geographic locations may vary in terms of their species complements. This gives rise to variability in dominance but does not change the relationship within the four major groupings. The species within the groupings become less consequential, varying in dominance depending on the region.

Habitat Areas of Particular Concern (HAPC)

Habitat areas of particular concern for the benthos of coral reefs may include a variety of situations. These may be the same as those which give rise to marine protected areas or where a conservation area has been set aside to protect organisms which may have been depleted through fishery harvest. Particular concern may be for an area where coastal development has adversely impacted near shore areas. With respect to this, it may be that areas within ocean current range should be protected to conserve areas which are unprotectable due to a requirement for subsistence fishing, recreational usage, damage done by circumstances of coastal development or activities inland such as agriculture. It may be that an area is of concern due to the long history of research at a particular site or area and the encroachment of development (e.g. Pago Pago Harbor, American Samoa). Reserves, national parks, wildlife refuges and other protected areas are existing operational areas of particular concern.

4.2.3.1 Algae

Algal Life Cycles

Both sexual and asexual reproduction are widespread in algae, and the predominance of one or the other is mainly linked to the class of algae in question (Cyanobacteria, Chlorophyta, Phaeophyta or Rhodophyta) and the predominant geographical and environmental conditions affecting the algal populations (Bold and Wynne, 1985). Unicellular algae reproduce mainly asexually, while multicellular algae have asexual or sexual life cycles of varying complexity. Sexual life cycles are classified into four basic types, according to the site of meiosis or reduction-division of the algal genome (table I). By far the most common type is the sporic life cycle, in which a usually diploid sporophyte stage alternates with a usually haploid gametophyte stage. The recurring sequence of these two stages is called alternation of generations, which can be either isomorphic (when both generations are morphologically similar) or heteromorphic (where one generation can differ markedly in morphology from the other).

Table 89. Classification of sexual algal life cycles (after South and Whittick, 1987)

Life cycle type	**Site of meiosis**	**Main algal groups concerned**
Zygotic	zygote	Unicellular algae (Chrysophyceae)
Sporic	sporangia	Rhodophyta, Phaeophyta, Chlorophyta
Gametic	gametangia	Chlorophyta
Somatic	thallus cells	Chlorophyta, Rhodophyta

Cyanophyta

In the Cyanophyta, reproduction is primarily by the production of asexual spores, which are released into the environment and grow into new individuals. These spores can be produced by budding from the free ends of the filaments, or by the fission of large vegetative cells within the thallus.

Phaeophyta

In most members of the Phaeophyta, sexual reproduction is sporic, with the alternation of a haploid gametophyte generation with a diploid sporophyte generation; both generations may or may not be morphologically similar. Spores are usually numerous and motile, being produced in unilocular sporangia.

Chlorophyta

The Chlorophyta life cycle is variable, but a typical case can be demonstrated in the common genera *Ulva*, where zoospores are produced in the thallus which are released and fuse to produce a new individual.

Rhodophyta

Most members of the Rhodophyta exhibit a sporic life cycle, a majority of which are of the triphasic *Polysiphonia*-type. The gametophytes and the tetrasporophyte are often isomorphic (although in some algae the tetrasporophyte can be crustose and alternate with large fleshy gametophytes). The Carposporophyte is reduced, and attached to the female gametophyte. The gametes are non-motile.

Distribution patterns of algae amongst the American Flag Pacific Islands (AFPI) (with nomenclature updated (following taxonomy in Silva *et al*. 1996), from available literature;

excludes varietal status of species). The attached AFPI algae distribution table lists 815 taxa of marine algae, statistically broken down as follows:

Table 90. Algae distribution in the American Affiliated Pacific Islands (AFPI)

AFPI locality	Cyanophyta	Chlorophyta	Phaeophyta	Rhodophyta	Total
American Samoa	15	31	14	68	128
Baker Is.	1	6	3	6	16
Howland Is.	0	5	1	3	9
Jarvis Is. [1]	-	-	-	-	-
Palmyra Is.	19	39	11	64	133
Kingman Reef [1]	-	-	-	-	-
Johnston Atoll	19	24	9	40	92
Hawaii [2]	3	48	29	343	423
NWHI	0	43	32	121	196
Wake Island	2	8	10	3	23
CNMI	5	55	20	57	137
Guam	16	58	29	98	201
Total	52	142	70	333	

[1] no data available at this time
[2] Abbott (1995) estimates the total Hawaiian flora at about 400 species

Comments

Because the reported distribution is related to the sampling effort in each particular locality, the comparisons are largely artificial at this stage. For instance, the Guam and North West Hawaiian floras are fairly well-known, while the Jarvis Is., Kingman Reef, Wake Is, Baker and Howland Islands floras are seriously under-collected or unknown. For the Hawaiian flora, there is a large amount of as yet unpublished material which will drastically increase the number of known species in the near future (Abbott 1995).

The most comparable groups of algae are the Phaeophyta and Chlorophyta, because they are mostly intertidal in habitat and thus most easily collected and inventoried, and there is a relatively constant number of common species across the AFPI islands for the better investigated localities.

Distribution Among Islands

From an examination of the species distribution table, the most commonly reported species (those which occur in 50% or more of the localities under study) for the islands of the AFPI are as follows, according to class:

Table 91. Most commonly reported algal species for the islands of the AFPI

Class	Most common species	Typical reef habitat
Cyanophyta	*Lyngbya majuscula*	inner reef flat
	Schizothrix calcicola	inner reef flat
Chlorophyta	*Boodlea spp.*	inner / outer reef flat
	Bryopsis pennata	inner reef flat / lagoon
	Caulerpa racemosa	inner / outer reef flat
	Caulerpa serrulata	inner reef flat / lagoon
	Dictyosphaeria spp.	inner reef flat / lagoon
	Halimeda discoidea	inner reef flat
	Halimeda opuntia	inner reef flat
	Neomeris annulata	inner reef flat
	Ventricaria ventricosa	reef flat / outer reef slope
Phaeophyta	*Dictyota friabilis*	reef flat
	Feldmannia indica	reef flat
	Hincksia breviarticulata	reef crest / exposed shoreline
	Lobophora variegata	reef flat / lagoon
	Sphacelaria spp.	reef flat / epiphytic
	Turbinaria ornata	reef flat / bommies in lagoon
Rhodophyta	*Amphiroa fragilissima*	inner reef flat
	Asparagopsis taxiformis	reef crest / outer reef slope
	Centroceras clavulatum	reef flat / epiphytic
	Gelidiopsis intricata	inner reef flat / lagoon
	Gelidium pusillum	inner reef flat
	Hydrolithon reinboldii	reef crest
	Hypnea esperi	inner reef flat
	Jania capillacea	reef flat
	Martensia fragilis	outer reef slope
	Neogoniolithon brassica-florida	reef crest
	Polysiphonia spp.	reef flat
	Porolithon onkodes	reef crest
	Portieria hornemanni	outer reef slope

Habitat distribution of the common algal species in the AFPI (After N' Yeurt, 1999)

The Flora of Fringing Reefs

In shallow, calm fringing areas where sediment accumulations are predominant, green and brown algae are most abundant with the most characteristic species being *Caulerpa spp.*, *Chlorodesmis fastigiata*, *Halimeda spp.*, *Neomeris spp.*, *Ventricaria ventricosa* and *Boodlea spp.* for the greens, and *Padina spp.* and *Dictyota spp.* for the browns. Common red algae include *Galaxaura* spp. and *Laurencia* spp. When water depth and movement are more important, hard substrata (coral colonies and rubble) are more numerous and ubiquitous species such as *Turbinaria spp.* and *Sargassum spp.* thrive. In very exposed places, the marine scenery is generally rocky or limited to small shelves below the border road. The violent wave action increases sea spray and enables the rise of certain species notably the two brown algae *Chnoospora minima* and *Hincksia breviarticulata*. On this type of shelf we generally find the flora of external reef shelves described later, confined to a few square meters owing to the intensity of the hydrodynamic factors such as wave action.

The Flora of the Barrier Reef

On barrier reefs, coral bommies are generally dominant, between which are spread out well sorted-out sediments. The pavement of the lagoon floor is visible in areas of strong hydrodynamism. Water level rarely exceeds 2.5 m. The flora is essentially one of hard substrata, and species exist in close link with the coral colonies, resulting in a mosaic pattern of species distribution. The summit of coral bommies skimming the water surface are generally colonised by the large brown algae *Turbinaria ornata* and *Sargassum spp.*, that form an elevated layer under which grow species such as *Amansia sp.*, and coralline algae. In areas where grazing by herbivores is more important, the bommies are covered by a fine tuft where a great number of discrete species belonging to the Ceramiaceae and Rhodomelaceae intermingle. In areas where hydrodynamism is more important, the encrusting coralline algae form pinkish, yellowish and bluish blotches on the upper parts of the substratum.

At the base of bommies, it is common to see large bunches of brown algae such as *Dictyota bartayresiana*, intermingled to the spread-out thalli of *Halimeda opuntia* and tufts of the red algae *Galaxaura fasciculata* and *G. filamentosa*. Most crevices are colonised by *Ventricaria ventricosa*, *Valonia fastigiata*, and *Dictyosphaeria spp*. Finally, where direct sunlight does not reach, live a range of encrusting coralline algae whose pink, violet and purple hues mingle with the soft green colours of *Halimeda spp.* and *Caulerpa spp.*

The Flora of the Outer Reef Flats

It is probably the richest and most diversified flora of the reef complex. On high islands, it is represented by a belt of the brown algae *Turbinaria ornata* and *Sargassum spp.*. We find in particular the erect and stiff tufts of *Laurencia spp. and Gelidiella spp.*, to which are attached the little bright green balls of *Chlorodesmis fastigiata*, or the light pink hemispherical cushions of the articulated Corallinaceae *Amphiroa spp.* and the opportunistic *Jania spp*. It is here that the encrusting calcified algae form the most important growths, with notably *Hydrolithon* spp. However, it is on the reef flats of atolls that Corallinaceae formations are the most exuberant. They form a compact pad of a beautiful brick-red colour, and in very exposed places even construct spectacular corbellings several tens of centimetres thick. The dominant species is *Hydrolithon onkodes* with a rather smooth texture. On atolls, large brown algae are absent and the fleshy species are limited to yellowish-brown rosettes of *Lobophora variegata* and *Turbinaria spp.*

The Flora of the Lagoons of Atolls

The sandy bottoms of the lagoons are often in deeper parts, covered with a mucous film rich in bacteria or of a carpet of Cyanobacteria where mingle tufts of filamentous red algae such as *Polysiphonia*, *Ceramium*. The hard substrata are always much richer in various green algae such as *Caulerpa* and *Halimeda*. Bommies in the lagoon offer a habitat for green genera such as *Cladophoropsis spp.* and very large varieties of *Dictyosphaeria cavernosa*.

The Flora of the Outer Reef Slope

It extends beyond 10 meters depth. The red algae are most abundant and diversified. It is the main area of encrusting coralline algae (mainly in the atolls), but also of elegant and fleshy forms such as *Gibsmithia hawaiiensis* and *Asparagopsis taxiformis*. As one goes deeper, coralline algae become the dominant species, although occasionally species of the green algal genus *Halimeda* and the brown algal genus *Lobophora* have been found up to depths of 130 metres (Littler *et al*. 1985) while the green alga *Caulerpa bikinensis* has been reported beyond depths of 70 metres (Meinesz *et al*. 1981).

<u>The Ecological Role of Algae in the Coral Reef Ecosystem</u>

Benthic algae are a very important, yet often overlooked component of any reef biome. Marine plants are responsible for the primary productivity of the reef ecosystem, owing to their photosynthetic ability which inputs solar-derived energy into the reef community. This energy is made available to other reef organisms in a variety of forms, ranging from direct input (grazing by hervibores; symbiotic relationships with invertebrates and fungi) or indirectly by the breaking down of plant products and detrital residues after death.

Algae play an important role in organic and inorganic material cycles within the reef community, by being able to retain and uptake key elements such as nitrogen and carbon. The primary role of marine algae in the carbon and nutrient cycles of coral reef ecosystems cannot be underestimated and has been the focus of much research (Dahl 1974; Wanders 1976; Hillis-Colinvaux 1980; Payri 1988; Charpy and Charpy-Roubaud 1990; Charpy-Roubaud and Sournia 1990; Charpy-Roubaud *et al*. 1990, Charpy *et al*. 1992; Gattuso *et al*. 1996).

Calcified (*Halimeda* and *Amphiroa spp.*) and crustose coralline algae play a major but easily overlooked role in coral reef construction and consolidation, and contribute a major part of reef carbonate sediments (Payri 1988). These organisms lay down calcium carbonate as calcite, which is much stronger than the brittle aragonite produced by corals, thus cementing and consolidating the reef structure. In particular, coralline algae are of primary importance in constructing the algal ridge that is characteristic of exposed Indo-Pacific reefs, which prevent oceanic waves from striking and eroding coastal areas (Nunn 1993; Keats 1996). At the other extreme, penetrating or boring algae such as Cyanophyta are important contributors to bioerosion and breakdown of dead reef structures (Littler and Littler 1994).

Marine macroalgae contribute significantly to organism interrelationships in reef ecosystems, either by the production of chemical or structural by-products on which other organisms depend, the providing of protective micro-habitats for other species of algae or marine invertebrates, or by offering surfaces promoting the settlement and growth of other algal species or the larvae of some herbivorous invertebrates such as abalone (Dahl 1974; Keats 1996). Symbiosis is also an important aspect of algal interrelationships in reef communities, with hermatypic corals relying on photosynthetic zooxanthellae for food. Marine plants thus offer a remarkable potential as experimenting organisms in the elucidation of the complex chemical and biological interactions that make up the fragile, closed ecosystems of tropical coral reefs (Littler and Littler 1994).

The Effects of Human Activities on Coral Reefs, in Relation to Algae

The impact of human habitation, and activities linked to industries and waste processing and disposal have proven negative impacts on coral reef ecology. An "healthy ecosystem" is a self-regulating unit where ecological productivity and capacity is maintained, with a diversity of flora and fauna present (Federal Register 1997: 66551). Some reef organisms are very sensitive to disruptions, and can act as timely indicators of changes in the natural balance of the ecosystem. For instance, the absence of *Acropora* coral on the backreef areas could indicate polluted waters with high levels of siltation, a situation reported from the stressed Aua Reef on Tutuila Island, American Samoa (Dahl and Lamberts 1977). The green algae *Enteromorpha* spp. and *Ulva* spp. thrive in high-nutrient areas, acting as bio-indicators of organic pollution linked to sewage outfalls, and also accumulate heavy metals present in industrial effluents (Tabudravu 1996). Dredging and increasing reclamation of coastal mangrove for industrial and urban use further contribute to siltation of the lagoon and the destruction of algal habitats and marine nursery areas. In this respect, algae can be classified as essential fish habitats (EFH) as they are direct contributors to the well-being and protection of fish species, both as a source of food and offering protection to larvae and small fish species. Overfishing in the lagoon reduces the number of herbivorous fishes, destroying the fragile equilibrium between reef organisms, while the input of excess nutrients via sewage and domestic effluents into the lagoon contributes to algal blooms. This can lead to the ecosystem shifting from coral dominance to algal dominance, and abnormal blooms of turf algae have been known to overgrow and kill healthy coral (Dahl 1974; Littler and Littler 1994) while >red tide= dinoflagellate blooms lead to anoxic conditions killing a wide range of marine organisms (Horiguchi and Sotto 1994). Increased chemical pollution of the lagoon could also lead to a bloom of reef-destroying organisms such as the crown-of-thorn starfish (Randall 1972).

Coral reefs have been known to recover relatively well if the stressing factors are removed soon enough before permanent damage is done (Dahl and Lamberts 1977). A strong and healthy barrier reef, in particular the *Porolithon* algal ridge of atolls, acts as a natural breakwater offering protection to coastal areas in the event of cyclones and such natural disasters, which are frequent in the region (Nunn 1993). However, the coral structure can be severely damaged and weakened as a result of siltation, eutrophication and the overgrowing of coral colonies by opportunistic filamentous algae (such as for instance happened in Kaneohe Bay, Hawaii; see Smith 1981), necessitating the construction of artificial barriers.

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Table 92. Algal species occurrence in the AFPI.

AS: American Samoa; PA: Palmyra Atoll; JA: Johnston Atoll; MHI: Main Hawaiian Islands; NWHI: Northwestern Hawaiian Islands; WA: Wake Atoll; CNMI: Commonwealth of Northern Mariana Islands; GU: Guam

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Division Cyanophyta (Blue-green)												
Anacystis dimidiata							X					
Aphanocapsa grevillei	X											
Arthrospira brevis												X
Arthrospira laxissima	X											
Calothrix aeruginosa					X							
Calothrix confervicola												X
Calothrix crustacea							X				X	X
Calothrix pilosa												X
Calothrix scopulorum							X					
Chroococcus turgidus					X							
Entophysalis conferta					X							X
Entophysalis deusta							X					X
Hormothamnion enteromorphoides							X	X				X
Hormothamnion solutum					X							X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Hydrocoleum lyngbyaceum							X					
Hyella caespitosa	X											
Isactis plana							X					
Lyngbya aestuarii					X		X					
Lyngbya confervoides					X		X					
Lyngbya gracilis					X							
Lyngbya infixa					X							
Lyngbya lutea							X					
Lyngbya majuscula	X				X		X	X		X	X	
Lyngbya pygmaea	X											
Lyngbya rivulariarum					X							
Lyngbya semiplana					X							
Lyngbya sordida					X							
Microchaete vitiensis	X											
Microcoleus chthonoplastes					X		X					
Microcoleus lyngbyaceus	X										X	X
Microcoleus tenerrimus							X					
Microcoleus vaginatus							X					
Oscillatoria bonnemaisonii					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Oscillatoria lutea												X
Oscillatoria nigro-viridis							X					
Oscillatoria submembranacea												X
Phormidium corium					X							
Phormidium crosbyanum										X		
Phormidium penicillatum					X							
Phormidium submembranaceum					X		X					
Porphyrosiphon notarisii												X
Radaisea sp.	X											
Schizothrix calcicola	X	X					X				X	X
Schizothrix mexicana	X										X	X
Scytonema figuratum	X											
Scytonema hofmannii	X											X
Scytonema stuposum	X											
Spirulina major					X							
Spirulina subsalsa												X
Spirulina tenerrima							X					
Symploca atlantica							X					
Symploca hydnoides	X				X			X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Symploca muscorum	X											
Division Chlorophyta (Green)												
Acetabularia clavata							X	X				
Acetabularia exigua											X	
Acetabularia moebii							X	X	X		X	
Acetabularia tsengiana							X					
Acetabularia sp.							X					
Anadyomene wrightii					X						X	X
Avrainvillea erecta												X
Avrainvillea lacerata					X							
Avrainvillea obscura											X	X
Avrainvillea pacifica												X
Boergesenia forbesii											X	X
Boodlea coacta											X	X
Boodlea composita					X		X	X	X			X
Boodlea vanbosseae	X				X				X		X	X
Bornetella oligospora											X	

Algae species	**AS**	**BK**	**HL**	**JV**	**PY**	**KG**	**JS**	**HI**	**NWHI**	**WK**	**MR**	**GU**
Bornetella sphaerica								X	X			
Bryopsis harveyana	X											
Bryopsis hypnoides									X			
Bryopsis pennata	X				X		X	X	X		X	X
Bryopsis plumosa											X	X
Bryopsis pottsii	X											
Bryopsis sp.								X				
Caulerpa ambigua					X		X	X	X		X	
Caulerpa cupressoides										X	X	X
Caulerpa elongata											X	
Caulerpa fastigiata											X	
Caulerpa filicoides											X	X
Caulerpa lentillifera								X				X
Caulerpa lessonii												X
Caulerpa okamurai											X	X
Caulerpa peltata	X								X	X	X	X
Caulerpa plumaris												X
Caulerpa racemosa	X						X	X	X		X	X
Caulerpa serrulata			X		X			X	X	X	X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Caulerpa sertularioides								X			X	X
Caulerpa taxifolia								X	X		X	X
Caulerpa urvilliana					X		X				X	X
Caulerpa vickersiae					X						X	
Caulerpa verticillata								X				X
Caulerpa webbiana								X	X		X	X
Chaetomorpha antennina	X							X	X			
Chaetomorpha indica								X				X
Chaetomorpha restricta	X											
Chamaedoris orientalis												X
Chlorodesmis fastigiata	X											X
Chlorodesmis hildebrandtii					X			X	X		X	X
Cladophora crystallina					X		X					
Cladophora fascicularis								X				
Cladophora glomerata	X											
Cladophora inserta					X							
Cladophora patentiramea					X							X
Cladophora patula								X				
Cladophora pinniger	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Cladophora socialis					X				X			
Cladophora vagabunda									X			
Cladophora sp.		X			X			X	X	X		
Cladophoropsis fascicularis											X	
Cladophoropsis gracillima		X	X		X							
Cladophoropsis infestans	X											
Cladophoropsis limicola	X											
Cladophoropsis luxurians								X				
Cladophoropsis membranacea								X			X	X
Cladophoropsis sundanensis					X			X				
Cladophoropsis sp.							X					
Codium arabicum							X	X	X			
Codium dichotomum								X				
Codium edule								X	X		X	
Codium geppiorum	X				X							
Codium mamillosum								X	X			
Codium ovale												
Codium phasmaticum								X				
Codium reediae								X	X			

Algae species	**AS**	**BK**	**HL**	**JV**	**PY**	**KG**	**JS**	**HI**	**NWHI**	**WK**	**MR**	**GU**
Codium spongiosum								X				
Codium tomentosa												X
Codium sp.							X		X			
Derbesia attenuata					X							
Derbesia marina					X		X					
Derbesia ryukiuensis					X							
Derbesia sp.							X					
Dictyosphaeria cavernosa		X	X		X			X	X	X	X	
Dictyosphaeria versluysii	X	X			X		X	X	X		X	X
Enteromorpha clathrata	X				X							X
Enteromorpha compressa												X
Enteromorpha flexuosa	X											
Enteromorpha intestinalis	X				X			X	X			
Enteromorpha kylinii		X			X		X					
Enteromorpha prolifera	X											
Enteromorpha tubulosa					X				X			
Enteromorpha sp. 1									X			
Enteromorpha sp. 2									X			
Enteromorpha sp. 3									X			

Algae species	**AS**	**BK**	**HL**	**JV**	**PY**	**KG**	**JS**	**HI**	**NWHI**	**WK**	**MR**	**GU**
Enteromorpha sp.								X				
Halimeda copiosa									X		X	
Halimeda cuneata											X	X
Halimeda cylindracea											X	
Halimeda discoidea	X				X		X	X	X		X	X
Halimeda fragilis					X							
Halimeda gigas												X
Halimeda gracilis					X						X	X
Halimeda incrassata	X										X	X
Halimeda lacunalis											X	
Halimeda macroloba	X										X	X
Halimeda macrophysa											X	
Halimeda opuntia	X				X				X	X	X	X
Halimeda tuna							X		X		X	X
Halimeda velasquezii									X			
Halimeda spp.			X									
Microdictyon japonicum								X	X			
Microdictyon pseudohaptera					X						X	X
Microdictyon setchellianum							X	X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Neomeris annulata	X							X	X	X	X	X
Neomeris bilimbata					X							
Neomeris dumetosa											X	X
Neomeris vanbosseae								X				
Ostreobium quekettii	X						X					X
Palmogloea protuberans							X					
Phaeophila dendroides					X							
Phaeophila engleri					X							
Phyllodictyon anastomosans								X	X			X
Pseudobryopsis oahuensis								X				
Pseudochlorodesmis furcellata											X	X
Pseudochlorodesmis parva							X					
Rhipidosiphon javensis								X	X		X	
Rhipilia geppii					X							
Rhipilia orientalis										X		
Rhipilia sinuosa												X
Rhizoclonium hieroglyphicum	X											
Rhizoclonium implexum	X				X							
Rhizoclonium samoense	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Rhizoclonium tortuosum												X
Siphonocladus tropicus								X				
Spongocladia vaucheriaeformis											X	X
Struvea delicatula											X	
Struvea tenuis											X	X
Tydemannia expeditionis	X										X	X
Udotea argentea											X	X
Udotea indica											X	
Ulva fasciata		X	X					X	X			
Ulva reticulata								X				
Ulva rigida									X			
Ulva sp.									X			
Valonia aegagropila								X	X		X	X
Valonia fastigiata	X											X
Valonia trabeculata								X				
Valonia utricularis					X						X	X
Ventricaria ventricosa	X						X	X	X		X	X
Zygomitis sp.					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Division Phaeophyta (Brown)												
Chnoospora implexa								X				X
Chnoospora minima	X							X	X			X
Colpomenia sinuosa								X	X			X
Dictyopteris australis								X	X			
Dictyopteris plagiogramma								X	X	X		
Dictyopteris repens	X								X	X	X	X
Dictyota acutiloba								X	X			
Dictyota bartayresiana								X			X	X
Dictyota cervicornis												X
Dictyota crenulata									X			
Dictyota divaricata					X			X	X	X	X	X
Dictyota friabilis	X		X		X			X	X			
Dictyota hamifera											X	
Dictyota lata	X											
Dictyota patens											X	X
Dictyota sandvicensis								X				
Dictyota sp.							X		X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Dictyota sp. 1										X		
Dictyota sp. 2										X		
Dilophus radicans												X
Ectocarpus vanbosseae	X											
Ectocarpus sp.					X		X					
Endarachne binghamiae								X				
Feldmannia indica	X	X			X		X		X		X	X
Feldmannia irregularis					X		X					
Hapalospongidion pangoense	X							X				X
Hincksia breviarticulata	X						X	X	X	X	X	
Hincksia conifera									X			
Hincksia mitchelliae									X			
Homoeostrichus flabellatus											X	
Hormophysa triquetra											X	
Hydroclathrus clathratus								X	X		X	X
Lobophora papenfussii					X							
Lobophora variegata					X		X	X	X	X	X	X
Nemacystus decipiens									X			
Padina australis								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Padina boergesenii									X			
Padina crassa									X			
Padina gymnospora												X
Padina japonica								X	X			
Padina jonesii											X	X
Padina pavonia								X		X		X
Padina tenuis											X	X
Padina thivyi								X				
Padina sp.										X		
Ralfsia occidentalis								X				
Rosenvingea intricata								X			X	X
Sargassum anapense	X											
Sargassum crassifolium												X
Sargassum cristaefolium											X	X
Sargassum echinocarpum								X	X			
Sargassum fonanonense	X											
Sargassum hawaiiensis									X			
Sargassum microphyllum											X	
Sargassum obtusifolium								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Sargassum piluliferum									X			
Sargassum polycystum												X
Sargassum polyphyllum								X	X			
Sargassum tenerrimum												X
Sargassum sp.									X			
Spatoglossum solierii								X				
Sphacelaria ceylanica	X											
Sphacelaria cornuta	X											
Sphacelaria furcigera	X				X		X	X				X
Sphacelaria novae-hollandiae					X		X	X	X			X
Sphacelaria rigidula									X			
Sphacelaria tribuloides							X		X			X
Sphacelaria sp.		X			X						X	
Sporochnus dotyi									X			
Stypopodium hawaiiensis								X	X		X	
Turbinaria condensata												X
Turbinaria ornata	X	X						X	X	X	X	X
Turbinaria trialata					X						X	X
Zonaria hawaiiensis												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Division Rhodophyta (Red)												
Acanthophora pacifica								X				
Acanthophora spicifera								X			X	X
Acrochaetium actinocladium								X				
Acrochaetium barbadense								X				
Acrochaetium butleriae								X				
Acrochaetium corymbifera								X				
Acrochaetium dotyi								X				
Acrochaetium gracile					X							
Acrochaetium imitator								X				
Acrochaetium liagorae								X				
Acrochaetium microscopicum								X				
Acrochaetium nemalionis								X				
Acrochaetium robustum					X			X				
Acrochaetium seriatum								X				
Acrochaetium trichogloeae								X				
Acrochaetium sp.									X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Acrosymphyton taylorii								X				
Actinotrichia fragilis	X							X			X	X
Actinotrichia robusta											X	
Aglaothamnion boergesenii								X		X		
Aglaothamnion cordatum								X	X			
Ahnfeltiopsis concinna								X				
Ahnfeltiopsis divaricata												
Ahnfeltiopsis flabelliformis												
Ahnfeltiopsis pygmaea												
Alsidium cymatophilum								X				
Alsidium pacificum					X							
Amansia glomerata									X			X
Amphiroa anceps	X											
Amphiroa beauvoisii								X	X			
Amphiroa crassa	X											
Amphiroa foliacea	X							X				X
Amphiroa fragilissima	X							X	X		X	X
Amphiroa rigida								X				
Amphiroa valonioides								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Amphiroa sp.							X					
Anotrichum secundum	X							X				
Anotrichum tenue								X				
Antithamnion antillanum					X		X	X				
Antithamnion decipiens								X	X			
Antithamnion erucacladellum								X				
Antithamnion nipponicum								X				
Antithamnion palmyrense					X							
Antithamnion percurrens								X				
Antithamnion sp.									X			
Antithamnionella breviramosa								X	X			
Antithamnionella graeffei								X				
Apoglossum gregarium								X				
Ardreanema seriospora								X				
Arthrocardia sp.								X				
Asparagopsis taxiformis	X				X			X	X		X	X
Asterocystis ornata					X		X					
Balliella repens								X				
Bangia atropurpurea								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Bostrychia tenella	X											
Botryocladia skottsbergii								X			X	
Botryocladia tenuissima								X				
Branchioglossum prostratum								X				
Callidictyon abyssorum								X				
Callithamniella pacifica								X				
Callithamnion marshallensis							X					
Callithamnion sp.							X		X			
Calloglossa leprieurii					X		X					
Calloglossa viellardii	X											
Caulacanthus ustulatus								X				
Carpopeltis bushiae												
Centroceras clavulatum	X				X		X	X	X		X	X
Centroceras corallophilloides								X				
Centroceras minutum					X			X				X
Ceramium aduncum								X				
Ceramium affine							X		X			
Ceramium borneense								X				
Ceramium byssoideum	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ceramium cingulum								X				
Ceramium clarionense					X			X	X			
Ceramium codii					X			X				
Ceramium dumosertum								X				
Ceramium fimbriatum							X	X				
Ceramium flaccidum								X	X			
Ceramium gracillimum		X			X		X					
Ceramium hamatispinum								X	X			
Ceramium hanaense								X				
Ceramium jolyi								X				
Ceramium masonii					X							
Ceramium maryae							X					
Ceramium mazatlanense	X							X	X		X	
Ceramium paniculatum								X				
Ceramium punctiforme	X							X				
Ceramium serpens					X			X				
Ceramium taylori					X							
Ceramium tenuissimum								X				
Ceramium tranquillum								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ceramium vagans					X		X	X				X
Ceramium womersleyi								X				
Ceramium zacae							X					
Ceramium sp.		X			X		X		X			
Ceratodictyon spongiosum											X	
Chamaebotrys boergesenii								X				
Champia compressa	X											X
Champia parvula							X	X	X			X
Champia vieillardii								X				
Cheilosporum acutilobum	X											
Cheilosporum spectabile	X											
Chondracanthus acicularis								X				
Chondracanthus tenellus								X				
Chondria arcuata								X				
Chondria dangeardii								X				
Chondria minutula								X				
Chondria polyrhiza								X				
Chondria simpliciuscula								X				
Chondria repens					X		X		X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Chondria sp.									X			
Chondria sp. 1									X			
Chondria sp. 2									X			
Chondrus ocellatus								X				
Chroodactylon ornatum								X				
Chrysymenia kairnbachii								X				
Chrysymenia okamurae								X				
Chrysymenia procumbens								X				
Coelarthrum albertisii									X			
Coelarthrum boergesenii									X			
Coelothrix irregularis								X				
Corallina elongata								X				
Corallophila apiculata					X		X	X	X			
Corallophila huysmansii							X	X				X
Corallophila itonoi								X				
Corallophila ptilocladioides								X				
Crouania mageshimensis								X	X			
Crouania minutissima							X	X	X			
Crouania sp.								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Cruoriella dubyi					X							
Cruoriopsis mexicana					X							
Cryptonemia decumbens	X											
Cryptonemia umbraticola					X			X				
Cryptonemia yendoi												
Cryptopleura corallinara								X				
Cubiculosporum koronicarpus								X				
Dasya adhaerens							X					
Dasya bailouvianna									X			
Dasya corymbifera									X			
Dasya kristeniae								X				
Dasya murrayana								X				
Dasya pilosa								X				
Dasya sinicola							X					
Dasya villosa									X			
Dasya sp.							X	X				
Dasyopsis sp.								X				
Dasyphila plumarioides												X
Delesseriopsis elegans								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Dermocorynus occidentalis								X				
Dermonema virens											X	
Dermonema pulvinatum								X				
Diplothamnion jolyi								X				
Ditria reptans								X	X			
Dotyophycus pacificum								X				
Dotyophycus yamadae								X				
Dotyella hawaiiensis								X	X			
Dotyella irregularis								X				
Dudresnaya hawaiiensis								X				
Dudresnaya littleri								X				
Dudresnaya sp.									X			
Erythrocladia irregularis					X							
Erythrocolon podagricum								X				
Erythrotrichia carnea					X			X				
Erythrotrichia parietalis					X							
Erythrotrichia sp.							X					
Eucheuma denticulatum							X					
Eupogodon sp.									X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Euptilocladia magruderi								X				
Exophyllum wentii								X				
Fernandosiphonia ecorticata								X				
Fernandosiphonia nana								X				
Fosliella farinosa												X
Galaxaura elongata											X	
Galaxaura fasciculata								X				
Galaxaura fastigiata								X				
Galaxaura filamentosa	X							X			X	X
Galaxaura glabriuscula												X
Galaxaura marginata	X							X			X	X
Galaxaura obtusata								X			X	
Galaxaura pacifica									X		X	
Galaxaura rugosa	X							X	X		X	
Galaxaura subfructiculosa											X	
Galaxaura subverticillata								X				
Galaxaura sp.									X			
Ganonema farinosum								X				
Gelidiella acerosa								X				X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Gelidiella antipai								X				
Gelidiella bornetii					X							
Gelidiella machrisiana								X				
Gelidiella myrioclada								X				X
Gelidiella stichidiospora					X							
Gelidiella womersleyana												
Gelidiella sp.	X											
Gelidiocolax mammillata								X				
Gelidiopsis acrocarpa												X
Gelidiopsis intricata	X				X			X	X		X	X
Gelidiopsis pannosa											X	X
Gelidiopsis repens	X											
Gelidiopsis rigida												X
Gelidiopsis scoparia								X				
Gelidiopsis variabilis								X				
Gelidiopsis sp.			X									
Gelidium abbotiorum	X											
Gelidium crinale					X		X	X				
Gelidium delicatulum	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Gelidium pluma								X				
Gelidium pusillum	X				X		X	X	X		X	X
Gelidium reediae								X				
Gelidium samoense	X											
Gibsmithia dotyi								X				
Gibsmithia hawaiiensis	X							X				
Gloiocladia iyoensis								X				
Goniolithon frutescens					X							
Goniotrichum alsidii							X					
Goniotrichum elegans					X							
Gracilaria abbottiana								X				
Gracilaria arcuata												X
Gracilaria bursapastoris								X				
Gracilaria cacalia												X
Gracilaria coronopifolia								X	X			
Gracilaria dawsonii								X				
Gracilaria dotyi								X				
Gracilaria edulis											X	
Gracilaria epihippisora								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Gracilaria filiformis								X				
Gracilaria lemaneiformis								X				
Gracilaria lichenoides								X				X
Gracilaria minor											X	X
Gracilaria radicans												X
Gracilaria parvispora								X				
Gracilaria salicornia								X				X
Gracilaria tikvahiae								X				
Gracilaria verrucosa												X
Grateloupia filicina								X				
Grateloupia hawaiiana								X				
Grateloupia phuquocensis								X				
Griffithsia heteromorpha								X				
Griffithsia metcalfii							X	X				
Griffithsia ovalis							X					
Griffithsia schousboei								X				
Griffithsia subcylindrica								X				
Griffithsia tenuis							X					X
Griffithsia sp.					X		X					

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Gymnogongrus sp.								X				
Gymnothamnion elegans								X				
Halarachnion calcareum												X
Halichrysis coalescens								X				
Haliptilon subulatum								X	X			
Haloplegma duperreyi	X							X	X			
Halymenia actinophysa								X				
Halymenia chiangiana								X				
Halymenia cromwellii								X				
Halymenia durvillaei												X
Halymenia formosa								X				
Halymenia lacerata											X	X
Halymenia stipitata								X				
Hawaiia trichia								X				
Helminthocladia rhizoidea								X				
Helminthocladia simplex								X				
Herposiphonia arcuata								X				X
Herposiphonia crassa								X				
Herposiphonia delicatula								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Herposiphonia dendroidea									X			X
Herposiphonia dubia								X	X			
Herposiphonia nuda								X	X			
Herposiphonia obscura								X				X
Herposiphonia pacifica								X	X			X
Herposiphonia parca								X	X			
Herposiphonia secunda	X				X			X	X			X
Herposiphonia variabilis								X				X
Herposiphonia sp.							X		X			
Heterosiphonia crispella					X		X	X	X			
Heteroderma subtilissima					X							
Heteroderma sp.					X							
Hydrolithon breviclavium								X				
Hydrolithon reinboldii	X							X	X			X
Hypnea cervicornis								X	X			
Hypnea chloroides								X				
Hypnea chordacea								X				
Hypnea esperi					X		X		X		X	X
Hypnea musciformis								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Hypnea nidulans	X				X							
Hypnea pannosa	X							X	X			X
Hypnea rugulosa								X				
Hypnea spinella					X			X	X			
Hypnea valentiae								X				
Hypnea sp.		X										
Hypnea sp. 1									X			
Hypnea sp. 2									X			
Hypneocolax stellaris								X				
Hypoglossum attenuatum	X										X	
Hypoglossum barbatum								X				
Hypoglossum caloglossoides								X				
Hypoglossum minimum								X				
Hypoglossum rhizophorum								X				
Hypoglossum simulans								X				
Hypoglossum sp.									X			
Janczewskia hawaiiana								X				
Jania adhaerens	X							X				
Jania capillacea	X	X			X		X		X		X	X

Algae species	**AS**	**BK**	**HL**	**JV**	**PY**	**KG**	**JS**	**HI**	**NWHI**	**WK**	**MR**	**GU**
Jania decussato-dichotoma					X		X		X		X	
Jania mexicana									X			
Jania microarthrodia			X					X	X	X		
Jania natalensis									X			
Jania pumila								X				
Jania radiata												X
Jania tenella					X						X	X
Jania ungulata									X			
Jania verrucosa								X				
Jania sp.								X				
Kallymenia sessilis								X				
Kappaphycus alvarezii								X				
Kappaphycus striatum								X				
Laurencia brachyclados								X				
Laurencia cartilaginea								X				
Laurencia ceylanica	X										X	X
Laurencia corymbosa									X			
Laurencia crustiformans								X				
Laurencia decumbens								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Laurencia dotyi								X				
Laurencia forsteri								X				
Laurencia galtsoffii								X	X			
Laurencia glandulifera								X				
Laurencia intricata											X	X
Laurencia majuscula								X	X			X
Laurencia mariannensis								X				
Laurencia mcdermidiae								X				
Laurencia nana		X	X									
Laurencia nidifica	X							X	X			
Laurencia obtusa								X	X		X	X
Laurencia papillosa	X											
Laurencia parvipapillata								X	X			
Laurencia perforata									X		X	
Laurencia pygmaea									X			
Laurencia rigida											X	X
Laurencia succisa								X			X	
Laurencia surculigera											X	
Laurencia tenera								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Laurencia tropica											X	
Laurencia undulata								X				
Laurencia yamadana								X				
Laurencia sp.					X		X		X			X
Laurencia sp. 1									X			
Laurencia sp. 2									X			
Laurencia sp. 3									X			
Laurencia sp. 4									X			
Laurencia sp. 5									X			
Lejolisia colombiana					X							
Lejolisea pacifica								X				
Leveillea jungermannioides								X			X	X
Liagora albicans								X				
Liagora boergesenii								X				
Liagora ceranoides								X	X			
Liagora coarctata									X			
Liagora divaricata								X				
Liagora farinosa									X			
Liagora hawaiiana								X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Liagora hirta	X											
Liagora kahukuana									X			
Liagora orientalis								X	X			
Liagora papenfussii								X	X			
Liagora perennis												
Liagora pinnata								X				
Liagora samaensis								X				
Liagora robusta									X			
Liagora setchellii								X	X			
Liagora tetrasporifera								X				
Liagora valida								X	X			
Liagora sp.	X									X	X	
Liagorophyla endophytica								X				
Lithophyllum kaiserii	X											
Lithophyllum kotschyanum								X			X	X
Lithophyllum moluccense	X										X	X
Lithophyllum sp.								X				
Lithoporella melobesioides											X	X
Lithoporella pacifica												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Lithoporella sp.	X											
Lithothamnion asperulum												X
Lithothamnion byssoides								X				
Lithothamnion funafutiense												X
Lithothamnion philippii												X
Lithothamnion spp.					X				X			
Lomentaria hakodatensis					X		X	X				
Lomentaria sp.		X										
Lophocladia kipukaia								X				
Lophocladia trichoclados									X			
Lophosiphonia bermudensis					X							
Lophosiphonia cristata								X	X			
Lophosiphonia obscura	X											
Lophosiphonia prostrata								X				
Lophosiphonia scopulorum					X							
Lophosiphonia sp.					X							
Martensia fragilis	X							X	X		X	X
Mastophora lamourouxii												X
Mastophora macrocarpa												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Mastophora melobesoides	X											
Mastophora plana												X
Mastophora rosea												X
Mazzaella volans								X				
Malaconema minimum								X				
Melanamansia daemelii								X				
Melanamansia fimbrifolia								X				
Melanamansia glomerata								X				
Mesophyllum erubescens	X											X
Mesophyllum mesomorphum	X							X				X
Mesophyllum simulans	X											X
Micropeuce setosus								X				
Monosporus indicus								X				
Murrayella periclados												X
Myriogramme bombayensis								X				
Naccaria hawaiiana								X				
Neogoniolithon brasica-florida	X				X			X			X	X
Neogoniolithon fosliei												X
Neogoniolithon medioramus												

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Neogoniolithon pacificum												X
Neogoniolithon reinboldii											X	
Neomartensia flabelliformis								X				
Nitophyllum adhaerens								X				
Osmundaria obtusiloba								X				
Ossiella pacifica								X				
Peleophycus multiprocarpium								X				
Peyssonelia conchicola								X				
Peyssonelia corallis											X	X
Peyssonelia delicata	X											
Peyssonelia foveolata	X											
Peyssonelia inamoena								X				
Peyssonelia mariti	X											
Peyssonelia rubra	X				X			X				
Peyssonelia sp.									X			
Phaeocolax kajimurai								X				
Platoma ardreanum								X				
Pleonosporium caribaeum								X				
Peonosporium intricatum								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Plocamium sandwicense								X	X			
Polyopes hakalauensis								X				
Polysiphonia anomala								X				
Polysiphonia apiculata								X				X
Polysiphonia beaudettei								X				
Polysiphonia delicatula								X				X
Polysiphonia exilis								X	X			
Polysiphonia flaccidissima								X				X
Polysiphonia hancockii								X				
Polysiphonia hawaiiensis								X				
Polysiphonia herpa								X				X
Polysiphonia homoia								X				
Polysiphonia howei								X				
Polysiphonia pentamera								X				
Polysiphonia poko								X				X
Polysiphonia polyphysa									X			
Polysiphonia poko								X				
Polysiphonia profunda								X				
Polysiphonia pseudovillum								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Polysiphonia rubrorhiza								X	X			
Polysiphonia saccorhiza								X	X		X	
Polysiphonia savatieri								X	X			X
Polysiphonia scopulorum	X				X			X	X			X
Polysiphonia setacea								X				X
Polysiphonia simplex								X	X			
Polysiphonia sparsa								X				X
Polysiphonia sphaerocarpa								X	X			X
Polysiphonia subtilissima								X				
Polysiphonia tepida								X				
Polysiphonia tongatensis	X							X				
Polysiphonia triton								X				
Polysiphonia tsudana								X				
Polysiphonia tuberosa												
Polysiphonia upolensis								X	X			X
Polysiphonia sp.	X				X		X		X		X	X
Polystrata dura	X											
Porolithon craspedium					X						X	X
Porolithon gardineri					X			X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Porolithon marshallense					X							
Porolithon onkodes	X				X			X			X	X
Porolithon sp.									X			
Porphyra vietnamensis								X				
Portieria hornemanni	X							X	X		X	X
Predaea laciniosa								X				
Predaea weldii								X				
Prionitis corymbifera								X				
Prionitis obtusa	X											
Pterocladia capillacea								X				
Pterocladia musiformis					X							
Pterocladia parva									X			X
Pterocladia tropica					X							
Pterocladia sp.					X							
Pterocladiella bulbosa								X				
Pterocladiella caerulescens								X				
Pterocladiella caloglossoides								X				
Pterocladiella capillacea								X				
Pterosiphonia pennata								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ptilocladia yuenii								X				
Ptilothamnion cladophorae								X				
Pugetia sp.									X			
Reticulocaulis mucosissimus								X				
Rhodolachne decussata								X				
Rhodymenia sp.	X											
Rhodymenia leptophylla								X				
Scinaia furcata								X				
Scinaia hormoides								X				
Spermothamnion sp.					X				X			
Spirocladia barodensis								X				
Spirocladia hodgsoniae								X				
Sporolithon erythraeum	X							X			X	
Sporolithon schmidtii												X
Sporolithon sibogae	X											
Spyridia filamentosa	X							X	X			X
Stenopeltis gracilis								X			X	
Stenopeltis liagoroides								X				
Stenopeltis setchelliae								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Stictosiphonia kelanensis												X
Stylonema alsidii	X							X				
Stylonema cornu-cervi								X				
Symphyocladia marchantioides								X			X	
Taenioma macrourum							X					
Taenioma perpusillum								X	X			
Tayloriella dictyurus								X				
Tenarea tessellatum								X				
Tiffaniella codicola									X			
Tiffaniella saccorhiza								X	X			
Titanophora marianensis												X
Titanophora pikeana								X				
Tolypiocladia glomerulata	X							X			X	X
Trichogloea lubrica								X				
Trichogloea requienii								X	X			
Trichogloeopsis hawaiiana								X	X			
Irichogloeopsis mucosissima								X				
Tricleocarpa cylindrica								X	X			
Tricleocarpa fragilis								X	X		X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ululania stellata								X				
Vanvoorstia coccinea								X				
Vanvoorstia spectabilis								X				
Womersleyella pacifica								X				
Wrangelia anastomosans											X	
Wrangelia dumontii								X				
Wrangelia elegantissima								X				
Wrangelia penicillata								X				
Wrangelia tenuis									X			
Wurdemannia miniata					X			X			X	X
Wurdemannia sp.							X					
Yamadaella coenomyce								X				

***References Used:** Birkland *et al*. 1994; Setchell 1924; Tsuda and Trono 1968; Dawson 1959; Dawson *et al*. 1955; Hillis- Colinvaux 1959; Buggeln and Tsuda 1969; Vernon *et al*. 1966; Abbott 1988; 1999; Bailey and Harvey 1862; Egerod 1952; Eldredge and Paulay 1996; Magruder and Hunt 1979; Abbott 1989; Anon 1999; Bailey and Harvey 1862; Eldredge *et al*. 1977; Tsuda 1981; Tsuda and Wray 1977; Eldredge and Paulay 1996; Gilbert 1978; Gordon 1976; Itono and Tsuda 1980; King and Puttock 1989; Nam and Saito 1991; Tsuda 1981; Tsuda and Wray 1977

4.2.3.2 Porifera (sponges)

Important Summary Documents

Moore (1955) described the paleosponges and their dominance in ancient reefs.
Early records of Pacific sponges Bowerbank (1873) and Agassiz (1906). Bergquist (1965,1967, and 1977) catalogued sponges in Micronesia and Hawaii. Kelly-Borges and Valentine (1995) have reviewed the status of the sponges of Hawaii.

Taxonomic Issues

No overall classification of the *Porifera* exists. Calcarea: Burton (1963); Vacelet (1970). Demospongiae Levi (1973) and Bergquist (1978). Sclerospongiae: Hartman & Goreau (1970, 1975) Hexactinellida: Ijima (1927). De Laubenfels (1950a,b 1951, 1954; 1957) recorded the sponges from Hawaii. Species numbers: 84 species in Hawaii Berquist (1977); Chave and Jones (1991); 5000-9000 spp. (Colin and Arneson, 1991) and 10,000 spp. George and George (1979) world-wide.

Habitat Utilization

Use of chemical agents in competing for substrate. Often found at depth, in caves, and vertical areas where not colonized by hard coral. Rutzler and Rieger (1973) described the burrowing sponge *Cliona* into a calcareous substrate.

Life History

Adult: Appearance and Physical Characteristics

Vary greatly in size. Most are irregular and exhibit massive, erect, encrusting, or branching growth pattern. Many are brightly colored. The body of the sponge is a system of water canals, where with incurrent pores allow water to flow into the atrium and out through the osculum (asconoid, syconoid, and leuconoid plans). The skeleton may be composed of calcareous and silaceous spicules, protein spongin fibers. The spicules exist in a variety of forms and are important in the identification and classification of species.

Of pharmaceutical interest due to the biologically active compounds, most probably used in defense. Some compounds affective against certain tumors and potential effective in treating other diseases.

Reproductive Strategies

Sexual (viviparous and oviparous), asexual and hermaphroditic. Synchronous release of gametes triggered by lunar or daily cycles. Eggs develop into larvae which swim or creep along the bottom. Asexual reproduction is through budding, fragmentation and gemmules (Barnes, 1987, Fromont, 1994). Recruitment may occur by fragmentation from predation (Kelly-Borges and Berguist, 1988).

Distribution

Table 93 shows the distribution of the sponges in some of the AFPI. In Guam and Mariana Islands Bryan(1973). Briggs (1974) provided information on broad distributions as did

Hooper and Levi, 1994. In Hawaii, biological interactions affect the occurrence of the sponge *Damiriana hawaiiana* Casper (1981). Encrusting sponges may kill corals (Plucer-Rosario, 1987).

Feeding and Food

Particle feeding and ingestion of plankton and bacteria (Reiswig 1971,1975a)
Utilization of DOM, directly or indirectly, by symbiotic cyanobacteria (Barnes 1987; Wilkinson, 1979, 1983).

Behavior

Symbiosis common which includes shrimps, crabs, barnacles, worms, brittlestars, holothurians, and other sponges (Colin and Arneson, 1991). *Tethya sp.* produces filamentous extensions for mobility. *Placospongia* rapidly closes its plate-like surface when touched. *Tedania* (fire sponge) causes burning due to spicules and chemicals. *Hippospongia* and *Spongia* are used as bath sponges.

Diurnal rhythm in the active flow of water (Reiswig, 1971)

Spawning: Spatial and Temporal Distribution

Lunar and diurnal periodicity

Appearance and Physical Characteristics of Eggs (size, shape, color, etc) and Duration of Phase

During mass spawning events (Reiswig, 1971), sperm appears as clouds of smoke. In some cases, release of eggs causes appearance of opaque mucous covering sponge (Colin and Arneson, 1995).

Larvae: Appearance and Physical Characteristics of Larvae

The larval metamorphosis is described by Simpson (1986).

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Table 93. Distribution of sponges within the American Affiliated Pacific Islands (AFPI) (after Kelly-Borges and Valentine, 1995)
AS: American Samoa; HI: Hawaiian Islands; NMI: Commonwealth of Northern Mariana Islands; GU: Guam

Taxonomy/occurrence	**AS**	**HI**	**CNMI**	**GU**
DEMOSPONGIAE				
Homosclerophorida				
Oscarella tenuis		X		
Plakina monolopha		X		
Plakortis simplex		X		
Astrophorida				
Ancorina acervus			X	
Asteropus kaena		X		
Dorypleres splendens			X	
Erylus caliculatus		X		
Erylus proximus		X		
Erylus rotundus		X		
Erylus sollasi		X		
Geodia gibberella		X		
Jaspis stellifera			X	
Melophlus sarasinorum				X
Rhabdastrella pleopora		X		
Stelletta debilis		X		
Zaplethes digonoxea		X		
Lithistida				
Aciculites papillata			X	
Leidermatium sp		X		
Spirophorida				
Cinachyra porosa			X	
Paratetilla bacca			X	
Hadromerida				

Taxonomy/occurrence	AS	HI	CNMI	GU
Anthosigmella valentis		X		
Chondrosia chucalla		X		
Chondrosia corticata			X	
Chondrosia sp		X		
Cliona vastifica		X		
Diplastrella spiniglobata		X		
Kotimea tethya		X		
Placospongia carinata			X	
Prosuberites oleteira		X		
Spheciospongia aurivilla			X	
Spheciospongia purpurea			X	
Spheciospongia vagabunda		X	X	
Spirastrella coccinea		X		
Spirastrella keaukaha		X		
Terpios aploos				X
Terpios granulosa		X		
Terpios hoshinoto				X
Terpios sp				X
Terpios zeteki		X		
Tethya coccinea			X	
Tethya diploderma		X		
Tethya robusta			X	
Timea xena		X		
Halichondrida				
Axechina lissa		X		
Axinella solenoides		X		
Axinyssa aplysinoides				X
Axinyssa pitys			X	
Axinyssa terpnis			X	

Taxonomy/occurrence	AS	HI	CNMI	GU
Axinyssa xutha			X	
Ciocalypta pencillus		X		
Cymbastella cantherella			X	
Densa mollis			X	
Eurypon distincta		X		
Eurypon nigra		X		
Halichondria coerulea		X		
Halichondria dura		X		
Halichondria melanadocia		X		
Higginsia anfractuosa			X	
Higginsia mixta			X	
Homaxinella anamesa		X		
Hymeniacidon chloris		X		
Myrmekioderma granulata			X	
Myrmekioderma sp.				X
Phycopsis aculeata		X		
Pseudaxinella australis			X	
Raphisia myxa		X		
Rhabderemia sorokinae			X	
Stylotella aldis			X	
Stylotella aurantium			X	X
Ulosa rhoda		X		
Haplosclerida				
Adocia gellindra		X		
Adocia turquosia			X	
Adocia viola				X
Aka mucosa			X	
Amphimedon sp				X
Callyspongia aerizusa			X	

Taxonomy/occurrence	AS	HI	CNMI	GU
Callyspongia diffusa		X		X
Callyspongia parva			X	
Gellius gracilis			X	
Haliclona acoroides			X	
Haliclona aquaeducta		X		
Haliclona flabellodigitata		X		
Haliclona koremella			X	
Haliclona lingulata				X
Haliclona pellasarca			X	
Haliclona permollis		X		
Haliclona streble			X	
Haliclona viridis			X	
Niphates cavernosa			X	
Niphates spinosella			X	
Sigmadocia amboinensis			X	
Sigmadocia symbiotica			X	
Toxadocia violacea		X		
Petrosida				
Pellina eusiphonia		X	X	
Pellina pulvilla				X
Pellina sitiens		X		
Petrosia puna		X		
Xestospongia sp				X
Poecilosclerida				
Acamas caledoniensis			X	
Amphinomia sulphurea			X	
Axociella kilauea		X		
Biemna fortis			X	
Clathria frondifera				X

Taxonomy/occurrence	AS	HI	CNMI	GU
Clathria procera		X		
Clathria vulpina			X	
Coelocartaria singaporense			X	
Crella spinulata			X	
Damiriana hawaiiana		X		
Desmacella lampra			X	
Echinodictyum antrodes				X
Esperiopsis anomala		X		
Iotrochota baculifera			X	
Iotrochota protea		X		
Kaneohea poni		X		
Lissodendoryx calypta		X		
Lissodendoryx oxytes			X	
Microciona eurypa			X	
Microciona cecile			X	
Microciona haematodes		X		
Microciona maunaloa		X		
Mycale cecilia		X		
Mycale contarenii		X		
Mycale maunakea		X		
Myxilla rosacea		X		
Naniupi ula		X		
Prianos phlox			X	
Strongylacidon sp.		X		
Tedania ignis		X		
Tedania macrodactyla		X		
Xytopsiphum kaneohe		X		
Xytopsiphum meganese		X	X	
Xytopsues zukerani		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
Zygomycale parishii		X		
Dictyoceratida				
Coscinoderma denticulatum		X		
Fasciospongia chondrodes			X	
Hippospongia densa		X		
Hippospongia metachromia			X	
Hyrtios erecta				X
Lendenfeldia dendyi			X	
Lufferiella sp		X		
Lufferiella variabilis				X
Spongia irregularis dura		X		
Spongia irregularis lutea		X		
Spongia irregularis mollior		X		
Spongia irregularis tenuis		X		
Spongia denticulata		X		
Spongia oceania		X		
Stelospongia lordii		X		
Strepsichordaia lendenfeldi			X	
Verongida				
Aplysinella strongylata			X	
Aplysinella tyroeis			X	
Ianthella basta				X
Psammaplysilla purpurea		X		
Psammaplysilla verongiformis			X	
Dendroceratida				
Aplysilla rosea		X		X
Aplysilla sulphurea		X		
Aplysilla violacea		X		
Dendrilla cactus		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
Dendrilla nigra			X	
Dysidea avara		X	X	X
Dysidea fragilis			X	
Dysidea herbacea		X		
Dysidea sp		X		X
Euryspongia lobata			X	
Pleraplysilla hyalina		X		
Slerosponges				
Acanthochaetetes wellsi			X	
Astrosclera willeyana			X	X
Stromatospongia micronesica			X	X
CALCAREA				
Clathrina sp		X		
Leucetta avacado				X
Leucetta solida		X		
Leuconia kaiana		X		
Leucosolenia eleanor		X		
Leucosolenia vesicula		X		
Murrayona phanolepis			X	
Sycandra coronata		X		
Sycandra parvula		X		
Sycandra staurifera		X		
HEXACTINELLIDA				
Euplectella sp		X		
Stylocalyx elegans		X		

4.2.3.3 *Millepora* sp. (Linnaeus, 1758) (stinging or fire coral)

Important Summary Documents

Lewis (1989) discussed the ecology of Millepora. Growth and age were investigated (Lewis, 1991).

Taxonomic Issues

Class Hydrozoa: Order Milleporina (Hydroidea): Family Milleporidae: 48 species
The history of *Millepora* taxonomy has been the opposite of scleractinian taxonomy where each minor growth form was often described as a new species (Veron, 1986).

Habitat Utilization

Found on projecting parts of the reef where tidal currents are strong. They are also abundant on upper reef slopes and in lagoons and may be a dominant component of some coral communities (Veron, 1986).

Life History

Adult: Appearance and Physical Characteristics

Colonial and hermatypic. Arborescent, plate-like, columnar or encrusting with a smooth surface perforated by near-microscopic pores. These are of two sizes: the larger are the gastropores, with each surrounded by five to seven smaller dactylopores. Fine straight hairs, visible under water, project from the colony surface. The growth variation is often based on environmental influences. Colors are green, cream or yellow. May be tan-coloured antler-like sheets with branch ends whitish.

Distribution

Globally, the genus is distributed from as far south as South Africa and southern Western Australia to the Kyushu Islands. From the African coast of western Indian Ocean and the Red Sea and the Marquesas in the east. The genus also occurs in the Central and Eastern Pacific and the Caribbean Sea.

Table 94 summarizes some Indo-Pacific species (adapted from Lewis 1989): their morphology, depth and reef zone and water circulation requirements.

Table 94. Species summary of the genus *Millepora* (Lewis 1989).

Species	Form	Location on reef	Habitat type
Millepora dichotoma	Fan, branches, vertical sheets and walls	0-5m, reef edge	Turbulent, area of the surf
M. exaesa	Robust branches or solid and round	0-10m, reef edge, outer reef slope	Moderate to turbulent
M. platyphylla	Sheets, leaves fans branches	0-10m, reef edge, reef flat	Strong to powerful, turbulent
M. tenella	Fans, branches, sheets	0-10m, reef edge, outer reef slope	medium to strong

Feeding and Food

Gastrozoiids consume food and are the colony polyps have tentacles and a gastrovascular cavity. The dactylozoiids are used for prey capture and have numerous tentacles, which convey a fuzzy appearance. They have a potent sting. Autotrophic due to zooxanthellae but may rely on small plankton and dissolved nutrients.

Reproductive Strategies

Alternation of generations: a sessile, asexual polyp stage and a free-living, sexual medusa stage. Medusa are reproduced by asexual division or budding. The medusa has separate sexes and produce eggs or sperm, which unite and develop into free-swimming planula larvae. Planula larvae are able to swim freely, though largely planktonic.

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Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.

4.2.3.4 Stylasteridae (Gray, 1847) (Stylasterines; lace corals)

Important Summary Documents

Veron (1986) Colin and Arneson (1995) and Fossa and Nilsen (1998) provide description of the family.

Taxonomic Issues

Class Hydrozoa; Class Stylasterina; Family Stylasteridae
Approximately 15 genera. Two are common reef genera: *Stylaster* Gray 1831 (48 species); *Distichopora* Lamarck 1816 (34 species) (Veron, 1986).
Taxonomy at the species level poorly known.

Habitat Utilization

With in the reef, sciaphilic or low light, often abundant under overhangs or on the roof of caves. Also found in deep reef conditions particularly if swept by tidal currents (Colin and Arneson, 1995)

Life History

Adult: Appearance and Physical Characteristics

Colonial, ahermatypic, usually arborescent, with tubular gastropores surrounded by smaller dactylopores and usually forming cyclosystems (Veron, 1986). Colour is bright and may be red, pink, orange, purple or white.

Stylaster spp.: Colonies are arborescent with fine branches, growing in one plane, which seldom anastomose. Cyclosystems alternate left and right side of branches.

Distichopora spp.: Colonies are arborescent with flattened, blunt-ended, non-anastomosing branches of uniform width, growing in one plane. There are no cyclosystems: gastropores are aligned along the lateral margins of branches with rows of dactylopores on either side (Veron, 1986; Sheer and Obrist, 1986).

Distribution

Stylaster spp.: Worldwide, extending to the Arctic and Antarctic.
Distichopora spp.: Circum-Australia, Central and the Indo-Pacific.

Feeding and Food

No zooxanthellae so heterotrophic, feeding presumably on small plankton. Dissolved nutrient absorption must be important.

Reproductive Strategies

Sexual individuals, the gonophores, develop in ampullae between the gastropores and release planula larvae.

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Veron J. E. N. 1986. *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.

4.2.3.5 Solanderidae (Gray) (hydroid fans)

Important Summary Documents

Cooke (1977) described Hawaiian fauna all, of which, have a wider distribution.

Taxonomic Issues

Class Hydrozoa; Order Hydroida; Suborder Athecata (=Anthomedusa; Gymnoblastea); Family Solanderiidae (George and George, 1977; Barnes, 1987).

Habitat Utilization

Shallow water to 100 metres (Colin and Arneson, 1995).
Often found in deeper water ore cave or overhang environment (Cooke, 1977).

Life History

Adult: Appearance and Physical Characteristics

Similar in appearance to gorgonians and other sea fans. May be branching, ramose or encrusting. Branching in one plane, perpendicular to the current or wave action. Commonly found in exposed areas on wave swept shallow outer reefs (Colin and Arneson, 1995). *Solanderia spp.* is branching and may be 30cm high. Family is characterized by the presence of a perisarc composed of anastomosing chitinous fibers with scattered capitate tentacles (Cooke, 1977).

Defense is accomplished by the specialized tentacle the dactylozooids.
Colour species dependent: dark brown to yellow brown, red with white tentacle.

Distribution

Occur from western Africa through the central Indo-Pacific. Northerly limit Japan and Hawaii.

From Cooke (1977):
Solanderia minima: Zanzibar, Africa; *Hawaii.*
S. secunda: Central Pacific
S. misakinensis: Japan; Hawaii
S. sp.: New Guinea (Colin and Arneson 1995)

Feeding and Food

Gastrozooids capture and ingest zooplankton that is small enough to be handled.
Extra-cellular digestion takes place in the gastrozooid. The partially digested broth the passes into the common gastrovascular cavity where intracellular digestion occurs.

Reproductive Strategies

Reproduction is by means of fixed gonophores or gonozooids. Applying generalized hydroid reproduction, the gonophores bud off both male and female, mobile medusae, which develop gonads and reproduce. The fertilized egg divides and develops into free-swimming larvae that attach to substrate to form a new hydroid.

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George, D. & J. George, 1979. An Illustrated Encyclopedia of Invertebrates in the Sea *Marine Life.*

4.2.3.6 Scleractinia (stony corals)

Important Summary Documents

Veron (1986) provides a popular taxonomic guide for stony corals and their biology. Birkeland (1997) is a modern synthesis of coral reef dynamics.

Fadlallah, (1983), Harrison and Wallace (1990) reviewed coral reproduction. Richmond and Hunter (1990) compared coral reproduction geographically. Table 96 summarizes the Scleractinia in the US Flag Pacific Islands, while Table 97 includes a summary of the likely zooxaznthellate corals to be found in the Western Pacific Region. .

Taxonomic Issues

Veron and Pichon (1976); Veron, Pichon and Wijsman-Best (1977); Veron and Pichon (1979); Veron and Pichon (1982); Veron and Wallace (1984) have revised the taxonomy of the order Scleractinia in the AIMS Monograph series. Many of the earlier checklists require revision for comparison. References for description and checklists of the AFPI are: Hawaii -Maragos (1977, 1992,1995); Guam - Jones and Randall (1973); CNMI - Randall (1995); American Samoa - Birkeland,, Randall and Amesbury (1994); Lamberts (1980); Wake I. - Anon. (1999); Midway Atoll, Northern Hawaiian Islands - DeFelice, Coles, Muir, Eldredge (1998); Johnston Atoll - Maragos and Jokiel (1986); Jokiel and Tyler (1992); Palmyra Atoll - Maragos (1979, 1988, in prep.)

Habitat Utilization

Stony coral attach to the reef substrate creating a variety of biological habitats on which many other groups rely for shelter and symbiosis. Coral skeletons with the aid of coralline algae create the reef structure.

The distribution of hard coral over the reef is the result of fortuitous settlement and environmental sorting. The history of disturbance in an area plays a large role in the nature of the coral assemblage. Generally, there is a near shore assemblage which is dominated by genera resistant to the influence of the terrestrial factors and tidal variation. (eg. siltation, flooding, and variation in temperature). The genus *Porites*, *Montipora* and *Pavona, in that order* to dominate the reef seleractinians in Hawaii. In Hawaii, the predominantly branching coral genus *Acropora* is rare and generally confined to several areas in the NWHI. Elsewhere in the region, *Acropora, faviids* and *Millepora* are dominant or very common along with the other genera mentioned above. In permanently sub-tidal areas and further offshore the *Acropora* dominate but often in association by substantial growths of a variety of other species. In Hawaii, this dominance is replaced by Montipora and Pocillopora. Stony coral are limited by light (depth), wave action and disturbance.

The AFPI span a broad biogeographic realm from Guam (144^0 45=E long.) to Hawaii (155^0 W. Long) and from American Samoa (15^0 S latitude) to the northern Hawaii Islands (28^0 40= N. Lat). In terms of coral development, the tropical/temperature gradient gives rise to a range of reef types and species assemblages. The luxuriance of the high island reefs of American Samoan, Guam are in contrast to the variety of reefs which occur in Hawaii. The

Jarvis, Baker, Howland, Palmyra Johnston and Wake reefs are atolls as are some of the reefs northern Hawaiian Islands. For most of these areas, varying degrees of information is available, though being generally scant.

Life History

Adult: Appearance and Physical Characteristics

Corals are similar to anemones in having a polyp form which may be colonial or solitary. They are characterized by a hard skeleton of aragonite (calcium carbonate). The colonial form may manifest a variety of forms: branching, tabulate, massive or encrusting. Some forms are species specific while some species respond to environmental influences which condition the colonial morphology. Polyps have tentacle though these are absent in some genera. They are often a crown, in multiples of six, (Hexacorallia) encircling the mouth though these may be manifest in furrows or over the surface as in the solitary *Fungia*. They possess nematocysts. Internally, the mouth opens into a gastrovascular cavity with mensentaries and mesentarial filaments. The mesentaries extend from the scleroseptum. The skeleton has a thecal wall, sclosepta and a basal plate (Barnes, 1987).

The colony expands by budding of new polyps from the bases of old polyps or from the oral discs of old polyps through intra-tentacular or extra-tentacular budding. Polyps of meandroid colonies share a common oral disc bearing many mouths (Barnes, 1987).

Age, Growth, Longevity

Corals can be very long lived for massive species. An estimated 1000 years has been estimated for some massive *Porites*, colonial sizes representing 300 is reasonably common. Growth rates have been recorded by Buddemeir and Kinzie (1976).

Corals as a group have a wide range of growth rates. The rate variable between 0.4 and 22.5 cm per year. The massive corals grow more slowly with a range of 0.4 to 1.8cm. (DeVantier, 1993). Growth also includes fusion of colonies (Table 95).

Table 95. Growth rates among some scleractinian coral.

Species	Growth (cm/yr)
<u>*Faviidae*</u> *Favia, Favites* *Goniastrea,* *Montastrea* *Platygyra*	0-1.38 Mean range 0.07-1.25
<u>*Poritidae*</u> *Porites* *Goniopora*	0-1.88 Mean range 0.13-0.97
<u>*Mussidae*</u> *Lobophyllia* *Symphyllia* *Acanthastrea*	0-1.65 Mean range 0.38-0.94
<u>*Oculinidae*</u> *Galaxea*	0.67-1.18 Mean range 0.54-0.93
<u>*Merulinidae*</u> *Hydnophora*	.56-1.15 Mean 0.86
<u>*Caryophylliidae*</u> *Physogyra* *Euphyllia* *Plerogyra*	0.5-0.75 Mean range 0.5-0.75
<u>*Acroporiidae*</u> *Acropora*	10.17-22.58
<u>*Pocilloporiidae*</u> *Pocillopora*	0.4-3.59

Reproductive Strategies

Corals reproduce by both sexual (external fertilization and development and brooded planulae) and asexual development (brooded planulae, polyp-balls, polyp bail-out, fission, fragmentation and re-cementation). May be bisexual or hermaphroditic (protandric, protogynous or synchronous) (Chorneski and Peters, 1987). Self fertilisation occurs (Heyward and Babcock, 1986).

<u>Asexual modes of reproduction</u>**:**

brooded planulae
polyp-balls: *Goniopora spp.* (Sammarco 1986)
polyp bail-out: *Seriatopora spp.* (Sammarco 1981,1982)
reversible metamorphosis: *Pocillopora damicornis* (Richmond 1985)
fission: *Fungiidae*

fragmentation and re-cementation: *Acropora spp* and others (Tunnicliffe, 1981)
Corals may be free spawners or brooders depending on their geographic distribution. In Hawaii , *Tubastrea* is a brooder but in Australia is a brooder and free spawner.(Harrison and Wallace, 1990)

Sexual maturity depends, on growth as well as colony age (Kojis and Quinn, 1985)
Brooders reach maturity a few years earlier than free spawners. Ahermatypic corals reach sexual maturity earlier than hermatypic corals (Harriot, 1983). Fecundity increases with age. (Soong and Lang, 1992). Availability of light influences fecundity whether through depth or an increase in suspended particles in the water (Kojis and Quinn, 1984) or the reduction of UV light (Jokiel and York, 1982).

Distribution

Table 96 details the occurrence of Scleractinia in the AFPI. Veron (1993b) detailed the global distribution of coral genera and regionally with species. Regional variation in generic occurrence has been documented with latitudinal gradients (Wells 1956).

Zonation within reefs due to environmental influences is well known.(In American Samoa: Birkeland et al. 1994, 1996; In Hawaii: Palmyra Atoll: Maragos 1977, 1988, 1992; In Guam: Jones and Randall).

Discrete coral populations may result from asexual reproduction and possess the same genotype (Hunter, 1985; Willis and Ayre, 1985; Ayre and Resing, 1986) though many appear heterogenous.

Feeding and Food

Stony coral s feed on planktonic organisms or dissolved organic matter (DOM). Capture of prey is by tentacles, suspension feeding occurs and some use mesenterial filaments. Most prey capture at night though some feed during the day.

The presence of symbiotic zooxanthellae makes some corals functional autotrophs (Muscatine et al. 1981) and contribute to all hermatypes nutrition. Muscatine and Porter (1977) determined plankton comprise approx. 20% of coral required nutrition. Franzisket (1970) showed coral could live without plankton, but additional nutrition was required from this source (Johannes et al. 1970). The relative dependance on heterotrophy varies with species and with environment. Sorokin (1973, 1995) described the relative dependence on predation, bacteria and DOM. The zooxanthellae receive elements from predation (i.e. nitrogen, iron, and vitamine B_{12}). Recycling of nutrients between corals and zooxanthellae is well known (Johannes 1974; Muscatine 1973; Porter, 1976).

Behavior

Competition for space is achieved by direct tentacular competition; mesenterial filaments, sweeper tentacles, allopathy, over-growth, shading.

Spawning: Spatial and Temporal Distribution

Mass spawning has been described by Babcock et al. (1986) and follows a lunar periodicity (Richmond and Hunter, 1990). Geographic variation introduces the effects of temperature and other climatic factors. In Australia, (GBR), *A .palifera* spawns only once per year at 23^0S latitude and through out the year at 14^0S lat.(Kojis and Quinn, 1984, 1986a).

Appearance and Physical Characteristics of Eggs (size, shape, color, etc) and Duration of Phase

Eggs are round and may be pink, orange, blue, purple or white. Pigmentation may be UV protection. White eggs are non-fertile in *Galaxea fascicularis.* Maturation of eggs and ejection may be controlled by the hormone Estradiol-17*b* (Atkinson and Atkinson, 1992). Form into egg sperm bundles. Some eggs contain zooxanthellae. Eggs range in size from 1.5 x 1.00mm (*Flabellum rubrum)* to Acorporidae and Mussidae 0.4-0.8mm; Faviidae and Pectiniidae 0.3- 0.5mm, Portitidae, Agariciidae, Fungiidae and Pocilloporidae 0.05-0.25mm. The total length of sperm is <0.005mm. Eggs and sperm production is cyclic and maturity is reached at the same time for most corals. For *Stylophora pistillata* (Rinkevich and Loya, 1979), the time is different for different colonies. *Acropora palifera* spawning may take place in several stages in synchrony with moon phases with six reproductive cycles per year (Kojis, 1986a, b). Free spawners have a 12 month maturation cycle but brooders have several cycles per year.

Spawning is in synchrony with the lunar cycle beginning on the 15^{th} to the 24^{th} night of the lunar cycle. Spawning starts at dusk and continues until midnight. It may vary geographically. A slick is often observed as the gammetes are brought together by currents. Likelihood of fertilization is increased and the abundance of material means predation is decreased through satiation.

Duration of gamete development after spawning is 30 minutes until the ability to fertilise, first cell division 1-2 hours, to planula stage 6-24 hours (Szmant-Froelich et al. 1980; Kojis and Quinn 1982, Bull 1986, Heyward 1986)

Larvae: Appearance and Physical Characteristics of Larvae

It is covered with cilia which provide locomotion. In *Porites porites*, 200 planula may be released from a section of colony ($2cm^2$) (Fadallah, 1983). They are ciliated, spherical initially and oval or pear-like when mobile.

Age, Growth and Duration of Larval Phase

Initially, they move to the surface of the water and drift as a ciliated ball. In 3-7 days they elongate into a conical shape. They have a cavity and mouth and are 1.5mm long with mesenteries developed. They then move to deeper water and seek substrate (Babcock and Heyward, 1986).

Coral with long lived larvae are: *Galaxea aspera* 49 days; Cyphastrea ocellina (Hawaii) 60 days; Acropora spp. 91 days; Pocillopora damicornis (Hawaii) 103 days (Gulko,1999).

Larval Feeding and Food

Nutrition in planulae is achieved as the result of energy reserves transferred from the embryonic cells. Zooxanthellae, most probably, provide nutrition through nutrient translocation. Some planula feed actively.

Habitat Utilization

Some planula have zooxanthallae and may exist for longer in the plankton and disperse further. Most settle with the proximity of the parent <1km. Discussion of factors in dispersal have been reviewed by Harrison and Wallace (1990). Currents must play a major role in the transport of the larvae. Longevity in the plankton will determine the potential distance of dispersal (Richmond, 1987).

Settlement sites are often cryptic. Clumping of planula may give rise to fusion into a single colony.

Habitat Features Affecting the Abundance and Density of Eggs and Larvae

Currents affect the abundance of eggs and larvae, often concentrating them into a dense mass and dispersing them with the flow. Rain storms may cause mass mortality at this stage as does grounding of the slick at low tide or along the shore. After settlement, the planulae develop primary polyps. The settlement site is important. If inshore, large amounts of organic particular matter and sediment will increase mortality. Wave action may destroy the primary polyps. Young polyps may abandon primary calyx, and relocate planktonically (Richmond, 1985) or through bailout responses.

There is the potential for rafting of coral polyps on driftwood or other current borne objects which would allow for the settlement by larvae and polyp growth (Jokiel, 1984).

Abundance and distribution of coral planulae was investigated in Kaneohe Bay, Oahu (Hodgson, 1985) and Bull (1986) for Australia.

Settlement occurs by finding a suitable location. The size of the new polyp is <2mm. Mortality at this stage is high. Both the environmental and biological environment affect the potential for coral development (Goreau, et al. 1981).

In Western Australia, large numbers of fish and coral died as the result of a coral spawn slick being embayed and using up the oxygen and then decaying (Simson 1993).

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4.2.3.7 Fungiidae (Dana, 1846) (mushroom corals)

Important Summary Documents

Veron (1986) provides a species summary of the systematics, anatomy and distribution in Australia and the Indo-Pacific. Veron (1993b) the family Fungiidae is discussed with respect to its global distribution.

Taxonomic Issues

Veron & Pichon (1979) revised the taxonomy of the family Fungiidae.

Has 11 extant genera: Cycloseris (7 spp.), *Diaseris* (4 nominal spp.), *Heliofungia*, *Fungia* (25 spp.), *Herpolitha* (2 spp.), *Polyphyllia* (3 spp.), *Halomitra* (1 spp.), *Sandalolitha* (2 spp.), *Lithophyllon (2 spp.)*, *Podabacia (*1 spp.) and *Zoopilus* (1 spp.).

Habitat Utilization

Begin life as anthocauli attached to a hard substrate. Detach to continue life as a free-living colony inhabiting reef areas unsuitable for permanently attached corals such as sand or rubble.

Life History

Adult: Appearance and Physical Characteristics

All shallow water with the exception of the *Fungiacyathus (not occur AFPI).* The majority are hermatypic, solitary, and free living (not *Lithophyllum or Podabacia)* with attached juvenile stage. They may be individual with one mouth or colonial with many mouths and other anatomy characteristic of a colonial form.

From Veron (1986):
Cycloseris (Edwards & Haime, 1849): Solitary, free-living, flat or dome-shaped, circular or slightly oval in outline with a central mouth. Fine tentacles cover the upper surface of the disc. Pale brown to cream with a darker margin.
Diaseris (Edwards & Haime, 1849): Circular though with an irregular margin and segments. Colour is brown to green.

Heliofungia (Wells, 1966): Solitary, free-living, flat with central mouth. Septa have large lobed teeth. Polyps are extended day and night, and as a single polyp are the largest of all corals. Tentacles are longest of the stony corals and dark purple or green tentacle with pale tips. The oral disc is striped and the single mouth is 30mm wide.

Fungia (Lamarck, 1801): Free-living, circular or elongate

Herpolitha (Eschscholtz, 1825)***:*** Free-living, elongate with and axial furrow that may extend to the corallum ends. Several centers or mouths occur in the furrow. Colonies may be heavily calcified and >1m in length. Tentacles are short and widely spaced.

Polyphyllia (Quoy and Gaimard, 1833): Free-living, elongate with many mouths and tentacles over the upper surface. Larger mouths are down the axial furrow. Long tentacles, which are always extended.

Halomitra (Dana, 1846): Colonies are large and free-living, circular and dome or bell shaped, thin and delicate and without an axial furrow. Corallites widely spaced. Tentacles are small and widely spaced and extended at night.

Sandalolitha (Quelch, 1884): Colonies are large, free-living, and circular to oval, dome-shaped, heavily constructed and without an axial furrow. Corallites are compacted. Pale or darks brown, sometimes with purple margins and white centers.

Lithophyllon *(*Rehberg, 1892): Colonies are attached, encrusting or laminar, unifacial. Colonies may be large, up to several metres. Polyps extended at night. Dull green, grey or brown with white margins or white centers.

Podabacia (Edwards and Haime, 1849): Colonies are attached, encrusting or laminar, unifacial and up to 1.5m in diameter.

Their coloration may be frown, green, red or pink. They may have contrasting stripped design.

Distribution

Cycloseris: Extends from southern Africa to the Red Sea and Arabian Gulf through the Indo- Pacific ranging from south Western Australia, Lord Howe I. and Easter I. in the south to southern Japan in the north. It occurs in the Hawaiian Islands, though not in Midway. It is present in the eastern Pacific from Baja California, northern Mexico to Columbia. The recorded occurrence in the AFPI is Johnston Atoll, Hawaii and Guam

Diaseris: Similar to *Cycloseris* though narrower, extending from southern Madagascar and the Red Sea. Across the Pacific at varying latitude in the north to include Japan and in the south of New Caledonia and the Tuamotus Is. The recorded occurrence in the AFPI is Hawaii.

Heliofungia: Indonesia, Australia, Philippines, Ryukyu Is. east to the Caroline and Solomon Is and south to New Caledonia. The genus does not occur in the AFPI.

Fungia: South of Madagascar, to the Red Sea, Northern Australia, the Great Barrier Reef, south to Lord Howe I. and across to Pitcairn I. Its northerly extent is southern India, Southeast Asia, southern Japan, Midway I., Hawaiian Is. Its easterly extent is the Marquesas Is. The recorded occurrence by virtue of *Fungia scutaria* is present in all AFPI where checklists have been made. Considering the other species of the genus, occurrence is limited to American Samoa, Palmyra Atoll, and Guam.

Herpolitha*:* South of Madagascar to the Red Sea, Northern Australia, the Great Barrier Reef, south to New Caledonia and across to Pitcairn I. Its northerly extent is southern India, Philippines, and Ryukyu Is., Japan. Its easterly extent is the Tuamotus Is. The AFPI that this species is found in is American Samoa, Palmyra Atoll and Guam.

Polyphyllia*:* Central Indo-Pacific: Northern Madagascar and the Seychelles Is in the west. Northern Australia, New Caledonia and Tonga in the south. American Samoa (only AFPI occurrence) in the east and Ryukyu Is, Japan in the north.

Halomitra: West Africa Madagascar in the west through Indonesia to the Line Is in the east. South to New Caledonia and Tonga and north to the Ryukyu I in the north. Present in the AFPI in American Samoa and Palmyra.

Sandalolitha: Occurs in Indonesia and Southeast Asia in the west to the Kyushu Is. in the north. Extends to Northern Australia and New Caledonia and Tubuai Is in the south. Also extends to the Tubuai Is and Line Is in the east. AFPI occurrence limited to American Samoa and Palmyra Atoll.

Lithophyllon: Similar to Sandalolitha, occurring to Indonesia in the west and the Malay Peninsula. Its southerly extent is northern Australia, New Caledonia, and Fiji to the east. It is confined to the western Pacific to include the Philippines and north to southern Japan. There are no occurrences in the AFPI.

Podobacia: Indo-Pacific: Occurs from west Africa and the Red Sea south to Madagascar, Northern Australia, New Caledonia to Tahiti. Range extends to the Fiji in the east. In the north, it extends along Southeast Asia to Japan. There are no occurrences in the AFPI.

Feeding and Food

Heterotrophic: prominent tentacles indicate prey capture. Autotrophic: abundant zooxanthellae.

Behavior

Are partially mobile. May free themselves if buried and some are capable of lateral movement, ability to right themselves, and able to climb over obstacles by using their tentacles and inflating their body cavities.

Mobility in *Cycloseris* by ciliary hairs, by inflation of the body cavity or use of tentacles. Tentacle extended at night.
Fungia and Herpolitha: Polyps are extended only at night.

Reproductive Strategies

Asexual: Fragmentation or natural regeneration through fracture. Many develop attached daughter polyps (acanthocauli) from the parent colony.

Sexual: Dioecious or hermaphroditic. Planula larvae settle to form the attached acanthocauli, which may grow to several centimeters before detaching due to degeneration of the stalk. *Heliofungia* has been reported as hermaphroditic while *Fungia* has separate sexes.

It is likely the family has separate sexes, the females either brood planulae or release gametes (Veron, 1986).

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Table 96. Distribution of Scleractinia (hard coral) in the American Flag Pacific Islands (AFPI).

AS: American Samoa; PA: Palmyra Atoll; JA: Johnston Atoll; MHI: Main Hawaiian Islands; NWHI: Northwestern Hawaiian Islands; WA: Wake Atoll; CNMI: Commonwealth of Northern Mariana Islands; GU: Guam

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Order SCLERACTINIA									
Family ASTROCOENIIDAE									
Stylocoeniella armata (Ehrenberg, 1834)	X						X	X	3
Stylocoeniella guentheri (Bassett-Smith, 1890)							X	X	2
Family THAMNASTERIIDAE									
Psammocora contigua (Esper, 1797)	X							X	2
Psammocora digitata Edward & Haime, 1851							X	X	2
Psammocora explanulata van der Horst, 1922				X					1
Psammocora folium (Syn)	X								1
Psammocora (P.) haimeana Edwards and Haime, 1851	X	X						X	3
Psammocora nierstraszi van der Horst,1921	X		X	X			X	X	5
Psammocora profundacella Gardiner,1898		X						X	2
Psammocora stellata (Verril,1866)		X	X	X	X			X	5
Psammocora superficiales Gardiner,1898	X								1
Psammocora (V.) tutuilensis (Syn)	X								1
Psammocora verrilli Vaughan				X				X	2

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Family POCILLOPORIDAE									
Pocillopora ankeli Sheer & Pillai, 1974	X								1
Pocillopora damicornis (Linnaeus,1758)	X	X	X	X	X			X	6
Pocillopora eydouxi *Edwards & Haime,1860*	X	X	X	X		X		X	6
Pocillopora ligulata Dana, 1846	X			X				X	3
Pocillopora molokensis Vaughan, 1907				X					1
Pocillopora setchelli Hoffmeister,1929	X						X	X	3
Pocillopora verrucosa (Ellis & Solander, 1786)	X	X	X	X	X	X	X	X	8
Pocillopora woodjonesi Vaughan,1918	X							X	2
Seriatopora crassa Quelch, 1886	X								1
Seriatopora hystrix Dana, 1846	X							X	2
Stylophora pistillata Esper, 1797	X	X					X	X	4
Family ACROPORIDAE									
Acropora (A.) aculeus (Dana, 1846)	X					X			2
Acropora (A.) acuminata (Verrill, 1864)	X	X						X	3
Acropora (A.) aspera (Dana, 1846)	X	X						X	3
Acropora (A.) azurea Veron & Wallace, 1984	X								1
Acropora (A.) bushyensis Veron & Wallace, 1984								X	1
Acropora (A.) carduus (Dana, 1846)		X						X	2

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Acropora (A.) cerealis (Dana, 1846)	X	X	X				X	X	5
Acropora (A.) clathrata (Brook, 1891)	X								1
Acropora (A.) cuspidata Dana	X								1
Acropora (A.) cytherea (Dana,1846)	X	X	X	X				X	5
Acropora (A.) danai (Milne-Edwards & Haime, 1860)	X	X					X	X	4
Acropora (A.) digitifera (Dana, 1846)	X	X					X	X	4
Acropora (A.) divaricata (Dana, 1846)	X								1
Acropora (A.) echinata (Dana, 1846)								X	1
Acropora (A.) elseyi (Brook, 1892)		X	X						2
Acropora (A.) florida (Dana, 1846)		X							1
Acropora (A.) formosa (Dana, 1846)	X	X						X	3
Acropora (A.) gemmifera *(Brook, 1892)*	X	X							2
Acropora (A.) granulosa (Edwards & Haime, 1860)	X						X	X	3
Acropora (A.) horrida *(Dana, 1846)*	X								1
Acropora (A.) humilis (Dana, 1846)	X	X	X	X			X	X	6
Acropora (A.) hyacinthus (Dana, 1846)	X	X					X	X	4
Acropora (A.) latistella (Brook, 1892)	X								1
Acropora (A.) listeri (Brook, 1893)	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Acropora (A.) longicyathus (Edwards & Haime, 1860)	X								1
Acropora (A.) millepora (Ehrenberg, 1834)	X							X	2
Acropora (A.) monticulosa (Bruggemanni, 1879)	X	X						X	3
Acropora (A.) multiacuta Nemenzo,1967		X							1
Acropora (A.) loripes (Brook, 1892)	X	X					X	X	4
Acropora (A.) nana (Studer, 1878)	X	X						X	3
Acropora (A.) nasuta (Dana, 1846)	X	X				X	X	X	5
Acropora (A.) nobilis (Dana, 1846)	X	X						X	3
Acropora (A.) ocellata (Klunzinger, 1897)	X							X	2
Acropora (A.) pagoensis Hoffmeister	X								1
Acropora (A.) palmerae Wells, 1954	X							X	2
Acropora (A.) paniculata Verrill,1902	X		X	X					3
Acropora (A.) paxilligera *(Dana, 1846)*	X								1
Acropora (A.) polystoma ***(Brook, 1891)***	X	X							2
Acropora (A.) pulchra (Brook, 1891)	X								1
Acropora (A.) rambleri (Bassett-Smith, 1890)	X							X	2
Acropora (A.) robusta (Dana, 1846)	X							X	2
Acropora (A.) samoensis (Brook, 1891)	X	X							2

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Acropora (A.) schmitti	X								1
Acropora (A.) secale (Studer, 1878)	X								1
Acropora (A.) selago (Studer, 1878)	X	X	X					X	4
Acropora (A.) studeri (Brook, 1893)								X	1
Acropora (A.) tenuis (Dana, 1846)	X						X	X	3
Acropora (A.) teres (Verrill, 1866)	X							X	2
Acropora (A.) valenciennesi (Edwards & Haime, 1860)	X								1
Acropora (A.) valida (Dana, 1846)	X	X	X	X		X		X	6
Acropora (A.) vaughani Wells, 1954		X							1
Acropora (A.) yongei Veron & Wallace, 1984	X		X						2
Acropora (A.) sp.1	X				X			X	3
Acropora (A.) sp.2	X								1
Acropora (A.) sp.3	X								1
Acropora (I.) brueggemanni ***(Brook, 1893)***	X	X						X	3
Acropora (I.) cuneata (Dana, 1846)	X	X							2
Acropora (I.) palifera (Lamarck, 1816)	X	X					X	X	4
Astreopora cucullata Lamberts, 1980	X								1
Astreopora explanata		X							1
									2

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Astreopora gracilis Bernard, 1896		X						X	
Astreopora listeri ***Bernard, 1896***	X							X	2
Astreopora myriophthalma (Lamarck, 1816)	X	X				X	X	X	5
Astreopora randalli Lamberts,1890	X								1
Astreopora sp. 1	X						X		2
Montipora aequituberculata Bernard, 1897	X			X				X	3
Montipora berryi Hoffmeister, 1925	X								1
Montipora bilaminata	X								1
Montipora caliculata (Dana, 1846)	X								1
Montipora conicula Wells								X	1
Montipora danae Edwards & Haime, 1851						X		X	2
Montipora dilatata Struder, 1901				X					1
Montipora efflorescens Bernard, 1897	X								1
Montipora ehrenbergii Verrill, 1875	X							X	2
Montipora elschneri Vaughan, 1918	X							X	2
Montipora eydouxi	X								1
Montipora flabellata Struder, 1901				X					1
Montipora floweri Wells, 1954								X	1
Montipora foliosa (Pallas, 1766)	X	X						X	3

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Montipora foveolata (Dana, 1846)	X	X				X		X	4
Montipora granulosa Bernard, 1897	X							X	2
Montipora hispida ***(Dana, 1846)***	X	X	X						3
Montipora hoffmeisteri Wells, 1954	X	X				X		X	4
Montipora incrassata Dana, 1846			X	X					2
Montipora informis *Bernard, 1897*	X					X			2
Montipora lobulata *Bernard, 1897*	X							X	2
Montipora marshallensis	X								1
Montipora millepora Crossland, 1952								X	1
Montipora monasteriata (Forskal, 1775)		X	X	X	X	X		X	6
Montipora peltiformis Bernard, 1897				X				X	2
Montipora spumosa (Lamarck, 1816)	X								1
Montipora tuberculosa (Lamarck, 1816)	X	X	X	X				X	5
Montipora turgescens Bernard, 1897					X				1
Montipora undata Bernard, 1897	X								1
Montipora venosa (Ehrenberg, 1834)	X								1
Montipora verrucosa (Lamarck, 1816)				X		X		X	3
Montipora sp.1 (green spine)	X				X		X	X	4

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Montipora sp.2 (ramose tuber.)	X						X	X	3
Montipora sp.3 (Pago)	X						X	X	3
Montipora sp.4 (Ramose pap.)							X	X	2
Montipora sp.5 (thick branch)							X	X	2
Family AGARICIIDAE									
Gardineroseris planulata (Dana, 1846)	X			X				X	3
Leptoseris hawaiiensis Vaughan, 1907			X	X				X	3
Leptoseris incrustans (Quelch, 1886)	X		X	X				X	4
Leptoseris mycetoseroides Wells, 1954	X	X		X		X		X	5
Leptoseris papyracea ***(Dana, 1846)***				X					1
Leptoseris scabra Vaughan, 1907			X	X					2
Pachyseris levicollis	X								1
Pachyseris speciosa (Dana, 1846)	X							X	2
Pachyseris rugosa (Lamarck, 1801)	X								1
Pavona clavus (Dana, 1846)	X	X	X	X	X		X	X	7
Pavona decussata (Dana, 1846)	X							X	2
Pavona diffluens (Lamarck, 1816)	X								1

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Pavona divaricata (Lamarck, 1816)	X							X	2
Pavona explanulata (Lamarck, 1816)	X	X							2
Pavona frondifera (Lamarck, 1816)	X							X	2
Pavona gigantea	X								1
Pavona maldivensis (Gardiner, 1905)	X	X	X	X			X	X	6
Pavona minuta Wells, 1954	X							X	2
Pavona qardineri van der Horst								X	1
Pavona varians Verrill, 1864	X	X	X	X		X	X	X	7
Pavona (P.) venosa (Ehrenberg, 1834)	X							X	2
Family BALANOPHYLLIDAE									
Balanophyllia sp.cf. *affinis* (Semper, 1872)				X					1
Balanophyllia hawaiiensis Vaughan, 1907				X					1
Family SIDERASTREIDAE									
Coscinaraea columna (Dana, 1846)	X							X	2
Coscinaraea wellsi Veron & Pichon, 1879				X					1
Family FUNGIIDAE									
Cycloseris hexagonalis ***Edwards & Haime, 1848***				X					1
Cycloseris patelliformis Boschma, 1923	X								1

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Cycloseris tenuis Dana, 1846				X					1
Cycloseris vaughani (Boschma, 1923)			X	X					2
Diaseris distorta Michelin, 1842				X					1
Fungia (D.) danai Edwards & Haime, 1851	X	X							2
Fungia (D.) valida Verrill, 1864		X							1
Fungia (C.) echinata (Pallas,1766)	X								1
Fungia (F.) fungites (Linnaeus, 1758)	X	X						X	3
Fungia (P.) paumotensis Stutchbury, 1833	X	X						X	3
Fungia (P.) scutaria Lamarck, 1801	X	X	X	X	X	X	X	X	8
Fungia (V.) concinna Verrill, 1864	X	X						X	3
Fungia (V.) granulosa Klunzinger, 1879	X			X					1
Fungia (V.) repanda Dana, 1846	X	X							2
Fungia (C.) simplex ***(Gardiner, 1905)***	X								1
Halomitra pileus (Linnaeus, 1758)	X	X							2
Herpolitha limax ***(Houttuyn, 1772)***	X	X						X	2
Polyphyllia talpina (Lamarck, 1801)	X								1
Sandalolitha robusta (Quelch,1886)	X	X							2
Family PORITIDAE									

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Alveopora allingi ***Hoffmeister, 1925***	X								1
Alveopora japonica								X	1
Alveopora superficialis Sheer & Pillai, 1976	X								1
Alveopora verrilliana Dana, 1846	X	X						X	3
Alveopora viridis Quoy & Gaimard, 1833	X								1
Goniopora arbuscula Umbgrove								X	1
Goniopora columna Dana, 1846	X							X	2
Goniopora parvistella Ortmann, 1888	X								1
Goniopora somaliensis Vaughan, 1907	X								1
Goniopora sp.1	X						X	X	3
Goniopora sp.2							X	X	2
Porites (P.) annae ***Crossland, 1952***	X							X	2
Porites (P.) australiensis Vaughan, 1918		X						X	2
Porites (P.) cocosensis Wells								X	1
Porites (P.) compressa Vaughan				X				X	2
Porites (P.) cylindrica Dana, 1846	X							X	2
Porites (P.) duerdeni Vaughan				X				X	2
Porites (P.) cf. *Evermanni* Vaughan, 1907				X					1
									1

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Porites (P.) latistella	X								
Porites (P.) lichen ***Dana, 1846***	X			X				X	3
Porites (P.) lobata Dana, 1846	X	X	X	X	X		X	X	7
Porites (P.) lutea Edwards & Haime, 1860	X	X	X			X	X	X	6
Porites (P.) matthaii Wells	X							X	2
Porites (P.) murrayensis Vaughan, 1918	X			X				X	3
Porites (P.) pukoensis Vaughan, 1907	X			X					2
Porites (P.) queenslandi septima	X								1
Porites (P.) solida (Forskal, 1775)						X			1
Porites (P.) stephensoni Crossland, 1952	X								1
Porites (P.) studeri Vaughan, 1907				X					1
Porites (P.) sp.1(nodular)	X				X			X	3
Porites (S.) horizontalata Hoffmeister, 1925	X							X	2
Porites (S.) rus (Forskal, 1775)	X			X				X	3
Porites (N.) vaughani ***Crossland, 1952***		X							1
*Stylaraea punctata (*__*Linnaeus, 1758)*__								X	1

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Synaraea horizontalata	X								1
Family FAVIIDAE									
Caulastrea furcata Dana, 1846	X								1
Cyphastrea chalcidicum (Forskal, 1775)			X	X	X			X	4
Cyphastrea microphthalma (Lamarck, 1816)	X					X			2
Cyphastrea serailia (Forskal, 1775)	*X*					*X*		*X*	3
Diploastrea heliopora ***(Lamarck, 1816)***	X						X	X	3
Echinopora hirsuitissima ***(Edwards & Haime, 1849)***	X								1
Echinopora lamellosa (Esper, 1795)	X					X	X	X	4
Favia favus (Forskal, 1775)	X					X		X	3
Favia helianthoides Wells, 1954	X								1
Favia laxa (Klunzinger, 1879)	X								1
Favia matthaii Vaughan, 1918	X							X	2
Favia pallida (Dana, 1846)	X	X				X	X	X	5
Favia rotumana (Gardiner, 1899)	X							X	2
Favia russelli (Wells)								X	1
Favia speciosa (Dana)	X	X					X	X	4
Favia stelligera (Dana, 1846)	X	X				X		X	4

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Favia sp.1 (small calice)	X	X					X		3
Favia sp.2							X		1
Favites abdita (Ellis & Solander, 1786)	X	X				X		X	4
Favites chinensis (Verrill, 1866)	X								1
Favites complanata (Ehrenberg, 1834)	X							X	2
Favites favosa (Ellis & Solander)								X	1
Favites flexuosa (Dana, 1846)	X	X				X		X	4
Favites halicora (Ehrenberg, 1834)	X	X				X			3
Favites pentagona (Esper, 1794*)*		X							1
Favites russelli (Wells, 1954)	X								1
Goniastrea australensis (Edwards & Haime, 1857)	X								1
Goniastrea edwardsi Chevalier, 1971	X							X	2
Goniastrea favulus (Dana, 1846)	X					X			2
Goniastrea palauensis (Yabe,Sugiyama & Eguchi, 1936)	X								1
Goniastrea pectinata (Ehrenberg, 1834)	X	X				X		X	4
Goniastrea retiformis (Lamarck, 1816)	X					X	X	X	4
Hydnophora exesa (Pallas, 1766)	X	X						X	3
Hydnophora microconos ***(Lamarck, 1816)***	X	X						X	3

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Hydnophora rigida ***(Dana, 1846)***	X								1
Leptastrea bottae ***(Edwards & Haime, 1849)***				X				X	2
Leptastrea cf. I*mmersa* Klunzinger, 1879	X								1
Leptastrea purpurea (Dana, 1846)	X	X	X	X	X	X	X	X	8
Leptastrea transversa Klunzinger, 1979	X	X						X	2
Leptoria phrygia (Ellis & Solander, 1786)	X					X	X	X	4
Montastrea annuligera ***(Edwards & Haime, 1849)***	X								1
Montastrea curta (Dana, 1846)	X	X				X	X		4
Montastrea valenciennesi (Edwards & Haime, 1848)						X			1
Oulangia bradleyi (Verrill, 1866)			X						1
Oulophyllia crispa (Lamarck, 1816)	X							X	2
Platygyra daedalea (Ellis & Solander, 1786)	X	X				X		X	4
Platygyra lamellina (Ehrenberg, 1834)	X	X					X	X	4
Platygyra pini Chevalier, 1975	X						X	X	3
Platygyra sinensis (Edwards & Haime, 1849)						X		X	2
Plesiastrea versipora ***(Lamarck, 1816)***	X	X						X	3

Family RHIZANGIIDAE

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Culicia rubeola (Quoy & Gaimard)							X		1
Culicia sp.cf. *tenella* Dana, 1846				X					1
Family OCULINIDAE									
Acrhelia horrescens ***(Dana, 1846)***	X							X	2
Galaxea cf. astreata ***(Lamarck, 1816)***	X							X	2
Galaxea fascicularis ***(Linnaeus, 1767)***	X						X	X	3
Family MERULINIDAE									
Clavarina triangularis Veron & Pichon, 1979	X								1
Merulina ampliata (Ellis & Solander, 1786)	X	X				X		X	4
Family MUSSIDAE									
Acanthastrea echinata (Dana, 1846)	X					X	X	X	4
Acanthastrea sp.1								X	1
Lobophyllia corymbosa (Forskal, 1775)	X	X						X	3
Lobophyllia hemprichii (Ehrenberg, 1834)	X							X	2
Symphyllia radians ***(Edwards & Haime, 1849)***						X			1
Symphyllia recta ***(Dana, 1846)***	X					X			2
Symphyllia valenciennesii ***Edwards & Haime,***	X								1

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
1849									
Family PECTINIIDAE									
Echinophyllia aspera *(Ellis & Solander, 1786)*	X							X	2
Mycedium elephantotos (Pallas, 1766)	X								1
Oxypora lacera (Verrill, 1864)	X								1
Family CARYOPHYLLIIDAE									
Euphyllia (E.) glabrescens (Chamisso & Eysenhardt, 1821)	X						X	X	3
Plerogyra simplex ***Rehberg, 1892***	X								1
Plerogyra sinuosa ***(Dana, 1846)***							X	X	2
Polycyathus verrilli ***Duncan***								X	1
Family DENDROPHYLLIIDAE									
Tubastrea aurea ***(Quoy & Gaimard)***	X						X		2
Tubastraea coccinea Lesson, 1831	X	X		X	X				4
Turbinaria frondens ***(Dana, 1846)***	X								1
Turbinaria peltata (Esper, 1794)	X								1
Turbinaria reniformis Bernard, 1896	X								1
Order COENOTHECALIA									1

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Family HELIOPORIDAE									
Heliopora coerulea (Pallas, 1766)	X						X	X	3
Order STOLONIFERA									
Family TUBIPORIDAE									
Tubipora musica ***Linnaeus, 1758***								X	1
Order MILLEPORINA									
Family MILLEPORIDAE									
Millepora dichotoma Forskal, 1775	X						X	X	3
Millepora exaesa Forskal, 1775						X	X	X	3
Millepora platyphyllia Hemprich & Ehrenberg, 1834	X						X	X	3
Millepora tenera Boschma, 1949	X		X						2
Millepora tuberosa Boschma, 1966	X								1
Millepora sp.1	X								1
Family STYLASTERIDAE									
Distochopora gracilis Dana, 1846	X								1
Distochopora violacea (Pallas, 1776)			X					X	2
Distochopora sp.1								X	1
Stylaster gracilis Dana, 1846	X								1

Coral Order, Family and Species	**AS**	**PA**	**JA**	**MHI**	**NWHI**	**WA**	**NMI**	**GU**	**Site Record**
Stylaster sp.			X						1
Order ALCYONACEA									
Family ALCYONIIDAE									
Lobophytum sp.1		X							1
Sinularia abrupta Tixier-Durivault, 1970				X					1
Sinularia sp.1		X							1
Corallimorpharia spp.	X								1
Palythoa sp.	X	X	X	X					4
Tethya sp.	X								1
Zoanthus sp.	X			X					2
Number of: Scleractinians	222	82	29	51	13	39	53	159	
Acyonarians	4	1		1					
Hydrozoans	7	1	3			1	3	5	
Coelothecalia	1							1	

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Comment: *Oulangia bradleyi (Verrill, 1866): Johnston Atoll.* This record does not conform to the current taxonomy though is included subject to further clarification.

Table 97. Zooxanthellate corals likely to be found in the American Flag Pacific Islands. (Adapted from Veron 1995.)

Family and genus	Extant species {no.}	Present distribution	General abundance
Astrocoeniidae Stylocoeniella	At least 3	Red Sea to central Pacific	Uncommon, cryptic
Pocilloporidae Pocillopora	Approx. 10	Red Sea and western Indian Ocean to far eastern Pacific	Very common, very conspicuous
Stylophora	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Seriatopora	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Acroporidae Montipora	At least 80	Red Sea and western Indian Ocean to southern Pacific	Extremely common , some species
Acropora	At least 150	Cosmopolitan in Indo-Pacific reefs	Extremely common, very conspicuous, usually dominant
Astreopora	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Poritidae Porites	Approx. 80	Cosmopolitan	Extremely common, conspicuous at generic level
Stylaraea	1	Red Sea and western Indian Ocean to westernPacific	Rare, occurs only in shallow,wave-washed biotopes
Goniopora	Approx. 30	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Alveopora	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Sometimes common, very conspicuous
Siderastreidae Psammocora	Approx. 15	Red Sea and western Indian Ocean to far eastern Pacific	Generally common, sometimes cryptic
Coscinaraea	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Agariciidae Pavona	Approx. 22	Red Sea and western Indian Ocean to far eastern Pacific	Very common, conspicuous
Leptoseris	Approx. 14	Red Sea and western Indian Ocean to far eastern Pacific and Caribbean and Gulf of Mexico	Sometimes common, mostly conspicuous
Gardineroseris	At least 2	Red Sea and western Indian Ocean to far eastern Pacific	Generally uncommon,

Family and genus	Extant species {no.}	Present distribution	General abundance
Pachyseris	Approx. 4	Red Sea and western Indian Ocean to western Pacific	Very common, very conspicuous
Fungiidae Cycloseris	Approx. 16	Red Sea and western Indian Ocean to far eastern Pacific	Generally uncommon, non-reefal
Diaseris	At least 3	Red Sea and western Indian Ocean to far eastern Pacific	Generally uncommon, non-reefal
Fungia	Approx. 33	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Herpolitha	2	Red Sea and western Indian Ocean to western Pacific	Generally common, very conspicuous
Sandalolitha	2	Central Indian Ocean to southern Pacific	Sometimes common, very conspicuous
Halomitra	2	Western Indian Ocean to southern Pacific	Generally uncommon, very conspicuous
Oculinldae Galaxea	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Acrhelia	1	Eastern Indian Ocean to southern Pacific	Generally uncommon, conspicuous
Pectiniidae Echinophyllia	Approx. 8	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Oxypora	At least 3	Western Indian Ocean to southern Pacific	Generally common, conspicuous
Mycediurn	At least 2	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Mussidae Acanthastrea	Approx. 6	Red Sea and western Indian Ocean to southern Pacific	Generally uncommon, Favites-like
Lobophyllia	Approx. 9	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Symphyllia	Approx. 6	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Merulinidae Hydnophora	Approx. 7	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Merulina	3	Red Sea and western Indian Ocean to southern Pacific	Sometimes common, conspicuous

Family and genus	Extant species {no.}	Present distribution	General abundance
Scapophyllia	1	Eastern Indian Ocean to southern Pacific	Generally uncommon
Faviidae	Approx. 4	Red Sea and western Indian	Generally common,
Favia	At least thirty	Cosmopolitan	Extremely common, conspicuous
Favites	Approx. 15	Red Sea and western Indian	Very common,
Goniastrea	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Very common, generally conspicuous
Platygyra	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Extremely common, conspicuous but may be confused with Goniastrea
Leptoria	2	Red Sea and western Indian	Sometimes common,
Oulophyllia	Approx. 3	Red Sea and western Indian Ocean to western Pacific	Sometimes common, conspicuous
Montastrea	Approx. 13	Cosmopolitan	Generally common, conspicuous
Plesiastrea	At least 2	Red Sea and western Indian Ocean to far eastern Pacific	Sometimes common
Diploastrea	1	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Leptastrea	Approx. 8	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Cyphastrea	Approx. 9	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Echinopora	Approx. 7	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Caryophylliidae Euphyllia	9	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Plerogyra	3	Red Sea and western Indian Ocean to southern Pacific	Generally uncommon, very conspicuous
Dendrophylliidae Turbinaria	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Duncanopsammia	1	Central Indo-Pacific	Uncommon, very

Family and genus	Extant species {no.}	Present distribution	General abundance
			conspicuous

4.2.3.8 Ahermatypic Corals (Azooxanthellate)

Important Summary Documents

Veron (1986) describes the three genera with photos of living and skeletal examples. Table 98 summarizes the ahermatypic corals from Hawaii.

Taxonomic Issues

Order Scleractinia; Family Dendrophylliidae; Genera *Dendrophyllia* (de Blainville, 1830), *Tubastraea (*Lesson. 1829), *Balanophyllia spp*. (Wood, 1844). *Duncanopsammia axifuga* is of the same family and has a skeletal structure and growth form intermediate between hermatypic and ahermatypic forms. As it is zooxanthellate, it is not described here. Other zooxanthellate corals such as *Heteropsammia* and *Psammoseris* (both Dendrophyllidae), *and Heterocyathus* (Caryophylliidae) are they small, single polyp forms and appear as partial ahermatypes (Veron, 1986). Their contribution to reef growth is minor and they occur on sand and rubble substrates. Heteropsammia spp. doesn't occur in the AFPI.

Other genera occur in deep water or deep inter-reef areas and are listed with their recorded depth range (after Veron, 1986): Letepsammia (165-457m); Fungiacyathus (190-600m); Madrepora (55-450m); Cyathelia (40m); Culicia and Astrangia (inter-tidal to 128m, largely temperate); Flabellum (10-824m); Placotrochus (to 188m); Monomyces (3-40m); Gardineria (55m); Anthemiphyllia (to 210m); Caryophyllia (119-1006m); Tethocyathus; Premocyathus (20-230m); Cythoceras (86-766m); Trochocyathus (86-531m); Deltocyathus (16-531m); Boureotrochus (210-531m); Sphenotrochus; Polycyathus (>40m); Aulocyathus (163-190m); Conotrochus (210-365); Stephanocyathus (366-1006m); Oryzotrochus (9-15m); Conocyathus (8-22m); Trematrochus (>27m); Dunocyathus (100-531m); Paracyathus(>20m); Patytrochus (28-183m); Cylindrophyllia; Peponocyathus (339-365); Holcotrochus (11-183m); Desmophyllum; Solenosmilia (860m); Stenocyathus (455-531m); Septosammia (8-86m); Endopachys; Notophyllia (36-457m); Thecopsammia (270m).

Habitat Utilization

Not dependent on light so able to colonizes overhangs and caves. Competes best in areas of low scleractinian coral or algal occurrence. *T. micrantha* competes best due to its erect arborescent nature and may be dominant below 15m in areas of exposed currents.

Life History

Adult: Appearance and Physical Characteristics

Dendrophyllidae :
Solitary and colonial corals with more than two rings of tentacles on the polyps. Numerous skeletal element of the ridges form an almost continuous sheet and rods connect adjacent ridges. *Dendrophyllia* and *Tubastrea spp.* may appear similar superficially but are separated by differences in septal plans.

Dendrophyllia spp.: Often brightly colored (yellow or orange) resulting from the corals own pigment, as no zooxanthellae are present. Colonies are dendroid and proliferate through extra-tentacular budding. Generally nocturnal but also diurnal extension.

Tubastraea spp.: Tubular corallites forming hemispherical colonies. *Tubastrea aurea* forms domed clumps up to 10cm dia. Polyps protrude for a common encrusting base. Usually found in low-light conditions in caves and beneath rocky overhangs. Common species *T. faulkneri, T. coccinea, T. diphana and T. micrantha.*

Tubastrea micrantha forms tree-like branching colonies to 1m in height. Colour dark brown and green. Occurs in deeper reef environments.

Balanophyllia spp.: Solitary corals which bud to form closely packed clumps. Clumps may be 50cm diam. Thick walls. Polyps are oval and tapering towards the base, and the septa are fuse. Color black, bright-orange or yellow polyps.

Feeding and Food

Heterotrophic with dependence on the capture of zooplankton. Nocturnal and diurnal feeding.

Reproductive Strategies

Dioecious. Fertilization is internal and larvae are brooded. Asexual larval reported (Richmond and Hunter, 1990). The larvae are 1mm long and crawl or swim after release before settling. They may also be free-spawners (Harrison and Wallace, 1990). Planula takes four to seven days before they settle and form a primary polyp.

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Table 98. Deep-water Ahermatypes from Hawaii. (From Maragos 1977; data Vaughan (1907)).

Species	Shallowest Collection Record
Anisopsammia amphelioides (Alcock)	40 fm
Anthemiphyllia pacifica Vaughan	92 fm
Balanophyllia desmophyllioides Vaughan	78 fm
Balanophyllia diomeseae Vaughan	148 fm
Balanophyllia hawaiiensis Vaughan	190 fm
Balanophyllia laysanensis Vaughan	130 fm
Bathyactis hawaiiensis Vaughan	963 fm
Caryophyllia alcocki Vaughan	876 fm
Caryophyllia hawaiiensis Vaughan	92 fm
Caryophyllia octopali Vaughan	28 fm
Ceratotrochus laxus Vaughan	319 fm
Cyathoceras diomedeae Vaughan	169 fm
Deltosyathus andamanicus Alcock	147 fm
Dendrophyllia oahensis Vaughan	154 fm
Dendrophyllia serpentina Vaughan	147 fm
Desmophyllum cristagalli Milne- Edwards & Haine	
Endopachys oahense Vaughan	53 fm
Flabellum deludens v. Marenzeller	670 fm
Flabellum parvoninum Lesson	127 fm
Gardineria hawaiiensis Vaughan	272 fm
Madracis kauaiensis Vaughan	24 fm
Madrepora kauaiensis Vaughan	294 fm
Paracyathus gardineri Vaughan	
Paracyathus mauiensis Vaughan	95 fm
Paracyathus molokensisx Vaughan	88 fm
Paracyathus tenuicalyx Vaughan	252 fm
Placotrochus fuscus Vaughan	148 fm
Stephanophyllia formosissima Moseley	66 fm
Trochocyathus oahensis Vaughan	252 fm

4.2.3.9 Actiniaria (anemones)

Important Summary Documents

Symbiosis between anemones and fish was first noted by Collingwood (1868). Fishelson (1970, 1971) speculated on the ecological role of this association. The taxonomy of symbiotic anemones was revised by Dunn (1981). The taxonomy of the Hawaiian anemones was described in Eldredge and Devaney (1977). Chia (1976) has described reproduction in terms of patterns and adaptive radiation. Fautin and Allen (1992) describe the biology of anemonefish and their host anemones. Table 99 summarizes the Actinaria from Hawaii.

Taxonomic Issues

Ecotypes are common (e.g. *Entacmaea quadricolor)* which has given rise to taxonomic confusion Allen (1975) described the deeper water as *Radianthus gelam* and the smaller individuals a *Physobranchia douglasi.* Their ability to adopt a varied coloration both in terms of background color and geographic variation has made taxonomy difficult.

Habitat Utilization

Anemones attach to hard substrate by their basal disc, burrow into soft substrate or attach as symbionts to sessile and mobile reef creatures.

Life History

Adult: Appearance and Physical Characteristic

Anemones have a body column and oral disc with tentacles with nematocysts and a central mouth. They are attached by a basal or pedal disc to the substrate (Barnes, 1980). They are often associated with symbiotic relationships such as with fish or shrimps (Fautin and Allen, 1992). *Heteractis magnifica* reaches a diameter of 30-50cm though may reach 1m.

Ten species are recognized as symbiotic anemones (Actiiidae; Thalassianthidae; Stichodactylidae).

Both *Actinodendron plumosum* and *Phyllodiscus semoni* have severe stings if touched.

Some species of anemones can exhibit mimicry appearing like their background or other reef entities like hard coral or algae.

Age, Growth, Longevity

The growth of tropical anemones is variable being largely dependent on nutrition. Longevity among tropical anemones is poorly known. Anemones approaching a meter in diameter may exceed 100 years old (Fautin and Allen, 1992). *Actinia tenebrosa* requires 8 to 66 years to reach a column diameter of 40mm and has an average longevity of 50 years (Ottaway, 1980).

Reproductive Strategies

Asexual: Common: Pedal laceration and longitudinal or transverse fission

Asexual reproduction has been observed as budding (Vine, 1986). Devaney & Eldredge (1977) describe *Boloceroides mcmurrichi* as reproducing sexually in spring and asexually in fall when the asexually young arise as buds on the outer tentacles and are shed when they have developed 10 to 30 tentacles.

Eggs and sperm are produced and host anemones appear to be characterised by separate sexes.

Absence of small individuals is indicative of low fertilization, larval survival or larval settlement or young have high mortality (Fautin and Allen, 1992).

Most are hermaphroditic but reproduce only one type of gamete per reproductive period. Groups of clones evident.

Distribution

Anemones are often widely distributed. The common anemone *Entacmaea quadricolor* is found from Samoa to East Africa and the Red Sea and from the surface down to 40 metres. Of nearly 1000 species, only 10 species are host to anemone fishes. In Hawaii, There is only one host species recorded from Hawaii though without commensal fish (Fautin and Allen, 1992).

Feeding and Food

Anemones are polyphagous opportunists (Ayre 1984). Prey is caught by the tentacles, paralyzed by nematocysts and carried to the mouth. The food consists of plankton borne crustacea but fish worms, and algal fragments are includes Sand dwelling anemones such as *Heteractis malu* ingest gastropods (Shick, 1990) as does *Catalophyllia sp.* Some anemones are suspension feeders (Barnes, 1980).

Specialized corallimorpharians such as *Rhodactis, Actinodiscus, Discosoma, Amplexidiscus* can capture large prey by enveloping them with the entire disk (Hamna and Dunn, 1980; Elliott and Cook, 1989).

Anemones which contain symbiotic zooxanthelle but also capture plankton and other detrital or water borne food. Those without zooxanthella are dependent on plankton and may capture pother food such as crustaceans or smaller fish.

Absorption of dissolved organic material (DOM) by anemones occurs Schlichter (1980) and Schlichter et al. (1987). DOM is important in times of no solid food. (Shick, 1975)

Extracellular digestion is achieved by mesenterial filaments (Nicol, 1959)

Some species of anemones extend their tentacles at night and diminutive during the day (*Alicia sp).* Others feed during daylight hours.

Behavior

The family Boloceriodidae contains anemones capable of swimming by beating their tentacles. The Hawaiian species *Boloceroides mcmurrichi* has a large crown of tentacles compared to a relatively small body. They become capable of swimming at the 10 to 30 tentacle stage (Devaney and Eldredge, 1977).

Edwardsia spp. are found on sandy bottoms and dig themselves into the substrate.

Anemones are basically sedentary but are able to move over the substrate slowly, some can swim for short distances.

There commensal behavior with fish where it gains protection and food and in turn protects the anemone from some predators and removes sediment and other material by its swimming motion (Barnes, 1987).

Spawning: Spatial and Temporal Distribution

Spawning is synchronised with the full moon or low tide (Fautin and Allen, 1992).

Eggs are fertilized in the gastrovascular cavity or occur outside in the seawater (Fautin and Allen, 1992).

Free swimming planula

Larval Feeding and Food

Ingest copepods, chaetognaths, or larvae of other cnidarians. Unicellullar algae and dinoflagellates has been observed Widersten, 1968; Siebert, 1974)

The planula may be planktotrophic or lecithotrophic and has a variable larval life span. The young sea anemone lives as a ciliate ball, unattached and free swimming. The larvae settles, attaches and forms tentacles.

Habitat Utilization

Asexual of reproduction give rise to many individuals in close proximity, often forming a continuous surface by adjacent oral discs. Like other sessile benthos, settlement of larval stages colonizes available substrate.

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Table 99. Actinaria from Hawaii (Cutress, 1977).

Order ACTINIARIA

Family BOLOCEROIDIDAE
Boloceroides memurrichi (Kwietniewski 1898)
Bunodeopsis medusoides (Fowler 1888)

Family ALICIIDAE
Triactis producta Klunzinger 1877

Family ACTINIIDAE
Anemonia mutabilis Verrill 1928
Anthopleura nidrescens (Verrill 1928)
Anthopleura sp. *A*
Anthopleura sp. *B*
Actiniogeton sesere (Haddon & Shackleton 1893)
Cladactella manni (Verrill 1899)

Family STOICHACTINIDAE
Antheopsis papillosa (Kwietniewski 1898)
Stoichactis sp.

Family PHYMANTHIDAE
Heteranthus verruculatus Klunzinger 1877

Family ISOPHELLIDAE
Telmatactis decora (Hemprich and Ehrenberg 1834)
Epiphellia pusilla (Verrill 1928)
Epiphellia humilis (Verrill 1928)

Family HORMATHIIDAE
Calliactis polypus (Forskal 1775)

Family SAGARTIIDAE
Anthothoe sp.

Family AIPTASIIDAE
Aiptasia pulchella Carlgren 1943

Family DIADUMENIDAE
Diadumene leucolena (Verrill 1866)

Family EDWARDSIDAE
Edwardsia sp. *A.*

Edwardsia sp. *B.*

4.2.3.10 Zoanthidae (colonial anemones)

Important Summary Documents

Hyman (1940) details systematics and anatomy. Mather and Bennett (1993) discuss the order Zoanthidae. Burnett et al. (1997) a good summary of systematics for some central Indo-Pacific species. Walsh (1967) produced an annotated bibliography for the family. Table 100 summarizes Zoanthiniaria from Hawaii.

Taxonomic Issues

Class Anthozoa; subclass Zoantharia (=Hexacorallia); order Zoanthiniaria (=Zoanthidea); suborder Brachcnemina; family Zoanthidae; genera Acrozoanthus; *Zoanthus; Isaurus; Protopalythoa; Palythoa; Sphenopus. s*uborder Macrocnemina; family Epizoanthidae; genera *Epizoanthus; family* Epizoanthidae, *Thoracactis*; genus *Parazoanthus, Gerardia, Isozoanthus* (Barnes, 1987; Muirhead and Ryland, 1985).

Poorly known due to reliance on preserved specimens and a high degree of inter-population variability. Nominal species 300.

Differentiated from the Actinaria by the presence of a fifth cycle of mesenteries.

Zoanthiniarian systematics is discussed by Herberts (1972a; 1987) and Mather and Bennett (1993).

Habitat Utilization

Often distinct zonation: back reef flats, lagoon floors, reef crests and shallow sublitoral zone. Palythoa spp.: Growth in large numbers on reef flats immediately behind the reef crest, also found on lagoon floors and the spur and groove channels of reef slopes. Tide pools in Hawaii.

Parazoanthus ssp., Epizoanthus ssp. , Acrozoanthus spp.: May colonize worm tubes, hydroids, sponges and gorgonian skeletons. May be epizootic on sponges, or ascideans as ATuff Balls or providing as protection (Colin and Arneson, 1995).

Protopalythoa spp.: Shallow fore reefs, reef crests or outer reef flat areas. Shallow reef zones may be dominated by this genus and cover may be >90%. May occur as small assemblages of polyps or separate individuals.

Zoanthus spp.: They are found in back reef areas and the shallow sub-littoral zone.

Life History

Adult: Appearance and Physical Characteristics

Zoanthid anemones are solitary or colonial, zooxanthellate (except *Sphenopus*). Principal tropical genera are *Palythoa*, *Protopalythoa* and *Zoanthus.* Generally, discs are 1-2cm in diameter with tentacles 3-5mm long but may extend to 2-3cm. Coloration varies from red, orange, yellow, turquoise, green or brown. The stem (scapus), disc (capitulum), tentacles or coenenchyma vary in coloration. Zooanthids differ from other Zoantharia in that they don't produce skeleton but incorporate sediment into the body wall. As well, they don't have a pedal disc and a differing septal arrangement (this forms the basis for the two suborders).

Isaurus spp.: Loosely connected colonies without connecting stolons. Height varies 15- 160cm. Colonies with < 50 individuals. Taxonomically best known (Muirhead and Ryland, 1985). Often inconspicuous. Nocturnal tentacular extension.

Palythoa spp.: Growth in massive colonies. Sand particles are encrusted into the coenenchyme. Colonies are convex and 30cm. Coenenchyme is light brown to yellow.
Often buried in the sand to the level of the disc.

Protopalythoa spp.: Generally in loosely connected colonies. Often the polyps lack contact or have contact at the base through a stolon. Polyp height is 15-25 mm high and 7-11mm in diameter. Expanded discs may attain a diameter of 2-3cm. May occur as large areas of colonization, small assemblages or individual polyps. Polyps are encrusted with sand particles. For some, full retraction is not possible due to the size of the disc. Colour is uniform on the stem and disc; brown or green. It may be variable due to the intensity of light.

Zoanthus spp.: Sediments are not incorporated in their tissues but are tolerant of sediment environments. Most species are brightly coloured, often contrasting disc, tentacles and stem.

Growth

Growth morphology may depend on the environment. *Z. pacificus* has a lamellar coenenchyme with crowded polyps and separate bases. In surge pools, the bases are joined and crowding less. In wave washed area the coenenchyme can be lamellar or stoloniforous with single polyps or groups of two or three (Walsh and Bowers, 1971).

In *Palythoa*, growth is by the spreading of the thickened coenenchyme. Yamazato et al. (1973), found 0.18 new polyps per day increase in *Palythoa tubercles.* Density of colonies may be 671 polyps/$0.1m^2$ (*Zoanthus sociatus*) and 302 polyps/ $0.1m^2$ for *Z. solanderi.* (Karlson, 1981). $12,000/m^2$ of *Palythoa vestitus* where found in Kaneohe Bay.

Distribution

Isaurus spp: Widespread in all tropical seas; present in Hawaii.

Palythoa spp.: Pan-tropical; present in Hawaii.

Protopalythoa spp.: Pan tropical; occurs in Hawaii, American Samoa and Tahiti.

Zoanthus spp.: Pan-tropical; occurs in Hawaii, American Samoa and Tahiti.

Feeding and Food

Heterotrophic (zooplankton); autotrophic (zooxanthellae) (Reimer 1971b).

Muscatine et al. (1983) determined zooxanthellae could provide 48% of the carbon requirement for *Zoanthus sociatus.*

Palythoa, Protopalythoa and Zoanthus are diurnal in expansion. Others are nocturnal Isaurus and Sphenopus. Able to ingest a variety of live and dead crustacea and fish portions (Reimer, 1971a). Crustacean and detrital fragments were found in *Zoanthus Sociatus*, though few contained food items with only a greater frequency at night (Sebens, 1977). Azooxanthellate genera (*Epizoanthus and Parazoanthus)* rely greatly on feeding to obtain sufficient nutrition.

The uptake of dissolved organic matter may contribute to nutrition (Reimer, 1971; Trench, 1974). The common presence of *Zoanthus* spp and *Protopalythoa* in shore may be due to the higher organic levels. With the reduction in sewage contamination in Kaneohe Bay, zoanthid population declined.

Isaurus spp: Autotrophic nutrition from the zooxanthellae but also feeds on plankton nocturnally. Polyps never open in the day.

Palythoa spp.: Generally autotrophic but tentacles and diurnal expansion indicate reliance on zooplankton.

Protopalythoa spp.: Heterotrophic; autotrophic

Zoanthus spp.: Heterotrophic; autotrophic

Reproductive Strategies

Asexual by the arising of new polyps from a spreading sheet of coenenchyma or stolons or budding from the parent polyp. Extensive monoclonal colonies occur.
Fragmentation is common.

Sexual reproduction: Both dioecious (gonochoristic) and sequential and simultaneous hermaphrodites.

Isaurus spp: Unknown.
Palythoa spp.: Readily reproduces asexually. Yamazoto et al. (1973) studied the reproductive cycle of *Palythoa tuberculosa* in Okinawa. The oocytes grow from March/April, to a peak in the middle of the year, which followed by a second peak in October indicative of two spawnings per year. Mature eggs are rather large with a length of 300-500um.

Protopalythoa spp.: Asexual and sexual. Babcock and Ryland (1990) and Ryland and Babcock (1991) describe reproduction and larval development.

Zoanthus spp.: Asexual and sexual. Cooke (1976) describes reproduction for *Zoanthus pacificus* and for *Z. solanderi and Z. sociatus* by Fadlallah et al. (1989).

Spawning: Spatial and Temporal Distribution

Ovaries develop initially in the cycle along the margin of the mesenteries with the testis later in the cycle. Seasonal free spawning. Report of spawning synchronous with the mass spawning of the stony coral, on the 4^{th} to 6^{th} nights after full moon in November (Ryland and Babcock, 1991). In Hawaii, *P. versitis* was only active May to September while *Z. pacificus* was bound to be sexually active all year but greatest during the summer (Cooke, 1976).

Eggs and Larvae

Egg diameter range from 75um to 280 um. Sperm are bell shaped and 50 um long. Egg counts range from 800 to 2400 (Ryland and Babcock, 1991). Larvae settle in areas of coralline algae and crawl to find a site. Suitable sites are often shaded. Fecundity is high and settlement rates are low. Sexual reproduction is therefore thought to allow for dispersal and colonization over large distances (Karlson, 1981).

The larvae are oval in shape and have a girdle of cilia near the oral end. The Larvae of *Protopalythoa spp*. are referred to as zoanthella and are elongate with a ventral band of long cilia (Hyman, 1940).

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Table 100. Zoanthiniaria from Hawaii: (Walsh and Bowers 1971).

Order ZOANTHINIARIA

Family ZOANTHIDAE
Isaurus elongatus Verrill 1928
Palythoa vestitus (Verrill 1928)
Palythoa tuberculosa (Esper 1791)
Palythoa psammophilia Walsh and Bowers 1971
Palythoa toxica Walsh and Bowers 1971
Zoanthus pacificus Walsh and Bowers 1971
Zoanthus kealakekuaensis Walsh and Bowers 1971

4.2.3.11 Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Alcyoniina (soft corals)

Important Summary Documents

Bayer et al. (1983) and Bayer (1981) details anatomical terminology and taxonomy.
Hyman, (1940) describes the anatomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); order Alcyonacea; suborder Alcyoniina: families: Paralcyoniidae; Alcyoniidae; Asterospiculariidae; Nephtheidae; Nidaliidae; Xeniidae

The taxonomy of common intertidal and lagoon genera *Sarcophyton* and *Sinularia* are revised in Verseveldt (1980, 1982).

Habitat Utilization

Colonies characteristic of large size grow in shallow water areas in high light intensity and intertidally. Generally colonies are smaller on roofs of caves.

Life History

Adult: Appearance and Physical Characteristics

Alcyonaria: Colonial, tentacles and mesenteries 8 with tentacles pinnate attached.
Alcyonacea: Alcyoniina (Soft corals): Fleshy, stolon, membranous, encrusting or erect with tree-like branching. Monomorphic polyps (autozooids: function in food intake, water movement and bear the gonads). Some genera have dimorphic polyps (autozooids and tentacle-less siphonozooids) e.g. *Lobophytum spp.* and *Sarcophyton spp*. Dimorphism attributed to need for transport of water (Bayer, 1973). Skeleton has calcite spicules (sclerites). Coenechyme is the general colonial mass filled with solenia that connect with the polyps and their anthocodium. Tentacular contraction possible in some and only partial in others.

Zooxanthellate with resulting colour of greens to brown or bright coloration in the sclerites.

Paralcyoniidae: Lobed to arborescent upper portions and are able to retract this region into the lower stalk. Rigidly reinforced with large sclerites.

Alcyoniidae: Large, lobed colonial forms with considerable amounts of scleritic coenenchyme.

Nephtheridae: The coenenchyme between polyps is thin, arboresent with polyps grouped at the ends of branches. Hydrostatic pressure important to provide support.

Nidalidae: Rigid, brittle, arborescent colonies with narrow stems and branches. Densely covered with spindle shaped sclerites. Similar in appearance to gorgonians Xeniidae: Fleshy with sclerite mass reduced. Characterized by tentacular oscillation.

Age, Growth, Longevity

Two main growth forms massive and arborescent.

Growth by vegetative budding from the system of solenial canals between confluent coenenchyme. Mucus production high in some and effective in cleaning of the surface of the colony. Colonies are often prolific with numerous colonies covering large areas. In Guam population density of up to 24 colonies per square meter of *Asterspicularia randalli* (Gawel, 1976).

Distribution

Occurring in all oceans at all latitudes, they are most abundant in the tropics.

Paralcyoniidae: *Studeiroides spp.: Indo-Pacific*

Alcyoniidae: *Sarcophyton spp./ Lobophytum spp.: Cladiella spp.:* Very common in the Indo-Pacific. *Sinularia spp.:* Indo-Pacific Philippines, Malayan Archipelago Great barrier Reef- Australia, Vietnam, Palau, New Caledonia and the Ryukyu Island, Japan.

Asterospiculariidae: *Asterospicularia sp.:* Guam

Nephtheidae: *Capnella spp. / Nepthea spp. / Dendroneptha spp.:* Very common in the Indo-Pacific.

Nidaliidae: *Chironephthya spp*./ *Nephthyigorgia spp/ Siphonogorgia spp.*: Very common in the Indo-Pacific.

Xeniidae: *Xenia spp./ Cespitularia spp.:* Indo-Pacific

Feeding and Food

Heterotrophic through zooplankton capture. Autotrophic through nutrient exchange with zooxanthellae, digestion of zooxanthellae and absorption of dissolved organic matter in the seawater (Fabricius, et al. 1995a,b).

Food is taken in through the mouth. Prey are immobilized by nematocysts and conveyed to the mouth by tentacles.

Behavior

Defensive

Chemical substances provide advantage over other organisms for protection by preventing feeding or securing space on the reef. Majority of species of soft corals contain toxic terpene compounds which they release in to their surroundings (Coll et al. 1982; and Coll and Sammarco 1983; 1986; Sammarco et al. 1983; Webb and Coll 1983). These may influence the reproductive capability or survivorship of scleractinian corals (Aceret et al. 1995a,b).

Physical defenses involve the use of sweeper tentacles, sclerites, overtopping,

Reproductive Strategies

Asexual: Almost all increase colonial numbers through mechanisms such as fragmentation, budding, transverse fission and pedal laceration.

Fragmentation: Takes place in *Dendronephthya* in 5-10 days (Fabricius, 1995). Fragmentation can occur through constriction or though parting of the stolons.

Sexual: Dioecious and hermaphroditic. Gonads occur on the mesenteries and reproduction involves the release of gametes into the surrounding water. Fertilization may occur externally through broadcast spawning or within the polyp cavity. Internal fertilization gives rise to an internal brooded planula. Also internal fertilization may give rise to an externally brooded planulae. (Benayahu, and Loya 1983, 1984a, 1984b; Yamazato et al. 1981).

Alcyonium, Heteroxenia, Lobophytum, Parerythropodium, Sarcophyton and Xenia planulae were released between 11 and 13 days after the full moon in November. Egg size range from 625um (*Lobophytum*) to 810um (*Sarcophytum)* (Alino and Coll, 1989). Some are may be dioecious, external surface planula brooders (Benayahu, and Loya, 1983; 1984b; 1986). Presence of zooxanthellae is likely in planulae.

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4.2.3.12 Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Scleraxonia; Holoaxonia (gorgonian corals, sea fans and sea whips)

Important Summary Documents

Bayer (1956, 1973, and 1981) summarizes taxonomy and anatomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Scleraxonia; Families: Briareidae; Anthothelidae; Subergorgiidae; Coralliidae; Melithaeidae; Parisididae; Holoaxonia; Families: Acanthogorgidae; Plexuridae; Gorgoniidae; Ellisellidae; Ifalukellidae: Chrysogorgiidae; Primnidae; Isididae.

Habitat Utilization

Strong current location; low light conditions such as depths and overhangs.

Life History

Adult: Appearance and Physical Characteristic

Generally arborescent in nature, some unbranched. Skeletal support by stiff axis utilizing the flexible gorgonin. Divided taxonomically on basis of a central supporting axis (gorgonin and fused sclerites) or core (cortex around chambered gorgonin). Polyps have pinnate tentacles, anthocodia sit in coenenchymal calyx and sheath is formed around the central axis.

The main stem is attached by to a plate or branchlets to the surface. Stem contains a central strengthening rod. The rod may be calcareous but is commonly of horny gorgonin. Short polyps occur all over the branches of the colony but not on the main stem. Colonies are often brightly colored and may reach 3m in height. Epizoic life common (George and George, 1979).

From (George and George, 1979):

Suborder Scleraxonia

Briareidae: Erect, finger-like processes of spongy texture (20cm height) or massive and encrusting. Zooxanthellate. Polyps monomorphic

Anthothelidae: Thinly branched sea-fan. Fragments easily. Polyps monomorphic.

Subergorgiidae: Sea-fan with anastomosing branches (1m height), strong and flexible, polyps monomorphic.

Coralliidae: Calcareous skeleton with color from pink to red. Retractile white feathery polyps and branch in any plane. Polyps dimorphic.

Melithaeidae: Sea-fan with jointed axis and brittle (50cm height).

Suborder Holoaxonia

Plexuridae: Dichotomously branched species.

Gorgoniidae: Sea-fan with anastomosing box-section branches, flattened, bushy or feathery branches (1m height).

Ellisellidae: Whip-like (1m long).

Primnidae: Stems stiff and heavily calcified. Polyp bases composed of spicules are arranged in whorls around the stem.

Isididae: Parallel with upright branches

Age, Growth, Longevity

Photosynthetic gorgonians grow rapidly 15 cm (*Gorgonia ventalin*); 2.5 cm/mon./branch *Pseudoplexaura spp and Pseudopterogorgia acerosa* (Sprung and Delbeek 1997)

0.8-4.5cm/yr. found in Puerto Rico. (Yoshioka and Buchanan-Yoshioka 1991)
Small colonies grow vertically faster but not necessarily in area.

Distribution

Cosmopolitan though most abundant in warmer waters.

Indo-Pacific occurrence:
Suborder Scleraxonia
Briareidae: *Solenopodium spp.; Briareum spp*.
Anthothelidae: *Erythropodium spp*
Subergorgiidae: *Subergorgia spp*
Melithaeidae: *Melithaea spp.; Mopsella spp*.
Ellisellidae: *Ellisella spp. / Junceella spp.*

Suborder: Holoaxonia
Acanthogorgidae: *Acanthogorgia spp.; Muricella spp.*
Plexuridae: *Bebryce spp.*
Gorgoniidae: *Lophogorgia spp.*
Chrysogorgiidae: *Stephanogorgia sp.*
Isididae: *Isis spp.*

Feeding and Food

Heterotrophic by the capture of zooplankton. Autotrophic through nutrient translocation from zooxanthellae. Relative few holoaxonic zooxanthellate genera in the Indo-Pacific. Particulate feeding described (Lasker, 1981)

Require strong current situations for effective feeding by fan-like colonies.

Behavior

Periodic shedding of the waxy cuticle as a means of surface cleaning.

Reproductive Strategies

Parthenogenetic planulae production possible with planulae internal brooders (Brazeau and Lasker, 1989) though most where produced through broadcast spawning (Lasker and Kim, 1996).

Clonal propagation occurs (Lasker 1990).

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4.2.3.13 *Heliopora coerulea* (DeBlainville, 1830) (Alcyonaria, Coenothecalia) (blue coral)

Important Summary Documents

Zann and Boulton (1985) detail the distribution, abundance and ecology in the Pacific. Hyman (1940) and Bayer (1973, 1981) describe the anatomy and taxonomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia): Order Coenothecalia (=Helioporacea); monotypic, family Helioporidae with a single species. It is a soft coral with a hard, >stony coral-like= skeleton.

Habitat Utilization

High abundance of *Heliopora* is attributed to a reduction in competition from *Acropora*, *Pocillopora* and faviids in areas where theses are mutually exclusive. *Heliopora* frequently co-existed with *Porites* and *Montipora*. In terms of interspecific aggression, Heliopora is a good competitor as both *Acropora* and *Pocillopora* are considered aggressive (Lang, 1973).

It is a warm-water generalist with a wide habitat range.

Life History

Adult: Appearance and Physical Characteristics

Zooxanthellate and colonial with a blue calcium carbonate skeleton which is the result of iron salts (Hill, 1960). Bouillon and Houvenaghel-Crevecoeur (1970) conclude the blue pigmentation is composed primarily of biliverdin IX and secondary oxidation products. (Hyman, 1940) describes the skeleton as composed of crystalline slivers of aragonite fused into a layer. There are no sclero-proteinaceous structures as in the rest of the Octocorallia. The skeleton contains strontium but in smaller amounts in comparison to hermatypic scleractinia.

Colour and growth form is highly variable: corallum pale to deep blue; living coral is light brown-grey with extended polyps grey-white. Growth forms: encrusting, columnar and branching (coalescent compressed, flabellate fronds, fine branching). May form massive micro-atolls (Zann and Boulton, 1985). Appears like a species of *Millepora*. There is a clear correlation between colony shape and environmental conditions **(**Veron 1986).

Skeleton with blind tubes internally one for the polyps and one for the solenia (Hyman, 1940).

Reproductive Strategies

Dioecious with fertilization taking place internally and the eggs are brooded externally (Babcock, 1990). External brooding is where they fertilized eggs are shed from the polyp and adhere to the side in mucus pouches were they the developed until they are released. Weingarten (1992) describes a synchronous annual of oocytic development following the general octocorallian reproductive strategy. The gametes are typically released in January, after the full moon, at the summer thermal maximum. Where its distribution is geographically marginal, it takes more than one year for the gametes to mature. It broods its larvae, which settle immediately after release.

Zann and Boulton (1985) suggest the limitation to its distribution to more isolated areas due to a relatively short larval life span. The short larval stage may be nutrient limited as the planula is azooxanthellate.

Distribution

Duration of larval life span, prevailing currents, and the geological and climatic history of isolated archipelagoes determine its distribution. Though widely distributed since the Cretaceous, now more abundant in the equatorial Central Pacific than in the Western Pacific. Comprises 16% of beach sediment in Tuvalu and 40% of substrate between 6m and 10m on Tarawa Atoll, Kirribati. Competition with Acroporidae and Faviidae influence its occurrence (Zann and Boulton, 1985). Globally, it occurs along West Africa, Red Sea, Indonesia and the Maldives, where it may be the dominant coral fauna. It occurs as far south as Madagascar and north to the Ryukyu Islands in Japan (Veron, 1986).

With regard to the AFPI, it is only present in Guam (Randall, 1977), Commonwealth of the Northern Marianas and American Samoa (rare) (U.S. Army Corps Engineers 1980).

Its habitat distribution is inter-tidal reef flats, reef front reef slope in Guam from < 1m to >30m. It is uncommon or rare (e.g. GBR; American Samoa) while it is abundant elsewhere. Heliopora zones have been described in the Marshall Islands and where it is considered as the most common coral (Emory et al. 1954; Wells, 1954a).

Feeding and Food

Heterotrophic and autotrophic by virtue of its zooxanthellae symbiosis. Prey capture is tentacular using nematocysts. Other sources of nutrition may be dissolved organic material and suspension feeding.

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4.2.3.14 *Tubipora Musica* (Linnaeus, 1758) (organ-pipe coral or star polyps)

Important Summary Documents

Veron (1986) describe the species.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); Order Stolonifera; Family Tubiporidae; Genus Tubipora with one species *Tubipora musica*

Four nominal species, probably one true species (Veron, 1986).

Order Stolonifera may be considered a sub-order, with the Order Alcyonacea. Two genera present, *Tubipora* and *Pachyclavularia,* often confused with *Clavularia spp.* One form has tentacles which look like *Alveopora* though eight tentacles.

Habitat Utilization

Requires high illumination and strong circulation through wave action or currents. Abundant in shallow lagoons in turbid water. Also found on reef slopes and in deep water with clear or turbid water. In back reef locations, large heads form in sand or coral rubble. On the reef flat the colonies are smaller and encrusting (Sprung and Delbeek, 1997).

Life History

Adult: Appearance and Physical Characteristic

Colonies are massive, formed by long, parallel, calcareous tubes (stolons) of fused spicules connected by horizontal platforms. The tubes contain the polyps (zooids), each of which has eight pinnate or feather-like tentacles. The skeleton is a permanent dark-red colour. Polyp colour greenish-brown or grey polyps (Veron, 1986; Barnes 1987).

Age, Growth, Longevity

Asexual growth by budding from the solenial canals. Linking of polyps by outward growth from the body wall. The secondary stolon are platform-like and the scerites fuse producing hard massive colonies.

Distribution

Extends from the Red Sea and west Africa, east to Fiji and the Marshall Is. Southerly distribution from south of Madagascar and south Western Australia, north to the Kyushu Is., Japan. Not present in Hawaii, though in Guam and the CNMI.

Feeding and Food

Heterotrophic, autotroph with zooxanthellae

Reproductive Strategies

Sexual and asexual. Sexual reproduction is unknown in *Tubipora musica.* An example of other genera within the family may provide an analogous understanding. Morphologically similar, *Briareum stechei, Pachyclavularia violacea* was found to be dioecious external brooder with the developing planulae residing just beside the mouth. The reddish-brown planulae were released between 11 and 13 days after the full moon in November (Alino and Coll, 1989). The colour of the planulae suggests the presence of zooxanthellae.

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