II. Descriptions of EFH for 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.

A. EFH for Management Unit Species – Fish

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.

Trophic ecology- 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 occured 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).

Bibliography

Chave, E.H. and B.C. Mundy. 1994. Deep-sea benthic fishes of the Hawaiian archipelago, Cross Seamount, and Johnson Atoll. Pacific Science 48: 367-409.

Choat, J.H. 1991. The biology of herbivorous fishes on coral reefs. In: Sale, P.F. (Ed.), The Ecology of Fishes on Coral Reefs. Academic Press, Inc., San Diego, pp. 120-155.

Choat, J.H. and L.M. Axe. 1996. Growth and longevity in acanthurid fishes; analysis of otolith increments. Mar. Ecol. Prog. Ser. 134: 15-26.

Clavijo, I. 1974. A contribution on feeding habits of three species of Acanthurids from the West Indies. M.S. thesis, Florida Atlantic Univ., Boca Raton, FL.

Craig, P.C., Choat, J.H., Axe, L.M., and S. Saucerman. 1997. Population biology and harvest of the coral reef surgeonfish *Acanthurus lineatus* in American Samoa. Fish. Bull. 95: 680-693.

Dalzell, P. 1989. The biology of surgeonfishes (Family: *Acanthuridae*), with particular emphasis on *Acanthurus nigricauda* and *A. xanthopterus* from northern Papua New Guinea, M. Phil. thesis, University of Newcastle upon Tyne.

Dalzell, P., Adams, T.J.H. and N.V.C. Polunin. 1996. Coastal fisheries in the Pacific islands. Oceanography and Marine Biology: an Annual Review 34: 395-531.

Davis GW. 1985. Reproductive patterns of three economically important surgeonfish species on Guam. M.S. thesis, Univ. of Guam, Mangilau, 44p.

Fishelson, L., Montgomery, L.W., and A.H. Myrberg, Jr. 1987. Biology of surgeonfish *Acanthurus nigrofuscus* with emphasis on changeover in diet and annual gonadal cycles. Mar. Ecol. Prog. Ser. 39: 37-47.

Friedlander, A.M. 1996. Assessment of the coral reef resources of Hawaii with emphasis on waters of federal jurisdiction. Report prepared for the Western Pacific Regional Fishery Management Council. 62 pp.

Friedlander, A.M., DeFelice, R.C., Parrish, J.D., and J.L. Frederick. 1997. Habitat resources and recreational fish populations at Hanalei Bay, Kauai. Final report to state of

Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Hawaii Cooperative Fishery Research Unit.

Friedlander AM and JD Parrish. 1998. Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. J. of Exp. Mar. Bio. and Ecol. 224: 1-30.

Green, A.L. 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the U.S. Pacific Islands. Report prepared for the Western Pacific Regional Fishery Management Council. 278 pp.

Hart, A.M., and G.R. Russ. 1996. Response of herbivorous fishes to crown-of-thorns starfish *Acanthaster planci* outbreaks. III. Age, growth, mortality and maturity indices of *Acanthurus nigrofuscus*. Mar. Ecol. Prog. Ser. 136: 25-35.

Johannes, R.E. 1978. Reproductive strategies of coastal marine fishes in the tropics. Env.Biol. Fish. 3(1): 65-84.

Jones, R.S. 1968. Ecological relationships in Hawaiian and Johnston Island Acanthuridae (Surgeon fish). Micronesica 4: 309-361.

Leis, J.M, and D.S. Rennis. 1983. The Larvae of Indo-Pacific Coral Reef Fishes. New South Wales Univ. Press, Sydney, Australia, and Univ. of Hawaii Press, Honolulu, Hawaii.

Lou, D.C. 1993. Growth in juvenile *Scarus rivulatus* and *Ctenochaetus binotatus*: a comparison of families Scaridae and Acanthuridae. J. of Fish Biol. 42: 15-23.

Lou, D.C. and N.A. Moltschanowskyj. 1992. Daily otolith increments in juvenile tropical parrotfishes and surgeonfishes. Aust. J. of Mar. and Freshwater Research 43: 973-981.

Miller, J.M. 1973. Nearshore distribution of Hawaiian marine fish larvae: effects of water quality, turbidity and currents. In J.H.S. Baxter (ed.) The early life history of fish, Springer-Verlag. NY. 1973. 765 pp.

Myers, R.F. 1991. Micronesian reef fishes. Coral Graphics, Guam.

Myers, R.F. 1996. Assessment of coral reef resources of Guam with emphasis on waters of federal jurisdiction. Report prepared for the Western Pacific Regional Fishery Management Council.

Randall, J.E. 1961. A contribution to the biology of the convict surgeonfish of the Hawaiian islands, *Acanthurus triostegus sandvicensis*. Pac. Sci. 15: 215-272.

Randall, J.E. 1996. Shore fishes of Hawaii. Natural World Press, Vida, OR.

Reeson PH. 1983. The biology, ecology and bionomics of the surgeonfishes, Acanthuridae. In "Caribbean Coral Reef Fishery Resources" (JL Munro, ed) ICLARM Stud. Rev. 7: 178-190.

Robertson, D.R. 1983. On the spawning behavior and spawning cycles of eight surgeonfishes (Acanthuridae) from the Indo-Pacific. Environ. Biol. Fishes 9: 193-223.

Robertson, D.R., Polunin, N.V., and K. Leighton. 1979. The behavioral ecology of three Indian Ocean surgeonfishes (Acanthuridae) from Indo-Pacific. Envir. Biol. Fish. 4: 125-170.

Thresher, R.E. 1984. Reproduction in reef fishes. T.F.H. Pub., Neptune City, NJ.

Watson, W. and J.M. Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii: A one-year study of fish eggs and larvae. Tech. Rep. - Univ. Hawaii Sea Grant Program TR-75-01: 1-178.

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

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.

Trophic ecology: 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.

Reproductive ecology: 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.

Bibliography

Clarke TA. 1971. The ecology of the scalloped hammerhead shark, *Sphyrna lewini*, in Hawaii. Pac Sci 25:133–44.

Compagno LJV. 1984. Sharks of the world. FAO Species Catalogue, FAO Fisheries Synopsis No. 125, vol. 4, part 1 and part 2. Rome: United Nations Development Programme, Food and Agriculture Organization of the United Nations, 655p.

Crow GL, CG Lowe and BM Wetherbee. 1996. Shark records from longline fishing programs in Hawaii with comments on Pacific Ocean distributions. Pac Sci 50(4): 382–92.

DeCrosta MA, LR Taylor and JD Parrish. 1984. Age determination, growth, and energetics of three species of carcharhinid sharks in Hawaii. Proc 2nd Symp Res Invest NWHI (2), UNIHI-SEAGRANT-MR-84-01:75–95.

Holland KN, Wetherbee BM, JD Peterson and CG Lowe. 1993. Movements and distribution of hammerhead shark pups on their natal grounds. Copeia 1993 (2): 495–502.

Kimley AP. 1980. Observations of courtship and copulation in the nurse shark, *Ginglymostoma cirratum*. Copeia, 1980:878–82.

Kimley AP. 1981. Grouping behavior in the scalloped hammerhead. Oceanus 24:65–71.

Kimley AP. 1985. Schooling in *Sphyrna lewini*, a species with low risk of predation: a non-egalitarian state. Z Tierpsychol 70:297–319.

Lowe CG, Wetherbee BM, GL Crow and AL Tester. 1996. Ontogenetic dietary shifts and feeding behavior of the tiger shark, *Galeocerdo cuvier*, in Hawaiian waters. Env Biol of Fishes.

Mckibben JN and DR Nelson. 1986. Patterns of movement and grouping of gray reef sharks, *Carcharhinus amblyrhynchos*, at Enewetak, Marshal Islands. Bull Mar Sci 38:89–110.

Michael SW. 1993. Reef sharks and rays of the world: a guide to their identification, behavior, and ecology. Monterey, CA: Sea Challengers, 1993.

Polovina JJ and BB Lau. 1993. Temporal and spatial distribution of catches of tiger sharks (*Galeocerdo cuvier*) in the pelagic longline fishery around the Hawaiian islands. 209–5. JJP, Honolulu Laboratory, Southwest Fisheries Science Center, NMFS.

Randall JE. 1977. Contribution to the biology of the whitetip reef shark. Pac Science 31:143–164.

Randall JE, JL Earle, RL Pyle, JD Parrish and T Hayes. Annotated checklist of the fishes of Midway Atoll, Northwestern Hawaiian Islands. Pac Sci 47(4):356–400.

Suzumoto A, RL Pyle and RB Reeve. 1991. Sharks Hawaii. Honolulu: Bishop Museum Pr. 44p.

Taylor L. 1994. Sharks of Hawai'i: their biology and cultural significance. Honolulu: Univ of Hawaii Pr.

Tricas TC and EM LeFeuvre. 1985. Mating in the reef whitetip shark, *Triaenodon obesus*. Mar Biol 84:233–7.

Tricas TC. 1981. Diel behavior of the tiger shark, *Galeocerdo cuvier*, at French Frigate Shoals, Hawaiian Islands. Copeia, 1981:904–8.

Wass RC. 1971. A comparative study of the life history, distribution and ecology of the sandbar shark and the gray reef shark. PhD thesis. Univ of Hawaii, Honolulu.

Wetherbee B. 1990. Feeding biology of sharks. Amer Littor. Soc Spec Publ 14:74–6.

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

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.

Dasyatidae - 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.

Myliobatidae - 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 are 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.

Mobulidae - 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.

Bibliography

Compagno LJV. 1990. Alternative life-history styles of cartilaginous fishes in time and space. Env Biol Fish 28:33–75.

Michael SW. 1993. Reef sharks and rays of the world: a guide to their identification, behavior, and ecology. Monterey, CA: Sea Challengers, 1993.

Tricas TC. 1980. Courtship and mating-related behaviors in myliobatid rays. Copeia, 1980:553–6.

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. 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.

Bibliography

Bensam P. 1966. The eggs and early development of a muraenid eel. J Mar Biol Assoc India, 8:181–7.

Brock RE. 1972. A contribution to the biology of *Gymnothorax javanicus* (Bleeker). MS thesis, Univ of Hawaii, Honolulu.

Castle PHJ. 1965. Muraenid leptocephali in Australian waters. Trans Roy Soc NZ, 7:125–133.

Castle PHJ. 1979. Early life history of the eel *Moringua edwardsi* (Pisces, Moringuidae) in the western north Atlantic. Bull. Mar. Sci. 29: 1–18.

Castle PHJ and DA Robertson. 1974. Early life history of the congrid eels *Gnathophis habenatus* and *G. incognitus* in New Zealand waters. NZ J Mar Freshwater Res, 8: 95–110

Eldred B. 1969. Embryology and larval development of the blackedge moray, *Gymnothorax nigromarginatus* (Girard, 1859). Fla Bd Conserv Mar Lab, Leafl Ser, 4(13):16pp.

Gosline W and DW Strasburg. 1956. The Hawaiian fishes of the family Moringuidae: another eel problem. Copeia, 1956: 9–18.

Raju SN. 1974. Distribution, growth and metamorphosis of leptocephali of the garden eels, *Taenioconger* sp. and *Gorgasia* sp. Copeia, 1974: 494–500.

Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii. Sea Grant Tech Rept. TR-75-01.

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				

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.

Bibliography

Clarke TA. 1987. Fecundity and spawning frequency of the Hawaiian anchovy or nehu, *Encrasicholina purpurea*. Fish Bull 85:127–38.

Clarke TA. 1992. Egg abundance and spawning biomass of the Hawaiian anchovy or nehu *Encrasicholina purpurea*, during 1984–1988 in Kaneohe Bay, Hawaii. Pac Sci 46:325–43.

Fukuhara O. 1983. Development and growth of laboratory reared *Engraulis japonica* (Houttuyn) larvae. J Fish Biol 23(6):641–52

Ikeda T and S Mito. 1988. Pelagic fish eggs. pp 999–1083 in Okiyama (ed) 1988.

Leary DF, GI Murphy and M Miller. 1975. Fecundity and length at first spawning of the Hawaiian anchovy or nehu (*Stolephorus purpureus* Fowler) in Kaneohe Bay, Oahu. Pac Sci 29:171–80.

Leis, JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

McGowan MF and FH Berry. 1984. Clupeiformes: development and relationships. pp 108–26 in ASIH Spec Publ 1.

Nakamura E. 1970. Synopsis of biological data on Hawaiian species of *Stolephorous*. In The Kuroshio: a symposium on the Japan Current, JC Marr (ed). Honolulu: East-West Centre Pr. 425–46.

Struhsaker P and JH Uchiyama. 1976. Age and growth of the nehu, *Stolephorus purpureus* (Pisces: Engraulidae) from Hawaii Islands as indicated by daily growth increments of sagittae. Fish Bull 74:9–17.

Whitehead PJP, GJ Nelson and T Wongratana. 1987. FAO species catalog 'Clupeoid fishes of the world' Part 2 - Engraulidae. FAO fisheries synopsis 125 (7–2):304–545. Rome: FAO.

Zhang X, Chen Z, Ruan J, He G and X Sha. 1982. On the development of the eggs and larvae of *Thrissa kammalensis* and *Thrissa mystax*. Acta Zoologica Sinica 28(2): 183–9 (in Chinese, English abstract).

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		

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.

Bibliography

Jiang S and L Lim. 1986. Studies on the eggs and larvae of *Sardinella aurita* (Cuv. and Val.) in the fishing grounds of southern Fujian and Tawan Bank. Chinese J. Oceanol. Limnol. 4(1):108–18.

Leis, JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

McGowan MF and FH Berry. 1984. Clupeiformes: development and relationships. pp 108–26 in ASIH Spec Publ 1.

Myers, RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Whitehead PJP. 1985. FAO species catalog 'Clupeoid fishes of the world' Part 1 - Chirocentridae, Clupeidae and Pristigasteridae. FAO fisheries synopsis 125(7–1): 1–303. Rome: FAO.

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

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).

Bibliography

Adams JA. 1960. A contribution to the biology and postlarval development of the sargassum fish, *Histrio histrio* (Linnaeus), with a discussion of the Sargassum complex. Bull Mar Sci, 10:55–82.

Burgess WE. 1976. Salts from the seven seas. Trop Fish Hobbyist 25:57–64.

Fujita S and K Uchida. 1959. Spawning habits and early development of a sargassum fish, *Pterophryne histrio* (Linne.). Sci Bull Fac Agric Kyushu Univ 17:277–82.

Hornell J. 1922. The Madras marine aquarium. Bull Madras Fish Bur 5:57–96.

Mosher C. 1954. Observations on the spawning behavior and the early larval development of the sargassum fish, *Histrio histrio* (Linnaeus). Zoologica 39:141–52.

Pietsch TW and DB Grobecker. 1987. Parental care as an alternative reproductive mode in an antennariid Anglerfish. Copeia, 1980:551–3.

Ray C. 1961. Spawning behavior and egg raft morphology of the ocellated fringed frogfish, *Antennarius nummifer* (Cuvier). Copeia, 1961:230–1.

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		

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.

Bibliography

Leis, JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

McCosker JE and RH Rosenblatt. 1987. Notes on the biology, taxonomy and distribution of flashlightfishes (Beryciformes: Anomalopidae). Japan J Ichthyol 34(2):157–64.

Meyer-Rochow VB. 1976. Some observations on spawning and fecundity in the luminescent fish *Photoblepharon palpebratus*. Mar Biol 37(3):325–8.

Myers, RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

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		

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.

Bibliography

Brecknock EL. 1969. Some aspects of the ecology of *Myripristis murdjan* in the Hawaiian islands. MS thesis, Univ of Hawaii, Honolulu, 22 p.

Dee AJ and RL Radtke. 1989. Age and growth of the brick soldierfish, *Myripristis amaena*. Coral Reefs 8:79–85.

Dee AJ and JD Parrish. 1994. Reproductive and trophic ecology of the soldierfish *Myripristis amaena* in tropical fisheries. Fish. Bull. 92:516–30.

Gladfelter WB and WS Johnson. 1983. Feeding niche separation in a guild of tropical reef fishes (Holocentridae). Ecology 64:552–63.

Irons DK, RK Kosaki and JD Parrish. 1990. Johnston Atoll resource survey. Final report of Phase Six (21 July 1989–20 July 1990). Project report to US Army Engineer District, Honolulu, HI, 150 pp.

Johannes RE. 1981. Words of the lagoon. Los Angeles: Univ Calif Pr, 320pp.

Jones S and M Kumaran. 1964. Notes on the eggs, larvae and juveniles of fishes from Indian waters XII. *Myripristis murdjan* (Forskal) and XIII. *Holocentrus sp.* Ind J Fish 18:155–67.

Mckenny TW. 1959. A contribution to the life history of the squirrelfish *Holocentrus vexillarius* Poey. Bull Mar Sci 9:174–221.

Schroeder RE. 1985. Recruitment rate patterns of coral reef fishes at Midway lagoon, Northwestern Hawaiian Islands. In C Gabrie and B Salvat (eds.), Proc Fifth Int Coral Reef Congress, Tahiti, 27 May–1 June 1985, vol. 5, p. 379–84. Antenne Museum-EOHE, Moorea, French Polynesia.

Wyatt JR. 1983. The biology, ecology and bionomics of the squirrelfishes, Holocentridae. ICLARM Stud Rev 7:50–8.

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		

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).

Bibliography

Mito, S. 1966. Fish eggs and larvae: Illustrations of the marine plankton of Japan 7:74pp.

Thresher, RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii: a one-year study of the fish eggs and larvae. Univ Hawaii Sea Grant Program Honolulu Tech Rept UNIHI-SEAGRANT-TR-75-01 178 pp.

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		

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.

Bibliography

Delsman HC. 1921. Fish eggs and larvae from the Java Sea. 1. *Fistularia serrata*. Treubia 2:97–108.

Leis JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Honolulu: Univ of Hawaii Pr.

Mito S. 1961. Pelagic fish eggs from Japanese waters - I. Clupeina, Chanina, Stomiatina, Myctophida, Anguillida, Belonida, and Syngnathida. Sci Bull Fac Agr Kyushu Univ 18(3) pp 285–310 plus plates 20–34 (in Japanese, English summary).

Mito, S. 1966. Fish eggs and larvae: Illustrations of the marine plankton of Japan 7: 74pp.

Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii: a one-year study of the fish eggs and larvae. Univ Hawaii Sea Grant Program Honolulu Tech Rept UNIHI-SEAGRANT-TR-75-01 178 pp.

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		

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.

Bibliography

Dawson CE. 1985. Indo-Pacific pipefishes (Red Sea to the Americas). The Gulf Coast Res Lab, Ocean Springs, MS.

Gronell A. 1984. Courtship, spawning and social organization of the pipefish, *Corythoichthys intestinalis* (Pisces, Syngnathidae) with notes on two congeneric species. Z Tierpsychol 65:1–24.

Strawn K. 1958. Life history of the pygmy sea horse *Hippocampus zosterae* at Cedar Key, FL. Copeia 1:16–22.

Vincent ACJ. 1996. The international trade in seahorses. Cambridge, UK: TRAFFIC Intl., 163 pp.

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		

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).

Bibliography

Leis, JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

Myers, R.F. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Smith MM and PC Heemstra (eds). 1986. Smith's sea fishes. Johannesburg, S Africa: Macmillan.

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		

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.

Bibliography

Leis, JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Sydney: New South Wales Univ Pr and Honolulu: Univ of Hawaii Pr.

Harmelin-Vivien ML and C Bouchon. 1983. Feeding behavior of some carnivorous fishes (Serranidae and Scorpaenidae) from Tulear (Madagascar). Mar Biol 37:329–40

Miller JM, W Watson and JM Leis. 1979. An atlas of common nearshore marine fish larvae of the Hawaiian islands. Misc Rep 80–02. Univ of Hawaii Sea Grant, Honolulu.

Mito S and K Uchida. 1958. On the egg development and hatched larvae of a scorpaenid fish, *Pterois lunulata*. Sci Bull Fac Agric , Kyushu Univ 16:381–85.

Moyer JT and MJ Zaiser. 1981. Social organization and spawning behavior of the pteroine fish *Dendrochirus zebra* at Miyake-jima, Japan. Japan J Ichthyol 28:52–69 .

Norris JE and JD Parrish. 1988. Predator-prey relationships among fishes in pristine coral reef communities. Proc Int Coral Reef Symp 6th (2):107–13.

Takai T and T Fukunaga. 1971. The life history of a ovo-viviparous scorpaenoid fish, *Sesbastes longispinis* (Matsubara). I. Egg and larval stages. J Shimonoseki Univ Fish. 20:91–5.

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		

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.

Bibliography

Harmelin-Vivien ML and C Bouchon. 1983. Feeding behavior of some carnivorous fishes (Serranidae and Scorpaenidae) from Tulear (Madagascar). Mar Biol 37:329–40.

Leis, JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Sydney: New South Wales U Pr. and Honolulu: Univ of Hawaii Pr.

Miller JM, W Watson, and JM Leis. 1979. An atlas of common nearshore marine fish larvae of the Hawaiian islands. Misc Rep 80-02. Univ of Hawaii Sea Grant, Honolulu, HI.

Mito S and K Uchida. 1958. On the egg development and hatched larvae of a scorpaenid fish, *Pterois lunulata*. Sci Bull Fac Agric, Kyushu Univ 16:381–5.

Moyer JT and MJ Zaiser. 1981. Social organization and spawning behavior of the pteroine fish *Dendrochirus zebra* at Miyake-jima, Japan. Japan J Ichthyol 28:52–69.

Norris JE and JD Parrish. 1988. Predator-prey relationships among fishes in pristine coral reef communities. Proc Int Coral Reef Symp 6th (2):107–113.

Orton GL. 1955. Early developmental stages of the California scorpionfish *Scorpaena guttata*. Copeia, 1955:210–214.

Randall JE, Earle JL, Pyle RL, JD Parrish and Hayes. 1993. Annotated checklist of the fishes of Midway Atoll, Northwestern Hawaiian Islands. Pac Sci 47(4):356–400.

Takai T and T Fukunaga. 1971. The life history of a ovo-viviparous scorpaenoid fish, *Sesbastes longispinis* (Matsubara). I. Egg and larval stages. J Shimonoseki Univ Fish 20:91–5.

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		

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 substrate from the shore to a 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)

Bibliography

Allen, G.R. 1985. Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. FAO Fish. Synop. no. 125, volume 6 208 p..

Brock, V.E., and T.C. Chamberlain. 1968. A geological and ecological reconnaissance off western Oahu, Hawaii, principally by means of the research submarine *Asherah*. Pac. Sci. 22:373-394.

Carpenter KE, Allen GR. 1989. FAO species catalogue. Volume 9, Emperor fishes and large-eye breams of the world (family Lethrinidae). FAO. Fisheries synopsis no 125, volume 9. Rome: FAO. 118p.

Ellis, D. A., E. E. Demartini, and R. B. Moffitt. 1992. Bottom trawl catches of juvenile opakapaka, *Pristipomoides filamentosus* (F. Lutjanidae), and associated fishes, Townsend Cromwell cruise TC-90-10, 1990. U. S. Dep. Commer., NOAA, NMFS, SWFC Admin. Rep. H-92-03. 33pp.

Everson, A.R., H.A. Williams, and B.M. Ito. 1989. Maturation and reproduction in two Hawaiian Eteline snappers, Uku, *Aprion virescens*, and Onaga, *Etelis coruscans*. U.S. Fish. Bull. 87:877-888.

Everson, A.R. 1984. Spawning and gonadal maturation of the ehu, *Etelis carbunculus*, in the Northwestern Hawaiian Islands. pp. 128-148 In: Grigg, R.W. and K.Y. Tanoue (Eds.). Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands. Vol. 2. University of Hawaii Sea Grant Miscellaneous Report UNIHI-SEAGRANT-MR-84-01. Honolulu, Hawaii.

Grimes, C.B. 1987. Reproductive biology of the Lutjanidae: a review. *In* J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 239-294. Westview Press, Boulder, Colorado.

Haight WR, Kobayashi D, Kawamoto KE. 1993a. Biology and management of deepwater snappers of the Hawaiian archipelago. Mar Fish Rev 55(2):20-27.

Haight, W.R., J.D. Parrish, and T.A. Hayes. 1993b. Feeding ecology of Lutjanid snappers at Penguin Bank, Hawaii. Trans. Am. Fish. Soc. 122:328-347.

Harliem-Vivien ML, Bouchon C. 1976. Feeding behavior of some carnivorous fishes (Serranidae and Scopaenidae) from Tulear (Madagascar). Mar Biol 37:329-40.

Heemstra PC, Randall JE. 1993. Groupers of the world (family Serranidae, subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper, and lyretail species known to date. Rome: FAO. 382 p. Fisheries synopsis no 125, volume 16.

Johannes RE. 1981. *Words of the lagoon*. Berkeley: Univ California Pr. 245 p.

Kendall AW Jr. 1984. Serranidae: development and relationships. In: Moser HG, Richards WJ, Cohen DM, Fahay MP, Kendall AW Jr, Richardson SL, editors. Ontogeny and systematics of fishes. An international symposium dedicated to the memory of Elbert Halvor Ahlstrom; 1984 Aug 15B18; La Jolla, CA. Am Soc of Icthyol and Herpetol. p. 499-510.

Kikkawa, B.S. 1984. Maturation, spawning, and fecundity of opakapaka, *Pristipomoides filamentosus*, in the Northwestern Hawaiian Islands. pp. 149-160 In: Grigg, R.W. and K.Y. Tanoue (Eds.). Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands. Vol. 2. University of Hawaii Sea Grant Miscellaneous Report UNIHI-SEAGRANT-MR-84-01. Honolulu, Hawaii.

Laroche, W.A., W.F. Smith-Vaniz and S.L. Richardson. 1984. Carangidae: development. *in* Ontogeny and systematics of fishes, based on an international symposium dedicated to the memory of Elbert Halvor Ahlstrom, August 15-18, 1983, La Jolla, California. Special publication of the American Society of ichthyologists and herpetologists, no 1. pp. 510-522.

Leis, J. M. 1987. Review of the early life history of tropical groupers (Serranidae) and snappers (Lutjanidae). *In* J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 329-373. Westview Press, Boulder, Colorado.

Lewis AD, Chapman LB, Sesewa A. 1983. Biological notes on coastal pelagic fishes in Fiji. Fiji: Fisheries Division (MAF). Technical report no 4.

Manooch, C. S. III. 1987. Age and growth of snappers and groupers. *In* J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 329-373. Westview Press, Boulder, Colorado.

Morgan JFC. 1982. Serranid fishes of Tanzania and Kenya. Ichthyol Bull. JLB Smith Inst Ichthyol 46:1B44, 6 pls.

Myers RF. 1991. *Micronesian reef fishes.* Barrigada, Guam: Coral Graphics.

Miller JM, Watson W, Leis JM. 1979. An atlas of common nearshore marine fish larvae of the Hawaiian Islands. Honolulu: University of Hawaii Sea Grant College Program. Miscellaneous report no UNIHI-SEAGRANT-MR-80-02.

Moffitt RB, Parrish FA. 1996. Habitat and life history of juvenile Hawaiian pink snapper, *Pristipomoides filamentosus*. Pac Sci 50(4):371-81.

Moffitt, R. B., F. A. Parrish, and J. Polovina. 1989. Community structure, biomass and productivity of deepwater artificial reefs in Hawaii. Bull. Mar. Sci. 44(2):616-630.

Munro, J.L. 1987. Workshop synthesis and directions for future research. *In* J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 329-373. Westview Press, Boulder, Colorado.

Parrish, F. A. 1989. Identification of habitat of juvenile snappers in Hawaii. Fish. Bull. U.S. 87:1001-1005

Parrish, J.D. 1987. Trophic biology of snappers and groupers. pp. 405-463 In: Polovina, J.J. and S.V. Ralston (Eds.). Tropical snappers and groupers: Biology and fishery management. Westview Press, Boulder, Colorado.

Ralston, S. 1987. Mortality rates of snappers and groupers. *In* J. J. Polovina and S. Ralston (editors), Tropical snappers and groupers: Biology and fisheries management, p. 375-404. Westview Press, Boulder, Colorado.

Ralston, S. 1981. A study of the Hawaiian deepsea handline fishery with special reference to the population dynamics of opakapaka, *Pristipomoides filamentosus* (Pisces: Lutjanidae). Ph.D. Thesis, Univ. Wash., Seattle, Washington, 204 p.

Ralston, S., R. M. Gooding, and G. M. Ludwig. 1986. An ecological survey and comparison of bottomfish resource assessments (submersible versus handline fishing) at Johnston Atoll. U. S. Fish. Bull. 84(1):141-155

Ralston, S., and G. T. Miyamoto. 1983. Analyzing the width of daily otolith increments to age the Hawaiian snapper, *Pristipomoides filamentosus*. Fish. Bull. 81(3):423-535.

Randall JE,, Ben-Tuvia A. 1983. A review of the groupers (Pisces: Serranidae: Epinephelinae) of the Red Sea, with description of a new species of *Cephalopholis*. Bull Mar Sci 33(2):373-426.

Sudekum AE, Parrish JD, Radtke RL, Ralston S. 1991. Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. Fish Bull (89):492-513.

Uchida, R.N. and J.H. Uchiyama (Eds.). 1986. Fishery Atlas of the Northwestern Hawaiian Islands. NOAA Technical Report NMFS 38. 142 pp.

Walker, M.H. 1978. Food and feeding habits of *Lethrinus chrysostomus* Richardson (Pisces: Percifomes) and other lethrinids on the Great Barrier Reef. Aust. J. Mar. Freshwater Res., 29:623-630

Yamaguchi, Y. 1953. The fishery and the biology of the Hawaiian opelu, *Decapterus pinnulatus*. M.S. Thesis, Univ. of Hawaii, Honolulu, 125 p.

Young, P.C., and R.B. Martin. 1982. Evidence for protogynous hermaphroditism in some lethrinid fishes. Fish. Biol. 21:475-484.

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

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).

Bibliography

Leis JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Honolulu: Univ of Hawaii Pr.

Randall, J.E. 1996. Shore fishes of Hawaii. Vida, OR: Natural World Pr.

Smith, CL. 1971. Secondary gonochorism in the serranid genus *Liopropoma*. Copeia, 1971:316–9.

Smith, CL and EH Atz. 1969. The sexual mechanism of the reef bass *Pseudogramma bermudensis* and its implications in the classification of the Pseudogrammidae (Pisces: Perciformes). Zeit Morph Tiere 65:315–26.

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		

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.

Bibliography

Mito, S. 1955. Breeding habits of a percoid fish, *Plesiops semeion*. Sci Bull Fac Agric, Kyushu Univ, 15:95–9.

Myers, RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Randall JE. 1986. Red Sea reef fishes. London: Immel Publ.

Thresher, RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

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		

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 29°C. 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.

Bibliography

Jillett JB. 1968. The biology of *Acanthoclinus quadridactylus* (Bloch and Schneider) (Teleostei-Blennioidea) II. Breeding and development. Aust J Mar Freshwater Res 19:1–8.

Lubbock R. 1975. Fishes of the family Pseudochromidae (Perciformes) in the northwest Indian Ocean and Red Sea. J. Zool., London, 176: 115-157.

Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Randall JE. 1986. Red Sea reef fishes. London: Immel Publ.

Thresher RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

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		

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.

Bibliography

Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Randall JE. 1986. Red Sea reef fishes. London: Immel Publ..

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		

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.

Bibliography

Leis JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Honolulu: Univ of Hawaii Pr.

Lobel PS. 1974. Sea spawnings—hawkfish. Octopus 1(7):23.

Randall JE. 1963. Review of the hawkfishes (family Cirrhitidae). Proc US Nat Mus 113: 389–450.

Suzuki K, Tanaka Y, Hioki S and Y Shiobara. 1980. Studies on reproduction and larval rearing of coastal marine fishes. pp. 53–82 in G Yamamoto (ed); Research in large scale aquaculture of marine fisheries resources. Inst of Oceanic Res and Dev Tokai Univ: Shimizu.

Thresher RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

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		

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 was 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).

Bibliography

Charney P. 1976. Oral brooding in the cardinalfishes *Phaeoptyx conklini* and *Apogon maculatus* from the Bahamas. Copeia, 1976:198–200.

Chave EH. 1978. General ecology of six species of Hawaiian cardinalfishes. Pac Sci 32: 245–69.

Chave EH and DW Eckert. 1974. Ecological aspects of the distribution of fishes at Fanning Island. Pac Sci 28(3):279–319.

Fraser TH. 1972. Comparative osteology of the shallow water cardinalfishes (Perciformes: Apogonidae) with reference to the systematics and evolution of the family. Ichthyol Bull 1–105.

Hobson ES. 1972. Activity of Hawaiian reef fishes during the evening and morning transitions between daylight and darkness. Fish Bull 70:715–40.

Hobson ES. 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish Bull 72:915–1031.

Hobson ES and R Chess. 1978. Trophic relationships among fishes and plankton in the lagoon at Enewetak Atoll, Marshall Islands. Fish Bull 76:133–53.

Oppenheimer JR. 1970. Mouthbreeding in fishes. Anim Behav 18:493–503.

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				

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.

Bibliography

Caldwell DK. 1962. Development and distribution of the short bigeye, *Pseudopriacanthus altus* (Gill) in the western North Atlantic. Fish Bull (US) 62:103–49.

Colin PL and I Clavijo. 1978. Mass spawning by the spotted goatfish, *Pseudupeneus maculatus*. Bull Mar Sci 28: 78–82.

Leis JM and DS Rennis. 1983. The larvae of Indo-Pacific coral reef fishes. Sydney: New South Wales Univ Pr. and Honolulu: Univ of Hawaii Pr.

Renzhai Z and L Suifen. 1982. The development of egg and larvae of *Priacanthus macracanthus* (Cuvier and Valenciennes). J Fisheries China 6(3):243–51.

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		

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).

Bibliography

Araga C. 1969. Young form of the rare coral fish, *Malacanthus latovittatus* from Tanabe Bay. Pub Seto Mar Biol Lab 16:405–10.

Ikeda T and S Mito. 1988. Pelagic fish eggs. pp 999–1083 in Okiyama (ed). An atlas of the early stage fishes in Japan. Tokyo: Tokai Univ Pr.

Johnson GD. 1984. Percoidei: development and relationships. pp 464-499 in ASIH Spec Publ 1.

Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

Randall JE. 1981. A review of the Indo-Pacific sand tilefish genus Hoplolatilus (Perciformes: Malacanthidae). Freshw and Mar Aquar 4(12):39–46.

Thresher RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

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		

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).

Bibliography

Johnson GD. 1984. Percoidei: development and relationships. pp 464-499 in ASIH Spec Publ 1.

Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

Nakajima H, H Kawahara, and S Takamatsu. 1987. The breeding behavior and the behavior of larvae and juveniles of the Sharksucker, *Echeneis naucrates*. Japan J Ichthyol 34(1):66–70.

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		

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 C° (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).

Bibliography

Humphreys RL Jr. 1986. Greater amberjack. In: Uchida RN, Uchiyama JH, editors. Fishery atlas of the Northwestern Hawaiian Islands. NOAA. Technical report nr NMFS 38.

Humphreys RL Jr. 1980. Feeding habits of the kahala, *Seriola dumerili*, in the Hawaiian archipelago. In: Grigg RW, Tanoue KY, editors. Proceedings of the Symposium on Resource Investigations in the Northwestern Hawaiian Islands, volume 2; 1980 May 25–27; Honolulu, HI. Honolulu: University of Hawaii. p 233–40. Report nr UNIHI-SEAGRANT-MR-84-01.

Johannes RE. 1981. Words of the lagoon. Berkeley: Univ California Pr. 245 p.

Kikkawa BS, Everson AR . 1984. Gonadal maturation, fecundity and spawning of the greater amberjack (*Seriola dumerili*) in Hawaiian waters with reference to ciquatoxin incidences. In: Grigg RW , Tanoue KY, editors. Proceedings of the Symposium on Resource Investigations in the Northwestern Hawaiian Islands, volume 2; 1980 May 25–27; Honolulu, HI. Honolulu: University of Hawaii. p 149–160. Report nr UNIHI-SEAGRANT-MR-84-01.

Laroche, W.A., W.F. Smith-Vaniz and S.L. Richardson. 1984. Carangidae: development. *in* Ontogeny and systematics of fishes, based on an international symposium dedicated to the memory of Elbert Halvor Ahlstrom, August 15-18, 1983, La Jolla, California. Special publication of the American Society of icthyologists and herpetologists, no 1. pp. 510-522.

Lewis AD, Chapman LB, Sesewa A. 1983. Biological notes on coastal pelagic fishes in Fiji. Fiji: Fisheries Division (MAF). Technical report nr 4.

Miller JM, Watson W, Leis JM. 1979. An atlas of common nearshore marine fish larvae of the Hawaiian Islands. Honolulu: University of Hawaii Sea Grant College Program. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-02.

Myers RF. 1991. *Micronesian reef fishes.* Barrigada, Guam: Coral Graphics.

Okamoto H, Kawamoto P. 1980. Progress report on the nearshore fishery resource assessment of the Northwestern Hawaiian Islands: 1977 to 1979. In: Grigg, RW, Pfund RT, editors. Proceedings of the Symposium on the status of resource investigations in the Northwestern Hawaiian Islands; 1980 Apr 24–25; Honolulu, HI.

p 71–80. Honolulu: University of Hawaii Sea Grant College Program. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.

Parrish J, Taylor L , DeCrosta M, Feldkamp S, Sanderson L, Sorden C. 1980. Trophic studies of shallow-water fish communities in the Northwestern Hawaiian Islands. In: Grigg RW, Pfund RT, editors. Proceedings of the Symposium on the status of resource investigations in the Northwestern Hawaiian Islands; 1980 Apr 24–25; Honolulu, HI. Honolulu: University of Hawaii Sea Grant College Program. p 175–88. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.

Ralston S, Gooding RM, Ludwig GM. 1986. An ecological survey and comparison of bottom fish resource assessments (submersible versus handline fishing) at Johnston Atoll. US Fish Bull. 84:141–55.

Randall, John E., Gerald R. Allen, and Roger C. Steene. 1990. Fishes of the Great Barrier Reef and Coral Sea. Crawford House Press, Bathhurst, Australia. 507 pp.

Seki MP. 1986. Butaguchi. In: Uchida RN, Uchiyama JH, editors. Fishery atlas of the Northwestern Hawaiian Islands. NOAA. Technical report nr NMFS 38.

Seki MP. 1984. The food and feeding habits of the white trevally, *Pseudocaranx dentex* in the Northwestern Hawaiian Islands. In: RW Grigg, Pfund RT, editors. Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands, volume 2; 1980 Apr 24–25; Honolulu, HI. Honolulu: University of Hawaii Sea Grant College Program. p 264-77. Miscellaneous report nr UNIHI-SEAGRANT-MR-80-04.

Smith's Sea Fishes. 1986. Smith, Margaret M., and Phillip C. Heemstra (eds). Springer-Verlag, Berlin.

Sudekum AE, Parrish JD, Radtke RL, Ralston S. 1991. Life history and ecology of large jacks in undisturbed, shallow, oceanic communities. Fish Bull (89):492–513.

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

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

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.

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

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.

Bibliography

Bell LJ and PL Colin. 1986. Mass spawning of *Caesio teres* at Enewetak Atoll, Marshall Islands. Envir Biol Fish 15(1):69–74.

Cabanban AS. 1984. Some aspects of the biology of *Pterocaesio pisang* in the central Visayas. MS thesis. Coll of Sci, Univ of the Philippines: 69pp.

Carpenter KE. 1988. Fusilier fishes of the world. FAO species catalogue No. 125, Vol. 8. Rome: United Nations Development Programme FAO of the United Nations.

Hiatt RW and DW Strasburg. 1960. Ecological relationships of fish fauna on coral reefs of the Marshall Islands. Ecol Monogr 30:65–127.

Hobson ES and JR Chess. 1978. Trophic relationships among fishes and plankton in the lagoon at Enewetak Atoll, Marshall Islands. Fish Bull NOAA/NMFS 76:133–53.

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		

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.

Bibliography

Baillon N and M Kulbicki. 1988. Ageing of adult tropical fish by otoliths: A comparison of three methods on *Diagramma pictum*. Proc 6th Int Coral Reef Symp, Australia, 1988. Vol. 2:341–6.

Brothers EB and WN McFarland. 1981. Correlations between otolith microstructure, growth and life history transitions in newly recruited french grunts. Rapp.P.-v. Re'un Cons Int Explor Mer 178:369–74.

Cummings WC, BD Brahy and JY Spires. 1966. Sound production, schooling and feeding habits of the margate, *Haemulon album* Cuvier, off North Bimini, Bahamas. Bull Mar Sci 16(3):626–40.

Gaut VC and JL Munro. 1983. The biology, ecology and bionomics of the the grunts, Pomadasyidae. ICLARM Stud Rev 7:110–41.

McFarland WN. 1980. Observations on recruitment in haemulid fishes. Proc Gulf Caribb Fish Inst 32:132–238.

Munro JL, VC Gaut, R Thompson and PH Reeson. 1973. The spawning seasons of Caribbean reef fishes. J Fish Biol. 5:69–84.

Podosinnikov AY. 1977. Early ontogeny of the "striped grunt," *Parapristipoma humile* (Pomadasyidae, Pisces). J Ichthy 17(4):683–4.

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		

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.

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

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 ($L\infty$) 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_∞ (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_∞). Onaga reaches sexual maturity at 61 cm FL (62% L_∞) (Everson et al. 1989). In the NWHI, ehu reaches maturity at about 30 cm FL (46% L_∞) and opakapaka reaches maturity at around 43 cm FL (48% L_∞) (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.

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

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.

Bibliography

Colin PL and IE Clavijo. 1978. Mass spawning by the spotted goatfish, *Pseudopeneus maculatus* (Bloch). Bull Mar Sci 28:780–2.

Friedlander AM, DeFelice RC, Parrish JD and JL Frederick. 1997. Habitat resources and recreational fish populations at Hanalei Bay, Kauai. Final report to state of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Hawaii Cooperative Fishery Research Unit.

Holland KN, JD Peterson, CG Lowe and BM Wetherbee. 1993. Movements, distribution and growth rates of the white goatfish *Mulloides flavolineatus* in a fisheries conservation zone. Bull of Mar Sci 52:982–92.

Mahi CA. 1969. The food and feeding habits of the kumu, *Parupeneus porphyreus*. MS thesis, Univ of Hawaii, Department of Zoology.

Moffitt RB. 1979. Age, growth, and reproduction of the kumu, *Parupeneus porphyreus* (Jenkins). MS thesis, Univ of Hawaii, Department of Zoology.

Munro JL. 1976. Aspects of the biology and ecology of Caribbean reef fishes: Mullidae (goat-fishes). J Fish Biol 9: 79–97.

Munro JL. 1983. The biology, ecology and bionomics of the goatfishes, Mullidae. ICLARM Stud Rev 7:142–54.

Sorden CT. 1982. Trophic relationships of goatfishes (family Mullidae) in the Northwestern Hawaiian Islands. MS thesis, Univ of Hawaii, Department of Zoology.

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

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).

Bibliography

Rimmer DW. 1986. Changes in diet and the development of microbial digestion in juvenile buffalo bream *Kyphosus cornellii*. Mar Biol 93:443–8.

Randall JE and HA Randall. 1960. Examples of mimicry and protective resemblance in tropical marine fishes. Bull Mar Sci 10:444–80.

Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii: A one-year study of fish eggs and larvae. Tech Rep, Univ Hawaii Sea Grant Program TR-75-01:1–178.

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		

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).

Bibliography

Akatsu S, Y Ogasawara and F Yasuda. 1977. Spawning behavior and development of eggs and larvae of the striped fingerfish, *Monodactylus sebae*. Japan J Ichthyol 23(4):208–14.

Breder CM and DE Rosen. 1966. Modes of reproduction in fishes. Jersey City, NJ: TFH Pub.

Heemstra PC. 1984. Monodactylidae. In: W Fischer and G Bianchi, eds. FAO species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51). Vol. 3. Rome: FAO.

Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

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		

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.

Bibliography

Chapman RW. 1978. Observations of spawning behavior in Atlantic spadefish, *Chaetodipterus faber*. Copeia 1978:336.

Johnson GD. 1984. Percoidei: Development and relationships. pp 464–99 in ASIH Spec Publ 1.

Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. Honolulu: Univ of Hawaii Pr.

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		

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.

Bibliography

Aiken K. 1983. The biology, ecology and bionomics of the butterfly and angelfishes, Chaetodontidae. ICLARM Stud Rev 7:166–77.

Allen GR, R Steene and M Allen. 1998. A guide to angelfishes & butterflyfishes. Perth, WA: Vanguard Pr.

Burgess WE. 1978. Butterflyfishes of the world. Neptune City, NJ: TFH Pub..

Colin PL. 1989. Aspects of the spawning of western Atlantic butterflyfishes (Pisces: Chaetodontidae). Env Biol Fishes 25:131–41.

Cox EF. 1986. The effects of a selective corallivore on growth rates and competition for space between two species of Hawaiian corals. J Exp Mar Biol Ecol 101:161–74.

Leis JM. 1989. Larval biology of butterflyfishes (Pisces, Chaetodontidae): What do we really know? Environ Biol 25(1-3):87–100.

Motta PJ. 1989. The butterflyfishes: success on the coral reef. The Netherlands: Kluwer Acad Pub. 256 pp.

Ralston S. 1976a. Age determination of a tropical reef butterflyfish utilising daily growth rings of otoliths. Fish Bull 74:990–4.

Ralston S. 1976b. Anomalous growth and reproductive patterns in populations of *Chaetodon miliaris* (Pisces, Chaetodontidae) from Kaneohe Bay, Oahu, Hawaiian Islands. Pac Sci 30(4):395–403.

Reese ES. 1973. Duration of residence by coral reef fishes on "home" reefs. Copeia, No. 1:145–9.

Reese ES. 1977. Coevolution of corals and coral feeding fishes of the family Chaetodontidae. Proc Int Coral Reef Symp, 3rd 2:268–74.

Reese ES. 1991. How behavior influences community structure of butterflyfishes (family Chaetodontidae) on Pacific coral reefs. Ecol Int Bull 19:29–41.

Sano M. 1989. Feeding habits of Japanese butterflyfishes (Chaetodontidae). Env Biol Fish 25(1-3):195–203.

Yabuta S. 1997. Spawning migrations in the monagamous butterflyfish, *Chaetodon trifasciatus*. Ichthyol Res 44(2):177–82.

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		

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).

Bibliography

Allen GR, R Steene and M Allen. 1998. A guide to angelfishes and butterflyfishes. Perth, WA: Vanguard Pr.

Aiken K. 1983. The biology, ecology and bionomics of the butterfly and angelfishes, Chaetodontidae. ICLARM Stud Rev 7:166– 77.

Hioki S, K Suzuki, and Y Tanaka. 1990. Development of eggs and larvae in the angelfish, *Centropyge ferrugatus*. Japan J Ichthyolo 37(1):34–8.

Lobel PS. 1978. Diel, lunar and seasonal periodicity in the reproductive behavior of the pomacanthid fish, *Centropyge potteri*, and some other reef fishes in Hawaii. Pac. Sci 32:193–207.

Moyer JT and A Nakazono. 1978. Population structure, reproductive behavior, and protogynous hermaphroditism in the angelfish *Centropyge interruptus* at Miyake-jima, Japan. Japan J Ichthyol 25(1):25–39.

Neudecker S and PS Lobel. 1982. Mating systems of chaetodontid and pomacanthid fishes at St. Croix. Z Tierpsychol 59:299–318.

Pyle RL and JE Randall. 1994. A review of hybridization in marine angelfishes (Perciformes: Pomacanthidae). Env Biol Fishes 41:127–45.

Thresher RE. 1982. Courtship and spawning in the emperor angelfish *Pomacanthus imperator*, with comments on reproduction by other pomacanthid fishes. Mar Biol 70:149–56.

Thresher RE and EB Brothers. 1985. Reproductive ecology and biogeography of Indo-West Pacific angelfishes (Pisces: Pomacanthidae). Evolution 39(4):878–87.

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		

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. If 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.

Bibliography

Allen GR, R Steene and M Allen. 1998. A guide to angelfishes and butterflyfishes. Perth, WA: Vanguard Pr.

Carlson BA. 1982. The masked angelfish, *Genicanthus personatus* Randall 1974. Fresh and Mar Aquar 5:31–2.

Chave EH and BC Mundy. 1994. Deep-sea benthic fishes of the Hawaiian archipelago, Cross Seamount, and Johnson Atoll. Pac Sci 48:367–409.

Howe JC. 1993. A comparative analysis of the feeding apparatus in pomacanthids, with special emphasis on oesophageal papillae in *Genicanthus personatus*. J Fish Biol 43:593–602.

Lobel PS. 1978. Diel, lunar and seasonal periodicity in the reproductive behavior of the pomacanthid fish, *Centropyge potteri*, and some other reef fishes in Hawaii. Pac. Sci 32:193–207.

Pyle RL. 1990. Rare and unusual marines: the masked angelfish *Genicanthus personatus* Randall. Freshw and Mar Aquar 13(10):112, 114, 116, 118.

Randall JE. 1975. A revision of the Indo-Pacific angelfish genus *Genicanthus* with descriptions of three new species. Bull Mar Sci 25:393–421.

Randall JE. 1976. Description of the male of the Hawaiian angelfish *Genicanthus personatus*. Bull Mar Sci 26:414–6.

Severns M and PF Fiene-Severns. 1993. Molokini Island, Hawaii's premier marine preserve. Hawaii: Pac Isl Pub.

Toyama D. 1988. The angelfish of Midway Island. Freshw and Mar Aquar 11(11):104–6.

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

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).

Bibliography

Allen GR. 1991. Damselfishes of the world. Hong Kong: Mergus Pr.

Fautin DG and GR Allen. 1992. Field guide to anemonefishes and their host sea anemones. Perth, WA: Western Australian Museum. 160 pp.

Hixon MA and WN Brostoff. 1983. Damselfish as keystone species in reverse: Intermediate disturbance and diversity of reef algae. Science 220:511–3.

Nolan RS. 1975. The ecology of patch reef fishes. Unpub PhD dissertation, Univ of Cal. San Diego, CA.

Ross RM. 1978. Territorial behavior and ecology of the anemonefish *Amphiprion melanopus* on Guam. Z Tierpsychol 46:71–83.

Thresher RE, PL Colin and LJ Bell. 1989. Planktonic duration, distribution and population structure of western and central Pacific damselfishes (Pomacentridae). Copeia 1989 (2):420–34.

Waldner RE and DR Robertson. 1980. Patterns of habitat partitioning by eight species of territorial Caribbean damselfishes (Pisces: Pomacentridae). Bull Mar Sci 30:171–86.

Wellington GM and BC Victor. 1989. Planktonic larval duration of one hundred species of Pacific and Atlantic damselfish. Mar Biol 101:557–67.

Williams DB. 1980. Dynamics of the pomacentrid community on small patch reefs in One Tree Lagoon (Great Barrier Reef). Bull Mar Sci 30:159–70.

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		

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 are 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.	*Choerodon anchorago*
Pseudodax moluccanus	*Cheilinus spp.*

Wetmorella spp.
Cymolutes spp.
Xyrichtys spp.
Pterogogus spp.
Cheilio inermis
Gomphosus varius
Hemigymnus spp.
Macropharyngdon spp.
Stethojulis spp.
Epibulis insidiator
Novaculichthys spp.
Pseudocheilinus spp.
Anampses spp.
Coris spp.
Halichoeres spp.
Hologymnosus spp.
Pseudojuloides 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.
Pseudocoris yamashiroi
Paracheilinus spp.
Thalassoma amblycephalum

The following corallivores feed on live coral polyps.

Labropsis xanthonata (adults)
Diproctacanthus xanthurus (plus cleaning)
Labrichthys unilineatus

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 xanthonata (juvenile)
Labropsis micronesica
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).

Bibliography

Chave EH and BC Mundy. 1994. Deep-sea benthic fishes of the Hawaiian archipelago, Cross Seamount, and Johnson Atoll. Pac Sci 48:367–409.

Colin PL and LJ Bell. 1991. Aspects of the spawning of labrid and scarid fishes (Pisces: Labroidei) at Enewetak Atoll, Marshall Islands with notes on other families. Env Biol of Fishes 31:229–60.

Dalzell P, TJH Adams and NVC Polunin. 1996. Coastal fisheries in the Pacific islands. Ocean and Mar Biol: Ann Rev 34:395–531.

Demartini EE, FA Parrish and JD Parrish. 1994. Temporal comparisons of reef fish populations at Midway Atoll, Northwestern Hawaiian Islands. Southwest Fisheries Science Center administrative report H-94-05.

Friedlander AM, RC DeFelice, JD Parrish and JL Frederick. 1997. Habitat resources and recreational fish populations at Hanalei Bay, Kauai. Final report to state of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Hawaii Cooperative Fishery Research Unit.

Green AL 1996. Spatial, temporal and ontogenetic patterns of habitat use by coral reef fishes (Family Labridae). Mar Ecol Prog Series 133:1–11.

Green AL 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the US Pacific Islands. Report prepared for the Western Pacific Regional Fishery Management Council. 278 pp.

Hobson EH 1984. The structure of reef fish communities in the Hawaiian archipelago. In Proceedings of the second symposium on resource investigations in the Northwestern Hawaiian Islands, volume 1, UNIHI-SEAGRANT-MR-84-01. pp. 101–22.

Hoover JP 1993. Hawaii's fishes. Honolulu: Mutual Pub.

Johannes RE 1978. Reproductive strategies of coastal marine fishes in the tropics. Env Biol Fish 3(1):65–84.

Leis JM and JM Miller. 1976. Offshore distributional patterns of Hawaiian fish larvae. Mar Biol 36:359–67.

Miller JM. 1973. Nearshore distribution of Hawaiian marine fish larvae: Effects of water quality, turbidity and currents. In J.H.S. Baxter (ed.) The early life history of fish, NY: Springer-Verlag. 765 pp.

Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Myers RF. 1996. Assessment of coral reef resources of Guam with emphasis on waters of federal jurisdiction. Report prepared for the Western Pacific Regional Fishery Management Council.

Parrish JD. 1989. Fish communities of interacting shallow-water habitats in tropical oceanic regions. Mar Ecol Prog Ser 58(1-2):143–60.

Randall JE. 1996. Shore fishes of Hawaii. Vida, OR: Natural World Pr.

Randall JE, JL Earle, RL Pyle, JD Parrish and T Hayes. 1993. Annotated checklist of the fishes of Midway Atoll, Northwestern Hawaiian Islands. Pac Sci 47(4):356–400.

Ross RM. 1983. Annual, semilunar, and diel reproductive rhythms in the Hawaiian labrid *Thalassoma duperrey*. Mar Biol 72:311–8.

Thresher RE. 1984. Reproduction in reef fishes. Neptune City, NJ: TFH Pub.

Victor BC. 1986. Duration of the planktonic larval stage of one hundred species of Pacific and Atlantic wrasses (family Labridae). Mar Biol 90:317–26.

Walsh WJ. 1987. Patterns of recruitment and spawning in Hawaiian reef fishes. Env Biol of Fishes 18(4):257–76.

Westneat MW. 1997. Labridae. Wrasses, hogfishes, razorfishes, corises, tuskfishes. In: KE Carpenter and V Niem, eds. FAO identification guide for fishery purposes: The Western Central Pacific.

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)

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).

Bibliography

Dalzell P, TJH Adams and NVC Polunin. 1996. Coastal fisheries in the Pacific islands. Ocean and Mar Biol: Ann Rev 34:395–531.

Green A. 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the US Pacific Islands. Report prepared for the Western Pacific Regional Fisheries Management Council, Honolulu, HI.

Hensley RA and TS Sherwood. 1993. An overview of Guam's Inshore Fisheries. Mar Fish Rev 55(2):129–38.

Kitalong A and P Dalzell. 1994. A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fisheries Research Technical Document, No. 6, South Pacific Commission, Noumea, New Caledonia.

Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

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		

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 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 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.

Bibliography

Bakus GJ. 1964. The effects of fish-grazing on invertebrate evolution in shallow tropical waters. Allan Hancock Found Pub 27:1–29.

Bellwood DR. 1997. Scaridae. Parrotfishes. In: KE Carpenter and V Niem, eds. FAO Identification guide for fishery purposes: The Western Central Pacific.

Brock RE. 1979. An experimental study on the effects of grazing by parrotfishes and role of refuges in benthic community structure. Mar Biol 51:381–8.

Choat JH, LM Axe and DC Lou. 1996. Growth and longevity in fishes of the family Scaridae. Mar Ecol Prog Ser 145:33–41.

Choat JH and JE Randall. 1986. A review of the parrotfishes (Family Scaridae) of the Great Barrier Reef of Australia with description of a new species. Rec Aust Mus 38:175–228.

Choat JH and DR Robertson. 1975. Protogynous hermaphroditism in fishes of the family scaridae. pp. 263-283. In: R Reinboth, ed. Intersexuality in the Animal Kingdom. Heidelberg, Germany: Springer Verlag.

Colin PL and LJ Bell. 1991. Aspects of the spawning of labrid and scarid fishes (Pisces:Labroidei) at Enewetak Atoll, Marshall Islands with notes on other families. Env Biol of Fishes 31:229–60.

Coutures E. 1994. La pêcherie néo-calédonienne de Perroquet à bosse (Bolbometopon muricatum, Valenciennes 1840): préliminaires à l'étude de la biologie de pêches. Nouméa: Université Française du Pacifique.

Dunlap MJ and JR Pawlik. 1996. Video-monitored predation by Caribbean reef fishes on an array of mangrove and reef sponges. Mar Biol 126:117–23.

Friedlander AM, RC DeFelice, JD Parrish and JL Frederick. 1997. Habitat resources and recreational fish populations at Hanalei Bay, Kauai. Final report to state of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Hawaii Cooperative Fishery Research Unit.

Johannes RE. 1978. Reproductive strategies of coastal marine fishes in the tropics. Env Biol Fishes 3:65–84.

Johannes RE. 1981. Words of the lagoon. Fishing and marine law in the Palau district of Micronesia. Berkeley: Univ of Calif Pr. 245 pp.

Lou DC 1993. Growth in juvenile *Scarus rivulatus* and *Ctenochaetus binotatus*: a comparison of families Scaridae and Acanthuridae. J of Fish Biol 42:15–23.

Lou DC and NA Moltschanowskyj. 1992. Daily otolith increments in juvenile tropical parrotfishes and surgeonfishes. Aust J of Mar and Freshw Research 43:973–81.

Randall JE and HA Randall. 1963. The spawning and early development of the Atlantic parrotfish, *Sparisoma rubripinna*, with notes on other scarid and labrid fishes. Zoologica 48:49–60.

Reeson PH. 1983. The biology, ecology and bionomics of the parrotfishes, Scaridae. In: JL Munro, ed. Caribbean Coral Reef Fishery Resources. ICLARM Stud Rev 7:166–77.

Watson W and JM Leis. 1974. Ichthyoplankton of Kaneohe Bay, Hawaii. Sea Grant Tech Rept TR-75-01.

Yogo Y, A Nakazono and H Tsukahara. 1980. Ecological studies on the spawning of the parrotfish, *Scarus sordidus* Forsskal. Sci Bull Fac Agric, Kyushu Univ 34:105–14.

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

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.

Bibliography

Couture E and C Chauvet. 1994. Croissance du perroquet à bosse (*Bolbometopon muricatum*) et son exploitation en Nouvelle-Calédonie. Information paper No. 4, 25th Regional Technical Meeting on Fisheries, South Pacific Commission, Noumea, New Caledonia. 4 pp.

Dalzell P, TJH Adams and NVC Polunin. 1996. Coastal fisheries in the Pacific islands. Ocean and Mar Biol: Ann Rev 34:395–531.

Green A. 1997. An assessment of the status of the coral reef resources, and their patterns of use, in the U.S. Pacific Islands. Report prepared for the Western Pacific Regional Fisheries Management Council; Honolulu, HI.

Hensley RA and TS Sherwood. 1993. An overview of Guam's Inshore Fisheries. Mar Fish Rev 55(2):129–38.

Johannes RE. 1981. Words of the lagoon: fishing and marine lore in the Palau district of Micronesia. Berkeley, CA: Univ of Cal Pr.

Kitalong A and P Dalzell. 1994. A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fisheries Research Technical Document, No. 6, South Pacific Commission, Noumea, New Caledonia.

Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

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		

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.

Bibliography

Kanayama RK. 1973. Life history aspects of the moi *Polydactylus sexfilis* (Cuvier and Valenciennes) in Hawaii. Report to the State of Hawaii, DLNR, Div. Fish and Game, Honolulu, HI. IV +50 pp.

Lowell NE. 1971. Some aspects of the life history and spawning of the moi (*Polydactylus sexfilis*). MS thesis, Univ. Hawaii. V +45 pp.

May RC, ed. 1979. Papers on culture of the moi, *Polydactylus sexfilis*. UNIHI-Seagrant-TP-79-03.

Myers RF. 1991. Micronesian reef fishes. Guam: Coral Graphics.

Ostrowski AC and A Molnar. 1997. Pacific threadfin, *Polydactylus sexfilis* (moi), hatchery manual. Ctr for Trop and Subtrop Aquacult Pub. #132.

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		

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.

Bibliography

Abe T. 1974. Sphyraenidae. In: W Fischer and PJP Whitehead, eds. FAO species identification sheets for fishery purposes: Eastern Indian Ocean and Western Central Pacific, vol. 4. Rome: FAO.

Au KC. 1979. Systematic study on the barracudas (Pisces: Sphyraenidae) from a northern sector of the South China Sea. J Nat Hist 13:619–49.

de Silva DP. 1963. Systematics and life history of the Great Barracuda, *Sphyraena barracuda* (Walbaum). Stud Trop Oceanog 1:179.

Edwards RRC, A Bakhader and S Shaher. 1985. Growth, mortality, age composition and fishery yields of fish from the Gulf of Aden. J Fish Biol 27:13–21.

Senou H. 1997. Sphyraenidae. Barricudas. In: KE Carpenter and V Niem, eds. FAO identification guide for fishery purposes: The Western Central Pacific.

Schultz LP. 1953. In: Schultz et al. Fishes of the Marshall and Marianas Islands. Bull US Nat Mus 202:279–87.

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		

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).

Bibliography

Marshall NB. 1950. Fishes from the Cocos-Keeling Islands. Bull Raffles Mus 22:166–205.

Mito S. 1965. On the development of the eggs and hatched larvae of a trachinoid fish, *Neopercis sexfasciata* (Temminck et Schlegel). Sci Bull Fac Agric, Kyushu Univ 15:507–12.

Stroud G. 1981. Aspects of the biology and ecology of weever-fishes (Mugiloididae) in northern Great Barrier Reef waters. PhD diss., James Cook Univ, Townsville, Australia.

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		

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 females 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.

Bibliography

Carlson BA. 1978. A contribution to the biology of the spotted blenny, *Exallias brevis* (Pisces; Blenniidae). Pac Sci 32:96.

Dotsu Y and T Oota. 1973. The life history of the blenniid fish, *Omobranchus loxozonus*. Bull Fac Fish Nagasaki Univ 36:13–22.

Randall JE and HA Randall. 1960. Examples of mimicry and protective resemblance in tropical marine fishes. Bull Mar Sci 10:444–80.

Smith-Vaniz WF. 1976. The sabre-toothed blennies, tribe Nemophini (Pisces: Blenniidae). Acad Natur Sci, Phila, Monogr 19:1–196.

Thresher RE. 1984. Reproduction in reef fishes. Neptune, NJ: TFH Pub.

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		

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.

Bibliography

Böhlke JE and CR Robins. 1969. Western Atlantic sponge-dwelling gobies of the genus *Evermannichthys*: their taxonomy, habits, and relationships. Proc. Acad. Nat. Sci. 121(1): 1-24.

Colin PL. 1972. Daily activity patterns and effects of environmental conditions on the behavior of the yellowhead jawfish, Opistognathus aurifrons, with notes on its ecology. Zoologica 57: 137-169.

Colin PL. 1975. Neon gobies. T.F.H. Publ., Neptune City, New Jersey. 304 pp.

Davis WP, JE Randall and DO French. 1977. The systematics, biology, and zoogeography of *Ptereleotris heteropterus*, pisces:Gobiidae. Proc. Third Internat. Coral Reef Symp., 1:261-266.

Hiatt RW and DW Strasburg. 1960. Ecological relationships of the fish fauna on coral reefs of the Marshall Islands. Ecol. Monogr. 30: 65-127.

Houde ED and JA Lovdal. 1984. Seasonality of occurrence, foods and food preferences of ichthyoplankton in Biscayne Bay, Florida. Estuarine, Coastal Shelf Sci. 18: 403-419.

Lassig B. 1977. Socioecological strategies adopted by obligate coral-dwelling fishes. Proc. Thir Internat. Coral Reef Symp. 1:56-570.

Randall JE. 1968. *Ioglossus helenae*, a new gobiid fish from the West Indies. Ichthyologica 39(3&4): 107-116.

Tyler JC. 1971. Habitat preferences of the fishes that dwell in shrub corals on the Great Barrier Reef. Proc. Acad. Nat. Sci. 123: 1-26.

Watson W. 1974. Diel changes in the vertical distributions of some common fish larvae in southern Kaneohe Bay, Oahu, Hawaii. Unpublished M.S. thesi, University of Hawaii, Honolulu, Hawaii.

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		

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).

Bibliography

Brock VE. 1954. A preliminary report on a method of estimating reef fish populations. J. Wildlife Mngmt. 18: 289-308.

Clark AM. and D Gulko. 1999. Hawaii's state of the reef report, 1998. Dept. of Land and Nat. Res., Honolulu, HI. 41pp.

Jones RS. 1968. Ecological relationships in Hawaiian and Johnston Island Acanthuridae (Surgeonfishes). Micronesica 4: 309-361.

Lobel PS. 1978. Diel, lunar, and seasonal periodicity in the reproductive behavior of the pomacanthid fish, *Centropyge potteri*, and some other reef fishes in Hawaii. Pac. Sci. 32: 193-207.

Thresher, R.E. 1984. Reproduction in reef fishes. T.F.H. Pub., Neptune City, NJ.

Walsh WJ. 1987. Patterns of recruitment and spawning in Hawaiian reef fishes. Env. Biol. of Fishes 18(4): 257-276.

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		

50. Zanclidae (Moorish idol)

This family consist 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.

Bibliography

Debelius H and HA Baensch. 1994. Baensch Marine Atlas. Tetra Press: Blacksburg, VA.

Johnson GD and BB Washington. 1987. Larvae of the Moorish idol, *Zanclus cornutus*, including a comparison with other larval acanthuroids. Bull. Mar. Sci. 40(3): 494-511.

Strasburg DW. 1962. Pelagic stages of *Zanclus canescens* from Hawaii. Copeia, 1962: 844-845.

Thresher, R.E. 1984. Reproduction in reef fishes. T.F.H. Pub., Neptune City, NJ.

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				

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 a 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.

Bibliography

Drew AW. 1971. Preliminary report on klsebuul and meyas, two fish of Palau Islands. 20 pp. (unpublished report, Micronesian Mariculture Demonstration Center, Belau).

Gunderman N, DM Popper and T Lichatowich. 1983. Biology and life cycle of *Siganus vermiculatus* (Siganidae, Pisces). Pac. Sci. 37: 165-180.

Hasse JJ, BB Madraisau and JP McVey. 1977. Some aspects of the life history of *Siganus canaliculatus* in Palau. Micronesica 13(2): 297-312.

Hubbs CL. 1958. Dikellorhynchus and kanazawichthys: nominal fish genera interpreted as based on prejuveniles of Malacanthus and Antennarius, respectively. Copeia 4: 282-285.

Johannes RE. 1978. Reproductive strategies of coastal marine fishes in the tropics. Env. Biol. Fishes 3: 65-84.

Johannes RE. 1981. Words of the lagoon. Univ. Calif. Press, Los Angeles, CA: 320pp.

Kami HT and II Ikehar. 1976. Notes on the annual juvenile siganid harvest in Guam. Micronesica 12(2): 323-325.

Lam TJ. 1974. Siganids: their biology and mariculture potential. Aquacult. 3: 325-354.

Manacop PR. 1937. The artificial fertilization of dangit, *Amphacanthus oramin* (Bloch and Schneider). Philippine J. Sci. 62: 229-237.

Mcvey JP. 1972. Observations on the early-stage formation of rabbit fish, *Siganus fuscescens*, at Palau Mariculture Demonstration Centre. South Pacific Isl. Fish. Newsletter 6: 11-12.

Popper D, RC May and T Lichatowich. 1976. An experiment inrearing larval *Siganus vermiculatus* (Valenciennes) and some observations on its spawning cycle. Aquacult. 7: 281-290.

Tsuda RT, Tobias WJ, Bryan PG, Fitzgerald WJ, Kami HT, and II Ikehara. 1976. Studies on the genus *Siganus* (rabbitfish) in Guam waters. Sea Grant Publ. UGSG-76-05. University of Guam Mar. Lab., tech. rept. #29.

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		

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 10°N and 20°S, 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.

Bibliography

Amesbury SS, Myers RF. 1982. Guide to the Coastal Resources of Guam. Volume 1, The fishes. University of Guam Marine Laboratory. Contribution # 173.

Collette BB, Nauen CE. 1983. An annotated and illustrated catalogue of tunas, mackerels, bonitos, and related species known to date. FAO Species Catalogue. Vol. 2, Scombrids of the world. Rome: Food and Agriculture Organization. 118pp.

Dunstan DJ. 1961. Trolling results of F/RV *Tagula* in Papua waters. Papua New Guin Agric J 13(4):148-156.

Haight WR. 1998. NMFS/JIMAR, Honolulu Laboratory. Unpublished data.

Lewis AD, Chapman LB, Sesewa A. 1983. Biological notes on coastal pelagic fishes in Fiji. Suva, Fiji: Fisheries Division (MAF). Technical report #4.

Myers RF. 1989. Micronesian reef fishes. Coral Graphics. 298pp.

Okiyama M, Ueyangi S. 1977. Larvae and juvenile of the Indo-Pacific dogtooth tuna, Gymnodarda unicolor (Ruppell). Bull Far Seas Fish Lab 15:35-49.

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 10°N and 20°S, 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

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.

Bibliography

Ahlstrom EH, Amaoka K, Hensley DA, HG Moser and BY Sumida. 1984. Pleuronectiformes: development. pp 640-670 in ASIH Spec Publ 1.

Boehlert GW. 1986. An approach to recruitment research in insular ecosystems. In "IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities" (D Pauly and A Yanez-Arancibia, eds), IOC Workshop rep. 40: 15-32. UNESCO, Paris.

Brownell CL. 1979. Stages in the early development of 40 marine fish species with pelagic eggs from the Cape of Good Hope. Icthyol Bull JLB Smith Inst No. 40. 84 pp.

Hensley DA and EH Ahlstrom. 1984. Pleuronectiformes: relationships. pp. 670-68 in ASIH Spec. Publ. 1.

Houde ED and JA Lovdal. 1984. Seasonality of occurrence, foods and food preferences of ichthyoplankton in Biscayne Bay, Florida. Estuarine, Coastal Shelf Sci. 18: 403-419.

Houde ED and RC Schekter. 1981. Growth rates, rations, and cohort consumption of marine fish larvae in relation to prey concentrations. Rapp. P.-V. Reun., Cons. Int. Explor. Mer 178: 441-453.

Leis JM and T Trnski. 1989. The larvae of Indo-Pacific shorefishes. U. of Hawaii Press: Honolulu, HI.

Liew HC. 1983. Studies on flatfish larvae (Fam. Psettodidae, and Bothidae, Pleuronectiformes) in the shelf waters of the central Great Barrier Reef, Australia. Unpublished M.S. thesis, James Cook University, Townsville, Australia.

Ozawa T and A Fukui. 1986. Studies on the development and distribution of the bothid larvae in the western north Pacific. pp 322-420 plus 23 plates in Ozawa T (ed) Studies on the oceanic icthyoplankton in the Western North Pacific. Kyushu Univ Press: Fukuoka.

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				

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 more drab. 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.

Bibliography

Aiken KA. 1983. The biology, ecology, and bionomics of the triggerfishes, Balistidae. ICLARM Stud. Rev. 7: 191-205.

Baldwin. 1966. Triggerfishes of the eastern Pacific. Proc. Calif. Acad. Sci., 4th Ser. 34: 429-474.

Breder CM and DE Rosen. 1966. Modes of reproduction in fishes. Natural History Press, Garden City, NY. 941 pp.

Fricke HW. 1980. Mating systems, maternal and biparental care in triggerfish. Z. Tierpsychol. 53: 105-122.

Matsuura K. 1976. Sexual dimorphism in a triggerfish, *Balistipus undulatus*. Japan J. Ichthyol. 23: 171-174.

Myers, R.F. 1989. Micronesian reef fishes. Coral Graphics, Guam.

Randall JE. 1971. The nominal triggerfishes *Pachynatus nycteris* and *Oncobalistes erythropterus*, junior synonyms of *Melichthys vidua*. Copeia, 1971: 462-469.

Randall JE, K Matsuura and A Zama. 1978. A revision of the triggerfish genus *Xanthichthys*, with description of a new species. Bull. Mar. Sci. 28: 688-706.

Randall JE and W Klausewitz. 1973. A review of the triggerfish genus *Melichthys*, with description of a new species from the Indian Ocean. Senckenberg. biol. 54: 57-69.

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		

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 27.5°C. 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.

Bibliography

Leis JM. 1978. Systematics and zoogeography of the porcupinefishes (Diodon, Diodontidae, Tetraodontiformes) with comments on egg and larval development. Fish. Bull. 76: 535-567.

Leis JM and JT Moyer. 1985. Development of eggs, larvae and pelagic juveniles of three Indo-Pacific ostraciid fishes (Tetraodontiformes): *Ostracion meleagris, Lactoria fornasini*, and *L. diaphana*. Japan. J. Ichthyol. 32(2): 189-202.

Mito S. 1962. Pelagic fish eggs from Japanese waters. 8. Chaetodontina, Balistina and Ostraciontina. Sci. Bull., Fac. Agric. Kyushu U. 19: 503-506.

Moyer JT. 1979. Mating strategies and reproductive behavior of ostraciid fishes at Miyake-jima, Japan. Japan. J. Ichthyol. 26: 148-160.

Randall JE. 1972. The Hawaiian trunkfishes of the genus *Ostracion*. Copeia, 1972: 756-768.

Thresher, R.E. 1984. Reproduction in reef fishes. T.F.H. Pub., Neptune City, NJ.

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		

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.

Bibliography

Allen GR and JE Randall. 1977. Review of the sharpnose pufferfishes (subfamily Canthigasterinae) of the Indo-Pacific. Rec. Aust. Mus 30: 475-517.

Fujita S. 1956. On the development of the egg and prelarval stages of the puffer, *Fugu* (Shosaifugu) *stictonotus* (Temminck et Schlegel). Sci. Bull. Fac. Agri., Kyushu Univ. 15: 525-530.

Gladstone W. 1985. Behavioral ecology of the sharpnose pufferfish, *Canthigaster valentini* (Bleeker), at Lizard Island, Great Barrier Reef. Unpub. PhD thesis, Macquarie U., North Ryde, Australia.

Kuthalingham MDK, G Luther and JJ Joel. 1973. On some growth stages and food of *Arothron stellatus* (Bloch)(Tetraodontidae:Pisces). Indian J. Zool. 20: 240-243.

Leis JM. 1978. Systematics and zoogeography of the porcupinefishes (*Diodon*, Diodontidae, Tetraodontiformes) with comments on egg and larval development. Fish. Bull. 76: 535-567.

Sakamoto T and K Suzuki. 1978. Spawning behavior and early life history of the porcupine puffer, *Diodon holacanthus*, in aquaria. Japan. J. Ichthyol. 24: 261-270.

Thresher, R.E. 1984. Reproduction in reef fishes. T.F.H. Pub., Neptune City, NJ.

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		