C. EFH for Management Unit Species – Sessile Benthos

The concept of essential fish habitat (EFH) is of obvious value when used as a tool to protect individual fisheries. It is defined as that habitat necessary for their various stages of managed species life histories to perpetuate. To consider the sessile benthos (SB) as required by the Interim Final Rule (IFR) for EFH, the concept must be qualified. This is because it is applied to broad groups of organisms, many of which form the habitat upon which all other species depend. Due to the large numbers of species of coral, algae and other sessile benthos (450 spp algae; 99 Scleractinia and 150 spp. of the other groups considered in Hawaii (Eldredge and Miller, 1995) and a total of approximately 1200 spp of the combined groups in the total AFPI), the concept loses definition and becomes too generalized to be of value. The vast numbers of SB do not represent a managed fishery. This is particularly the case when considering the benthos of coral and algae.

The fauna and flora, generally, lack mobility in the adult stages with the intermediate stages are transported in the water column until settlement. Once they have settled they largely become habitat. They are instrumental in the ecosystems primary production and are largely responsible for supporting the higher trophic levels, many with predator-prey relationships. The high degree of symbiosis begins with the zooxanthellate associations and encompasses a wide degree of associations involving all groups of the fauna and flora. Much of the physical relief of the reef is the result of the living environment as is the deposition of the coral reef itself. An overly simplistic assessment of the habitat requirements for the sessile benthos are suitable substrate, water quality and light. This, however, negates the history of the substrate development and the myriad of biological interactions, which qualify as a coral reef. Due to these considerations, the species and their fundamental roles in the ecosystem define the EFH as the coral reefs themselves. As such, all coral reefs in the AFPI should be designated EFH for the sessile benthos. This is because all of the coral reef associated fisheries for which the Magnuson-Stevens Fisheries Conservation and Management Act was designed to protect and conserve depend on the coral reef ecosystem.

As there is no fisheries extraction of the sessile benthos in the AFPI, the objective of the concept discussion shifts to the life history characteristics of the fauna and flora of the coral reef environment. It is the life history stages of the selected benthic groups that comprise the discussion of their importance in the EFH description. It is important in the consideration of the management unit species (MUS).

Life histories and habitat requirements rely on an understanding that the coral reef is a variable and dynamic entity. The composition of the reefs responds to environmental parameters such as temperature, dilution and sedimentation. Regionally, their composition varies in response to temperature by virtue of latitude, current regimes and events brought on by unique climatic events such as El Nino hot spots. Such major discontinuities in taxa occurrence such as the absence of the genus *Acropora* in Hawaii or reef cementing coralline alga in extra-tropical areas, require that we consider reefs on a regional basis, as well as, locally. The history of a particular area is as important as short-term community cycles and is often seen to be decadal in time frame, and most probably represents longer cycles. The fossil record of reefs shows a process of progressive change in the nature of reefs. Current concern for global warming and the effects of some of the hotspots may require this to be added to the equation, when human induced impacts are considered.

The interconnectivity of the coral reef, in terms of potential recruitment, provide us with an understanding of the reef environment that is at once very robust and able to restore itself after the most destructive natural events. The coral reef is fragile, in that, if the composition of a reef is changed then the effect is likely to be manifest down current as well. A chronic change in the environmental parameters of an area is likely to result in a permanent change in the community composition. In summary, EFHs are not a useful concept for the numerous sessile benthos at the species level but rather a conformation of the importance of the many non-commercial species that comprise the coral reef ecosystem. In developing this as an operational framework, Conservation of these broad groups may be accomplished in two ways. 1) It may be appropriate to establish criteria for the amount of reef that is allowed to be affected by development, fishing practices or tourism. This quantity would be established in relation to the amount of area of unaffected reef, within the range of the ocean currents that would allow restoration or maintenance of this area through recruitment. 2) Equally useful is the concept of the *management unit species (MUS)* in making the description of the ecosystem more manageable with better resolution in its definition. Here generic assemblages or their interactions are considered entities, which allow a more categorical method of management.

The Management Unit Species (MUS): An Ecosystem Approach

The concept of the management unit species (MUS) is a useful concept when considering a resource composed of species or higher taxa who share the same habitat, have the same trophic ecology or respond to changing environmental variables in a predictable way. Coral reef zonation, as the result of an environmental regime, reflects a natural MUS organization. Whether through tolerance or requirement, benthos is sorted into a zonation with respect to the proximity to land, depth or wave action. Impacts which add nutrients, as the result of some human activity, to a naturally low-nutrient coral reef and the community changes from being micro-algal and coral dominated, to being macro-algal and with a great reduction in the hard coral component. In the case of increases in sediments and freshwater, there is a reduction in species numbers in both groups to those which are resistant to such effects. Tidal influences of periodic exposure, ponded waters or exposure to wave action have a dramatic effect in conditioning species compliments.

The MUS may be defined in relation to the environmental variables, be it natural or induced. With respect to this, taxonomic classification does not conform to groupings by environmental tolerances. As a result, a wide range of taxonomic groups is considered depending on the type of organism. This section describes these groups as general taxonomic entities. Depending on the availability of information or scale of consideration, in an operational sense, the appropriate taxonomic level should be used. As an example, *Porites/Favid* assemblages are characteristic of areas of periodic flooding. *Acropora* assemblages and a micro-algal assemblage are characteristic of normal seawater salinity with clear, flowing aerated water. Add wave action to this and the coral assemblages become reduced in diversity and morphology characterized by robust or encrusting forms. Coralline alga dominated. The dynamic potential inherent in coral reef communities becomes apparent with a change in the environment as the result of some change in a natural parameter resulting from development or terrestrial activity.

In conforming to the MUS approach, using the general taxonomic groupings of sessile benthos was considered for designations of the MUS. Within these groups species can be clumped based on selection by environmental parameters. Suggested divisions are the hard and soft coral and the micro and macro-alga. Other benthic groups of reef associated organisms (*Porifera, Actinaria, Hydroidea, Gorgonacea and Zooanthidea*), generally, are less dominate in reef communities and more liable to conform, in terms of abundance, to the dominance exhibited by the primary groupings. In terms of the reef community composition, these more minor groups are largely coral or algal associated with the type and abundance of coral or alga conditioning their occurrence. It is useful to consider the light limited environments of depth or caves where the groups such as the *Gorgonacea* and *Porifera* may be dominant.

It would be in error not to emphasize considering the regionality of such a framework. The Caribbean and Florida seaboard are very different than the Indo-Pacific. Within the Indo-Pacific, species occurrence, generally, winnows from west to east and is limited when approaching the temperate boundaries. As a result, geographic locations may vary in terms of their species complements. This gives rise to variability in dominance but does not change the relationship within the four major groupings. The species within the groupings become less consequential, varying in dominance depending on the region.

Habitat Areas of Particular Concern (HAPC)

Habitat areas of particular concern for the benthos of coral reefs may include a variety of situations. These may be the same as those which give rise to marine protected areas or where a conservation area has been set aside to protect organisms which may have been depleted through fishery harvest. Particular concern may be for an area where coastal development has adversely impacted near shore areas. With respect to this, it may be that areas within ocean current range should be protected to conserve areas which are unprotectable due to a requirement for subsistence fishing, recreational usage, damage done by circumstances of coastal development or activities inland such as agriculture. It may be that an area is of concern due to the long history of research at a particular site or area and the encroachment of development (e.g. Pago Pago Harbor, American Samoa). Reserves, national parks, wildlife refuges and other protected areas are existing operational areas of particular concern.

1. Algae

Algal Life Cycles

Both sexual and asexual reproduction are widespread in algae, and the predominance of one or the other is mainly linked to the class of algae in question (Cyanobacteria, Chlorophyta, Phaeophyta or Rhodophyta) and the predominant geographical and environmental conditions affecting the algal populations (Bold and Wynne, 1985). Unicellular algae reproduce mainly asexually, while multicellular algae have asexual or sexual life cycles of varying complexity. Sexual life cycles are classified into four basic types, according to the site of meiosis or reduction-division of the algal genome (table I). By far the most common type is the sporic life cycle, in which a usually diploid sporophyte stage alternates with a usually haploid gametophyte stage. The recurring sequence of these two stages is called alternation of generations, which can be either isomorphic (when both generations are morphologically similar) or heteromorphic (where one generation can differ markedly in morphology from the other).

Table II.C.1: Classification of sexual algal life cycles (after South and Whittick, 1987)

Life cycle type	Site of meiosis	Main algal groups concerned
Zygotic	zygote	Unicellular algae (Chrysophyceae)
Sporic	sporangia	Rhodophyta, Phaeophyta, Chlorophyta
Gametic	gametangia	Chlorophyta
Somatic	thallus cells	Chlorophyta, Rhodophyta

Cyanophyta

In the Cyanophyta, reproduction is primarily by the production of asexual spores, which are released into the environment and grow into new individuals. These spores can be produced by budding from the free ends of the filaments, or by the fission of large vegetative cells within the thallus.

Phaeophyta

In most members of the Phaeophyta, sexual reproduction is sporic, with the alternation of a haploid gametophyte generation with a diploid sporophyte generation; both generations may or may not be morphologically similar. Spores are usually numerous and motile, being produced in unilocular sporangia.

Chlorophyta

The Chlorophyta life cycle is variable, but a typical case can be demonstrated in the common genera *Ulva*, where zoospores are produced in the thallus which are released and fuse to produce a new individual.

Rhodophyta

Most members of the Rhodophyta exhibit a sporic life cycle, a majority of which are of the triphasic *Polysiphonia*-type. The gametophytes and the tetrasporophyte are often isomorphic (although in some algae the tetrasporophyte can be crustose and alternate with large fleshy gametophytes). The Carposporophyte is reduced, and attached to the female gametophyte. The gametes are non-motile.

Distribution patterns of algae amongst the American Flag Pacific Islands (AFPI) (with nomenclature updated (following taxonomy in Silva *et al.* 1996), from available literature; excludes varietal status of species). The attached AFPI algae distribution table lists 815 taxa of marine algae, statistically broken down as follows:

Table II.C.2: Algae distribution in the American Affiliated Pacific Islands (AFPI)

AFPI locality	Cyanophyta	Chlorophyta	Phaeophyta	Rhodophyta	Total
American Samoa	15	31	14	68	128
Baker Is.	1	6	3	6	16
Howland Is.	0	5	1	3	9
Jarvis Is. [1]	-	-	-	-	-
Palmyra Is.	19	39	11	64	133
Kingman Reef [1]	-	-	-	-	-
Johnston Atoll	19	24	9	40	92
Hawaii [2]	3	48	29	343	423
NWHI	0	43	32	121	196
Wake Island	2	8	10	3	23
CNMI	5	55	20	57	137
Guam	16	58	29	98	201
Total	52	142	70	333	

[1] no data available at this time

[2] Abbott (1995) estimates the total Hawaiian flora at about 400 species

Comments

Because the reported distribution is related to the sampling effort in each particular locality, the comparisons are largely artificial at this stage. For instance, the Guam and North West Hawaiian floras are fairly well-known, while the Jarvis Is., Kingman Reef, Wake Is, Baker and Howland Islands floras are seriously under-collected or unknown. For the Hawaiian flora, there is a large amount of as yet unpublished material which will drastically increase the number of known species in the near future (Abbott 1995).

The most comparable groups of algae are the Phaeophyta and Chlorophyta, because they are mostly intertidal in habitat and thus most easily collected and inventoried, and there is a relatively constant number of common species across the AFPI islands for the better investigated localities.

Distribution Among Islands

From an examination of the species distribution table, the most commonly reported species (those which occur in 50% or more of the localities under study) for the islands of the AFPI are as follows, according to class:

Table II.C.3: Most commonly reported species for the islands of the AFPI

Class	Most common species	Typical reef habitat
Cyanophyta	*Lyngbya majuscula*	inner reef flat
	Schizothrix calcicola	inner reef flat
Chlorophyta	*Boodlea spp.*	inner / outer reef flat
	Bryopsis pennata	inner reef flat / lagoon
	Caulerpa racemosa	inner / outer reef flat
	Caulerpa serrulata	inner reef flat / lagoon
	Dictyosphaeria spp.	inner reef flat / lagoon
	Halimeda discoidea	inner reef flat
	Halimeda opuntia	inner reef flat
	Neomeris annulata	inner reef flat
	Ventricaria ventricosa	reef flat / outer reef slope
Phaeophyta	*Dictyota friabilis*	reef flat
	Feldmannia indica	reef flat
	Hincksia breviarticulata	reef crest / exposed shoreline
	Lobophora variegata	reef flat / lagoon
	Sphacelaria spp.	reef flat / epiphytic
	Turbinaria ornata	reef flat / bommies in lagoon
Rhodophyta	*Amphiroa fragilissima*	inner reef flat
	Asparagopsis taxiformis	reef crest / outer reef slope
	Centroceras clavulatum	reef flat / epiphytic
	Gelidiopsis intricata	inner reef flat / lagoon
	Gelidium pusillum	inner reef flat
	Hydrolithon reinboldii	reef crest
	Hypnea esperi	inner reef flat
	Jania capillacea	reef flat
	Martensia fragilis	outer reef slope
	Neogoniolithon brassica-florida	reef crest
	Polysiphonia spp.	reef flat
	Porolithon onkodes	reef crest
	Portieria hornemanni	outer reef slope

Habitat distribution of the common algal species in the AFPI (After N' Yeurt, 1999)

The Flora of Fringing Reefs

In shallow, calm fringing areas where sediment accumulations are predominant, green and brown algae are most abundant with the most characteristic species being *Caulerpa spp.*, *Chlorodesmis fastigiata*, *Halimeda spp.*, *Neomeris spp.*, *Ventricaria ventricosa* and *Boodlea spp.* for the greens, and *Padina spp.* and *Dictyota spp.* for the browns. Common red algae include *Galaxaura* spp. and *Laurencia* spp. When water depth and movement are more important, hard substrata (coral colonies and rubble) are more numerous and ubiquitous species such as *Turbinaria spp.* and *Sargassum spp.* thrive. In very exposed places, the marine scenery is generally rocky or limited to small shelves below the border road. The violent wave action increases sea spray and enables the rise of certain species notably the two brown algae *Chnoospora minima* and *Hincksia breviarticulata*. On this type of shelf we generally find the flora of external reef shelves described later, confined to a few square meters owing to the intensity of the hydrodynamic factors such as wave action.

The Flora of the Barrier Reef

On barrier reefs, coral bommies are generally dominant, between which are spread out well sorted-out sediments. The pavement of the lagoon floor is visible in areas of strong hydrodynamism. Water level rarely exceeds 2.5 m. The flora is essentially one of hard substrata, and species exist in close link with the coral colonies, resulting in a mosaic pattern of species distribution. The summit of coral bommies skimming the water surface are generally colonised by the large brown algae *Turbinaria ornata* and *Sargassum spp.*, that form an elevated layer under which grow species such as *Amansia sp.*, and coralline algae. In areas where grazing by herbivores is more important, the bommies are covered by a fine tuft where a great number of discrete species belonging to the Ceramiaceae and Rhodomelaceae intermingle. In areas where hydrodynamism is more important, the encrusting coralline algae form pinkish, yellowish and bluish blotches on the upper parts of the substratum.

At the base of bommies, it is common to see large bunches of brown algae such as *Dictyota bartayresiana*, intermingled to the spread-out thalli of *Halimeda opuntia* and tufts of the red algae *Galaxaura fasciculata* and *G. filamentosa*. Most crevices are colonised by *Ventricaria ventricosa*, *Valonia fastigiata*, and *Dictyosphaeria spp.* Finally, where direct sunlight does not reach, live a range of encrusting coralline algae whose pink, violet and purple hues mingle with the soft green colours of *Halimeda spp.* and *Caulerpa spp.*

The Flora of the Outer Reef Flats

It is probably the richest and most diversified flora of the reef complex. On high islands, it is represented by a belt of the brown algae *Turbinaria ornata* and *Sargassum spp.*. We find in particular the erect and stiff tufts of *Laurencia spp. and Gelidiella spp.*, to which are attached the little bright green balls of *Chlorodesmis fastigiata*, or the light pink hemispherical cushions of the articulated Corallinaceae *Amphiroa spp.* and the opportunistic *Jania spp.* It is here that the encrusting calcified algae form the most important growths, with notably *Hydrolithon* spp. However, it is on the reef flats of atolls that Corallinaceae formations are the most exuberant. They form a compact pad of a beautiful brick-red colour, and in very exposed places even construct spectacular corbellings several tens of centimetres thick. The dominant species is *Hydrolithon onkodes* with a rather smooth texture. On atolls, large brown algae are absent and the fleshy species are limited to yellowish-brown rosettes of *Lobophora variegata* and *Turbinaria spp.*

The Flora of the Lagoons of Atolls

The sandy bottoms of the lagoons are often in deeper parts, covered with a mucous film rich in bacteria or of a carpet of Cyanobacteria where mingle tufts of filamentous red algae such as *Polysiphonia*, *Ceramium*. The hard substrata are always much richer in various green algae such as *Caulerpa* and *Halimeda*. Bommies in the lagoon offer a habitat for green genera such as *Cladophoropsis spp.* and very large varieties of *Dictyosphaeria cavernosa*.

The Flora of the Outer Reef Slope

It extends beyond 10 meters depth. The red algae are most abundant and diversified. It is the main area of encrusting coralline algae (mainly in the atolls), but also of elegant and fleshy forms such as *Gibsmithia hawaiiensis* and *Asparagopsis taxiformis*. As one goes deeper, coralline algae become the dominant species, although occasionally species of the green algal genus *Halimeda* and the brown algal genus *Lobophora* have been found up to depths of 130 metres (Littler *et al.* 1985) while the green alga *Caulerpa bikinensis* has been reported beyond depths of 70 metres (Meinesz *et al.* 1981).

The Ecological Role of Algae in the Coral Reef Ecosystem

Benthic algae are a very important, yet often overlooked component of any reef biome. Marine plants are responsible for the primary productivity of the reef ecosystem, owing to their photosynthetic ability which inputs solar-derived energy into the reef community. This energy is made available to other reef organisms in a variety of forms, ranging from direct input (grazing by hervibores; symbiotic relationships with invertebrates and fungi) or indirectly by the breaking down of plant products and detrital residues after death.

Algae play an important role in organic and inorganic material cycles within the reef community, by being able to retain and uptake key elements such as nitrogen and carbon. The primary role of marine algae in the carbon and nutrient cycles of coral reef ecosystems cannot be underestimated and has been the focus of much research (Dahl 1974; Wanders 1976; Hillis-Colinvaux 1980; Payri 1988; Charpy and Charpy-Roubaud 1990; Charpy-Roubaud and Sournia 1990; Charpy-Roubaud *et al.* 1990, Charpy *et al.* 1992; Gattuso *et al.* 1996).

Calcified (*Halimeda* and *Amphiroa spp.*) and crustose coralline algae play a major but easily overlooked role in coral reef construction and consolidation, and contribute a major part of reef carbonate sediments (Payri 1988). These organisms lay down calcium carbonate as calcite, which is much stronger than the brittle aragonite produced by corals, thus cementing and consolidating the reef structure. In particular, coralline algae are of primary importance in constructing the algal ridge that is characteristic of exposed Indo-Pacific reefs, which prevent oceanic waves from striking and eroding coastal areas (Nunn 1993; Keats 1996). At the other extreme, penetrating or boring algae such as Cyanophyta are important contributors to bioerosion and breakdown of dead reef structures (Littler and Littler 1994).

Marine macroalgae contribute significantly to organism interrelationships in reef ecosystems, either by the production of chemical or structural by-products on which other organisms depend, the providing of protective micro-habitats for other species of algae or marine invertebrates, or by offering surfaces promoting the settlement and growth of other algal species or the larvae of some herbivorous invertebrates such as abalone (Dahl 1974; Keats 1996). Symbiosis is also an important aspect of algal interrelationships in reef communities, with hermatypic corals relying on photosynthetic zooxanthellae for food. Marine plants thus offer a remarkable potential as experimenting organisms in the elucidation of the complex chemical and biological interactions that make up the fragile, closed ecosystems of tropical coral reefs (Littler and Littler 1994).

The Effects of Human Activities on Coral Reefs, in Relation to Algae

The impact of human habitation, and activities linked to industries and waste processing and disposal have proven negative impacts on coral reef ecology. An "healthy ecosystem" is a self-regulating unit where ecological productivity and capacity is maintained, with a diversity of flora and fauna present (Federal Register 1997: 66551). Some reef organisms are very sensitive to disruptions, and can act as timely indicators of changes in the natural balance of the ecosystem. For instance, the absence of *Acropora* coral on the backreef areas could indicate polluted waters with high levels of siltation, a situation reported from the stressed Aua Reef on Tutuila Island, American Samoa (Dahl and Lamberts 1977). The green algae *Enteromorpha* spp. and *Ulva* spp. thrive in high-nutrient areas, acting as bio-indicators of organic pollution linked to sewage outfalls, and also accumulate heavy metals present in industrial effluents (Tabudravu 1996). Dredging and increasing reclamation of coastal mangrove for industrial and urban use further contribute to siltation of the lagoon and the destruction of algal habitats and marine nursery areas. In this respect, algae can be classified as essential fish habitats (EFH) as they are direct contributors to the well-being and protection of fish species, both as a source of food and offering protection to larvae and small fish species. Overfishing in the lagoon reduces the number of herbivorous fishes, destroying the fragile equilibrium between reef organisms, while the input of excess nutrients via sewage and domestic effluents into the lagoon contributes to algal blooms. This can lead to the ecosystem shifting from coral dominance to algal dominance, and abnormal blooms of turf algae have been known to overgrow and kill healthy coral (Dahl 1974; Littler and Littler 1994) while >red tide= dinoflagellate blooms lead to anoxic conditions killing a wide range of marine organisms (Horiguchi and Sotto 1994). Increased chemical pollution of the lagoon could also lead to a bloom of reef-destroying organisms such as the crown-of-thorn starfish (Randall 1972).

Coral reefs have been known to recover relatively well if the stressing factors are removed soon enough before permanent damage is done (Dahl and Lamberts 1977). A strong and healthy barrier reef, in particular the *Porolithon* algal ridge of atolls, acts as a natural breakwater offering protection to coastal areas in the event of cyclones and such natural disasters, which are frequent in the region (Nunn 1993). However, the coral structure can be severely damaged and weakened as a result of siltation, eutrophication and the overgrowing of coral colonies by opportunistic filamentous algae (such as for instance happened in Kaneohe Bay, Hawaii; see Smith 1981), necessitating the construction of artificial barriers.

References

Abbott, I. A. (1988). Food and food products from seaweeds. In: *Algae and HumanAffairs*, edited by Lembi, C. A. and Waaland, J. R. Cambridge: Cambridge University Press, pp. 136-147.

Abbott, I. A. (1989). Marine Algae of the Northwest Hawaiian Islands. *Pacific Science* 43(3): 223-233.

Abbott, I. A. (1999). *Marine Red Algae of the Hawaiian Islands*. Bishop Museum Press, Honolulu. xvi + 477 + [1] p.

Abbott, I. A. (1995). The state of systematics of marine algae in tropical island Pacific. *In: Marine and Coastal Biodiversity in the Tropical Island Pacific Region. Volume 1. Species*

Systematics and Information Management Priorities, edited by Maragos, J. E.; Peterson, M. N. A.; Eldredge, L. G.; Bardach, J. E. and Takeuchi, H. F., pp. 25-38. East-West Center, Honolulu.

Anon. (1997). Rules and regulations. *Federal Register* 62(244): 66551.

Anon. (1999). *Baseline Marine Biological Survey, Peacock Point Outfall and other Point- Source Discharges, Wake Atoll, Pacific Ocean*. Report to the Department of Army by the Department of Interior, Fisheries and Wildlife Service (FWS) and the Department of Commerce, National Marine Fisheries Service (NMFS). Honolulu, Hawaii. 23 p.

Bailey, J. W. and Harvey, W. H. (1862). Algae. In: *United States Exploring Expedition During the Years 1838-1842, Under the Command of Charles Wilkes, U. S. N.* edited by Bailey, J. W. and Harvey, W. H. Philadelphia: C. Sherman, pp. 155-192.

Birkland, C.; Randall, R. and Amesbury, S. (1994). Coral and reef fish assessment of Fagatele Bay National Marine Sanctuary. *Report to NOAA, Technical Memoranda Series* NOS / MEM 3. 127 p.

Bold, H. C. and Wynne, M. J. (1985). *Introduction to the Algae. Structure and Reproduction*. Prentice-Hall, Englewood Cliffs. xvi + 720 p.

Brock, V. E.; Van Heukelem, W. and Helfrich, P. (1966). An ecological reconnaissance of Johnston Island and the effects of dredging. Second annual report submitted to the United States Atomic Energy Commission. *Hawaii Institute of Marine Biology Technical Report* 11: 68 p.

Buggeln, R. G. and Tsuda, R. T. (1969). A record of benthic marine algae from Johnston Atoll. *Atoll Research Bulletin* (120): 1-20.

Charpy-Roubaud, C., and Sournia, A. (1990). The comparative estimation of phytoplanktonic, microphytobenthic and macrophytobenthic primary production in the oceans. *Marine Microbial Food Webs* 4(1): 31-57.

Charpy-Roubaud, C. J., Charpy, L. and Cremoux, J. L. (1990). Nutrient budget of the lagoonal waters in an open central South Pacific atoll (Tikehau, Tuamotu, French Polynesia). *Marine Biology* 107: 67-73.

Charpy, L., and Charpy-Roubaud, C. J. (1990). A model of the relationship between light and primary production in an atoll lagoon. *Journal of the marine biology Association of the United Kingdom* 70: 357-369.

Charpy, L., Blanchot, J. and Lo, L. (1992). Contribution des cyanobactéries (*Synechococcus* spp.) à la production phytoplanctonique dans un lagon d'atoll fermé (Takapoto, Tuamotu, Polynésie Française). *Cahiers de Recherche de l'Académie des Sciences de Paris* 314(3): 395- 401.

Dahl, A. L. (1974). The structure and dynamics of benthic algae in the coral reef ecosystem.

Proceedings of the Second International Coral Reef Symposium 1: 21-25. Great Barrier Reef Committee, Brisbane.

Dahl, A. L., and A. E. Lamberts. (1977). Environmental impact on a Samoan coral reef: a resurvey of Mayor's 1917 transect. *Pacific Science* 31(3): 309-319.

Dawson, E. Y. (1959). Changes in Palmyra Atoll and its vegetation through the activities of man, 1913-1958. *Pacific Naturalist* 1(2): 1-51.

Dawson, E. Y.; Aleem, A. A. and Halstead, B. W. (1955). Marine algae from Palmyra Island with special reference to the feeding habits and toxicology of reef fishes. *Allan Hancock Foundation Publications, Occasional Paper* 17: 1-39.

Egerod, L. E. (1952). An analysis of the siphonous Chlorophycophyta with special reference to the Siphonocladales, Siphonales and Dasycladales of Hawaii. *University of California Publications in Botany* 25(5): 325-454.

Eldredge, L. G. and Paulay, G. (1996). *Baseline biodiversity assessment of natural harbors at Guam and Hawaii.* Report to the Insular Pacific Regional Marine Research Program, Honolulu.

Eldredge, L. G.; Tsuda, R. T.; Moore, P.; Chernin, M. and Neudecker, S. (1977). A natural history of Maug, Northern Mariana Islands. *University of Guam Marine Laboratory Technical Report* 43: 83 p.

Gattuso, J.-P.; Pichon, M.; Delesalle, B.; Canon, C. and Frankignoulle, M. (1996). Carbon fluxes in coral reefs. I. Lagrangian measurement of community metabolism and resulting air-sea CO_2 disequilibrium. *Marine Ecology - Progress Series* 145: 109-121.

Gilbert, W. J. (1978). *Rhipilia sinuosa* sp. nov. (Chlorophyta, Siphonales) from Micronesia. *Phycologia* 17(3): 311-313.

Hillis-Colinvaux, L. (1959). A Revision of the Genus *Halimeda* (Order Siphonales). *Publications of the Institute of Marine Sciences, University of Texas* (6): 321-403.

Hillis-Colinvaux, L. (1980). Ecology and taxonomy of *Halimeda* primary producers of coral reefs. *Advances in Marine Biology* 17: 1-327.

Horiguchi, T. and F. B. Sotto. (1994). On the identity of a red-tide Dinoflagellate in Maribago Bay, Philippines. *Bulletin of Plankton Society of Japan* 41(2): 166-169.

Itono, H. and Tsuda, R. T. (1980). *Titanophora marianensis* sp. nov. (Nemastomataceae, Rhodophyta) from Guam. *Pacific Science* 34(1): 21-24.

Keats, D. W. (1996). *Practical Taxonomy of Indo-Pacific Non-geniculate Coralline Algae. Course Manual.* Marine Studies Programme, The University of the South Pacific and The International Ocean Institute, Suva. 27 p.

King, R. J. and Puttock, C. F. (1989). Morphology and taxonomy of *Bostrychia* and *Stictosiphonia* (Rhodomelaceae / Rhodophyta). *Australian Systematic Botany* 2: 1-73.

Lee, R. E. (1980). *Phycology.* Cambridge University Press, New York. xi + 478 p.

Littler, M. M. and Littler, D. S. (1994). Essay: Tropical reefs as complex habitats for diverse macroalgae. In: *Seaweed Ecology and Physiology*, edited by Lobban, C. S. and Harrison P. J., pp. 72-75. Cambridge: Cambridge University Press.

Littler, M. M., Littler, D. S., Blair, S. M., and Norris, J. N. (1985). Deepest known plant life discovered on an uncharted seamount. *Science* 227: 57-59.

Magruder, W. H. and J. W. Hunt. (1979). *Seaweeds of Hawaii. A photographic identification guide.* Oriental Publishing Company, Honolulu. 116 p.

Meinesz, A., Jaubert, J., and Denizot, M. (1981). Distribution of the algae belonging to the genus *Caulerpa* in French Polynesia (atoll of Takapoto and island of Moorea). *Proceedings of the Fourth International Coral Reef Symposium, Manila* 2: 431-437.

Nam, K. W. and Saito, Y. (1991). Anatomical characteristics of *Laurencia papillosa* (Rhodomelaceae, Rhodophyta) from Guam and Palau. *Micronesica* 24(1): 87-94.

Nunn, P. D. (1993). Role of *Porolithon* algal-ridge growth in the development of the windward coast of Tongatapu Island, Tonga, South Pacific. *Earth Surface Processes and Landforms* 18: 427-439.

N'Yeurt, A. D. R. (1999). *A Preliminary Illustrated Field Guide to the Common Marine Algae of the Cook Islands (Rarotonga and Aitutaki).* World Wide Fund for Nature, Rarotonga. 74 p.

Payri, C. E. (1988). *Halimeda* contribution to organic and inorganic production in a Tahitian reef system. *Coral Reefs* 6: 251-262.

Randall, J. E. (1972). Chemical pollution in the sea and the crown-of-thorns starfish (*Acanthaster planci*). *Biotropica* 4(3): 132-144.

Setchell, W. A. (1924). American Samoa, Part I: Vegetation of Tutuila Island. *Carnegie Institution of Washington, Publications* 341: 1-188, plates 18-20, 36-37.

Silva, P. C., Basson, P. W., and Moe, R. L. (1996). Catalogue of the Benthic Marine Algae of the Indian Ocean. *University of California Publications in Botany* 79: 1-1259.

Smith, S. V. (1981). Kaneohe Bay sewage diversion experiment: perspectives on ecosystem responses to nutritional perturbations. *Pacific Science* 35: 279-395.

South, G. R. and Whittick, A. (1987). *Introduction to Phycology.* Blackwell Scientific Publications, Oxford. viii + 341 p.

Tabudravu, J. N. (1996). *Experimental and field evaluation of Enteromorpha flexuosa as an indicator of heavy metal pollution by zinc, lead and copper in coastal water of Lami, Fiji.* M.Sc., The University of the South Pacific, Suva. xi + 146 p. + Appendix.

Trainor, F. R. (1978). *Introductory Phycology.* John Wiley and Sons, New York. vii + 525 p.

Tsuda, R. T. (1981). Bibliography of marine benthic algae of Micronesia: addendum. *Micronesica* 17(1-2): 213-218.

Tsuda, R. T. and Wray, F. O. (1977). Bibliography of marine benthic algae in Micronesia. Micronesica 13(1): 85-120.

Tsuda, R. T. and Trono, G. (1968). Marine benthic algae from Howland Island and Baker Island, Central Pacific. *Pacific Science* 22(2): 194-197.

Wanders, J. B. W. (1976). The role of benthic algae in the shallow reef of Curaçao (Netherlands Antilles). I.: primary productivity in the coral reef. *Aquatic Botany* 2: 235-270.

Table II.C.4: Algal species occurrence in the AFPI.

AS: American Samoa; PA: Palmyra Atoll; JA: Johnston Atoll; MHI: Main Hawaiian Islands; NWHI: Northwestern Hawaiian Islands; WA: Wake Atoll; CNMI: Commonwealth of Northern Mariana Islands; GU: Guam

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Division Cyanophyta (Blue-green)												
Anacystis dimidiata							X					
Aphanocapsa grevillei	X											
Arthrospira brevis												X
Arthrospira laxissima	X											
Calothrix aeruginosa					X							
Calothrix confervicola												X
Calothrix crustacea							X				X	X
Calothrix pilosa												X
Calothrix scopulorum							X					
Chroococcus turgidus					X							
Entophysalis conferta					X							X
Entophysalis deusta							X					X
Hormothamnion enteromorphoides							X	X				X
Hormothamnion solutum					X							X
Hydrocoleum lyngbyaceum							X					
Hyella caespitosa	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Isactis plana							X					
Lyngbya aestuarii					X		X					
Lyngbya confervoides					X		X					
Lyngbya gracilis					X							
Lyngbya infixa					X							
Lyngbya lutea							X					
Lyngbya majuscula	X				X		X	X		X	X	
Lyngbya pygmaea	X											
Lyngbya rivulariarum					X							
Lyngbya semiplana					X							
Lyngbya sordida					X							
Microchaete vitiensis	X											
Microcoleus chthonoplastes					X		X					
Microcoleus lyngbyaceus	X										X	X
Microcoleus tenerrimus							X					
Microcoleus vaginatus							X					
Oscillatoria bonnemaisonii					X							
Oscillatoria lutea												X
Oscillatoria nigro-viridis							X					
Oscillatoria submembranacea												X
Phormidium corium					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Phormidium crosbyanum										X		
Phormidium penicillatum					X							
Phormidium submembranaceum					X		X					
Porphyrosiphon notarisii												X
Radaisea sp.	X											
Schizothrix calcicola	X	X					X				X	X
Schizothrix mexicana	X										X	X
Scytonema figuratum	X											
Scytonema hofmannii	X											X
Scytonema stuposum	X											
Spirulina major					X							
Spirulina subsalsa												X
Spirulina tenerrima							X					
Symploca atlantica							X					
Symploca hydnoides	X				X			X				
Symploca muscorum	X											
Division Chlorophyta (Green)												
Acetabularia clavata							X	X				
Acetabularia exigua											X	

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Acetabularia moebii							X	X	X		X	
Acetabularia tsengiana							X					
Acetabularia sp.							X					
Anadyomene wrightii					X						X	X
Avrainvillea erecta												X
Avrainvillea lacerata					X							
Avrainvillea obscura											X	X
Avrainvillea pacifica												X
Boergesenia forbesii											X	X
Boodlea coacta											X	X
Boodlea composita					X		X	X	X			X
Boodlea vanbosseae	X				X				X		X	X
Bornetella oligospora											X	
Bornetella sphaerica								X	X			
Bryopsis harveyana	X											
Bryopsis hypnoides									X			
Bryopsis pennata	X				X		X	X	X		X	X
Bryopsis plumosa											X	X
Bryopsis pottsii	X											
Bryopsis sp.								X				
Caulerpa ambigua					X		X	X	X		X	

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Caulerpa cupressoides										X	X	X
Caulerpa elongata											X	
Caulerpa fastigiata											X	
Caulerpa filicoides											X	X
Caulerpa lentillifera								X				X
Caulerpa lessonii												X
Caulerpa okamurai											X	X
Caulerpa peltata	X								X	X	X	X
Caulerpa plumaris												X
Caulerpa racemosa	X						X	X	X		X	X
Caulerpa serrulata			X		X			X	X	X	X	X
Caulerpa sertularioides								X			X	X
Caulerpa taxifolia								X	X		X	X
Caulerpa urvilliana					X		X				X	X
Caulerpa vickersiae					X						X	
Caulerpa verticillata								X				X
Caulerpa webbiana								X	X		X	X
Chaetomorpha antennina	X							X	X			
Chaetomorpha indica								X				X
Chaetomorpha restricta	X											
Chamaedoris orientalis												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Chlorodesmis fastigiata	X											X
Chlorodesmis hildebrandtii					X			X	X		X	X
Cladophora crystallina					X		X					
Cladophora fascicularis								X				
Cladophora glomerata	X											
Cladophora inserta					X							
Cladophora patentiramea					X							X
Cladophora patula								X				
Cladophora pinniger	X											
Cladophora socialis					X				X			
Cladophora vagabunda									X			
Cladophora sp.		X			X			X	X	X		
Cladophoropsis fascicularis											X	
Cladophoropsis gracillima		X	X		X							
Cladophoropsis infestans	X											
Cladophoropsis limicola	X											
Cladophoropsis luxurians								X				
Cladophoropsis membranacea								X			X	X
Cladophoropsis sundanensis					X			X				
Cladophoropsis sp.							X					
Codium arabicum							X	X	X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Codium dichotomum								X				
Codium edule								X	X		X	
Codium geppiorum	X				X							
Codium mamillosum								X	X			
Codium ovale												
Codium phasmaticum								X				
Codium reediae								X	X			
Codium spongiosum								X				
Codium tomentosa												X
Codium sp.							X		X			
Derbesia attenuata					X							
Derbesia marina					X		X					
Derbesia ryukiuensis					X							
Derbesia sp.							X					
Dictyosphaeria cavernosa		X	X		X			X	X	X	X	
Dictyosphaeria versluysii	X	X			X		X	X	X		X	X
Enteromorpha clathrata	X				X							X
Enteromorpha compressa												X
Enteromorpha flexuosa	X											
Enteromorpha intestinalis	X				X			X	X			
Enteromorpha kylinii		X			X		X					

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Enteromorpha prolifera	X											
Enteromorpha tubulosa					X				X			
Enteromorpha sp. 1									X			
Enteromorpha sp. 2									X			
Enteromorpha sp. 3									X			
Enteromorpha sp.								X				
Halimeda copiosa									X		X	
Halimeda cuneata											X	X
Halimeda cylindracea											X	
Halimeda discoidea	X				X		X	X	X		X	X
Halimeda fragilis					X							
Halimeda gigas												X
Halimeda gracilis					X						X	X
Halimeda incrassata	X										X	X
Halimeda lacunalis											X	
Halimeda macroloba	X										X	X
Halimeda macrophysa											X	
Halimeda opuntia	X				X				X	X	X	X
Halimeda tuna							X		X		X	X
Halimeda velasquezii									X			
Halimeda spp.			X									

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Microdictyon japonicum								X	X			
Microdictyon pseudohaptera					X						X	X
Microdictyon setchellianum							X	X	X			
Neomeris annulata	X							X	X	X	X	X
Neomeris bilimbata					X							
Neomeris dumetosa											X	X
Neomeris vanbosseae								X				
Ostreobium quekettii	X						X					X
Palmogloea protuberans							X					
Phaeophila dendroides					X							
Phaeophila engleri					X							
Phyllodictyon anastomosans								X	X			X
Pseudobryopsis oahuensis								X				
Pseudochlorodesmis furcellata											X	X
Pseudochlorodesmis parva							X					
Rhipidosiphon javensis								X	X		X	
Rhipilia geppii					X							
Rhipilia orientalis										X		
Rhipilia sinuosa												X
Rhizoclonium hieroglyphicum	X											
Rhizoclonium implexum	X				X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Rhizoclonium samoense	X											
Rhizoclonium tortuosum												X
Siphonocladus tropicus								X				
Spongocladia vaucheriaeformis											X	X
Struvea delicatula											X	
Struvea tenuis											X	X
Tydemannia expeditionis	X										X	X
Udotea argentea											X	X
Udotea indica											X	
Ulva fasciata		X	X					X	X			
Ulva reticulata								X				
Ulva rigida									X			
Ulva sp.									X			
Valonia aegagropila								X	X		X	X
Valonia fastigiata	X											X
Valonia trabeculata								X				
Valonia utricularis					X						X	X
Ventricaria ventricosa	X						X	X	X		X	X
Zygomitis sp.					X							
Division Phaeophyta (Brown)												

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Chnoospora implexa								X				X
Chnoospora minima	X							X	X			X
Colpomenia sinuosa								X	X			X
Dictyopteris australis								X	X			
Dictyopteris plagiogramma								X	X	X		
Dictyopteris repens	X								X	X	X	X
Dictyota acutiloba								X	X			
Dictyota bartayresiana								X			X	X
Dictyota cervicornis												X
Dictyota crenulata									X			
Dictyota divaricata					X			X	X	X	X	X
Dictyota friabilis	X		X		X			X	X			
Dictyota hamifera											X	
Dictyota lata	X											
Dictyota patens											X	X
Dictyota sandvicensis								X				
Dictyota sp.							X		X			
Dictyota sp. 1										X		
Dictyota sp. 2										X		
Dilophus radicans												X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ectocarpus vanbosseae	X											
Ectocarpus sp.					X		X					
Endarachne binghamiae								X				
Feldmannia indica	X	X			X		X		X		X	X
Feldmannia irregularis					X		X					
Hapalospongidion pangoense	X							X				X
Hincksia breviarticulata	X						X	X	X	X	X	
Hincksia conifera									X			
Hincksia mitchelliae									X			
Homoeostrichus flabellatus											X	
Hormophysa triquetra											X	
Hydroclathrus clathratus								X	X		X	X
Lobophora papenfussii					X							
Lobophora variegata					X		X	X	X	X	X	X
Nemacystus decipiens									X			
Padina australis								X				
Padina boergesenii									X			
Padina crassa									X			
Padina gymnospora												X
Padina japonica								X	X			
Padina jonesii											X	X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Padina pavonia								X		X		X
Padina tenuis											X	X
Padina thivyi								X				
Padina sp.										X		
Ralfsia occidentalis								X				
Rosenvingea intricata								X			X	X
Sargassum anapense	X											
Sargassum crassifolium												X
Sargassum cristaefolium											X	X
Sargassum echinocarpum								X	X			
Sargassum fonanonense	X											
Sargassum hawaiiensis									X			
Sargassum microphyllum											X	
Sargassum obtusifolium								X	X			
Sargassum piluliferum									X			
Sargassum polycystum												X
Sargassum polyphyllum								X	X			
Sargassum tenerrimum												X
Sargassum sp.									X			
Spatoglossum solierii								X				
Sphacelaria ceylanica	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Sphacelaria cornuta	X											
Sphacelaria furcigera	X				X		X	X				X
Sphacelaria novae-hollandiae					X		X	X	X			X
Sphacelaria rigidula									X			
Sphacelaria tribuloides							X		X			X
Sphacelaria sp.		X			X						X	
Sporochnus dotyi									X			
Stypopodium hawaiiensis								X	X		X	
Turbinaria condensata												X
Turbinaria ornata	X	X						X	X	X	X	X
Turbinaria trialata					X						X	X
Zonaria hawaiiensis												X
Division Rhodophyta (Red)												
Acanthophora pacifica								X				
Acanthophora spicifera								X			X	X
Acrochaetium actinocladium								X				
Acrochaetium barbadense								X				
Acrochaetium butleriae								X				
Acrochaetium corymbifera								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Acrochaetium dotyi								X				
Acrochaetium gracile					X							
Acrochaetium imitator								X				
Acrochaetium liagorae								X				
Acrochaetium microscopicum								X				
Acrochaetium nemalionis								X				
Acrochaetium robustum					X			X				
Acrochaetium seriatum								X				
Acrochaetium trichogloeae								X				
Acrochaetium sp.									X			
Acrosymphyton taylorii								X				
Actinotrichia fragilis	X							X			X	X
Actinotrichia robusta											X	
Aglaothamnion boergesenii								X		X		
Aglaothamnion cordatum								X	X			
Ahnfeltiopsis concinna								X				
Ahnfeltiopsis divaricata												
Ahnfeltiopsis flabelliformis												
Ahnfeltiopsis pygmaea												
Alsidium cymatophilum								X				
Alsidium pacificum					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Amansia glomerata									X			X
Amphiroa anceps	X											
Amphiroa beauvoisii								X	X			
Amphiroa crassa	X											
Amphiroa foliacea	X							X				X
Amphiroa fragilissima	X							X	X		X	X
Amphiroa rigida								X				
Amphiroa valonioides								X				
Amphiroa sp.							X					
Anotrichum secundum	X							X				
Anotrichum tenue								X				
Antithamnion antillanum					X		X	X				
Antithamnion decipiens								X	X			
Antithamnion erucacladellum								X				
Antithamnion nipponicum								X				
Antithamnion palmyrense					X							
Antithamnion percurrens								X				
Antithamnion sp.									X			
Antithamnionella breviramosa								X	X			
Antithamnionella graeffei								X				
Apoglossum gregarium								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ardreanema seriospora								X				
Arthrocardia sp.								X				
Asparagopsis taxiformis	X				X			X	X		X	X
Asterocystis ornata					X		X					
Balliella repens								X				
Bangia atropurpurea								X	X			
Bostrychia tenella	X											
Botryocladia skottsbergii								X			X	
Botryocladia tenuissima								X				
Branchioglossum prostratum								X				
Callidictyon abyssorum								X				
Callithamniella pacifica								X				
Callithamnion marshallensis							X					
Callithamnion sp.							X		X			
Calloglossa leprieurii					X		X					
Calloglossa viellardii	X											
Caulacanthus ustulatus								X				
Carpopeltis bushiae												
Centroceras clavulatum	X				X		X	X	X		X	X
Centroceras corallophilloides								X				
Centroceras minutum					X			X				X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ceramium aduncum								X				
Ceramium affine							X		X			
Ceramium borneense								X				
Ceramium byssoideum	X											
Ceramium cingulum								X				
Ceramium clarionense					X			X	X			
Ceramium codii					X			X				
Ceramium dumosertum								X				
Ceramium fimbriatum							X	X				
Ceramium flaccidum								X	X			
Ceramium gracillimum		X			X		X					
Ceramium hamatispinum								X	X			
Ceramium hanaense								X				
Ceramium jolyi								X				
Ceramium masonii					X							
Ceramium maryae							X					
Ceramium mazatlanense	X							X	X		X	
Ceramium paniculatum								X				
Ceramium punctiforme	X							X				
Ceramium serpens					X			X				
Ceramium taylori					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ceramium tenuissimum								X				
Ceramium tranquillum								X				
Ceramium vagans					X		X	X				X
Ceramium womersleyi								X				
Ceramium zacae							X					
Ceramium sp.		X			X		X		X			
Ceratodictyon spongiosum											X	
Chamaebotrys boergesenii								X				
Champia compressa	X											X
Champia parvula							X	X	X			X
Champia vieillardii								X				
Cheilosporum acutilobum	X											
Cheilosporum spectabile	X											
Chondracanthus acicularis								X				
Chondracanthus tenellus								X				
Chondria arcuata								X				
Chondria dangeardii								X				
Chondria minutula								X				
Chondria polyrhiza								X				
Chondria simpliciuscula								X				
Chondria repens					X		X		X			

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Chondria sp.									X			
Chondria sp. 1									X			
Chondria sp. 2									X			
Chondrus ocellatus								X				
Chroodactylon ornatum								X				
Chrysymenia kairnbachii								X				
Chrysymenia okamurae								X				
Chrysymenia procumbens								X				
Coelarthrum albertisii									X			
Coelarthrum boergesenii									X			
Coelothrix irregularis								X				
Corallina elongata								X				
Corallophila apiculata					X		X	X	X			
Corallophila huysmansii							X	X				X
Corallophila itonoi								X				
Corallophila ptilocladioides								X				
Crouania mageshimensis								X	X			
Crouania minutissima							X	X	X			
Crouania sp.								X				
Cruoriella dubyi					X							
Cruoriopsis mexicana					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Cryptonemia decumbens	X											
Cryptonemia umbraticola					X			X				
Cryptonemia yendoi												
Cryptopleura corallinara								X				
Cubiculosporum koronicarpus								X				
Dasya adhaerens							X					
Dasya bailouvianna									X			
Dasya corymbifera									X			
Dasya kristeniae								X				
Dasya murrayana								X				
Dasya pilosa								X				
Dasya sinicola							X					
Dasya villosa									X			
Dasya sp.							X	X				
Dasyopsis sp.								X				
Dasyphila plumarioides												X
Delesseriopsis elegans								X				
Dermocorynus occidentalis								X				
Dermonema virens											X	
Dermonema pulvinatum								X				
Diplothamnion jolyi								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Ditria reptans								X	X			
Dotyophycus pacificum								X				
Dotyophycus yamadae								X				
Dotyella hawaiiensis								X	X			
Dotyella irregularis								X				
Dudresnaya hawaiiensis								X				
Dudresnaya littleri								X				
Dudresnaya sp.									X			
Erythrocladia irregularis					X							
Erythrocolon podagricum								X				
Erythrotrichia carnea					X			X				
Erythrotrichia parietalis					X							
Erythrotrichia sp.							X					
Eucheuma denticulatum							X					
Eupogodon sp.									X			
Euptilocladia magruderi								X				
Exophyllum wentii								X				
Fernandosiphonia ecorticata								X				
Fernandosiphonia nana								X				
Fosliella farinosa												X
Galaxaura elongata											X	

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Galaxaura fasciculata								X				
Galaxaura fastigiata								X				
Galaxaura filamentosa	X							X			X	X
Galaxaura glabriuscula												X
Galaxaura marginata	X							X			X	X
Galaxaura obtusata								X			X	
Galaxaura pacifica									X		X	
Galaxaura rugosa	X							X	X		X	
Galaxaura subfructiculosa											X	
Galaxaura subverticillata								X				
Galaxaura sp.									X			
Ganonema farinosum								X				
Gelidiella acerosa								X				X
Gelidiella antipai								X				
Gelidiella bornetii					X							
Gelidiella machrisiana								X				
Gelidiella myrioclada								X				X
Gelidiella stichidiospora					X							
Gelidiella womersleyana												
Gelidiella sp.	X											
Gelidiocolax mammillata								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Gelidiopsis acrocarpa												X
Gelidiopsis intricata	X				X			X	X		X	X
Gelidiopsis pannosa											X	X
Gelidiopsis repens	X											
Gelidiopsis rigida												X
Gelidiopsis scoparia								X				
Gelidiopsis variabilis								X				
Gelidiopsis sp.			X									
Gelidium abbotiorum	X											
Gelidium crinale					X		X	X				
Gelidium delicatulum	X											
Gelidium pluma								X				
Gelidium pusillum	X				X		X	X	X		X	X
Gelidium reediae								X				
Gelidium samoense	X											
Gibsmithia dotyi								X				
Gibsmithia hawaiiensis	X							X				
Gloiocladia iyoensis								X				
Goniolithon frutescens					X							
Goniotrichum alsidii							X					
Goniotrichum elegans					X							

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Gracilaria abbottiana								X				
Gracilaria arcuata												X
Gracilaria bursapastoris								X				
Gracilaria cacalia												X
Gracilaria coronopifolia								X	X			
Gracilaria dawsonii								X				
Gracilaria dotyi								X				
Gracilaria edulis											X	
Gracilaria epihippisora								X				
Gracilaria filiformis								X				
Gracilaria lemaneiformis								X				
Gracilaria lichenoides								X				X
Gracilaria minor											X	X
Gracilaria radicans												X
Gracilaria parvispora								X				
Gracilaria salicornia								X				X
Gracilaria tikvahiae								X				
Gracilaria verrucosa												X
Grateloupia filicina								X				
Grateloupia hawaiiana								X				
Grateloupia phuquocensis								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Griffithsia heteromorpha								X				
Griffithsia metcalfii							X	X				
Griffithsia ovalis							X					
Griffithsia schousboei								X				
Griffithsia subcylindrica								X				
Griffithsia tenuis							X					X
Griffithsia sp.					X		X					
Gymnogongrus sp.								X				
Gymnothamnion elegans								X				
Halarachnion calcareum												X
Halichrysis coalescens								X				
Haliptilon subulatum								X	X			
Haloplegma duperreyi	X							X	X			
Halymenia actinophysa								X				
Halymenia chiangiana								X				
Halymenia cromwellii								X				
Halymenia durvillaei												X
Halymenia formosa								X				
Halymenia lacerata											X	X
Halymenia stipitata								X				
Hawaiia trichia								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Helminthocladia rhizoidea								X				
Helminthocladia simplex								X				
Herposiphonia arcuata								X				X
Herposiphonia crassa								X				
Herposiphonia delicatula								X	X			
Herposiphonia dendroidea									X			X
Herposiphonia dubia								X	X			
Herposiphonia nuda								X	X			
Herposiphonia obscura								X				X
Herposiphonia pacifica								X	X			X
Herposiphonia parca								X	X			
Herposiphonia secunda	X				X			X	X			X
Herposiphonia variabilis								X				X
Herposiphonia sp.							X		X			
Heterosiphonia crispella					X		X	X	X			
Heteroderma subtilissima					X							
Heteroderma sp.					X							
Hydrolithon breviclavium								X				
Hydrolithon reinboldii	X							X	X			X
Hypnea cervicornis								X	X			
Hypnea chloroides								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Hypnea chordacea								X				
Hypnea esperi					X		X		X		X	X
Hypnea musciformis								X				
Hypnea nidulans	X				X							
Hypnea pannosa	X							X	X			X
Hypnea rugulosa								X				
Hypnea spinella					X			X	X			
Hypnea valentiae								X				
Hypnea sp.		X										
Hypnea sp. 1									X			
Hypnea sp. 2									X			
Hypneocolax stellaris								X				
Hypoglossum attenuatum	X										X	
Hypoglossum barbatum								X				
Hypoglossum caloglossoides								X				
Hypoglossum minimum								X				
Hypoglossum rhizophorum								X				
Hypoglossum simulans								X				
Hypoglossum sp.									X			
Janczewskia hawaiiana								X				
Jania adhaerens	X							X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Jania capillacea	X	X			X		X		X		X	X
Jania decussato-dichotoma					X		X		X		X	
Jania mexicana									X			
Jania microarthrodia			X					X	X	X		
Jania natalensis									X			
Jania pumila								X				
Jania radiata												X
Jania tenella					X						X	X
Jania ungulata									X			
Jania verrucosa								X				
Jania sp.								X				
Kallymenia sessilis								X				
Kappaphycus alvarezii								X				
Kappaphycus striatum								X				
Laurencia brachyclados								X				
Laurencia cartilaginea								X				
Laurencia ceylanica	X										X	X
Laurencia corymbosa									X			
Laurencia crustiformans								X				
Laurencia decumbens								X				
Laurencia dotyi								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Laurencia forsteri								X				
Laurencia galtsoffii								X	X			
Laurencia glandulifera								X				
Laurencia intricata											X	X
Laurencia majuscula								X	X			X
Laurencia mariannensis								X				
Laurencia mcdermidiae								X				
Laurencia nana		X	X									
Laurencia nidifica	X							X	X			
Laurencia obtusa								X	X		X	X
Laurencia papillosa	X											
Laurencia parvipapillata								X	X			
Laurencia perforata									X		X	
Laurencia pygmaea									X			
Laurencia rigida											X	X
Laurencia succisa								X			X	
Laurencia surculigera											X	
Laurencia tenera								X				
Laurencia tropica											X	
Laurencia undulata								X				
Laurencia yamadana								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Laurencia sp.					X		X		X			X
Laurencia sp. 1									X			
Laurencia sp. 2									X			
Laurencia sp. 3									X			
Laurencia sp. 4									X			
Laurencia sp. 5									X			
Lejolisia colombiana					X							
Lejolisea pacifica								X				
Leveillea jungermannioides								X			X	X
Liagora albicans								X				
Liagora boergesenii								X				
Liagora ceranoides								X	X			
Liagora coarctata									X			
Liagora divaricata								X				
Liagora farinosa									X			
Liagora hawaiiana								X	X			
Liagora hirta	X											
Liagora kahukuana									X			
Liagora orientalis								X	X			
Liagora papenfussii								X	X			
Liagora perennis												

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Liagora pinnata								X				
Liagora samaensis								X				
Liagora robusta									X			
Liagora setchellii								X	X			
Liagora tetrasporifera								X				
Liagora valida								X	X			
Liagora sp.	X									X	X	
Liagorophyla endophytica								X				
Lithophyllum kaiserii	X											
Lithophyllum kotschyanum								X			X	X
Lithophyllum moluccense	X										X	X
Lithophyllum sp.								X				
Lithoporella melobesioides											X	X
Lithoporella pacifica												X
Lithoporella sp.	X											
Lithothamnion asperulum												X
Lithothamnion byssoides								X				
Lithothamnion funafutiense												X
Lithothamnion philippii												X
Lithothamnion spp.					X				X			
Lomentaria hakodatensis					X		X	X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Lomentaria sp.		X										
Lophocladia kipukaia								X				
Lophocladia trichoclados									X			
Lophosiphonia bermudensis					X							
Lophosiphonia cristata								X	X			
Lophosiphonia obscura	X											
Lophosiphonia prostrata								X				
Lophosiphonia scopulorum					X							
Lophosiphonia sp.					X							
Martensia fragilis	X							X	X		X	X
Mastophora lamourouxii												X
Mastophora macrocarpa												X
Mastophora melobesoides	X											
Mastophora plana												X
Mastophora rosea												X
Mazzaella volans								X				
Malaconema minimum								X				
Melanamansia daemelii								X				
Melanamansia fimbrifolia								X				
Melanamansia glomerata								X				
Mesophyllum erubescens	X											X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Mesophyllum mesomorphum	X							X				X
Mesophyllum simulans	X											X
Micropeuce setosus								X				
Monosporus indicus								X				
Murrayella periclados												X
Myriogramme bombayensis								X				
Naccaria hawaiiana								X				
Neogoniolithon brasica-florida	X				X			X			X	X
Neogoniolithon fosliei												X
Neogoniolithon medioramus												
Neogoniolithon pacificum												X
Neogoniolithon reinboldii											X	
Neomartensia flabelliformis								X				
Nitophyllum adhaerens								X				
Osmundaria obtusiloba								X				
Ossiella pacifica								X				
Peleophycus multiprocarpium								X				
Peyssonelia conchicola								X				
Peyssonelia corallis											X	X
Peyssonelia delicata	X											
Peyssonelia foveolata	X											

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Peyssonelia inamoena								X				
Peyssonelia mariti	X											
Peyssonelia rubra	X				X			X				
Peyssonelia sp.									X			
Phaeocolax kajimurai								X				
Platoma ardreanum								X				
Pleonosporium caribaeum								X				
Peonosporium intricatum								X				
Plocamium sandwicense								X	X			
Polyopes hakalauensis								X				
Polysiphonia anomala								X				
Polysiphonia apiculata								X				X
Polysiphonia beaudettei								X				
Polysiphonia delicatula								X				X
Polysiphonia exilis								X	X			
Polysiphonia flaccidissima								X				X
Polysiphonia hancockii								X				
Polysiphonia hawaiiensis								X				
Polysiphonia herpa								X				X
Polysiphonia homoia								X				
Polysiphonia howei								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Polysiphonia pentamera								X				
Polysiphonia poko								X				X
Polysiphonia polyphysa									X			
Polysiphonia poko								X				
Polysiphonia profunda								X				
Polysiphonia pseudovillum								X				
Polysiphonia rubrorhiza								X	X			
Polysiphonia saccorhiza								X	X		X	
Polysiphonia savatieri								X	X			X
Polysiphonia scopulorum	X				X			X	X			X
Polysiphonia setacea								X				X
Polysiphonia simplex								X	X			
Polysiphonia sparsa								X				X
Polysiphonia sphaerocarpa								X	X			X
Polysiphonia subtilissima								X				
Polysiphonia tepida								X				
Polysiphonia tongatensis	X							X				
Polysiphonia triton								X				
Polysiphonia tsudana								X				
Polysiphonia tuberosa												
Polysiphonia upolensis								X	X			X

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Polysiphonia sp.	X				X		X		X		X	X
Polystrata dura	X											
Porolithon craspedium					X						X	X
Porolithon gardineri					X			X				
Porolithon marshallense					X							
Porolithon onkodes	X				X			X			X	X
Porolithon sp.									X			
Porphyra vietnamensis								X				
Portieria hornemanni	X							X	X		X	X
Predaea laciniosa								X				
Predaea weldii								X				
Prionitis corymbifera								X				
Prionitis obtusa	X											
Pterocladia capillacea								X				
Pterocladia musiformis					X							
Pterocladia parva									X			X
Pterocladia tropica					X							
Pterocladia sp.					X							
Pterocladiella bulbosa								X				
Pterocladiella caerulescens								X				
Pterocladiella caloglossoides								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Pterocladiella capillacea								X				
Pterosiphonia pennata								X				
Ptilocladia yuenii								X				
Ptilothamnion cladophorae								X				
Pugetia sp.									X			
Reticulocaulis mucosissimus								X				
Rhodolachne decussata								X				
Rhodymenia sp.	X											
Rhodymenia leptophylla								X				
Scinaia furcata								X				
Scinaia hormoides								X				
Spermothamnion sp.					X				X			
Spirocladia barodensis								X				
Spirocladia hodgsoniae								X				
Sporolithon erythraeum	X							X			X	
Sporolithon schmidtii												X
Sporolithon sibogae	X											
Spyridia filamentosa	X							X	X			X
Stenopeltis gracilis								X			X	
Stenopeltis liagoroides								X				
Stenopeltis setchelliae								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Stictosiphonia kelanensis												X
Stylonema alsidii	X							X				
Stylonema cornu-cervi								X				
Symphyocladia marchantioides								X			X	
Taenioma macrourum							X					
Taenioma perpusillum								X	X			
Tayloriella dictyurus								X				
Tenarea tessellatum								X				
Tiffaniella codicola									X			
Tiffaniella saccorhiza								X	X			
Titanophora marianensis												X
Titanophora pikeana								X				
Tolypiocladia glomerulata	X							X			X	X
Trichogloea lubrica								X				
Trichogloea requienii								X	X			
Trichogloeopsis hawaiiana								X	X			
Irichogloeopsis mucosissima								X				
Tricleocarpa cylindrica								X	X			
Tricleocarpa fragilis								X	X		X	X
Ululania stellata								X				
Vanvoorstia coccinea								X				

Algae species	AS	BK	HL	JV	PY	KG	JS	HI	NWHI	WK	MR	GU
Vanvoorstia spectabilis								X				
Womersleyella pacifica								X				
Wrangelia anastomosans											X	
Wrangelia dumontii								X				
Wrangelia elegantissima								X				
Wrangelia penicillata								X				
Wrangelia tenuis									X			
Wurdemannia miniata					X			X			X	X
Wurdemannia sp.							X					
Yamadaella coenomyce								X				

***References Used:** Birkland *et al.* 1994; Setchell 1924; Tsuda and Trono 1968; Dawson 1959; Dawson *et al.* 1955; Hillis- Colinvaux 1959; Buggeln and Tsuda 1969; Vernon *et al.* 1966; Abbott 1988; 1999; Bailey and Harvey 1862; Egerod 1952; Eldredge and Paulay 1996; Magruder and Hunt 1979; Abbott 1989; Anon 1999; Bailey and Harvey 1862; Eldredge *et al.* 1977; Tsuda 1981; Tsuda and Wray 1977; Eldredge and Paulay 1996; Gilbert 1978; Gordon 1976; Itono and Tsuda 1980; King and Puttock 1989; Nam and Saito 1991; Tsuda 1981; Tsuda and Wray 1977

2. Porifera (sponges)

Important Summary Documents

Moore (1955) described the paleosponges and their dominance in ancient reefs.
Early records of Pacific sponges Bowerbank (1873) and Agassiz (1906). Bergquist (1965,1967, and 1977) catalogued sponges in Micronesia and Hawaii. Kelly-Borges and Valentine (1995) have reviewed the status of the sponges of Hawaii.

Taxonomic Issues

No overall classification of the *Porifera* exists. Calcarea: Burton (1963); Vacelet (1970). Demospongiae Levi (1973) and Bergquist (1978). Sclerospongiae: Hartman & Goreau (1970, 1975) Hexactinellida: Ijima (1927). De Laubenfels (1950a,b 1951, 1954; 1957) recorded the sponges from Hawaii. Species numbers: 84 species in Hawaii Berquist (1977); Chave and Jones (1991); 5000-9000 spp. (Colin and Arneson, 1991) and 10,000 spp. George and George (1979) world-wide.

Habitat Utilization

Use of chemical agents in competing for substrate. Often found at depth, in caves, and vertical areas where not colonized by hard coral. Rutzler and Rieger (1973) described the burrowing sponge *Cliona* into a calcareous substrate.

Life History

Adult: Appearance and Physical Characteristics

Vary greatly in size. The majority are irregular and exhibit massive, erect, encrusting, or branching growth pattern. Many are brightly colored. The body of the sponge is a system of water canals, where with incurrent pores allow water to flow into the atrium and out through the osculum (asconoid, syconoid, and leuconoid plans). The skeleton may be composed of calcareous and silaceous spicules, protein spongin fibers. The spicules exist in a variety of forms and are important in the identification and classification of species.

Of pharmaceutical interest due to the biologically active compounds, most probably used in defense. Some compounds affective against certain tumors and potential effective in treating other diseases.

Reproductive Strategies

Sexual (viviparous and oviparous), asexual and hermaphroditic. Synchronous release of gametes triggered by lunar or daily cycles. Eggs develop into larvae which swim or creep along the bottom. Asexual reproduction is through budding, fragmentation and gemmules (Barnes, 1987, Fromont, 1994). Recruitment may occur by fragmentation from predation (Kelly-Borges and Berguist, 1988).

Distribution

Table 5 shows the distribution of the sponges in some of the AFPI. In Guam and Mariana Islands Bryan(1973). Briggs (1974) provided information on broad distributions as did Hooper and Levi, 1994. In Hawaii, biological interactions affect the occurrence of the sponge *Damiriana hawaiiana* Casper (1981). Encrusting sponges may kill corals (Plucer-Rosario, 1987).

Feeding and Food

Particle feeding and ingestion of plankton and bacteria (Reiswig 1971,1975a)
Utilization of DOM, directly or indirectly, by symbiotic cyanobacteria (Barnes 1987; Wilkinson, 1979, 1983).

Behavior

Symbiosis common which includes shrimps, crabs, barnacles, worms, brittlestars, holothurians, and other sponges (Colin and Arneson, 1991). *Tethya sp.* produces filamentous extensions for mobility. *Placospongia* rapidly closes its plate-like surface when touched. *Tedania* (fire sponge) causes burning due to spicules and chemicals. *Hippospongia* and *Spongia* are used as bath sponges.

Diurnal rhythm in the active flow of water (Reiswig, 1971)

Spawning: Spatial and Temporal Distribution

Lunar and diurnal periodicity

Appearance and Physical Characteristics of Eggs (size, shape, color, etc) and Duration of Phase

During mass spawning events (Reiswig, 1971), sperm appears as clouds of smoke. In some cases, release of eggs causes appearance of opaque mucous covering sponge (Colin and Arneson, 1995).

Larvae: Appearance and Physical Characteristics of Larvae

The larval metamorphosis is described by Simpson (1986).

References

Agassiz, A. 1906. General Report of the Expedition. Report on the scientific results of the expedition to the Eastern Tropical Pacific, in charge of A. Agassiz, by the U.S. Fisheries Commission Steamer Albatross,1904-1905 and 1888-1904. 21:Memoirs of the Museum of Comparative Zoology, Harvard Collection 41:261-323.

Barnes, R. D. 1987: *Invertebrate Zoology, Fifth Edition.* Saunders College Publ., International Edition.

Bergquist, P. R. 1965. The Sponges of Micronesia. I. The Palau Archipelago. Pacific Science 3(2): 123-204.

Bergquist, P. R. 1967. Additions to the sponge fauna of the Hawaiian Islands. Micronesica 3:159-173.

Bergquist, P.R. 1978. *Sponges*. 268 pp. London: Hutchinson.

Bergquist, P.R. 1979. Porifera. In Reef and Shore Fauna of Hawaii. Section 1. Protozoa through Ctenophora, ed. D. M. Devaney and L. G. Eldredge. Bernice P. Bishop Museum Special Publications 64(1): 53-70.

Bowerbank, J. S. 1873. Contributions to a general history of the Spongidae. Part IV. Proceedings of the Zoological Society of London. 4:3-25.

Briggs, J. C. 1974. Marine Zoogeography. New York: McGraw Hill.

Bryan, P. G. 1973. Growth rate, toxicity and distribution of the encrusting sponge Terpios sp. (Hadromerida, Suberitidae) in Guam, Mariana Islands. Micronesica 9(2): 237-242.

Burton, M. 1963. *A revision of the classification of the calcareous sponges.* 693 pp. London: British Museum (Natural History).

Chave, E. H., & A. T. Jones. 1991. Deep-water megafauna of the Kohala and Haleakala slopes, Alenuihaha Channel, Hawaii. *Deep-Sea Research* 38, no. 7:781-803.

Colin, P. L. & Arneson, C., 1995: A Field Guide to the Marine Invertebrates Occurring on Tropical Pacific Coral Reefs, Seagrass Beds and Mangroves. *Tropical Pacific Invertebrates.*

Colin, P. L., and C. Arneson. In press. Tropical Pacific Invertebrates. San Diego: Coral Reef Press.

de Laubenfels, M. W. 1950a. The sponges of Kaneohe Bay. Pacific Science 4(1): 3-36.

de Laubenfels, M. W. 1950b. Sponges in Hawaii. Cooperative Fishery Investigations Circular 9 (June):1-2.

de Laubenfels, M. W. 1951. The sponges of the islands of Hawaii. Pacific Science 5(3): 256-271.

de Laubenfels, M. W. 1954. The sponges of the West Central Pacific. Oregon State Monographs in Zoology 7:1-306.

de Laubenfels, M. W. 1957. New species and records of Hawaiian sponges. Pacific Science 11:236-251.

Fromont, P. J. 1994. Reproductive development and timing of tropical sponges (Order Haplosclerida) from the Great Barrier Reef. Coral Reefs 13:127-133.

George, D. & J. George, 1979: An Illustrated Encyclopedia of Invertebrates in the Sea, *Marine Life.*

Hartman, W. D., & Goreau, T. F. 1970. Jamaican coralline sponges: their morphology, ecology, and fossil relatives. *Symp. Zool. Soc. Lond.,* No. 25, 205-43.

Hartman, W. D., & Goreau, T. F. 1975. A Pacific tabulate sponge, living representative of a new order of sclerosponges. *Postilla,* **167,** 1-14.

Hooper, J. N. A., and C. Levi. 1994. Biogeography of Indo-Pacific Sponges: Microcionidae, Raspailiidae, Axinellidae. In Sponges in Time and Space, ed. R. W. M. van Soest, Th. M. G. van Kempen, and J. C. Braekman, 191-212. Rotterdam: Balkema.

Ijima, I. 1927. The Hexactinellida of the Siboga expedition. Siboga Exped., **6**, 1-383.

Kelly-Borges, M. and C. Valentine 1995 The sponges of the tropical island region of Oceania: a taxonomic status review. In: Maragos, J.E. Peterson, M.N.A., Eldredge, L.G., Bardach, J.E. and H.F. Takeuchi (eds.) Proceedings of the Workshop on Marine/Coastal Biodiversity in the Tropical Island Pacific Region (November 2-4, 1994), Volume I, pp. 83-120. East-West Center and Pacific Science Association, Honolulu, Hawaii.

Kelly-Borges, M., and P. R. Bergquist. 1988. Success in a shallow reef environment, sponge recruitment by fragmentation through predation. Proceedings of the 6th International Coral Reef Symposium, Townsville, Australia, 2:757-762.

Levi, C. 1973. Systematique de la Classe des Demospongiaria (Demosponges), 37-631. In: Grasse P.-P. (ed.). *Traite de Zoologie, III, Spongiaires*. Paris: Masson.

Moore, R. D. (Ed.), 1955: Treatise on Invertebrate Paleontology. Arcaeocyatha, Polifera. Vol. E. Geological Society of America and University of Kansas Press, Lawrence, Kans. No. 25., 189-203.

Plucer-Rosario, G. 1987. The effect of substratum on the growth of Terpios, an encrusting sponge which kills coral. Coral Reefs 5(4): 197-200.

Reiswig, H. M., 1971: *In Situ* pumping activities of tropical Damospongiae. Mar. Biol., 9(1): 38-50.

Reiswig, H. M., 1971: Particle feeding in natural populations of three marine damosponges. Biol. Bull., *141*(3): 568-591.

Reiswig, H. M., 1975a: Bacteria as food for temperate-water marine sponges. Can. J. Zool., *53*(5): 582-589.

Rutzler, K., and Reiger, G., 1973: Sponge burrowing: fine structure of *Cliona lampa* penetrating calcareous substrata. Mar. Biol., *21:*144-162.

Simpson, T. L., 1968: The biology of the marine sponge *Microciona prolifera..* Temperature related, annual changes in functional and reproductive elements with a description of larval metamorphosis. J. Exp. Mar. Biol. Ecol., *2:*252-277.

Vacelet, J. 1970. Les eponges Pharetronides actuelles. *Symp. Zool. Soc. Lond.*, Wilkinson, C. R., 1979: Nutrient translocation from symbiotic cyanobacteria to coral reef sponges. See Levi and Boury-Esnault, pp. 373-380.

Wilkinson, C. R., 1983: Net primary productivity in coral reef sponges. Science, *219:*410-411.

Table II.C.5: Distribution of sponges within the American Affiliated Pacific Islands (AFPI) (after Kelly-Borges and Valentine, 1995)

AS: American Samoa; HI: Hawaiian Islands; NMI: Commonwealth of Northern Mariana Islands; GU: Guam

Taxonomy/occurrence	AS	HI	CNMI	GU
DEMOSPONGIAE				
Homosclerophorida				
Oscarella tenuis		X		
Plakina monolopha		X		
Plakortis simplex		X		
Astrophorida				
Ancorina acervus			X	
Asteropus kaena		X		
Dorypleres splendens			X	
Erylus caliculatus		X		
Erylus proximus		X		
Erylus rotundus		X		
Erylus sollasi		X		
Geodia gibberella		X		
Jaspis stellifera			X	
Melophlus sarasinorum				X
Rhabdastrella pleopora		X		
Stelletta debilis		X		
Zaplethes digonoxea		X		
Lithistida				
Aciculites papillata			X	
Leidermatium sp		X		
Spirophorida				
Cinachyra porosa			X	
Paratetilla bacca			X	
Hadromerida				
Anthosigmella valentis		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
Chondrosia chucalla		X		
Chondrosia corticata			X	
Chondrosia sp		X		
Cliona vastifica		X		
Diplastrella spiniglobata		X		
Kotimea tethya		X		
Placospongia carinata			X	
Prosuberites oleteira		X		
Spheciospongia aurivilla			X	
Spheciospongia purpurea			X	
Spheciospongia vagabunda		X	X	
Spirastrella coccinea		X		
Spirastrella keaukaha		X		
Terpios aploos				X
Terpios granulosa		X		
Terpios hoshinoto				X
Terpios sp				X
Terpios zeteki		X		
Tethya coccinea			X	
Tethya diploderma		X		
Tethya robusta			X	
Timea xena		X		
Halichondrida				
Axechina lissa		X		
Axinella solenoides		X		
Axinyssa aplysinoides				X
Axinyssa pitys			X	
Axinyssa terpnis			X	
Axinyssa xutha			X	
Ciocalypta pencillus		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
Cymbastella cantherella			X	
Densa mollis			X	
Eurypon distincta		X		
Eurypon nigra		X		
Halichondria coerulea		X		
Halichondria dura		X		
Halichondria melanadocia		X		
Higginsia anfractuosa			X	
Higginsia mixta			X	
Homaxinella anamesa		X		
Hymeniacidon chloris		X		
Myrmekioderma granulata			X	
Myrmekioderma sp.				X
Phycopsis aculeata		X		
Pseudaxinella australis			X	
Raphisia myxa		X		
Rhabderemia sorokinae			X	
Stylotella aldis			X	
Stylotella aurantium			X	X
Ulosa rhoda		X		
Haplosclerida				
Adocia gellindra		X		
Adocia turquosia			X	
Adocia viola				X
Aka mucosa			X	
Amphimedon sp				X
Callyspongia aerizusa			X	
Callyspongia diffusa		X		X
Callyspongia parva			X	
Gellius gracilis			X	

Taxonomy/occurrence	AS	HI	CNMI	GU
Haliclona acoroides			X	
Haliclona aquaeducta		X		
Haliclona flabellodigitata		X		
Haliclona koremella			X	
Haliclona lingulata				X
Haliclona pellasarca			X	
Haliclona permollis		X		
Haliclona streble			X	
Haliclona viridis			X	
Niphates cavernosa			X	
Niphates spinosella			X	
Sigmadocia amboinensis			X	
Sigmadocia symbiotica			X	
Toxadocia violacea		X		
Petrosida				
Pellina eusiphonia		X	X	
Pellina pulvilla				X
Pellina sitiens		X		
Petrosia puna		X		
Xestospongia sp				X
Poecilosclerida				
Acamas caledoniensis			X	
Amphinomia sulphurea			X	
Axociella kilauea		X		
Biemna fortis			X	
Clathria frondifera				X
Clathria procera		X		
Clathria vulpina			X	
Coelocartaria singaporense			X	
Crella spinulata			X	

Taxonomy/occurrence	AS	HI	CNMI	GU
Damiriana hawaiiana		X		
Desmacella lampra			X	
Echinodictyum antrodes				X
Esperiopsis anomala		X		
Iotrochota baculifera			X	
Iotrochota protea		X		
Kaneohea poni		X		
Lissodendoryx calypta		X		
Lissodendoryx oxytes			X	
Microciona eurypa			X	
Microciona cecile			X	
Microciona haematodes		X		
Microciona maunaloa		X		
Mycale cecilia		X		
Mycale contarenii		X		
Mycale maunakea		X		
Myxilla rosacea		X		
Naniupi ula		X		
Prianos phlox			X	
Strongylacidon sp.		X		
Tedania ignis		X		
Tedania macrodactyla		X		
Xytopsiphum kaneohe		X		
Xytopsiphum meganese		X	X	
Xytopsues zukerani		X		
Zygomycale parishii		X		
Dictyoceratida				
Coscinoderma denticulatum		X		
Fasciospongia chondrodes			X	
Hippospongia densa		X		

Taxonomy/occurrence	AS	HI	CNMI	GU
Hippospongia metachromia			X	
Hyrtios erecta				X
Lendenfeldia dendyi			X	
Lufferiella sp		X		
Lufferiella variabilis				X
Spongia irregularis dura		X		
Spongia irregularis lutea		X		
Spongia irregularis mollior		X		
Spongia irregularis tenuis		X		
Spongia denticulata		X		
Spongia oceania		X		
Stelospongia lordii		X		
Strepsichordaia lendenfeldi			X	
Verongida				
Aplysinella strongylata			X	
Aplysinella tyroeis			X	
Ianthella basta				X
Psammaplysilla purpurea		X		
Psammaplysilla verongiformis			X	
Dendroceratida				
Aplysilla rosea		X		X
Aplysilla sulphurea		X		
Aplysilla violacea		X		
Dendrilla cactus		X		
Dendrilla nigra			X	
Dysidea avara		X	X	X
Dysidea fragilis			X	
Dysidea herbacea		X		
Dysidea sp		X		X
Euryspongia lobata			X	

Taxonomy/occurrence	AS	HI	CNMI	GU
Pleraplysilla hyalina		X		
Slerosponges				
Acanthochaetetes wellsi			X	
Astrosclera willeyana			X	X
Stromatospongia micronesica			X	X
CALCAREA				
Clathrina sp		X		
Leucetta avacado				X
Leucetta solida		X		
Leuconia kaiana		X		
Leucosolenia eleanor		X		
Leucosolenia vesicula		X		
Murrayona phanolepis			X	
Sycandra coronata		X		
Sycandra parvula		X		
Sycandra staurifera		X		
HEXACTINELLIDA				
Euplectella sp		X		
Stylocalyx elegans		X		

3. *Millepora* sp. (Linnaeus, 1758) (stinging or fire coral)

Important Summary Documents

Lewis (1989) discussed the ecology of Millepora. Growth and age were investigated (Lewis, 1991).

Taxonomic Issues

Class Hydrozoa: Order Milleporina (Hydroidea): Family Milleporidae: 48 species
The history of *Millepora* taxonomy has been the opposite of scleractinian taxonomy where each minor growth form was often described as a new species (Veron, 1986).

Habitat Utilization

Found on projecting parts of the reef where tidal currents are strong. They are also abundant on upper reef slopes and in lagoons and may be a dominant component of some coral communities (Veron, 1986).

Life History

Adult: Appearance and Physical Characteristics

Colonial and hermatypic. Arborescent, plate-like, columnar or encrusting with a smooth surface perforated by near-microscopic pores. These are of two sizes: the larger are the gastropores, with each surrounded by five to seven smaller dactylopores. Fine straight hairs, visible under water, project from the colony surface. The growth variation is often based on environmental influences. Colors are green, cream or yellow. May be tan-coloured antler-like sheets with branch ends whitish.

Distribution

Globally, the genus is distributed from as far south as South Africa and southern Western Australia to the Kyushu Islands. From the African coast of western Indian Ocean and the Red Sea and the Marquesas in the east. The genus also occurs in the Central and Eastern Pacific and the Caribbean Sea.

Following is a summary of some Indo-Pacific species (adapted from Lewis 1989): their morphology, depth and reef zone and water circulation requirements.

Table II.C.6: Species summary of the genus *Millepora* (Lewis 1989).

Species	Form	Location on reef	Habitat type
Millepora dichotoma	Fan, branches, vertical sheets and walls	0-5m, reef edge	Turbulent, area of the surf
M. exaesa	Robust branches or solid and round	0-10m, reef edge, outer reef slope	Moderate to turbulent
M. platyphylla	Sheets, leaves fans branches	0-10m, reef edge, reef flat	Strong to powerful, turbulent
M. tenella	Fans, branches, sheets	0-10m, reef edge, outer reef slope	medium to strong

Feeding and Food

Gastrozoiids consume food and are the colony polyps have tentacles and a gastrovascular cavity. The dactylozoiids are used for prey capture and have numerous tentacles, which convey a fuzzy appearance. They have a potent sting. Autotrophic due to zooxanthellae but may rely on small plankton and dissolved nutrients.

Reproductive Strategies

Alternation of generations: a sessile, asexual polyp stage and a free-living, sexual medusa stage. Medusa are reproduced by asexual division or budding. The medusa has separate sexes and produce eggs or sperm, which unite and develop into free-swimming planula larvae. Planula larvae are able to swim freely, though largely planktonic.

References

Lewis J.B. (1989). The ecology of Millepora. Coral Reefs 8 (3): 99-107.

Lewis J.B. (1991). Banding age and growth in the calcareous hydrozoan *Millepora complanata Lamark.* Coral Reefs 9 (4): 209-214

Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.

4. Stylasteridae (Gray, 1847) (Stylasterines; lace corals)

Important Summary Documents

Veron (1986) Colin and Arneson (1995) and Fossa and Nilsen (1998) provide description of the family.

Taxonomic Issues

Class Hydrozoa; Class Stylasterina; Family Stylasteridae
Approximately 15 genera. Two are common reef genera: *Stylaster* Gray 1831 (48 species); *Distichopora* Lamarck 1816 (34 species) (Veron, 1986).
Taxonomy at the species level poorly known.

Habitat Utilization

With in the reef, sciaphilic or low light, often abundant under overhangs or on the roof of caves. Also found in deep reef conditions particularly if swept by tidal currents (Colin and Arneson, 1995)

Life History

Adult: Appearance and Physical Characteristics

Colonial, ahermatypic, usually arborescent, with tubular gastropores surrounded by smaller dactylopores and usually forming cyclosystems (Veron, 1986). Colour is bright and may be red, pink, orange, purple or white.

Stylaster spp.: Colonies are arborescent with fine branches, growing in one plane, which seldom anastomose. Cyclosystems alternate left and right side of branches.

Distichopora spp.: Colonies are arborescent with flattened, blunt-ended, non-anastomosing branches of uniform width, growing in one plane. There are no cyclosystems: gastropores are aligned along the lateral margins of branches with rows of dactylopores on either side (Veron, 1986; Sheer and Obrist, 1986).

Distribution

Stylaster spp.: Worldwide, extending to the Arctic and Antarctic.
Distichopora spp.: Circum-Australia, Central and the Indo-Pacific.

Feeding and Food

No zooxanthellae so heterotrophic, feeding presumably on small plankton. Dissolved nutrient absorption must be important.

Reproductive Strategies

Sexual individuals, the gonophores, develop in ampullae between the gastropores and release planula larvae.

References

Colin, P. L., and C. Arneson. 1995. Tropical Pacific Invertebrates. San Diego: Coral Reef Press, California, USA.

Fossa and Nilsen 1998. The Modern Coral Reef Aquarium, Vol. 2. Birget Schmettkamp Verlag, Bornheim, Germany.

Sheer, G. and Obrist K. 1986. Distichopora nitida Verrill (Cnidaria, Hydrozoa) from the Maldives, a new record from the Indian Ocean. Coral Reefs 5: 151-154.

Veron J. E. N. 1986. *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.

5. Solanderidae (Gray) (hydroid fans)

Important Summary Documents

Cooke (1977) described Hawaiian fauna all, of which, have a wider distribution.

Taxonomic Issues

Class Hydrozoa; Order Hydroida; Suborder Athecata (=Anthomedusa; Gymnoblastea); Family Solanderiidae (George and George, 1977; Barnes, 1987).

Habitat Utilization

Shallow water to 100 metres (Colin and Arneson, 1995).
Often found in deeper water ore cave or overhang environment (Cooke, 1977).

Life History

Adult: Appearance and Physical Characteristics

Similar in appearance to gorgonians and other sea fans. May be branching, ramose or encrusting. Branching in one plane, perpendicular to the current or wave action. Commonly found in exposed areas on wave swept shallow outer reefs (Colin and Arneson, 1995). *Solanderia spp.* is branching and may be 30cm high. Family is characterized by the presence of a perisarc composed of anastomosing chitinous fibers with scattered capitate tentacles (Cooke, 1977).

Defense is accomplished by the specialized tentacle the dactylozooids.
Colour species dependent: dark brown to yellow brown, red with white tentacle.

Distribution

Occur from western Africa through the central Indo-Pacific. Northerly limit Japan and Hawaii.

From Cooke (1977):
Solanderia minima: Zanzibar, Africa; *Hawaii.*
S. secunda: Central Pacific
S. misakinensis: Japan; Hawaii
S. sp.: New Guinea (Colin and Arneson 1995)

Feeding and Food

Gastrozooids capture and ingest zooplankton that is small enough to be handled. Extra-cellular digestion takes place in the gastrozooid. The partially digested broth the passes into the common gastrovascular cavity where intracellular digestion occurs.

Reproductive Strategies

Reproduction is by means of fixed gonophores or gonozooids. Applying generalized hydroid reproduction, the gonophores bud off both male and female, mobile medusae, which develop gonads and reproduce. The fertilized egg divides and develops into free-swimming larvae that attach to substrate to form a new hydroid.

References

Barnes, R. D. 1987. Invertebrate zoology. Saunders College, Philadelphia.

Colin, P. L., and C. Arneson. 1995. Tropical Pacific Invertebrates. San Diego: Coral Reef Press.

Cooke, J. 1977. Order Hydroida. In Devany D. M. & L. G. Eldredge (eds.) 1977. Reef and Shore Fauna of Hawaii. Bernice P. Bishop Museum Special Publication **64** (1).

George, D. & J. George, 1979. An Illustrated Encyclopedia of Invertebrates in the Sea *Marine Life.*

6. Scleractinia (stony corals)

Important Summary Documents

Veron (1986) provides a popular taxonomic guide for stony corals and their biology. Birkeland (1997) is a modern synthesis of coral reef dynamics.
Fadlallah, (1983), Harrison and Wallace (1990) reviewed coral reproduction. Richmond and Hunter (1990) compared coral reproduction geographically.

Taxonomic Issues

Veron and Pichon (1976); Veron, Pichon and Wijsman-Best (1977); Veron and Pichon (1979); Veron and Pichon (1982); Veron and Wallace (1984) have revised the taxonomy of the order Scleractinia in the AIMS Monograph series. Many of the earlier checklists require revision for comparison. References for description and checklists of the AFPI are: Hawaii -Maragos (1977, 1992,1995); Guam - Jones and Randall (1973); CNMI - Randall (1995); American Samoa - Birkeland,, Randall and Amesbury (1994); Lamberts (1980); Wake I. - Anon. (1999); Midway Atoll, Northern Hawaiian Islands - DeFelice, Coles, Muir, Eldredge (1998); Johnston Atoll - Maragos and Jokiel (1986); Jokiel and Tyler (1992); Palmyra Atoll - Maragos (1979, 1988, in prep.)

Habitat Utilization

Stony coral attach to the reef substrate creating a variety of biological habitats on which many other groups rely for shelter and symbiosis. Coral skeletons with the aid of coralline algae create the reef structure.

The distribution of hard coral over the reef is the result of fortuitous settlement and environmental sorting. The history of disturbance in an area plays a large role in the nature of the coral assemblage. Generally, there is a near shore assemblage which is dominated by genera resistant to the influence of the terrestrial factors and tidal variation. (eg. siltation, flooding, and variation in temperature). The genus *Porites, Montipora* and *Pavona, in that order* to dominate the reef seleractinians in Hawaii. In Hawaii, the predominantly branching coral genus *Acropora* is rare and generally confined to several areas in the NWHI. Elsewhere in the region, *Acropora, faviids* and *Millepora* are dominant or very common along with the other genera mentioned above. In permanently sub-tidal areas and further offshore the *Acropora* dominate but often in association by substantial growths of a variety of other species. In Hawaii, this dominance is replaced by Montipora and Pocillopora. Stony coral are limited by light (depth), wave action and disturbance.

The AFPI span a broad biogeographic realm from Guam (144^0 45=E long.) to Hawaii (155^0 W. Long) and from American Samoa (15^0 S latitude) to the northern Hawaii Islands (28^0 40= N. Lat). In terms of coral development, the tropical/temperature gradient gives rise to a range of reef types and species assemblages. The luxuriance of the high island reefs of American Samoan, Guam are in contrast to the variety of reefs which occur in Hawaii. The Jarvis, Baker, Howland, Palmyra Johnston and Wake reefs are atolls as are some of the reefs northern Hawaiian Islands. For most of these areas, varying degrees of information is available, though being generally scant.

Life History

Adult: Appearance and Physical Characteristics

Corals are similar to anemones in having a polyp form which may be colonial or solitary. They are characterized by a hard skeleton of aragonite (calcium carbonate). The colonial form may manifest a variety of forms: branching, tabulate, massive or encrusting. Some forms are species specific while some species respond to environmental influences which condition the colonial morphology. Polyps have tentacle though these are absent in some genera. They are often a crown, in multiples of six, (Hexacorallia) encircling the mouth though these may be manifest in furrows or over the surface as in the solitary *Fungia*. They possess nematocysts. Internally, the mouth opens into a gastrovascular cavity with mensentaries and mesentarial filaments. The mesentaries extend from the scleroseptum. The skeleton has a thecal wall, sclosepta and a basal plate (Barnes, 1987).

The colony expands by budding of new polyps from the bases of old polyps or from the oràl discs of old polyps through intra-tentacular or extra-tentacular budding. Polyps of meandroid colonies share a common oral disc bearing many mouths (Barnes, 1987).

Age, Growth, Longevity

Corals can be very long lived for massive species. An estimated 1000 years has been estimated for some massive *Porites,* colonial sizes representing 300 is reasonably common. Growth rates have been recorded by Buddemeir and Kinzie (1976).
Corals as a group have a wide range of growth rates. The rate variable between 0.4 and 22.5 cm per year. The massive corals grow more slowly with a range of 0.4 to 1.8cm. (DeVantier, 1993). Growth also includes fusion of colonies.

Table II.C.7: Growth rates among some scleractinian coral.

Species	Growth (cm/yr)
Faviidae *Favia, Favites* *Goniastrea,* *Montastrea* *Platygyra*	0-1.38 Mean range 0.07-1.25
Poritidae *Porites* *Goniopora*	0-1.88 Mean range 0.13-0.97
Mussidae *Lobophyllia* *Symphyllia* *Acanthastrea*	0-1.65 Mean range 0.38-0.94
Oculinidae *Galaxea*	0.67-1.18 Mean range 0.54-0.93
Merulinidae *Hydnophora*	.56-1.15 Mean 0.86
Caryophylliidae *Physogyra* *Euphyllia* *Plerogyra*	0.5-0.75 Mean range 0.5-0.75
Acroporiidae *Acropora*	10.17-22.58
Pocilloporiidae *Pocillopora*	0.4-3.59

Reproductive Strategies

Corals reproduce by both sexual (external fertilization and development and brooded planulae) and asexual development (brooded planulae, polyp-balls, polyp bail-out, fission, fragmentation and re-cementation). May be bisexual or hermaphroditic (protandric, protogynous or synchronous) (Chorneski and Peters, 1987). Self fertilisation occurs (Heyward and Babcock, 1986).

Asexual modes of reproduction:

brooded planulae
polyp-balls: *Goniopora spp.* (Sammarco 1986)
polyp bail-out: *Seriatopora spp.* (Sammarco 1981,1982)
reversible metamorphosis: *Pocillopora damicornis* (Richmond 1985)
fission: *Fungiidae*
fragmentation and re-cementation: *Acropora spp* and others (Tunnicliffe, 1981)

Corals may be free spawners or brooders depending on their geographic distribution. In Hawaii , *Tubastrea* is a brooder but in Australia is a brooder and free spawner.(Harrison and Wallace, 1990)

Sexual maturity depends, on growth as well as colony age (Kojis and Quinn, 1985)
Brooders reach maturity a few years earlier than free spawners. Ahermatypic corals reach sexual maturity earlier than hermatypic corals (Harriot, 1983). Fecundity increases with age. (Soong and Lang, 1992). Availability of light influences fecundity whether through depth or an increase in suspended particles in the water (Kojis and Quinn, 1984) or the reduction of UV light (Jokiel and York, 1982).

Distribution

Table 6 details the occurrence of Scleractinia in the AFPI. Veron (1993b) detailed the global distribution of coral genera and regionally with species. Regional variation in generic occurrence has been documented with latitudinal gradients (Wells 1956).

Zonation within reefs due to environmental influences is well known.(In American Samoa: Birkeland et al. 1994, 1996; In Hawaii: Palmyra Atoll: Maragos 1977, 1988, 1992; In Guam: Jones and Randall).

Discrete coral populations may result from asexual reproduction and possess the same genotype (Hunter, 1985; Willis and Ayre, 1985; Ayre and Resing, 1986) though many appear heterogenous.

Feeding and Food

Stony coral s feed on planktonic organisms or dissolved organic matter (DOM). Capture of prey is by tentacles, suspension feeding occurs and some use mesenterial filaments. Most prey capture at night though some feed during the day.

The presence of symbiotic zooxanthellae make some corals functional autotrophs (Muscatine et al. 1981) and contribute to all hermatypes nutrition. Muscatine and Porter (1977) determined plankton comprise approx. 20% of coral required nutrition. Franzisket (1970) showed coral could live without plankton, but additional nutrition was required from this source (Johannes et al. 1970). The relative dependance on heterotrophy varies with species and with environment. Sorokin (1973, 1995) described the relative dependence on predation, bacteria and DOM. The zooxanthellae receive elements from predation (i.e. nitrogen, iron, and vitamine B_{12}). Recycling of nutrients between corals and zooxanthellae is well known (Johannes 1974; Muscatine 1973; Porter, 1976).

Behavior

Competition for space is achieved by direct tentacular competition ; mesenterial filaments, sweeper tentacles, allopathy, over-growth, shading.

Spawning: Spatial and Temporal Distribution

Mass spawning has been described by Babcock et al. (1986) and follows a lunar periodicity (Richmond and Hunter , 1990). Geographic variation introduces the effects of temperature and other climatic factors. In Australia, (GBR), *A .palifera* spawns only once per year at 23^0S latitude and through out the year at 14^0S lat.(Kojis and Quinn, 1984, 1986a).

Appearance and Physical Characteristics of Eggs (size, shape, color, etc) and Duration of Phase

Eggs are round and may pink, orange, blue, purple or white. Pigmentation may be UV protection. White eggs are non-fertile in *Galaxea fascicularis.* Maturation of eggs and ejection may be controlled by the hormone Estradiol-17*b* (Atkinson and Atkinson, 1992). Form into egg sperm bundles. Some eggs contain zooxanthellae. Eggs range in size from 1.5 x 1.00mm (*Flabellum rubrum)* to Acorporidae and Mussidae 0.4-0.8mm; Faviidae and Pectiniidae 0.3- 0.5mm, Portitidae, Agariciidae, Fungiidae and Pocilloporidae 0.05-0.25mm. The total length of sperm is <0.005mm. Eggs and sperm production is cyclic and maturity is reached at the same time for most corals. For *Stylophora pistillata* (Rinkevich and Loya, 1979), the time is different for different colonies. *Acropora palifera* spawning may take place in several stages in synchrony with moon phases with six reproductive cycles per year (Kojis, 1986a, b). Free spawners have a 12 month maturation cycle but brooders have several cycles per year.

Spawning is in synchrony with the lunar cycle begin on the 15th to the 24th night of the lunar cycle. Spawning starts at dusk and continues until midnight. It may vary geographically. A slick is often observed as the gammetes are brought together by currents. Likelihood of fertilization is increased and the abundance of material means predation is decreased through satiation.

Duration of gamete development after spawning is 30 minutes until the ability to fertilise, first cell division 1-2 hours, to planula stage 6-24 hours (Szmant-Froelich et al. 1980; Kojis and Quinn 1982, Bull 1986, Heyward 1986)

Larvae: Appearance and Physical Characteristics of Larvae

It is covered with cilia which provides locomotion. In *Porites porites,* 200 planula may be released from a section of colony ($2cm^2$) (Fadallah, 1983). They are ciliated, spherical initially and oval or pear-like when mobile.

Age, Growth and Duration of Larval Phase

Initially, they move to the surface of the water and drift as a ciliated ball. In 3-7 days they elongate into a conical shape. They have a cavity and mouth and are 1.5mm long with mesenteries developed. They then move to deeper water and seek substrate (Babcock and Heyward, 1986).

Coral with long lived larvae are: *Galaxea aspera* 49 days; Cyphastrea ocellina (Hawaii) 60 days; Acropora spp. 91 days; Pocillopora damicornis (Hawaii) 103 days (Gulko,1999).

Larval Feeding and Food

Nutrition in planulae is achieved as the result of energy reserves transferred from the embryonic cells. Zooxanthellae, most probably, provide nutrition through nutrient translocation. Some planula feed actively.

Habitat Utilization

Some planula have zooxanthallae and may exist for longer in the plankton and disperse further. Most settle with the proximity of the parent <1km. Discussion of factors in dispersal have been reviewed by Harrison and Wallace (1990). Currents must play a major role in the transport of the larvae. Longevity in the plankton will determine the potential distance of dispersal (Richmond, 1987).

Settlement sites are often cryptic. Clumping of planula may give rise to fusion into a single colony.

Habitat Features Affecting the Abundance and Density of Eggs and Larvae

Currents affect the abundance of eggs and larvae, often concentrating them into a dense mass and dispersing them with the flow. Rain storms may cause mass mortality at this stage as does grounding of the slick at low tide or along the shore. After settlement, the planulae develop primary polyps. The settlement site is important. If inshore, large amounts of organic particular matter and sediment will increase mortality. Wave action may destroy the primary polyps. Young polyps may abandon primary calyx, and relocate planktonically (Richmond, 1985) or through bailout responses.

There is the potential for rafting of coral polyps on driftwood or other current borne objects which would allow for the settlement by larvae and polyp growth (Jokiel, 1984).

Abundance and distribution of coral planulae was investigated in Kaneohe Bay, Oahu (Hodgson, 1985) and Bull (1986) for Australia.

Settlement occurs by finding a suitable location. The size of the new polyp is <2mm. Mortality at this stage is high. Both the environmental and biological environment affect the potential for coral development (Goreau, et al. 1981).

In Western Australia, large numbers of fish and coral died as the result of a coral spawn slick being embayed and using up the oxygen and then decaying (Simson 1993).

References

Anon. (1999). *Baseline Marine Biological Survey, Peacock Point Outfall and other Point Source Discharges, Wake Atoll, Pacific Ocean.* Report to the Department of Army by the Department of Interior, Fisheries and Wildlife Service (FWS) and the Department of Commerce, National Marine Fisheries Service (NMFS). Honolulu, Hawaii. 23 p.

Atkinson, S. and Atkinson, M.J. 1992. Detection of estradiol 17*b* during a mass coral spawn. Coral Reefs 11 (1): 33-36.

Ayre, F.J. and Resing J.M. 1986. Sexual and asexual production of planula in reef corals. Mar. Biol. (90): 187-190.

Babcock, R.C., G. D. Bull, P. L. Harrison, A. J. Heyward, J. K. Oliver, C. C. Wallace & B. L. Willis (1986): Synchrounous spawnings of 105 scleractinian coral species on the Great Barrier Reef. Mar. Biol. (90): 379-394

Babcock, R.C. and Heyward A.J. (1986). Larval development of certain gamete-spawning scleractinian corals. Coral Reefs 5: 111-116.

Barnes, R. D. (1987): Invertebrate zoology. Saunders Colledge, Philadelphia.

Birkeland, C. 1997a Introduction. In: C. Birkeland (ed.) Life and death of coral reefs. Chapman and Hall, Melbourne.

Birkeland, C., Randall, R. and S. Amesbury 1994 Coral and reef-fish assessment of the Fagatele Bay National Marine Sanctuary. Report to the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 126 pp.

Birkeland , C., Randall, R., Green, A.L. Smith, B. and S. Wilkens 1996 A re-survey of the marine resources of Fagatele Bay National Marine Sanctuary, American Samoa. A report to be submitted to the NOAA Technical Report Series. 223 pp.

Buddemeir, R.W. and Kinzie, R.A. 1976. Coral Growth. *Oceanogr. Mar. Biol. Ann. Rev. 14: 183-225.*

Bull, G. 1986. Distribution and abundance of coral plankton. Coral Reefs (4): 197-200.

Chorneski E.A. and Peters E.C., 1987. Sexual reproduction and colony growth in the scleractinian coral *Porites asteroides*. Biol. Bull. (172): 161-177.

DeFelice R.C., Coles, S.L., Muir D., Eldredge L.G. 1998. Investigations of the marine communities of Midway Harbour and adjacent lagoon, Northwestern Hawaiian Islands.

Report to U.S. Fish and Wildlife Service, Pacific Islands Area Office, Honolulu, Hawaii.

DeVantier, L.M. 1993. The Coral Communities of the Brook Islands, 1987 - 1992. Rpt. Qld. Dept. Environment and Heritage, Coastal Protection Unit.

Fadlallah, Y. H., 1983: Sexual reproduction, development and larval biology in scleractinian corals. A review. Coral Reefs, *2*(3):129-150.

Franzisket, L., 1970. The atrophy of hermatypic reef corals maintained in darkness and their subsequent regeneration in light. Inter. Rev. Gesamten Hydrobiol., *55*(1): 1-12.

Goreau, N.I., Goreau, T.J. and Hayes R.L. (1981) Settling, survivorship and spatial aggregation in planulae and juveniles of *Porites porites (Pallas)* Bull. Mar. Sci. 31: 424-435.

Grigg, R.W. 1981. *Acropora* in Hawaii. Part2 Zoogeography. Pac..Sci. 35: 15-24.

Grigg, R.W., Wells, J. and Wallace, C. 1981. *Acropora* in Hawaii PartI. History of the scientific record , systematica and ecology Pac. Sci. 35: 1-13.

Gulko, D. Hawaiian Coral Reef Ecology. Mutual Publishing. pp. 245.

Harriott, V. J. 1983: Reproductive ecology of scleractinian species at Lizard Island, Great Barrier Reef. Coral Reefs **2** (1): 9-18

Harrison, P. L. & C. C. Wallace 1990: Reproduction, dispersal and Recruitment of Scleractinian Corals. In: Dubinsky, Z. (ed.) Ecosystems of the World, vol. 25 Coral Reefs. Elsevier, N.Y. pp 133-208.

Heyward, A. J. 1986: Sexual reproduction in the five species of the coral Montipora. In: P. L. Jokiel, R. H. Richmond & R. A. Rogers (Eds.) Coral Reef Population Biology. Hawaii Inst. Mar. Biol. Tech. Rep. No.37: 170-178.

Heyward, A. J. & R. C. Babcock 1986: Self- and crossfertilasation in scleractinian corals. Mar. Biol. (90): 191-195.

Johannes, R. E., S. L. Coles & N. T. Kuenzel (1970): The role of zooplankton in the nutrition of some corals. Limnol. Oceanogr. (15): 579-586.

Jokiel, P. L. & R. H. York Jr. 1982: Solar ultraviolet photobiology of the reef coral Pocillopora damicornis and symbiotic zooxanthellae. Bull. Mar. Sci. **32**: 301-315.

Jokiel, P. L. 1984: Long Distance Dispersal of Reef Coral by Rafting. Coral Reefs **3** (2): 113- 116.

Jokiel, P. L. 1985: Lunar periodicity of planula release in the reef coral Pocillopora damicornis in relation to various environmental factors. Proc. 5th.Int. Coral Reef Congress, Tahiti, 1985. (4): 307-312.

Jokiel, P.L. and Tyler W.A. 1992. Distribution of Stony Corals in Johnston Atoll Lagoon, Proceedings of the 7th International Coral Reef Symposium, Guam, 1992, Vol.2.

Jones, R.S. and R.H. Randall 1973 A study of biological impact caused by natural and man-induced changes on a tropical reef. U.S. Environmental Protection Agency. University of Guam, Marine Laboratory Technical Report No.7.

Hodgson, G, 1985. Abundance and distribution of planktonic coral larvae in Kaneohe Bay, Oahu, Hawaii. Mar. Ecol. Progr. Ser. 26:61-71.

Hunter, C.L. 1985 Assessment of clonal diversity and population structure of *Porites compressa* (Cnidaria; Scleractinia) Proc. 5th Int. Coral Reef Congress, Tahiti, 1985. (6): 69-74.

Kojis, B. L. & N. J. Quinn 1984: Seasonal and depth variation in fecundity of Acropora palifera at two reefs in Papua New Guinea. Coral Reefs **3** (3): 165-172.

Kojis, B. L. & N. J. Quinn 1985: Puberty in Goniastrea favulus. Age or size limited ? Proc. 5th. Int. Coral Reef Congress., Tahiti, 1985 (4): 289-293.

Kojis, B. L. 1986a: Sexual reproduction in Acropora (Isopora) species (Coelenterata: Scleractinia). I: A. cuenata and A palifera on Heron Island reef, Great Barrier Reef. Mar. Biol. (91): 291-309.

Kojis, B. L. 1986b: Sexual reproduction in Acropora (Isopora) species (Coelenterata: Scleractinia). II: Latitude variation in A. palifera from the Great Barrier Reef and Papua New Guinea. Mar. Biol. (91): 311-318.

Lamberts, A. 1980. Checklist of Samoan Coral Genera and Species. In: American Samoa Coral Reef Inventory, U.S. Army Corps of Engineers for Development Plan Office, American Samoan Govt..

Maragos, J.E. 1977 Order Scleractinia: stony corals. In: Devaney, D. and L. Eldredge (eds.) Reef and shore fauna of Hawaii. Section 1: Protozoa through Ctenophora. Bishop Museum Press, Honolulu, Hawaii. 278 pp.

Maragos, J.E. 1995 Revised checklist of extant Shallow-water stony coral species from Hawaii (Cnidaria: Anthozoa: Scleractinia). Bishop Museum Occasional Papers 42: 54-55.

Maragos, J.E. 1979a. Palmyra Atoll: Preliminary environmental survey and assessment. U.S. Army Corp of Engineers, Pacific Ocean Division, Fort Shafter, Honolulu Hawaii. 31pp+62pls.

Maragos, J.E. 1988. Notes on the abundance and distribution of reef coral and reef features at Palmyra Atoll, Line Islands. US Army Corps of Engineers, Pacific Ocean Division, Fort Shafter, Honolulu Hawaii, 18pp+13pls.

Maragos, J.E. 1992. Status of coral reefs off the southeast coast of Moloka'i, Hawaii 1990-91. Lacayo Planning Report.

Maragos, J.E. and P. Jokiel 1986 Reef corals of Johnston Atoll: one of the world's most isolated reefs. Coral Reefs 4: 141-150.

Muscatine, L. (1973): Nutrition of corals, In: O. A. Jones & R. Endean (edt.): Biology and Geology of Coral Reefs (2): 77-115.

Muscatine, L., L. R. McCloskey & R. E. Marian (1981): Estimating the daily contribution of carbon from zooxanthellae to coral animal respiration. Limnol. Oceanogr. **26**: 601-611.

Muscatine, L. & J. W. Porter (1977): Reef corals: mutalistic symbiosis adapted to nutrient- poor environments. Bioscience (27): 454-459.

Porter, J.W., 1976: Autotrophy, heterotrophy, and resource partitioning in Caribbean reef-building corals. Am. Nat., *110:*731-742.

Randall, R.H. 1995 Biogeography of reef-building corals in the Mariana and Palau Islands in relation to back-arc rifting and the formation of the Eastern Philippine Sea. Nat. Hist. Res. 3(2): 193-210.

Richmond, R.H. 1985. Reversible metamorphosis in coral planula larvae. Mar. Ecol. Prog. Ser. 22: 181-185.

Richmond, R. H. 1987. Energetic, competeny and long distance dispersal of planula larvae of the coral Pocillopora damicornis. Mar. Biol. 93: 527-533.

Richmond, R. H. & C. L. Hunter 1990: Review B Reproduction and recruitment of corals: comparison among the Caribbean, the Tropical Pacific, and the Red Sea. Mar. Ecol. Prog. Ser. 1: 145-152.

Rinkevich, B. & Y. Loya 1979: The reproduction of the Red Sea coral Stylophora pistillata. II. Synchronisation in the breeding and seasonality of planula shedding. Mar. Ecol. Progr. Ser. 1: 145-152.

Sammarco, P. W. 1981: A new mode of reproduction in corals under stress: is there a life after death in Seriatopora ? Aust. Mar. Sci. Biol. Ecol. (75): 20 (Abstract).

Sammarco, P. W. 1982: Polyp bail-out: An escape response to environmental stress and a new means of reproduction in corals. Mar. Ecol. Progr. Ser. 10: 57-65.

Sammarco, P. W. 1986: Coral Reproduction, Dispersal, and Survival. Oceanus **29** (2): 28-19.

Simson, C.J., Cary, J.L. and Masini, R.J. (1993). Destruction of corals and other reef animals by coral spawn slicks on Ningaloo Reef, Western Australia. Coral Reefs: 12: 185-192.

Szmant, A. M. 1986: Reproductive ecology of Caribbean reef corals. Coral Reefs **5** (1): 43-53.

Szmant-Froehlich, A.M., Yepich, M. P., Pilson, M.E.Q. 1980: Gametogenesis and early development of the temperate coral *Astrangia danae (Anthosxoa:Scleractinia).* Biol Bull. (158): 257-269.

Soong, K. & J. C. Lang 1992: Reproductive integration in reef corals. Biol. Bull. (183): 418-431.

Sorokin, Y.I. 1973. On the feeding of some scleratinian corals with bacteria and dissolved organic matter. Limnol. Oceanogr. (18) 380-385.

Sorokin , Y.I. 1995. Coral Reef Ecology, 2nd ed. Springer Verlag, New York, USA.

Szmant, A. M. 1986: Reproductive ecology of Caribbean reef corals. Coral Reefs **5** (1): 43-53.

Szmant-Froehlich, A.M., Yepich, M. P., Pilson, M.E.Q. 1980: Gametogenesis and early development of the temperate coral *Astrangia danae (Anthosxoa:Scleractinia).* Biol Bull. (158): 257-269.

Tunnicliffe, V. (1981) Breakage and propagation of the stony coral *Acropora cervicornis.* Proc. Natl Acad. Sci 78(9): 2427-2431.

Vaughan, T.W. 1907. *Recent madrreporaria of the Hawaiian Islands and Laysan.* U.S. National Mus. Bull. 59. Washington D.C.

Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 1511

Veron, J. E. N. 1993b: A Biogeographic Database of Hermatypic Corals. Species of the Central Indo-Pacific. Genera of the World. AIMS Monograph Series Volume 10, Australian Institute of Marine Science (AIMS), Townsville, Australia.

Veron J. E. N. & Pichon, M. 1976: Scleractinia of eastern Australia, Part 1: Families Thamnasteriidae, Astrocoenidae, Pocilloporidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 1, 86pp.

Veron J. E. N., Pichon M. & Wijsman-Best M. 1977: Scleractinia of eastern Australia, Part 2: Families Faviidae, Trachyphyllidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 3, 232pp.

Veron J. E. N. & Pichon M. 1979: Scleractinia of eastern Australia, Part 3 Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectinidae, Caryophyllidae, Dendrophylliidae. *Aust. Inst. Mar. Sci., Monogr. Ser.* 4, 422pp.

Veron J. E. N. & Pichon M. 1982: Scleractinia of eastern Australia, Part 4: Family Poritidae, *Aust. Ins. Mar. Sci., Monogr. Ser.* 5, 159pp.

Veron J. E. N. & Wallace C. C. 1984: Scleractinia of eastern Australia, Part 5: Families Acroporidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 6, 485pp.

Wells, J.W. 1956. A survey of the distribution of reef coral genera in the Great Barrier Reef region. Rep. Gt. Barrier Reef Comm. No. 6(2).

Willis, B.L. and Ayre D.J. 1985. Asexual reproduction and generic determination of growth form in the coral *Pavona cactus*: biochemical genetic and immunogenetic evidence. Oecologia (65); 516-525.

7. Fungiidae (Dana, 1846) (mushroom corals)

Important Summary Documents

Veron (1986) provides a species summary of the systematics, anatomy and distribution in Australia and the Indo-Pacific. Veron (1993b) the family Fungiidae is discussed with respect to its global distribution.

Taxonomic Issues

Veron & Pichon (1979) revised the taxonomy of the family Fungiidae.

Has 11 extant genera: Cycloseris (7 spp.), *Diaseris* (4 nominal spp.), *Heliofungia, Fungia* (25 spp.), *Herpolitha* (2 spp.), *Polyphyllia* (3 spp.), *Halomitra* (1 spp.), *Sandalolitha* (2 spp.), *Lithophyllon (2 spp.), Podabacia (*1 spp.) and *Zoopilus* (1 spp.).

Habitat Utilization

Begin life as anthocauli attached to a hard substrate. Detach to continue life as a free-living colony inhabiting reef areas unsuitable for permanently attached corals such as sand or rubble.

Life History

Adult: Appearance and Physical Characteristics

All shallow water with the exception of the *Fungiacyathus (not occur AFPI).* The majority are hermatypic, solitary, and free living (not *Lithophyllum or Podabacia)* with attached juvenile stage. They may be individual with one mouth or colonial with many mouths and other anatomy characteristic of a colonial form.

From Veron (1986):
Cycloseris (Edwards & Haime, 1849): Solitary, free-living, flat or dome-shaped, circular or slightly oval in outline with a central mouth. Fine tentacles cover the upper surface of the disc. Pale brown to cream with a darker margin.
Diaseris (Edwards & Haime, 1849): Circular though with an irregular margin and segments. Colour is brown to green.

Heliofungia (Wells, 1966): Solitary, free-living, flat with central mouth. Septa have large lobed teeth. Polyps are extended day and night, and as a single polyp are the largest of all corals. Tentacles are longest of the stony corals and dark purple or green tentacle with pale tips. The oral disc is striped and the single mouth is 30mm wide.

Fungia (Lamarck, 1801): Free-living, circular or elongate

Herpolitha (Eschscholtz, 1825)***:*** Free-living, elongate with and axial furrow that may extend to the corallum ends. Several centers or mouths occur in the furrow. Colonies may be heavily calcified and >1m in length. Tentacles are short and widely spaced.

Polyphyllia (Quoy and Gaimard, 1833): Free-living, elongate with many mouths and tentacles over the upper surface. Larger mouths are down the axial furrow. Long tentacles, which are always extended.

Halomitra (Dana, 1846): Colonies are large and free-living, circular and dome or bell shaped, thin and delicate and without an axial furrow. Corallites widely spaced. Tentacles are small and widely spaced and extended at night.

Sandalolitha (Quelch, 1884): Colonies are large, free-living, and circular to oval, dome-shaped, heavily constructed and without an axial furrow. Corallites are compacted.
Pale or darks brown, sometimes with purple margins and white centers.

Lithophyllon *(*Rehberg, 1892): Colonies are attached, encrusting or laminar, unifacial. Colonies may be large, up to several metres. Polyps extended at night. Dull green, grey or brown with white margins or white centers.

Podabacia (Edwards and Haime, 1849): Colonies are attached, encrusting or laminar, unifacial and up to 1.5m in diameter.

Their coloration may be frown, green, red or pink. They may have contrasting stripped design.

Distribution

Cycloseris: Extends from southern Africa to the Red Sea and Arabian Gulf through the Indo-Pacific ranging from south Western Australia, Lord Howe I. and Easter I. in the south to southern Japan in the north. It occurs in the Hawaiian Islands, though not in Midway. It is present in the eastern Pacific from Baja California, northern Mexico to Columbia. The recorded occurrence in the AFPI is Johnston Atoll, Hawaii and Guam

Diaseris: Similar to *Cycloseris* though narrower, extending from southern Madagascar and the Red Sea. Across the Pacific at varying latitude in the north to include Japan and in the south of New Caledonia and the Tuamotus Is. The recorded occurrence in the AFPI is Hawaii.

Heliofungia: Indonesia, Australia, Philippines, Ryukyu Is. east to the Caroline and Solomon Is and south to New Caledonia. The genus does not occur in the AFPI.

Fungia: South of Madagascar, to the Red Sea, Northern Australia, the Great Barrier Reef, south to Lord Howe I. and across to Pitcairn I. Its northerly extent is southern India, Southeast Asia, southern Japan, Midway I., Hawaiian Is. Its easterly extent is the Marquesas Is. The recorded occurrence by virtue of *Fungia scutaria* is present in all AFPI where checklists have been made. Considering the other species of the genus, occurrence is limited to American Samoa, Palmyra Atoll, and Guam.

Herpolitha: South of Madagascar to the Red Sea, Northern Australia, the Great Barrier Reef, south to New Caledonia and across to Pitcairn I. Its northerly extent is southern India, Philippines, and

Ryukyu Is., Japan. Its easterly extent is the Tuamotus Is. The AFPI that this species is found in is American Samoa, Palmyra Atoll and Guam.

Polyphyllia: Central Indo-Pacific: Northern Madagascar and the Seychelles Is in the west. Northern Australia, New Caledonia and Tonga in the south. American Samoa (only AFPI occurrence) in the east and Ryukyu Is, Japan in the north.

Halomitra: West Africa Madagascar in the west through Indonesia to the Line Is in the east. South to New Caledonia and Tonga and north to the Ryukyu I in the north. Present in the AFPI in American Samoa and Palmyra.

Sandalolitha: Occurs in Indonesia and Southeast Asia in the west to the Kyushu Is. in the north. Extends to Northern Australia and New Caledonia and Tubuai Is in the south. Also extends to the Tubuai Is and Line Is in the east. AFPI occurrence limited to American Samoa and Palmyra Atoll.

Lithophyllon: Similar to Sandalolitha, occurring to Indonesia in the west and the Malay Peninsula. Its southerly extent is northern Australia, New Caledonia, and Fiji to the east. It is confined to the western Pacific to include the Philippines and north to southern Japan. There are no occurrences in the AFPI.

Podobacia: Indo-Pacific: Occurs from west Africa and the Red Sea south to Madagascar, Northern Australia, New Caledonia to Tahiti. Range extends to the Fiji in the east. In the north, it extends along Southeast Asia to Japan. There are no occurrences in the AFPI.

Feeding and Food

Heterotrophic: prominent tentacles indicate prey capture. Autotrophic: abundant zooxanthellae.

Behavior

Are partially mobile. May free themselves if buried and some are capable of lateral movement, ability to right themselves, and able to climb over obstacles by using their tentacles and inflating their body cavities.

Mobility in *Cycloseris* by ciliary hairs, by inflation of the body cavity or use of tentacles. Tentacle extended at night.
Fungia and Herpolitha: Polyps are extended only at night.

Reproductive Strategies

Asexual: Fragmentation or natural regeneration through fracture. Many develop attached daughter polyps (acanthocauli) from the parent colony.

Sexual: Dioecious or hermaphroditic. Planula larvae settle to form the attached acanthocauli, which may grow to several centimeters before detaching due to degeneration of the stalk. *Heliofungia* has been reported as hermaphroditic while *Fungia* has separate sexes. It is likely the family has separate sexes, the females either brood planulae or release gametes (Veron, 1986).

References:

Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.

Veron, J. E. N. (1993b): A Biogeographic Database of Hermatypic Corals. Species of the Central Indo-Pacific. Genera of the World. AIMS Monograph Series Volume 10, Australian Institute of Marine Science (AIMS), Townsville, Australia.

Veron J. E. N. & Pichon M. 1979: Scleractinia of eastern Australia, Part 3: Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectinidae, Caryophyllidae, Dendrophylliidae. *Aust. Inst. Mar. Sci., Monogr. Ser.* 4, 422pp.

Table II.C.8: Distribution of Scleractinia (hard coral) in the American Flag Pacific Islands (AFPI).

AS: American Samoa; PA: Palmyra Atoll; JA: Johnston Atoll; MHI: Main Hawaiian Islands; NWHI: Northwestern Hawaiian Islands; WA: Wake Atoll; CNMI: Commonwealth of Northern Mariana Islands; GU: Guam

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Order SCLERACTINIA									
Family ASTROCOENIIDAE									
Stylocoeniella armata (Ehrenberg, 1834)	X						X	X	3
Stylocoeniella guentheri (Bassett-Smith, 1890)							X	X	2
Family THAMNASTERIIDAE									
Psammocora contigua (Esper, 1797)	X							X	2
Psammocora digitata Edward & Haime, 1851							X	X	2
Psammocora explanulata van der Horst, 1922				X					1
Psammocora folium (Syn)	X								1
Psammocora (P.) haimeana Edwards and Haime, 1851	X	X						X	3
Psammocora nierstraszi van der Horst,1921	X		X	X			X	X	5
Psammocora profundacella Gardiner,1898		X						X	2
Psammocora stellata (Verril,1866)		X	X	X	X			X	5
Psammocora superficiales Gardiner,1898	X								1
Psammocora (V.) tutuilensis (Syn)	X								1
Psammocora verrilli Vaughan				X				X	2
Family POCILLOPORIDAE									
Pocillopora ankeli Sheer & Pillai, 1974	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Pocillopora damicornis (Linnaeus,1758)	X	X	X	X	X			X	6
Pocillopora eydouxi ***Edwards & Haime,1860***	X	X	X	X		X		X	6
Pocillopora ligulata Dana, 1846	X			X				X	3
Pocillopora molokensis Vaughan, 1907				X					1
Pocillopora setchelli Hoffmeister,1929	X						X	X	3
Pocillopora verrucosa (Ellis & Solander, 1786)	X	X	X	X	X	X	X	X	8
Pocillopora woodjonesi Vaughan,1918	X							X	2
Seriatopora crassa Quelch, 1886	X								1
Seriatopora hystrix Dana, 1846	X							X	2
Stylophora pistillata Esper, 1797	X	X					X	X	4
Family ACROPORIDAE									
Acropora (A.) aculeus (Dana, 1846)	X					X			2
Acropora (A.) acuminata (Verrill, 1864)	X	X						X	3
Acropora (A.) aspera (Dana, 1846)	X	X						X	3
Acropora (A.) azurea Veron & Wallace, 1984	X								1
Acropora (A.) bushyensis Veron & Wallace, 1984								X	1
Acropora (A.) carduus (Dana, 1846)		X						X	2
Acropora (A.) cerealis (Dana, 1846)	X	X	X				X	X	5
Acropora (A.) clathrata (Brook, 1891)	X								1
Acropora (A.) cuspidata Dana	X								1
Acropora (A.) cytherea (Dana,1846)	X	X	X	X				X	5

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Acropora (A.) danai (Milne-Edwards & Haime, 1860)	X	X					X	X	4
Acropora (A.) digitifera (Dana, 1846)	X	X					X	X	4
Acropora (A.) divaricata (Dana, 1846)	X								1
Acropora (A.) echinata (Dana, 1846)								X	1
Acropora (A.) elseyi (Brook, 1892)		X	X						2
Acropora (A.) florida (Dana, 1846)		X							1
Acropora (A.) formosa (Dana, 1846)	X	X						X	3
Acropora (A.) gemmifera *(Brook, 1892)*	X	X							2
Acropora (A.) granulosa (Edwards & Haime, 1860)	X						X	X	3
Acropora (A.) horrida *(Dana, 1846)*	X								1
Acropora (A.) humilis (Dana, 1846)	X	X	X	X			X	X	6
Acropora (A.) hyacinthus (Dana, 1846)	X	X					X	X	4
Acropora (A.) latistella (Brook, 1892)	X								1
Acropora (A.) listeri (Brook, 1893)	X								1
Acropora (A.) longicyathus (Edwards & Haime, 1860)	X								1
Acropora (A.) millepora (Ehrenberg, 1834)	X							X	2
Acropora (A.) monticulosa (Bruggemanni, 1879)	X	X						X	3
Acropora (A.) multiacuta Nemenzo,1967		X							1
Acropora (A.) loripes (Brook, 1892)	X	X					X	X	4

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Acropora (A.) nana (Studer, 1878)	X	X						X	3
Acropora (A.) nasuta (Dana, 1846)	X	X				X	X	X	5
Acropora (A.) nobilis (Dana, 1846)	X	X						X	3
Acropora (A.) ocellata (Klunzinger, 1897)	X							X	2
Acropora (A.) pagoensis Hoffmeister	X								1
Acropora (A.) palmerae Wells, 1954	X							X	2
Acropora (A.) paniculata Verrill,1902	X		X	X					3
Acropora (A.) paxilligera *(Dana, 1846)*	X								1
Acropora (A.) polystoma ***(Brook, 1891)***	X	X							2
Acropora (A.) pulchra (Brook, 1891)	X								1
Acropora (A.) rambleri (Bassett-Smith, 1890)	X							X	2
Acropora (A.) robusta (Dana, 1846)	X							X	2
Acropora (A.) samoensis (Brook, 1891)	X	X							2
Acropora (A.) schmitti	X								1
Acropora (A.) secale (Studer, 1878)	X								1
Acropora (A.) selago (Studer, 1878)	X	X	X					X	4
Acropora (A.) studeri (Brook, 1893)								X	1
Acropora (A.) tenuis (Dana, 1846)	X						X	X	3
Acropora (A.) teres (Verrill, 1866)	X							X	2

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Acropora (A.) valenciennesi (Edwards & Haime, 1860)	X								1
Acropora (A.) valida (Dana, 1846)	X	X	X	X		X		X	6
Acropora (A.) vaughani Wells, 1954		X							1
Acropora (A.) yongei Veron & Wallace, 1984	X		X						2
Acropora (A.) sp.1	X				X			X	3
Acropora (A.) sp.2	X								1
Acropora (A.) sp.3	X								1
Acropora (I.) brueggemanni ***(Brook, 1893)***	X	X						X	3
Acropora (I.) cuneata (Dana, 1846)	X	X							2
Acropora (I.) palifera (Lamarck, 1816)	X	X					X	X	4
Astreopora cucullata Lamberts, 1980	X								1
Astreopora explanata		X							1
Astreopora gracilis Bernard, 1896		X						X	2
Astreopora listeri ***Bernard, 1896***	X							X	2
Astreopora myriophthalma (Lamarck, 1816)	X	X				X	X	X	5
Astreopora randalli Lamberts,1890	X								1
Astreopora sp. 1	X						X		2
Montipora aequituberculata Bernard, 1897	X			X				X	3
Montipora berryi Hoffmeister, 1925	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Montipora bilaminata	X								1
Montipora caliculata (Dana, 1846)	X								1
Montipora conicula Wells								X	1
Montipora danae Edwards & Haime, 1851						X		X	2
Montipora dilatata Struder, 1901				X					1
Montipora efflorescens Bernard, 1897	X								1
Montipora ehrenbergii Verrill, 1875	X							X	2
Montipora elschneri Vaughan, 1918	X							X	2
Montipora eydouxi	X								1
Montipora flabellata Struder, 1901				X					1
Montipora floweri Wells, 1954								X	1
Montipora foliosa (Pallas, 1766)	X	X						X	3
Montipora foveolata (Dana, 1846)	X	X				X		X	4
Montipora granulosa Bernard, 1897	X							X	2
Montipora hispida ***(Dana, 1846)***	X	X	X						3
Montipora hoffmeisteri Wells, 1954	X	X				X		X	4
Montipora incrassata Dana, 1846			X	X					2
Montipora informis *Bernard, 1897*	X					X			2
Montipora lobulata *Bernard, 1897*	X							X	2

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Montipora marshallensis	X								1
Montipora millepora Crossland, 1952								X	1
Montipora monasteriata (Forskal, 1775)		X	X	X	X	X		X	6
Montipora peltiformis Bernard, 1897				X				X	2
Montipora spumosa (Lamarck, 1816)	X								1
Montipora tuberculosa (Lamarck, 1816)	X	X	X	X				X	5
Montipora turgescens Bernard, 1897					X				1
Montipora undata Bernard, 1897	X								1
Montipora venosa (Ehrenberg, 1834)	X								1
Montipora verrucosa (Lamarck, 1816)				X		X		X	3
Montipora sp.1 (green spine)	X				X		X	X	4
Montipora sp.2 (ramose tuber.)	X						X	X	3
Montipora sp.3 (Pago)	X						X	X	3
Montipora sp.4 (Ramose pap.)							X	X	2
Montipora sp.5 (thick branch)							X	X	2
Family AGARICIIDAE									
Gardineroseris planulata (Dana, 1846)	X			X				X	3
Leptoseris hawaiiensis Vaughan, 1907			X	X				X	3
Leptoseris incrustans (Quelch, 1886)	X		X	X				X	4
Leptoseris mycetoseroides Wells, 1954	X	X		X		X		X	5
Leptoseris papyracea ***(Dana, 1846)***				X					1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Leptoseris scabra Vaughan, 1907			X	X					2
Pachyseris levicollis	X								1
Pachyseris speciosa (Dana, 1846)	X							X	2
Pachyseris rugosa (Lamarck, 1801)	X								1
Pavona clavus (Dana, 1846)	X	X	X	X	X		X	X	7
Pavona decussata (Dana, 1846)	X							X	2
Pavona diffluens (Lamarck, 1816)	X								1
Pavona divaricata (Lamarck, 1816)	X							X	2
Pavona explanulata (Lamarck, 1816)	X	X							2
Pavona frondifera (Lamarck, 1816)	X							X	2
Pavona gigantea	X								1
Pavona maldivensis (Gardiner, 1905)	X	X	X	X			X	X	6
Pavona minuta Wells, 1954	X							X	2
Pavona qardineri van der Horst								X	1
Pavona varians Verrill, 1864	X	X	X	X		X	X	X	7
Pavona (P.) venosa (Ehrenberg, 1834)	X							X	2
Family BALANOPHYLLIDAE									
Balanophyllia sp.cf. *affinis* (Semper, 1872)				X					1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Balanophyllia hawaiiensis Vaughan, 1907				X					1
Family SIDERASTREIDAE									
Coscinaraea columna (Dana, 1846)	X							X	2
Coscinaraea wellsi Veron & Pichon, 1879				X					1
Family FUNGIIDAE									
Cycloseris hexagonalis ***Edwards & Haime, 1848***				X					1
Cycloseris patelliformis Boschma, 1923	X								1
Cycloseris tenuis Dana, 1846				X					1
Cycloseris vaughani (Boschma, 1923)			X	X					2
Diaseris distorta Michelin, 1842				X					1
Fungia (D.) danai Edwards & Haime, 1851	X	X							2
Fungia (D.) valida Verrill, 1864		X							1
Fungia (C.) echinata (Pallas,1766)	X								1
Fungia (F.) fungites (Linnaeus, 1758)	X	X						X	3
Fungia (P.) paumotensis Stutchbury, 1833	X	X						X	3
Fungia (P.) scutaria Lamarck, 1801	X	X	X	X	X	X	X	X	8
Fungia (V.) concinna Verrill, 1864	X	X						X	3
Fungia (V.) granulosa Klunzinger, 1879	X			X					1
Fungia (V.) repanda Dana, 1846	X	X							2
Fungia (C.) simplex ***(Gardiner, 1905)***	X								1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Halomitra pileus (Linnaeus, 1758)	X	X							2
Herpolitha limax ***(Houttuyn, 1772)***	X	X						X	2
Polyphyllia talpina (Lamarck, 1801)	X								1
Sandalolitha robusta (Quelch,1886)	X	X							2
Family PORITIDAE									
Alveopora allingi ***Hoffmeister, 1925***	X								1
Alveopora japonica								X	1
Alveopora superficialis Sheer & Pillai, 1976	X								1
Alveopora verrilliana Dana, 1846	X	X						X	3
Alveopora viridis Quoy & Gaimard, 1833	X								1
Goniopora arbuscula Umbgrove								X	1
Goniopora columna Dana, 1846	X							X	2
Goniopora parvistella Ortmann, 1888	X								1
Goniopora somaliensis Vaughan, 1907	X								1
Goniopora sp.1	X						X	X	3
Goniopora sp.2							X	X	2
Porites (P.) annae ***Crossland, 1952***	X							X	2
Porites (P.) australiensis Vaughan, 1918		X						X	2
Porites (P.) cocosensis Wells								X	1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Porites (P.) compressa Vaughan				X				X	2
Porites (P.) cylindrica Dana, 1846	X							X	2
Porites (P.) duerdeni Vaughan				X				X	2
Porites (P.) cf. *Evermanni* Vaughan, 1907				X					1
Porites (P.) latistella	X								1
Porites (P.) lichen ***Dana, 1846***	X			X				X	3
Porites (P.) lobata Dana, 1846	X	X	X	X	X		X	X	7
Porites (P.) lutea Edwards & Haime, 1860	X	X	X			X	X	X	6
Porites (P.) matthaii Wells	X							X	2
Porites (P.) murrayensis Vaughan, 1918	X			X				X	3
Porites (P.) pukoensis Vaughan, 1907	X			X					2
Porites (P.) queenslandi septima	X								1
Porites (P.) solida (Forskal, 1775)						X			1
Porites (P.) stephensoni Crossland, 1952	X								1
Porites (P.) studeri Vaughan, 1907				X					1
Porites (P.) sp.1(nodular)	X				X			X	3
Porites (S.) horizontalata Hoffmeister, 1925	X							X	2
Porites (S.) rus (Forskal, 1775)	X			X				X	3

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Porites (N.) vaughani ***Crossland, 1952***		X							1
Stylaraea punctata ***(Linnaeus, 1758)***								X	1
Synaraea horizontalata	X								1
Family FAVIIDAE									
Caulastrea furcata Dana, 1846	X								1
Cyphastrea chalcidicum (Forskal, 1775)			X	X	X			X	4
Cyphastrea microphthalma (Lamarck, 1816)	X					X			2
Cyphastrea serailia (Forskal, 1775)	*X*					*X*		*X*	3
Diploastrea heliopora ***(Lamarck, 1816)***	X						X	X	3
Echinopora hirsuitissima ***(Edwards & Haime, 1849)***	X								1
Echinopora lamellosa (Esper, 1795)	X					X	X	X	4
Favia favus (Forskal, 1775)	X					X		X	3
Favia helianthoides Wells, 1954	X								1
Favia laxa (Klunzinger, 1879)	X								1
Favia matthaii Vaughan, 1918	X							X	2
Favia pallida (Dana, 1846)	X	X				X	X	X	5
Favia rotumana (Gardiner, 1899)	X							X	2
Favia russelli (Wells)								X	1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Favia speciosa (Dana)	X	X					X	X	4
Favia stelligera (Dana, 1846)	X	X				X		X	4
Favia sp.1 (small calice)	X	X					X		3
Favia sp.2							X		1
Favites abdita (Ellis & Solander, 1786)	X	X				X		X	4
Favites chinensis (Verrill, 1866)	X								1
Favites complanata (Ehrenberg, 1834)	X							X	2
Favites favosa (Ellis & Solander)								X	1
Favites flexuosa (Dana, 1846)	X	X				X		X	4
Favites halicora (Ehrenberg, 1834)	X	X				X			3
Favites pentagona (Esper, 1794)		X							1
Favites russelli (Wells, 1954)	X								1
Goniastrea australensis (Edwards & Haime, 1857)	X								1
Goniastrea edwardsi Chevalier, 1971	X							X	2
Goniastrea favulus (Dana, 1846)	X					X			2
Goniastrea palauensis (Yabe,Sugiyama & Eguchi, 1936)	X								1
Goniastrea pectinata (Ehrenberg, 1834)	X	X				X		X	4
Goniastrea retiformis (Lamarck, 1816)	X					X	X	X	4
Hydnophora exesa (Pallas, 1766)	X	X						X	3

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Hydnophora microconos ***(Lamarck, 1816)***	X	X						X	3
Hydnophora rigida ***(Dana, 1846)***	X								1
Leptastrea bottae ***(Edwards & Haime, 1849)***				X				X	2
Leptastrea cf. *Immersa* Klunzinger, 1879	X								1
Leptastrea purpurea (Dana, 1846)	X	X	X	X	X	X	X	X	8
Leptastrea transversa Klunzinger, 1979	X	X						X	2
Leptoria phrygia (Ellis & Solander, 1786)	X					X	X	X	4
Montastrea annuligera ***(Edwards & Haime, 1849)***	X								1
Montastrea curta (Dana, 1846)	X	X				X	X		4
Montastrea valenciennesi (Edwards & Haime, 1848)						X			1
Oulangia bradleyi (Verrill, 1866)			X						1
Oulophyllia crispa (Lamarck, 1816)	X							X	2
Platygyra daedalea (Ellis & Solander, 1786)	X	X				X		X	4
Platygyra lamellina (Ehrenberg, 1834)	X	X					X	X	4
Platygyra pini Chevalier, 1975	X						X	X	3
Platygyra sinensis (Edwards & Haime, 1849)						X		X	2
Plesiastrea versipora ***(Lamarck, 1816)***	X	X						X	3
Family RHIZANGIIDAE									

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Culicia rubeola (Quoy & Gaimard)							X		1
Culicia sp.cf. *tenella* Dana, 1846				X					1
Family OCULINIDAE									
Acrhelia horrescens ***(Dana, 1846)***	X							X	2
Galaxea cf. astreata ***(Lamarck, 1816)***	X							X	2
Galaxea fascicularis ***(Linnaeus, 1767)***	X						X	X	3
Family MERULINIDAE									
Clavarina triangularis Veron & Pichon, 1979	X								1
Merulina ampliata (Ellis & Solander, 1786)	X	X				X		X	4
Family MUSSIDAE									
Acanthastrea echinata (Dana, 1846)	X					X	X	X	4
Acanthastrea sp.1								X	1
Lobophyllia corymbosa (Forskal, 1775)	X	X						X	3
Lobophyllia hemprichii (Ehrenberg, 1834)	X							X	2
Symphyllia radians ***(Edwards & Haime, 1849)***						X			1
Symphyllia recta ***(Dana, 1846)***	X					X			2
Symphyllia valenciennesii ***Edwards & Haime, 1849***	X								1
Family PECTINIIDAE									

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Echinophyllia aspera ***(Ellis & Solander, 1786)***	X							X	2
Mycedium elephantotos (Pallas, 1766)	X								1
Oxypora lacera (Verrill, 1864)	X								1
Family CARYOPHYLLIIDAE									
Euphyllia (E.) glabrescens (Chamisso & Eysenhardt, 1821)	X						X	X	3
Plerogyra simplex ***Rehberg, 1892***	X								1
Plerogyra sinuosa ***(Dana, 1846)***							X	X	2
Polycyathus verrilli ***Duncan***								X	1
Family DENDROPHYLLIIDAE									
Tubastrea aurea ***(Quoy & Gaimard)***	X						X		2
Tubastraea coccinea Lesson, 1831	X	X		X	X				4
Turbinaria frondens ***(Dana, 1846)***	X								1
Turbinaria peltata (Esper, 1794)	X								1
Turbinaria reniformis Bernard, 1896	X								1
Order COENOTHECALIA									1
Family HELIOPORIDAE									
Heliopora coerulea (Pallas, 1766)	X						X	X	3
Order STOLONIFERA									

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Family TUBIPORIDAE									
Tubipora musica ***Linnaeus, 1758***								X	1
Order MILLEPORINA									
Family MILLEPORIDAE									
Millepora dichotoma Forskal, 1775	X						X	X	3
Millepora exaesa Forskal, 1775						X	X	X	3
Millepora platyphyllia Hemprich & Ehrenberg, 1834	X						X	X	3
Millepora tenera Boschma, 1949	X		X						2
Millepora tuberosa Boschma, 1966	X								1
Millepora sp.1	X								1
Family STYLASTERIDAE									
Distochopora gracilis Dana, 1846	X								1
Distochopora violacea (Pallas, 1776)			X					X	2
Distochopora sp.1								X	1
Stylaster gracilis Dana, 1846	X								1
Stylaster sp.			X						1
Order ALCYONACEA									
Family ALCYONIIDAE									
Lobophytum sp.1		X							1

Coral Order, Family and Species	AS	PA	JA	MHI	NWHI	WA	NMI	GU	Site Record
Sinularia abrupta Tixier-Durivault, 1970				X					1
Sinularia sp.1		X							1
Corallimorpharia spp.	X								1
Palythoa sp.	X	X	X	X					4
Tethya sp.	X								1
Zoanthus sp.	X			X					2
Number of: Scleractinians	222	82	29	51	13	39	53	159	
Acyonarians	4	1		1					
Hydrozoans	7	1	3			1	3	5	
Coelothecalia	1							1	

References

American Samoa:

Birkeland, C., Randall, R. and S. Amesbury 1994 Coral and reef-fish assessment of the Fagatele Bay National Marine Sanctuary. Report to the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 126 pp.

Lamberts, A. 1980. Checklist of Samoan Coral Genera and Species. In: American Samoa Coral Reef Inventory, U.S. Army Corps of Engineers for Development Plan Office, American Samoan Govt..

Palmyra Atoll:

Maragos, J.E. 1979a. Palmyra Atoll: Preliminary environmental survey and assessment. U.S. Army Corp of Engineers, Pacific Ocean Division, Fort Shafter, Honolulu Hawaii. 31pp+62pls.

Maragos, J.E. 1988. Notes on the abundance and distribution of reef coral and reef features at Palmyra Atoll, Line Islands. US Army Corps of Engineers, Pacific Ocean Division, Fort Shafter, Honolulu Hawaii, 18pp+13pls.

Johnston Atoll:

Maragos, J.E. and P. Jokiel 1986 Reef corals of Johnston Atoll: one of the worlds most isolated reefs. Coral Reefs 4: 141-150.

Hawaii:

Maragos, J.E. 1977 Order Scleractinia: stony corals. In: Devaney, D. and L. Eldredge (eds.) Reef and shore fauna of Hawaii. Section 1: Protozoa through Ctenophora. Bishop Museum Press, Honolulu, Hawaii. 278 pp.

Maragos, J.E. 1995 Revised checklist of extant Shallow-water stony coral species from Hawaii (Cnidaria: Anthozoa: Scleractinia). Bishop Museum Occasional Papers 42: 54-55.

Northern Hawaiian Islands:

DeFelice R.C., Coles, S.L., Muir D., Eldredge L.G. 1998. Investigations of the marine communities of Midway Harbour and adjacent lagoon, Northwestern Hawaiian Islands. Report to U.S. Fish and Wildlife Service, Pacific Islands Area Office, Honolulu, Hawaii.

Wake Atoll:

Anon. (1999). *Baseline Marine Biological Survey, Peacock Point Outfall and other Point-Source Discharges, Wake Atoll, Pacific Ocean.* Report to the Department of Army by the Department of Interior, Fisheries and Wildlife Service (NMFS). Honolulu, Hawaii. 23 p.

Commonwealth of Northern Mariana Islands:

Randall, R.H. 1995 Biogeography of reef-building corals in the Mariana and Palau Islands in relation to back-arc rifting and the formation of the Eastern Philippine Sea. Nat. Hist. Res. 3(2): 193-210.

Guam:

Jones, R.S. and R.H. Randall 1973b. A study of Biological Impact Caused by Natural and Man-induced Changes on a Tropical Reef. University of Guam, Marine Laboratory Technical Report No. 7.

Taxonomy conforms to:

Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.

Veron J. E. N. & Pichon, M. 1976: Scleractinia of eastern Australia, Part 1: Families Thamnasteriidae, Astrocoenidae, Pocilloporidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 1, 86pp.

Veron J. E. N., Pichon M. & Wijsman-Best M. 1977: Scleractinia of eastern Australia, Part 2: Families Faviidae, Trachyphyllidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 3, 232pp.

Veron J. E. N. & Pichon M. 1979: Scleractinia of eastern Australia, Part 3 Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectinidae, Caryophyllidae, Dendrophylliidae. *Aust. Inst. Mar. Sci., Monogr. Ser.* 4, 422pp.

Veron J. E. N. & Pichon M. 1982: Scleractinia of eastern Australia, Part 4: Family Poritidae, *Aust: Ins. Mar. Sci., Monogr. Ser.* 5, 159pp.

Veron J. E. N. & Wallace C. C. 1984: Scleractinia of eastern Australia, Part 5: Families Acroporidae. *Aust. Ins. Mar. Sci., Monogr. Ser.* 6, 485pp.

Comment: *Oulangia bradleyi (Verrill, 1866): Johnston Atoll.* This record does not conform to the current taxonomy though is included subject to further clarification.

Table II.C.9: Zooxanthellate corals likely to be found in the American Flag Pacific Islands. (Adapted from Veron 1995.)

Family and genus	Extant species {no.}	Present distribution	General abundance
Astrocoeniidae Stylocoeniella	At least 3	Red Sea to central Pacific	Uncommon, cryptic
Pocilloporidae Pocillopora	Approx. 10	Red Sea and western Indian Ocean to far eastern Pacific	Very common, very conspicuous
Stylophora	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Seriatopora	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Acroporidae	At least 80	Red Sea and western Indian	Extremely common
Acropora	At least 150	Cosmopolitan in Indo-Pacific reefs	Extremely common, very conspicuous, usually dominant
Astreopora	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Poritidae Porites	Approx. 80	Cosmopolitan	Extremely common, conspicuous at generic level
Stylaraea	1	Red Sea and western Indian Ocean to westernPacific	Rare, occurs only in shallow,wave-washed biotopes
Goniopora	Approx. 30	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Alveopora	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Sometimes common, very conspicuous
Siderastreidae Psammocora	Approx. 15	Red Sea and western Indian Ocean to far eastern Pacific	Generally common, sometimes cryptic
Coscinaraea	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Agariciidae Pavona	Approx. 22	Red Sea and western Indian Ocean to far eastern Pacific	Very common, conspicuous
Leptoseris	Approx. 14	Red Sea and western Indian Ocean to far eastern Pacific and Caribbean and Gulf of Mexico	Sometimes common, mostly conspicuous
Gardineroseris	At least 2	Red Sea and western Indian	Generally

Family and genus	Extant species {no.}	Present distribution	General abundance
Pachyseris	Approx. 4	Red Sea and western Indian	Very common, very
Fungiidae Cycloseris	Approx. 16	Red Sea and western Indian Ocean to far eastern Pacific	Generally uncommon, non-reefal
Diaseris	At least 3	Red Sea and western Indian Ocean to far eastern Pacific	Generally uncommon, non-reefal
Fungia	Approx. 33	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Herpolitha	2	Red Sea and western Indian Ocean to western Pacific	Generally common, very conspicuous
Sandalolitha	2	Central Indian Ocean to southern Pacific	Sometimes common, very conspicuous
Halomitra	2	Western Indian Ocean to southern Pacific	Generally uncommon, very conspicuous
Oculinldae Galaxea	Approx. 5	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Acrhelia	1	Eastern Indian Ocean to southern Pacific	Generally uncommon, conspicuous
Pectiniidae Echinophyllia	Approx. 8	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Oxypora	At least 3	Western Indian Ocean to southern Pacific	Generally common, conspicuous
Mycedium	At least 2	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Mussidae Acanthastrea	Approx. 6	Red Sea and western Indian Ocean to southern Pacific	Generally uncommon, Favites-like
Lobophyllia	Approx. 9	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous
Symphyllia	Approx. 6	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Merulinidae Hydnophora	Approx. 7	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Merulina	3	Red Sea and western Indian Ocean to southern Pacific	Sometimes common, conspicuous

Family and genus	Extant species {no.}	Present distribution	General abundance
Scapophyllia	1	Eastern Indian Ocean to	Generally
Faviidae	Approx. 4	Red Sea and western Indian	Generally common,
Favia	At least thirty	Cosmopolitan	Extremely common, conspicuous
Favites	Approx. 15	Red Sea and western Indian	Very common,
Goniastrea	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Very common, generally conspicuous
Platygyra	Approx. 12	Red Sea and western Indian Ocean to southern Pacific	Extremely common, conspicuous but may be confused with Goniastrea
Leptoria	2	Red Sea and western Indian	Sometimes common,
Oulophyllia	Approx. 3	Red Sea and western Indian Ocean to western Pacific	Sometimes common, conspicuous
Montastrea	Approx. 13	Cosmopolitan	Generally common, conspicuous
Plesiastrea	At least 2	Red Sea and western Indian Ocean to far eastern Pacific	Sometimes common
Diploastrea	1	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Leptastrea	Approx. 8	Red Sea and western Indian Ocean to southern Pacific	Generally common, conspicuous
Cyphastrea	Approx. 9	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Echinopora	Approx. 7	Red Sea and western Indian Ocean to southern Pacific	Very common, conspicuous
Caryophylliidae Euphyllia	9	Red Sea and western Indian Ocean to southern Pacific	Generally common, very conspicuous
Plerogyra	3	Red Sea and western Indian Ocean to southern Pacific	Generally uncommon, very conspicuous
Dendrophylliidae Turbinaria	Approx. 15	Red Sea and western Indian Ocean to southern Pacific	Very common, very conspicuous

Family and genus	Extant species {no.}	Present distribution	General abundance
Duncanopsammia	1	Central Indo-Pacific	Uncommon, very conspicuous

8. Ahermatypic Corals (Azooxanthellate)

Important Summary Documents

Veron (1986) describes the three genera with photos of living and skeletal examples.

Taxonomic Issues

Order Scleractinia; Family Dendrophylliidae; Genera *Dendrophyllia* (de Blainville, 1830), *Tubastraea* (Lesson. 1829), *Balanophyllia spp.* (Wood, 1844). *Duncanopsammia axifuga* is of the same family and has a skeletal structure and growth form intermediate between hermatypic and ahermatypic forms. As it is zooxanthellate, it is not described here. Other zooxanthellate corals such as *Heteropsammia* and *Psammoseris* (both Dendrophyllidae), *and Heterocyathus* (Caryophylliidae) are they small, single polyp forms and appear as partial ahermatypes (Veron, 1986). Their contribution to reef growth is minor and they occur on sand and rubble substrates. Heteropsammia spp. doesn't occur in the AFPI.

Other genera occur in deep water or deep inter-reef areas and are listed with their recorded depth range (after Veron, 1986): Letepsammia (165-457m); Fungiacyathus (190-600m); Madrepora (55-450m); Cyathelia (40m); Culicia and Astrangia (inter-tidal to 128m, largely temperate); Flabellum (10-824m); Placotrochus (to 188m); Monomyces (3-40m); Gardineria (55m); Anthemiphyllia (to 210m); Caryophyllia (119-1006m); Tethocyathus; Premocyathus (20-230m); Cythoceras (86-766m); Trochocyathus (86-531m); Deltocyathus (16-531m); Boureotrochus (210-531m); Sphenotrochus; Polycyathus (>40m); Aulocyathus (163-190m); Conotrochus (210-365); Stephanocyathus (366-1006m); Oryzotrochus (9-15m); Conocyathus (8-22m); Trematrochus (>27m); Dunocyathus (100-531m); Paracyathus(>20m); Patytrochus (28-183m); Cylindrophyllia; Peponocyathus (339-365); Holcotrochus (11-183m); Desmophyllum; Solenosmilia (860m); Stenocyathus (455-531m); Septosammia (8-86m); Endopachys; Notophyllia (36-457m); Thecopsammia (270m).

Habitat Utilization

Not dependent on light so able to colonizes overhangs and caves. Competes best in areas of low scleractinian coral or algal occurrence. *T. micrantha* competes best due to its erect arborescent nature and may be dominant below 15m in areas of exposed currents.

Life History

Adult: Appearance and Physical Characteristics

Dendrophyllidae :
Solitary and colonial corals with more than two rings of tentacles on the polyps. Numerous skeletal element of the ridges form an almost continuous sheet and rods connect adjacent ridges. *Dendrophyllia* and *Tubastrea spp.* may appear similar superficially but are separated by differences in septal plans.

Dendrophyllia spp.: Often brightly colored (yellow or orange) resulting from the corals own pigment, as no zooxanthellae are present. Colonies are dendroid and proliferate through extra-tentacular budding. Generally nocturnal but also diurnal extension.

Tubastraea spp.: Tubular corallites forming hemispherical colonies. *Tubastrea aurea* forms domed clumps up to 10cm dia. Polyps protrude for a common encrusting base. Usually found in low-light conditions in caves and beneath rocky overhangs. Common species *T. faulkneri, T. coccinea, T. diphana and T. micrantha.*

Tubastrea micrantha forms tree-like branching colonies to 1m in height. Colour dark brown and green. Occurs in deeper reef environments.

Balanophyllia spp.: Solitary corals which bud to form closely packed clumps. Clumps may be 50cm diam. Thick walls. Polyps are oval and tapering towards the base, and the septa are fuse. Color black, bright-orange or yellow polyps.

Feeding and Food

Heterotrophic with dependence on the capture of zooplankton. Nocturnal and diurnal feeding.

Reproductive Strategies

Dioecious. Fertilization is internal and larvae are brooded. Asexual larval reported (Richmond and Hunter, 1990). The larvae are 1mm long and crawl or swim after release before settling. They may also be free-spawners (Harrison and Wallace, 1990). Planula takes four to seven days before they settle and form a primary polyp.

References

Harrison, P. L. & C. C. Wallace (1990): Reproduction, dispersal and Recruitment of Scleractinian Corals. In: Dubinsky, Z. (ed.) Ecosystems of the World, vol. 25 Coral Reefs. Elsevier, N.Y. pp 133-208.

Richmond, R. H. & C. L. Hunter (1990): Review B Reproduction and recruitment of corals: comparison among the Caribbean, the Tropical Pacific, and the Red Sea. Mar. Ecol. Prog. Ser. 1: 145-152.

Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.

Table II.C.10: Deep-water Ahermatypes from Hawaii. (From Maragos 1977; data Vaughan (1907)).

Species	Shallowest Collection Record
Anisopsammia amphelioides (Alcock)	40 fm
Anthemiphyllia pacifica Vaughan	92 fm
Balanophyllia desmophyllioides Vaughan	78 fm
Balanophyllia diomeseae Vaughan	148 fm
Balanophyllia hawaiiensis Vaughan	190 fm
Balanophyllia laysanensis Vaughan	130 fm
Bathyactis hawaiiensis Vaughan	963 fm
Caryophyllia alcocki Vaughan	876 fm
Caryophyllia hawaiiensis Vaughan	92 fm
Caryophyllia octopali Vaughan	28 fm
Ceratotrochus laxus Vaughan	319 fm
Cyathoceras diomedeae Vaughan	169 fm
Deltosyathus andamanicus Alcock	147 fm
Dendrophyllia oahensis Vaughan	154 fm
Dendrophyllia serpentina Vaughan	147 fm
Desmophyllum cristagalli Milne- Edwards & Haine	
Endopachys oahense Vaughan	53 fm
Flabellum deludens v. Marenzeller	670 fm
Flabellum parvoninum Lesson	127 fm
Gardineria hawaiiensis Vaughan	272 fm
Madracis kauaiensis Vaughan	24 fm
Madrepora kauaiensis Vaughan	294 fm
Paracyathus gardineri Vaughan	
Paracyathus mauiensis Vaughan	95 fm
Paracyathus molokensisx Vaughan	88 fm
Paracyathus tenuicalyx Vaughan	252 fm
Placotrochus fuscus Vaughan	148 fm
Stephanophyllia formosissima Moseley	66 fm
Trochocyathus oahensis Vaughan	252 fm

9. Actiniaria (anemones)

Important Summary Documents

Symbiosis between anemones and fish was first noted by Collingwood (1868). Fishelson (1970, 1971) speculated on the ecological role of this association. The taxonomy of symbiotic anemones was revised by Dunn (1981). The taxonomy of the Hawaiian anemones were described in Eldredge and Devaney (1977). Chia (1976) has described reproduction in terms of patterns and adaptive radiation. Fautin and Allen (1992) describe the biology of anemonefish and their host anemones.

Taxonomic Issues

Ecotypes are common (e.g. *Entacmaea quadricolor)* which has given rise to taxonomic confusion Allen (1975) described the deeper water as *Radianthus gelam* and the smaller individuals a *Physobranchia douglasi.* Their ability to adopt a varied coloration both in terms of background color and geographic variation has made taxonomy difficult.

Habitat Utilization

Anemones attach to hard substrate by their basal disc, burrow into soft substrate or attach as symbionts to sessile and mobile reef creatures.

Life History

Adult: Appearance and Physical Characteristic

Anemones have a body column and oral disc with tentacles with nematocysts and a central mouth. They are attached by a basal or pedal disc to the substrate (Barnes, 1980). They are often associated with symbiotic relationships such as with fish or shrimps (Fautin and Allen, 1992). *Heteractis magnifica* reaches a diameter of 30-50cm though may reach 1m.

Ten species are recognized as symbiotic anemones (Actiidae; Thalassianthidae; Stichodactylidae).

Both *Actinodendron plumosum* and *Phyllodiscus semoni* have severe stings if touched.

Some species of anemones can exhibit mimicry appearing like their background or other reef entities like hard coral or algae.

Age, Growth, Longevity

The growth of tropical anemones is variable being largely dependent on nutrition. Longevity among tropical anemones is poorly known. Anemones approaching a meter in diameter may exceed 100 years old (Fautin and Allen, 1992). *Actinia tenebrosa* requires 8 to 66 years to reach a column diameter of 40mm and has an average longevity of 50 years (Ottaway, 1980).

Reproductive Strategies

Asexual: Common: Pedal laceration and longitudinal or transverse fission

Asexual reproduction has been observed as budding (Vine, 1986). Devaney & Eldredge (1977) describe *Boloceroides mcmurrichi* as reproducing sexually in spring and asexually in fall when the asexually young arise as buds on the outer tentacles and are shed when they have developed 10 to 30 tentacles.

Eggs and sperm are produced and host anemones appear to be characterised by separate sexes.

Absence of small individuals is indicative of low fertilization, larval survival or larval settlement or young have high mortality (Fautin and Allen, 1992).

Most are hermaphroditic but reproduce only one type of gamete per reproductive period. Groups of clones evident.

Distribution

Anemones are often widely distributed. The common anemone *Entacmaea quadricolor* is found from Samoa to East Africa and the Red Sea and from the surface down to 40 metres. Of nearly 1000 species, only 10 species are host to anemone fishes. In Hawaii, There is only one host species recorded from Hawaii though without commensal fish (Fautin and Allen, 1992).

Feeding and Food

Anemones are polyphagous opportunists (Ayre 1984). Prey is caught by the tentacles, paralyzed by nematocysts and carried to the mouth. The food consists of plankton borne crustacea but fish worms, and algal fragments are includes Sand dwelling anemones such as *Heteractis malu* ingest gastropods (Shick, 1990) as does *Catalophyllia sp.* Some anemones are suspension feeders (Barnes , 1980).

Specialized corallimorpharians such as *Rhodactis, Actinodiscus, Discosoma, Amplexidiscus* can capture large prey by enveloping them with the entire disk (Hamna and Dunn, 1980; Elliott and Cook, 1989).

Anemones which contain symbiotic zooxanthelle but also capture plankton and other detrital or water borne food. Those without zooxanthella are dependent on plankton and may capture pother food such as crustaceans or smaller fish.

Absorption of dissolved organic material (DOM) by anemones occurs Schlichter (1980) and Schlichter et al. (1987). DOM is important in times of no solid food. (Shick, 1975)

Extracellular digestion is achieved by mesenterial filaments (Nicol, 1959)

Some species of anemones extend their tentacles at night and diminutive during the day (*Alicia sp).* Others feed during daylight hours.

Behavior

The family Boloceriodidae contains anemones capable of swimming by beating their tentacles. The Hawaiian species *Boloceroides mcmurrichi* has a large crown of tentacles compared to a relatively small body. They become capable of swimming at the 10 to 30 tentacle stage (Devaney and Eldredge, 1977).

Edwardsia spp. are found on sandy bottoms and dig themselves into the substrate.

Anemones are basically sedentary but are able to move over the substrate slowly, some can swim for short distances.

There commensal behavior with fish where it gains protection and food and in turn protects the anemone from some predators and removes sediment and other material by its swimming motion (Barnes, 1987).

Spawning: Spatial and Temporal Distribution

Spawning is synchronised with the full moon or low tide (Fautin and Allen, 1992).

Eggs are fertilized in the gastrovascular cavity or occurs outside in the seawater (Fautin and Allen, 1992).

Free swimming planula

Larval Feeding and Food

Ingest copepods, chaetognaths, or larvae of other cnidarians. Unicellullar algae and dinoflagellates has been observed Widersten, 1968; Siebert, 1974)

The planula may be planktotrophic or lecithotrophic and has a variable larval life span. The young sea anemone lives as a ciliate ball, unattached and free swimming. The larvae settles, attaches and forms tentacles.

Habitat Utilization

Asexual of reproduction give rise to many individuals in close proximity, often forming a continuous surface by adjacent oral discs. Like other sessile benthos, settlement of larval stages colonizes available substrate.

References

Allen, G. R. (1975): The Anemonefishes: their Classification and Biology. 2nd edition TFH Publ. Inc. USA.

Ayre , D. J. (1984) The sea anemone *Actinia tenebrosa*: an opportunistic insectivore. *Ophelia,* 23, 149-153.

Barnes, R. D. (1980): Invertebrate zoology. Saunders Colledge, Philadelphia.

Chia, F. S., 1976: Sea anemone reproduction: patterns and adaptive radiation. *In Mackie,* G. O. (Ed.): Coelenterate Ecology and Behaviour. Plenum Press, N. Y. pp. 261-270.

Collingwood, C. (1868): Note on the existence of gigantic sea- anemones in the China Sea, containing within them quasiparasitic fish. Ann. Mag. Nat. His. Ser. 4, **1** (1): 31-33.

Cutress, C. E. (1977): Order Corallimorpharia. In: Devany & Eldredge (eds.): Reef and Shore Fauna of Hawaii, section 1: Protozoa through Ctenophora. B. P Bishop Museum Special Publication 64 (1): I-XII, p.130.

Devaney D. M. & L. G. Eldredge (edts.) 1977. Reef and Shore Fauna of Hawaii. Bernice P. Bishop Museum Special Publication **64** (1)

Dunn, D. F. (1981): The Clownfish Sea Anemones: Stichodactilidae (Colenterata: Actinaria) and Other Sea Anemones Symbiotic with Pomacentrid Fishes. Trans. Amer. Phil. Soc. **71** (1): 1-113.

Elliot, J. and Cook, C. B. (1989) Diel variation in Prey Capture Behavior by the Corallimorpharian *Discosoma Sanctithomae.* Mechanical and Chemical Activation of Feeding. *Biol. Bull.,* 176, 218-228

Fautin, D. G. & G. R. Allen (1992): Field Guide to Anemonefishes and their Host Sea Anemones. West Australian Museum, Perth.

Fishelson, L. (1970): Littoral fauna of the Red Sea: the population of non scleractinian anthozoans of shallow waters of the Red Sea (Eilat). Mar. Biol. **6** (2): 106-116.

Fishelson, L. (1971): Ecology and distribution of the benthic fauna in the shallow waters of the Red Sea. Mar. Biol. **10** (2): 113-133

Grigg R.W. and Opresko D. (1977): Order Antipatharia In: Devany & Eldredge (eds.): Reef and Shore Fauna of Hawaii, section 1: Protozoa through Ctenophora. B. P Bishop Museum Special Publication 64 (1): I-XII, p.130.

Hamner, W. M. & D. F. Dunn (1980): Tropical Corallimorpharia (Coelenterata:Anthozoa): Feeding by Envelopment. Micronesia **16** (1): 37-41.

Nicol, J. A. C. (1959) Digestion in sea anemones. *J. Mar. Bio. Ass. UK,* 38, 469-476.

Ottaway, J.R., 1980: Population ecology of the intertidal anemone, *Actinia tenebrosa:* 4. Growth rates and longevities. Aust. J. Mar. Freshw. Res., *31*(3): 385-396.

Schlichter, D. (1980) Adaptations of cnidarians for itegumentary absorption of dissolved organic matter. *Rev. Can. Biol.,* 39, 259-282.

Schlichter, D., Bajorat, K. H., Buck, M., Eckes, P., Gutknecht, D., Kraus, P., Krish, H., Schmitz, B. (1987) Epidermal nutrition of sea anenomies by absorption of organic compounds dissolved in the oceans. *Zool. Beitr. N.F.,*30, 29-47.

Shick, J. M. (1975) Uptake and utilization of dissolved glycine by *Aurellia aurita* scyphistomae: Temperature effects on the uptake process: nutritional role of amino acids. *Biol. Bull.* 148, 117-140.

Shick, J. M. (1990) Diffusion limitation hyperoxic enhancement of oxygen consumption in zooxanthellate sea anemones, zoanthids and corals. *Biol. Bull.* 179, 148-158.

Siebert, A. E., Jr. (1974) A description of the embryology, laval development and feeding of the sea anemones Anthopleura elegantissima and *A xanthogrammica.. Can J. Zool.,* 52, 1383-1388.

Vine, P. (1986): Red Sea Invertebrates. Immel Publ., London, UK.

Walsh G. E. and Bowers R.L. (1977): Order Zonthiniaria. In: Devany & Eldredge (eds.): Reef and Shore Fauna of Hawaii, section 1: Protozoa through Ctenophora. B. P Bishop Museum Special Publication 64 (1): I-XII, p.130.

Widersten, B. (1968) On the morphology and development in some cnidarin larvae. *Zool. Bidr. Uppsala,* 37, 139-179 + 3 plates

Table II.C.11: Actinaria from Hawaii (Cutress, 1977).

Order ACTINIARIA

Family BOLOCEROIDIDAE
Boloceroides memurrichi (Kwietniewski 1898)
Bunodeopsis medusoides (Fowler 1888)

Family ALICIIDAE
Triactis producta Klunzinger 1877

Family ACTINIIDAE
Anemonia mutabilis Verrill 1928
Anthopleura nidrescens (Verrill 1928)
Anthopleura sp. *a*
Anthopleura sp. *b*
Actiniogeton sesere (Haddon & Shackleton 1893)
Cladactella manni (Verrill 1899)

Family STOICHACTINIDAE
Antheopsis papillosa (Kwietniewski 1898)
Stoichactis sp.

Family PHYMANTHIDAE
Heteranthus verruculatus Klunzinger 1877

Family ISOPHELLIDAE
Telmatactis decora (Hemprich and Ehrenberg 1834)
Epiphellia pusilla (Verrill 1928)
Epiphellia humilis (Verrill 1928)

Family HORMATHIIDAE
Calliactis polypus (Forskal 1775)

Family SAGARTIIDAE
Anthothoe sp.

Family AIPTASIIDAE
Aiptasia pulchella Carlgren 1943

Family DIADUMENIDAE
Diadumene leucolena (Verrill 1866)

Family EDWARDSIDAE
Edwardsia sp. *a*;. *Edwardsia* sp. *b*.

10. Zoanthidae (colonial anemones)

Important Summary Documents

Hyman (1940) details systematics and anatomy. Mather and Bennett (1993) discuss the order Zoanthidae. Burnett et al. (1997) a good summary of systematics for some central Indo-Pacific species. Walsh (1967) produced an annotated bibliography for the family.

Taxonomic Issues

Class Anthozoa; subclass Zoantharia (=Hexacorallia); order Zoanthiniaria (=Zoanthidea); suborder Brachcnemina; family Zoanthidae; genera Acrozoanthus; *Zoanthus; Isaurus; Protopalythoa; Palythoa; Sphenopus.* suborder Macrocnemina; family Epizoanthidae; genera *Epizoanthus; family* Epizoanthidae, *Thoracactis*; genus *Parazoanthus, Gerardia, Isozoanthus* (Barnes, 1987; Muirhead and Ryland, 1985).

Poorly known due to reliance on preserved specimens and a high degree of inter-population variability. Nominal species 300.

Differentiated from the Actinaria by the presence of a fifth cycle of mesenteries.

Zoanthiniarian systematics is discussed by Herberts (1972a; 1987) and Mather and Bennett (1993).

Habitat Utilization

Often distinct zonation: back reef flats, lagoon floors, reef crests and shallow sublitoral zone. Palythoa spp.: Growth in large numbers on reef flats immediately behind the reef crest, also found on lagoon floors and the spur and groove channels of reef slopes. Tide pools in Hawaii.

Parazoanthus ssp., Epizoanthus ssp., Acrozoanthus spp.: May colonize worm tubes, hydroids, sponges and gorgonian skeletons. May be epizootic on sponges, or ascideans as ATuff Balls or providing as protection (Colin and Arneson, 1995).

Protopalythoa spp.: Shallow fore reefs, reef crests or outer reef flat areas. Shallow reef zones may be dominated by this genus and cover may be >90%. May occur as small assemblages of polyps or separate individuals.

Zoanthus spp.: They are found in back reef areas and the shallow sub-littoral zone.

Life History

Adult: Appearance and Physical Characteristics

Zoanthid anemones are solitary or colonial, zooxanthellate (except *Sphenopus*). Principal tropical genera are *Palythoa, Protopalythoa* and *Zoanthus.* Generally, discs are 1-2cm in diameter with tentacles 3-5mm long but may extend to 2-3cm. Coloration varies from red, orange, yellow, turquoise, green or brown. The stem (scapus), disc (capitulum), tentacles or coenenchyma vary in coloration. Zooanthids differ from other Zoantharia in that they don't produce skeleton but incorporate sediment into the body wall. As well, they don't have a pedal disc and a differing septal arrangement (this forms the basis for the two suborders).

Isaurus spp.: Loosely connected colonies without connecting stolons. Height varies 15- 160cm. Colonies with < 50 individuals. Taxonomically best known (Muirhead and Ryland, 1985). Often inconspicuous. Nocturnal tentacular extension.

Palythoa spp.: Growth in massive colonies. Sand particles are encrusted into the coenenchyme. Colonies are convex and 30cm. Coenenchyme is light brown to yellow.
Often buried in the sand to the level of the disc.

Protopalythoa spp.: Generally in loosely connected colonies. Often the polyps lack contact or have contact at the base through a stolon. Polyp height is 15-25 mm high and 7-11mm in diameter. Expanded discs may attain a diameter of 2-3cm. May occur as large areas of colonization, small assemblages or individual polyps. Polyps are encrusted with sand particles. For some, full retraction is not possible due to the size of the disc. Colour is uniform on the stem and disc; brown or green. It may be variable due to the intensity of light.

Zoanthus spp.: Sediments are not incorporated in their tissues but are tolerant of sediment environments. Most species are brightly coloured, often contrasting disc, tentacles and stem.

Growth

Growth morphology may depend on the environment. *Z. pacificus* has a lamellar coenenchyme with crowded polyps and separate bases. In surge pools, the bases are joined and crowding less. In wave washed area the coenenchyme can be lamellar or stoloniforous with single polyps or groups of two or three (Walsh and Bowers, 1971).

In *Palythoa,* growth is by the spreading of the thickened coenenchyme. Yamazato et al. (1973), found 0.18 new polyps per day increase in *Palythoa tubercles.* Density of colonies may be 671 polyps/0.1m^2 (*Zoanthus sociatus*) and 302 polyps/ 0.1m^2 for *Z. solanderi.* (Karlson, 1981). 12,000/m^2 of *Palythoa vestitus* where found in Kaneohe Bay.

Distribution

Isaurus spp: Widespread in all tropical seas; present in Hawaii.

Palythoa spp.: Pan-tropical; present in Hawaii.

Protopalythoa spp.: Pan tropical; occurs in Hawaii, American Samoa and Tahiti.

Zoanthus spp.: Pan-tropical; occurs in Hawaii, American Samoa and Tahiti.

Feeding and Food

Heterotrophic (zooplankton); autotrophic (zooxanthellae) (Reimer 1971b).

Muscatine et al. (1983) determined zooxanthellae could provide 48% of the carbon requirement for *Zoanthus sociatus.*

Palythoa, Protopalythoa and Zoanthus are diurnal in expansion. Others are nocturnal Isaurus and Sphenopus. Able to ingest a variety of live and dead crustacea and fish portions (Reimer, 1971a). Crustacean and detrital fragments were found in *Zoanthus Sociatus*, though few contained food items with only a greater frequency at night (Sebens, 1977). Azooxanthellate genera (*Epizoanthus and Parazoanthus)* rely greatly on feeding to obtain sufficient nutrition.

The uptake of dissolved organic matter may contribute to nutrition (Reimer, 1971; Trench, 1974). The common presence of *Zoanthus* spp and *Protopalythoa* in shore may be due to the higher organic levels. With the reduction in sewage contamination in Kaneohe Bay, zoanthid population declined.

Isaurus spp: Autotrophic nutrition from the zooxanthellae but also feeds on plankton nocturnally. Polyps never open in the day.

Palythoa spp.: Generally autotrophic but tentacles and diurnal expansion indicate reliance on zooplankton.

Protopalythoa spp.: Heterotrophic; autotrophic

Zoanthus spp.: Heterotrophic; autotrophic

Reproductive Strategies

Asexual by the arising of new polyps from a spreading sheet of coenenchyma or stolons or budding from the parent polyp. Extensive monoclonal colonies occur.
Fragmentation is common.

Sexual reproduction: Both dioecious (gonochoristic) and sequential and simultaneous hermaphrodites.

Isaurus spp: Unknown.
Palythoa spp.: Readily reproduces asexually. Yamazoto et al. (1973) studied the reproductive cycle of *Palythoa tuberculosa* in Okinawa. The oocytes grow from March/April, to a peak in the middle of the year, which followed by a second peak in October indicative of two spawnings per year. Mature eggs are rather large with a length of 300-500um.

Protopalythoa spp.: Asexual and sexual. Babcock and Ryland (1990) and Ryland and Babcock (1991) describe reproduction and larval development.

Zoanthus spp.: Asexual and sexual. Cooke (1976) describes reproduction for *Zoanthus pacificus* and for *Z. solanderi and Z. sociatus* by Fadlallah et al. (1989).

Spawning: Spatial and Temporal Distribution

Ovaries develop initially in the cycle along the margin of the mesenteries with the testis later in the cycle. Seasonal free spawning. Report of spawning synchronous with the mass spawning of the stony coral, on the 4th to 6th nights after full moon in November (Ryland and Babcock, 1991). In Hawaii, *P. versitis* was only active May to September while *Z. pacificus* was bound to be sexually active all year but greatest during the summer (Cooke, 1976).

Eggs and Larvae

Egg diameter range from 75um to 280 um. Sperm are bell shaped and 50 um long. Egg counts range from 800 to 2400 (Ryland and Babcock, 1991). Larvae settle in areas of coralline algae and crawl to find a site. Suitable sites are often shaded. Fecundity is high and settlement rates are low. Sexual reproduction is therefore thought to allow for dispersal and colonization over large distances (Karlson, 1981).

The larvae are oval in shape and have a girdle of cilia near the oral end. The Larvae of *Protopalythoa spp.* are referred to as zoanthella and are elongate with a ventral band of long cilia (Hyman, 1940).

References

Babcock, R. C. & J. S. Ryland (1990). Larval development of a tropical zoanthid (*Protopalythoa sp.*) Invert. Reprod. Develop. **17**: 229-236.

Barnes, R. D. (1987). Invertebrate zoology. Saunders College, Philadelphia.

Burnett, W. J., J. A. H. Benzie, J. A. Beardmore & J. S. Ryland (1997): Zoanthids (Anthozoa, Hexacorallia) from the Great Barrier Reef and Torres Street, Australia: systematics, evolution and a key to species. Coral Reefs **16**: 55-68.

Colin, P. L., and C. Arneson. 1995. Tropical Pacific Invertebrates. San Diego: Coral Reef Press.

Cooke, W.J. (1976). Reproduction, growth and some tolerances of *Zoanthus pacificus* and *Palythoa vestitus* in Kaneohe Bay, Hawaii. In G. O. Mackie (Red.): Coelenterate ecology and behavior. Plenum Press. N.Y., USA: 281-288.

Fadlallah, Y. H., Karlson R. H., and Sebens K.P. (1984). A comparative study of sexual reproduction in three species of Panamanian zoanthids (Coelenterata: Anthozoa). Bull. Mar. Sci. (35): 80-89.

Herberts, C (1972a): Etude Systematique de Quelques Zoanthaires Tempe et Reopicaux Tethys, Suppl. E 69-156.

Herberts, C (1987). Orre des Zoanthaires. In: P.P. Grasse and D. Doumenci (Red.) Traite de Zoologie, anatomie, systematique, biologie. Tome 3: 170-178.

Hyman, L.H. (1940). Chapter VII. Metazoa of the tissue grade of construction Bthe radiate phyla-Phylum Cnidaria. In: The Invertebrates: Protozoa through Ctenophora Vol. 1. McGraw-Hill, New York, pp. 365-696.

Karlson, R.H. 1881. Reproductive patterns in *Zoanthus spp.* from Discovery Bay Jamaica. Proc. 4th Int. Coral Reef Symp. Vol. 2L 699-704.

Mather, P. and Bennett I. (ed.) 1993. A Coral Reef Handbook 3rd ed. Surry, Beatty and Sons PTY Ltd., Chipping Norton, NSW, Australia.

Muirhead, A. and Ryland J. S. (1985). A review of the genus Isaurus Gray, 1828 (Zoanthidea), including new records from Fiji. Jour. Nat. Hist. (19): 323-335.

Muscatine, L., Falkowski, P.G. and Dubinsky, Z. (1983). Carbon budgets in symbiotic associations. In E.A. Schenk and W. Schwemmler (eds.) Endocytobiology, Vol 2, Walter de Gruther, Berlin, pp. 649-658.

Reimer, A. A. (1971a): Feeding Behaviour in the Hawaiian Zoanthids, Palythoa and Zoanthus. Pacific Science **25** (4): 512-520.

Reimer, A. A. (1971b): Observations on the relationships between several species of tropical zoanthids (Zoanthidae, Coelenterata) and their zooxanthellae. J. Exp. Mar. Biol. Ecol. (7): 207-214.

Ryland, J. S. & R. C. Babcock (1991): Annual cycle of gametogenesis and spawning in the tropical zoanthid, *Protopalythoa sp.* Hydrobiologia (216/217): 117-123.

Sebens, K.P. 1977. Autotrophic and heterotrophic nutrition of coral reef zoanthids. In: Proc. 3rd Int. Coral Reef Symp. 397-404.

Trench R.K. (1974) Nutritional potentials in *Zoanthus sociatus* (Coelenterata, Anthozoa) Helg. Wiss Meers. 26:174-216.

Walsh G.E. 1967. An Annotated Bibliography of the Families Zoanthidae, Epizoanthidae, and Parazoanthidae (Coelenterata, Zoantharia). Univ. Hawaii Hawaii Inst. Marine Biology Tech. Rep. 13. 77pp.

Walsh G.E. and Bowers R.L. 1977. Order Zoanthiniaria. In: Reef and Shore Fauna of Hawaii. Section 1. Protozoa through Ctenophora, ed. D. M. Devaney and L. G. Eldredge. Bernice P. Bishop Museum Special Publications 64(1): 148-157.

Yamazato, K., F. Yoshimoto & N. Yoshihara (1973): Reproductive cycle in a zoanthid *Palythoa tuberculosa Esper*. Publs. Seto mar. biol. Lab. (20): 275-283.

Table II.C.12. Zoanthiniaria from Hawaii: (Walsh and Bowers 1971).

Order ZOANTHINIARIA

Family ZOANTHIDAE
Isaurus elongatus Verrill 1928
Palythoa vestitus (Verrill 1928)
Palythoa tuberculosa (Esper 1791)
Palythoa psammophilia Walsh and Bowers 1971
Palythoa toxica Walsh and Bowers 1971
Zoanthus pacificus Walsh and Bowers 1971
Zoanthus kealakekuaensis Walsh and Bowers 1971

11. Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Alcyoniina (soft corals)

Important Summary Documents

Bayer et al. (1983) and Bayer (1981) details anatomical terminology and taxonomy.
Hyman, (1940) describes the anatomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); order Alcyonacea; suborder Alcyoniina: families: Paralcyoniidae; Alcyoniidae; Asterospiculariidae; Nephtheidae; Nidaliidae; Xeniidae

The taxonomy of common intertidal and lagoon genera *Sarcophyton* and *Sinularia* are revised in Verseveldt (1980, 1982).

Habitat Utilization

Colonies characteristic of large size grow in shallow water areas in high light intensity and intertidally. Generally colonies are smaller on roofs of caves.

Life History

Adult: Appearance and Physical Characteristics

Alcyonaria: Colonial, tentacles and mesenteries 8 with tentacles pinnate attached.
Alcyonacea: Alcyoniina (Soft corals): Fleshy, stolon, membranous, encrusting or erect with tree-like branching. Monomorphic polyps (autozooids: function in food intake, water movement and bear the gonads). Some genera have dimorphic polyps (autozooids and tentacle-less siphonozooids) e.g. *Lobophytum spp.* and *Sarcophyton spp.* Dimorphism attributed to need for transport of water (Bayer, 1973). Skeleton has calcite spicules (sclerites). Coenechyme is the general colonial mass filled with solenia that connect with the polyps and their anthocodium. Tentacular contraction possible in some and only partial in others.

Zooxanthellate with resulting colour of greens to brown or bright coloration in the sclerites.

Paralcyoniidae: Lobed to arborescent upper portions and are able to retract this region into the lower stalk. Rigidly reinforced with large sclerites.

Alcyoniidae: Large, lobed colonial forms with considerable amounts of scleritic coenenchyme.

Nephtheridae: The coenenchyme between polyps is thin, arboresent with polyps grouped at the ends of branches. Hydrostatic pressure important to provide support.

Nidalidae: Rigid, brittle, arborescent colonies with narrow stems and branches. Densely covered with spindle shaped sclerites. Similar in appearance to gorgonians Xeniidae: Fleshy with sclerite mass reduced. Characterized by tentacular oscillation.

Age, Growth, Longevity

Two main growth forms massive and arborescent.

Growth by vegetative budding from the system of solenial canals between confluent coenenchyme. Mucus production high in some and effective in cleaning of the surface of the colony. Colonies are often prolific with numerous colonies covering large areas. In Guam population density of up to 24 colonies per square meter of *Asterspicularia randalli* (Gawel, 1976).

Distribution

Occurring in all oceans at all latitudes, they are most abundant in the tropics.

Paralcyoniidae: *Studeiroides spp.: Indo-Pacific*

Alcyoniidae: *Sarcophyton spp./ Lobophytum spp.: Cladiella spp.:* Very common in the Indo-Pacific. *Sinularia spp.:* Indo-Pacific Philippines, Malayan Archipelago Great barrier Reef- Australia, Vietnam, Palau, New Caledonia and the Ryukyu Island, Japan.

Asterospiculariidae: *Asterospicularia sp.:* Guam

Nephtheidae: *Capnella spp. / Nepthea spp. / Dendroneptha spp.:* Very common in the Indo-Pacific.

Nidaliidae: *Chironephthya spp./ Nephthyigorgia spp/ Siphonogorgia spp.*: Very common in the Indo-Pacific.

Xeniidae: *Xenia spp./ Cespitularia spp.:* Indo-Pacific

Feeding and Food

Heterotrophic through zooplankton capture. Autotrophic through nutrient exchange with zooxanthellae, digestion of zooxanthellae and absorption of dissolved organic matter in the seawater (Fabricius, et al. 1995a,b).

Food is taken in through the mouth. Prey are immobilized by nematocysts and conveyed to the mouth by tentacles.

Behavior

Defensive

Chemical substances provide advantage over other organisms for protection by preventing feeding or securing space on the reef. Majority of species of soft corals contain toxic terpene compounds which they release in to their surroundings (Coll et al. 1982; and Coll and Sammarco 1983; 1986; Sammarco et al. 1983; Webb and Coll 1983). These may influence the reproductive capability or survivorship of scleractinian corals (Aceret et al. 1995a,b).

Physical defenses involve the use of sweeper tentacles, sclerites, overtopping,

Reproductive Strategies

Asexual: Almost all increase colonial numbers through mechanisms such as fragmentation, budding, transverse fission and pedal laceration.

Fragmentation: Takes place in *Dendronephthya* in 5-10 days (Fabricius, 1995). Fragmentation can occur through constriction or though parting of the stolons.

Sexual: Dioecious and hermaphroditic. Gonads occur on the mesenteries and reproduction involves the release of gametes into the surrounding water. Fertilization may occur externally through broadcast spawning or within the polyp cavity. Internal fertilization gives rise to an internal brooded planula. Also internal fertilization may give rise to an externally brooded planulae. (Benayahu, and Loya 1983, 1984a, 1984b; Yamazato et al. 1981).

Alcyonium, Heteroxenia, Lobophytum, Parerythropodium, Sarcophyton and Xenia planulae were released between 11 and 13 days after the full moon in November. Egg size range from 625um (*Lobophytum*) to 810um (*Sarcophytum)* (Alino and Coll, 1989). Some are may be dioecious, external surface planula brooders (Benayahu, and Loya, 1983; 1984b; 1986). Presence of zooxanthellae is likely in planulae.

References

Aceret T.L., Sammarco, P.W. and J.C. Coll. 1995a. Toxic effects of alcyonacean diterpenes on scleractinian corals. J. Esp. Mar. Biol. Ecol. 188:63-78.

Aceret T.L., Sammarco, P.W. and J.C. Coll. 1995b. Effects of diterpenes derived from the soft coral *Sinularia flexibilis* on the eggs, sperm and embryos of the scleractinian corals M*ontipora digitata* and *Acropora tenuis*. Mar. Biol. 122:317- 323.

Alino, P.M. and Coll, J.C. 1989. Observations of the synchronized mass spawning and post-settlement activity of octocorals on the Great Barrier Reef, Australia: Biological aspects. Bull. Mar. Sci. 45:697-707.

Bayer F. M. 1973. Colonial Organization in Octocorals, In: Boardman R.S., Cheetham A.H. and W.A. Oliver (eds.). *Animal Colonies: Development and Function Through Time. Dowden, Hutchinson and Ross Stroudsburg, Pa. USA.*

Bayer, F. M. 1981. Key to the genera of Octocorallia exclusive Pennatulacea (Coelenterata: Anthozoa) with diagnoses of new taxa. Proc. Biol. Soc. Wash. **94** (3): 902- 947.

Bayer, F.M. Grasshoff, M. Verseveldt J., 1983. Illustrated trilingual glossary of morphological terms applied to Octocorallia. E.J. Brill/ Fr. W. Backhuys: Leiden.

Benayahu, Y. and Loya Y. 1983. Surface brooding in the Red Sea soft coral *Parerythropodium fulvum fulvum* (Forksal, 1975). Biol Bull. 165: 353-369.

Benayahu, Y. and Loya Y. 1984a. Life history studies on the Red Sea soft coral *Xenia macrospiculata* Gohar, 1940. I. Annual dynamics of gonadal development. Bio. Bull. 166:32-43.

Benayahu, Y. and Loya Y. 1984b. Life history studies on the Red Sea soft coral *Xenia macrospiculata* Gohar, 1940. II. Planulae shedding and post larval development. Bio. Bull. 166:44-53.

Benayahu, Y. and Loya Y. 1986. Sexual reproduction of a soft coral: synchronous and brief annual spawning of *Sarcophyton glaucum* (Quoy and Gaimard, 1833). Biol. Bull. 170:32-42.

Coll, J. C., S. Barre, P. W. Sammarco, W.T. Williams & G. J. Bakus 1982: Chemical defenses in soft corals (Coelenterata: Octocorallia) of the Great Barrier Reef: a study of comparative toxicites. Mar. Ecol. Prog. Ser. 8: 271-278.

Coll C. & P. W. Sammarco 1983: Terpenoid Toxins of soft coral (Coelenterata: Octocorallia): their nature, toxicity, and ecological significance. Toxicon, suppl. (3): 69.

Coll C. & P. W. Sammarco 1986: Soft Corals: Chemistry and Ecology. Oceanus **29** (2): 33-37.

Fabricius, K.E. 1995. Slow population turnover in the soft coral genera *Sinularia and* Sarcophyton *on* mid- and outer-shelf reefs to the Great Barrier Reef. Mar. Ecol. Progr. Ser. 126: 145-152.

Fabricius, K.E., Benayahu, Y. and Genin. A. 1995a. Herbivory in asymbiotic soft corals. Science 268: 90-92.

Fabricius, K.E., Genin. A. and Benayahu, Y. 1995b. Flow-dependent herbivory and growth in zooxanthellae-free soft corals. Limnol. Oceanogr. 40:1290-1301.

Gawel, M.J. 1976: *Asterospicularia randalli*: A new species of Asterspicularidae (Octocorallia: Alcyonacea) from Guam. Micronesia 12 (2): 303-307.

Hyman, L.H. (1940). Chapter VII. Metazoa of the tissue grade of construction Bthe radiate phyla-Phylum Cnidaria. In: The Invertebrates: Protozoa through Ctenophora Vol. 1. McGraw-Hill, New York, pp. 365-696.

Sammarco, P. W., J. C. Coll, S. LaBarre & B. Willis 1982: Competitive strategies of soft corals (Coelenterata: Octocorallia): allelopathic effects on selected scleractinian corals. Coral Reefs **1**(3): 173-178.

Verseveldt, J. (1980): A revision of the genus Sinularia May (Octocorallia, Alcyonacea). Zool. Verhandlingen, Leiden (179): 1-128, figs. 1-68, pls. 1-38.

Verseveldt, J. (1982): A revision of the genus Sarcophyton Lesson (Octocorallia, Alcyonacea). Zool. Verhandlingen, Leiden (192): 1-91, 21 plates.

Webb, L. & J. C. Coll 1983: Effects on Alcyonaria coral terpenes on scleractinian coral photosynthesis and respiration. Toxicon suppl. 3: 69.

Yamazato, K., Sato, M. and Yamashiro H. 1981. Reproductive biology of an alcyonacean coral, *Lobophytum crassum* Marenzeller. Proc, 4th Int. Coral Reef Symp. Manila, vol. 2.

12. Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Scleraxonia; Holoaxonia (gorgonian corals, sea fans and sea whips)

Important Summary Documents

Bayer (1956, 1973, and 1981) summarizes taxonomy and anatomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); Order Alcyonacea; Suborder Scleraxonia; Families: Briareidae; Anthothelidae; Subergorgiidae; Coralliidae; Melithaeidae; Parisididae; Holoaxonia; Families: Acanthogorgidae; Plexuridae; Gorgoniidae; Ellisellidae; Ifalukellidae: Chrysogorgiidae; Primnidae; Isididae.

Habitat Utilization

Strong current location; low light conditions such as depths and overhangs.

Life History

Adult: Appearance and Physical Characteristic

Generally arborescent in nature, some unbranched. Skeletal support by stiff axis utilizing the flexible gorgonin. Divided taxonomically on basis of a central supporting axis (gorgonin and fused sclerites) or core (cortex around chambered gorgonin). Polyps have pinnate tentacles, anthocodia sit in coenenchymal calyx and sheath is formed around the central axis.

The main stem is attached by to a plate or branchlets to the surface. Stem contains a central strengthening rod. The rod may be calcareous but is commonly of horny gorgonin. Short polyps occur all over the branches of the colony but not on the main stem. Colonies are often brightly colored and may reach 3m in height. Epizoic life common (George and George, 1979).

From (George and George, 1979):

Suborder Scleraxonia

Briareidae: Erect, finger-like processes of spongy texture (20cm height) or massive and encrusting. Zooxanthellate. Polyps monomorphic

Anthothelidae: Thinly branched sea-fan. Fragments easily. Polyps monomorphic.

Subergorgiidae: Sea-fan with anastomosing branches (1m height), strong and flexible, polyps monomorphic.

Coralliidae: Calcareous skeleton with color from pink to red. Retractile white feathery polyps and branch in any plane. Polyps dimorphic.

Melithaeidae: Sea-fan with jointed axis and brittle (50cm height).

Suborder Holoaxonia

Plexuridae: Dichotomously branched species.

Gorgoniidae: Sea-fan with anastomosing box-section branches, flattened, bushy or feathery branches (1m height).

Ellisellidae: Whip-like (1m long).

Primnidae: Stems stiff and heavily calcified. Polyp bases composed of spicules are arranged in whorls around the stem.

Isididae: Parallel with upright branches

Age, Growth, Longevity

Photosynthetic gorgonians grow rapidly 15 cm (*Gorgonia ventalin*); 2.5 cm/mon./branch *Pseudoplexaura spp and Pseudopterogorgia acerosa* (Sprung and Delbeek 1997)

0.8-4.5cm/yr. found in Puerto Rico. (Yoshioka and Buchanan-Yoshioka 1991)
Small colonies grow vertically faster but not necessarily in area.

Distribution

Cosmopolitan though most abundant in warmer waters.

Indo-Pacific occurrence:
Suborder Scleraxonia
Briareidae: *Solenopodium spp.; Briareum spp.*
Anthothelidae: *Erythropodium spp*
Subergorgiidae: *Subergorgia spp*
Melithaeidae: *Melithaea spp.; Mopsella spp.*
Ellisellidae: *Ellisella spp. / Junceella spp.*

Suborder: Holoaxonia
Acanthogorgidae: *Acanthogorgia spp.; Muricella spp.*
Plexuridae: *Bebryce spp.*
Gorgoniidae: *Lophogorgia spp.*
Chrysogorgiidae: *Stephanogorgia sp.*
Isididae: *Isis spp.*

Feeding and Food

Heterotrophic by the capture of zooplankton. Autotrophic through nutrient translocation from zooxanthellae. Relative few holoaxonic zooxanthellate genera in the Indo-Pacific. Particulate feeding described (Lasker, 1981)

Require strong current situations for effective feeding by fan-like colonies.

Behavior

Periodic shedding of the waxy cuticle as a means of surface cleaning.

Reproductive Strategies

Parthenogenetic planulae production possible with planulae internal brooders (Brazeau and Lasker, 1989) though most where produced through broadcast spawning (Lasker and Kim, 1996).

Clonal propagation occurs (Lasker 1990).

References

Bayer, F.M. 1956: Octocorallia In Moore, R.C. (ed.): Treatise on Invertebrate Paleontology. Part F Coelenterata: 166-231, Geological Society of American University of Kansas Press.

Bayer F. M. 1973. Colonial Organization in Octocorals, In: Boardman R.S., Cheetham A.H. and W.A. Oliver (eds.). *Animal Colonies: Development and Function Through Time. Dowden, Hutchinson and Ross Stroudsburg, Pa. USA*

Bayer, F. M. 1981. Key to the genera of Octocorallia exclusive Pennatulacea (Coelenterata: Anthozoa) with diagnoses of new taxa. Proc. Biol. Soc. Wash. **94** (3): 902- 947

Brazeau, F.A. and Lasker. H.R. 1989. The reproductive cycle and spawning in a Caribbean gorgonian. Biol Bull. 176:1-7.

George, D. & J. George, 1979: An Illustrated Encyclopedia of Invertebrates in the Sea *Marine Life.*

Lasker, H. R., 1981: A comparison of particulate feeding abilities of three species of gorgonian soft corals. Marine Ecol. Prog. Ser., *5*:61-67.

Lasker, H.R. 1990. Clonal propagation and population dynamic of a gorgonian coral. Ecology 71:1578-1589.

Lasker, H.R. AND Kim K. 1996. Larval development and settlement behaviour of the gorgonian coral *Plexaura kuna* (Lasker, Kim and Coffroth). J. Exp. Mar. Biol. Ecol. 207: 161-175.

Sprung, J. & J. C. Delbeek (1997): The Reef Aquarium, vol. 2. Ricordea Publishing, Miami, USA.

Yoshioka and Buchanan-Yoshioka 1991. A comparison of the survivorship and growth of shallow-water gorgonian species of Puerto Rico (West Indies.). Mar. Ecol. Progr. Ser. 69:253-260.

13. *Heliopora coerulea* (DeBlainville, 1830) (Alcyonaria, Coenothecalia) (blue coral)

Important Summary Documents

Zann and Boulton (1985) detail the distribution, abundance and ecology in the Pacific. Hyman (1940) and Bayer (1973, 1981) describe the anatomy and taxonomy.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia): Order Coenothecalia (=Helioporacea); monotypic, family Helioporidae with a single species. It is a soft coral with a hard, >stony coral-like= skeleton.

Habitat Utilization

High abundance of *Heliopora* is attributed to a reduction in competition from *Acropora, Pocillopora* and faviids in areas where theses are mutually exclusive. *Heliopora* frequently co-existed with *Porites* and *Montipora.* In terms of interspecific aggression, Heliopora is a good competitor as both *Acropora* and *Pocillopora* are considered aggressive (Lang, 1973).

It is a warm-water generalist with a wide habitat range.

Life History

Adult: Appearance and Physical Characteristics

Zooxanthellate and colonial with a blue calcium carbonate skeleton which is the result of iron salts (Hill, 1960). Bouillon and Houvenaghel-Crevecoeur (1970) conclude the blue pigmentation is composed primarily of biliverdin IX and secondary oxidation products. (Hyman, 1940) describes the skeleton as composed of crystalline slivers of aragonite fused into a layer. There are no sclero-proteinaceous structures as in the rest of the Octocorallia. The skeleton contains strontium but in smaller amounts in comparison to hermatypic scleractinia.

Colour and growth form is highly variable: corallum pale to deep blue; living coral is light brown-grey with extended polyps grey-white. Growth forms: encrusting, columnar and branching (coalescent compressed, flabellate fronds, fine branching). May form massive micro-atolls (Zann and Boulton, 1985). Appears like a species of *Millepora.* There is a clear correlation between colony shape and environmental conditions (Veron 1986).

Skeleton with blind tubes internally one for the polyps and one for the solenia (Hyman, 1940).

Reproductive Strategies

Dioecious with fertilization taking place internally and the eggs are brooded externally (Babcock, 1990). External brooding is where they fertilized eggs are shed from the polyp and adhere to the side in mucus pouches were they the developed until they are released. Weingarten (1992) describes a synchronous annual of oocytic development following the general octocorallian reproductive strategy. The gametes are typically released in January, after the full moon, at the summer thermal maximum. Where its distribution is geographically marginal, it takes more than one year for the gametes to mature. It broods its larvae, which settle immediately after release.

Zann and Boulton (1985) suggest the limitation to its distribution to more isolated areas due to a relatively short larval life span. The short larval stage may be nutrient limited as the planula is azooxanthellate.

Distribution

Duration of larval life span, prevailing currents, and the geological and climatic history of isolated archipelagoes determine its distribution. Though widely distributed since the Cretaceous, now more abundant in the equatorial Central Pacific than in the Western Pacific. Comprises 16% of beach sediment in Tuvalu and 40% of substrate between 6m and 10m on Tarawa Atoll, Kirribati. Competition with Acroporidae and Faviidae influence its occurrence (Zann and Boulton, 1985). Globally, it occurs along West Africa, Red Sea, Indonesia and the Maldives, where it may be the dominant coral fauna. It occurs as far south as Madagascar and north to the Ryukyu Islands in Japan (Veron, 1986).

With regard to the AFPI, it is only present in Guam (Randall, 1977), Commonwealth of the Northern Marianas and American Samoa (rare) (U.S. Army Corps Engineers 1980).

Its habitat distribution is inter-tidal reef flats, reef front reef slope in Guam from < 1m to >30m. It is uncommon or rare (e.g. GBR; American Samoa) while it is abundant elsewhere. Heliopora zones have been described in the Marshall Islands and where it is considered as the most common coral (Emory et al. 1954; Wells, 1954a).

Feeding and Food

Heterotrophic and autotrophic by virtue of its zooxanthellae symbiosis. Prey capture is tentacular using nematocysts. Other sources of nutrition may be dissolved organic material and suspension feeding.

References

Babcock, R. C. (1990). Reproduction and development of the blue coral *Heliopora coerulea (Alcyonaria: Coenothecalia). Mar. Biol 104:475-481.*

Bayer F. 1973. Colonial Organization in Octocorals, In: Boardman R.S., Cheetham A.H. and W.A. Oliver (eds.). *Animal Colonies: Development and Function Through Time. Dowden, Hutchinson and Ross Stroudsburg, Pa. USA*

Bayer, F. M. 1981. Key to the genera of Octocorallia exclusive Pennatulacea (Coelenterata: Anthozoa) with diagnoses of new taxa. Proc. Biol. Soc. Wash. **94** (3): 902- 947.

Bouillon J. and Houvenaghel-Crevecoeur N. 1970. Etude monographique du Heliopora de Blainville (Coenothecalia-Alcyonaria-Coelenterata). Musee Royal De L=Afrique Central, Trevuren. Annales Sciences Zoologiques 178: 1-83.

Emery L.O., Tracy J.I. Ladd H.S. 1954. Geology of Bikini and nearby atolls. Prof. Pap. US Geol. Survey 260A:1-265.

Hyman, L.H. 1940. Chapter VII. Metazoa of the tissue grade of construction Bthe radiate phyla-Phylum Cnidaria. In: The Invertebrates: Protozoa through Ctenophora Vol. 1. McGraw-Hill, New York, pp. 365-696.

Hill, D. 1960. Possible intermediates between Alcyonaria, Tabulata and Rugosa, and Rugosa and Hexacorallia. 21st Geol. Congr. 22:51-58.

Lang, J., 1973. Interspecific aggression by scleractinian corals: 2. Why the race is not only to the swift. Bull. Mar. Sci., *23*(2): 260-279.

Randall, R.H. (1977). Corals. Univ. Guam Mar. Lab. Tech. Rep. 31:63-92.

U.S. Army Corps Engineers. Pac. Ocean Div. (1980). American Samoa Coral Reef Inventory. Development Planning Office, Amer. Samoa Govt.

Veron J. E. N. 1986: *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.

Weingarten R.A. 1992. Notes on the reproduction and development of the *Heliopora coerulea*, the blue coral. FAMA 15 (1): 160-170.

Wells J.W. (1954a). Recent corals of the Marshall Islands. US Geol. Surv. Prof. Pap. 260: 1-260: 285-486.

Zann, L. P. & L. Boulton (1985). The distribution, abundance and ecology of the blue coral Heliopora coerulea (De Blainville) in the Pacific. Coral Reefs 4 (2): 125-134.

14. *Tubipora Musica* (Linnaeus, 1758) (organ-pipe coral or star polyps)

Important Summary Documents

Veron (1986) describe the species.

Taxonomic Issues

Subclass Alcyonaria (=Octocorallia); Order Stolonifera; Family Tubiporidae; Genus Tubipora with one species *Tubipora musica*

Four nominal species, probably one true species (Veron, 1986).

Order Stolonifera may be considered a sub-order, with the Order Alcyonacea. Two genera present, *Tubipora* and *Pachyclavularia,* often confused with *Clavularia spp.* One form has tentacles which look like *Alveopora* though eight tentacles.

Habitat Utilization

Requires high illumination and strong circulation through wave action or currents. Abundant in shallow lagoons in turbid water. Also found on reef slopes and in deep water with clear or turbid water. In back reef locations, large heads form in sand or coral rubble. On the reef flat the colonies are smaller and encrusting (Sprung and Delbeek, 1997).

Life History

Adult: Appearance and Physical Characteristic

Colonies are massive, formed by long, parallel, calcareous tubes (stolons) of fused spicules connected by horizontal platforms. The tubes contain the polyps (zooids), each of which has eight pinnate or feather-like tentacles. The skeleton is a permanent dark-red colour. Polyp colour greenish-brown or grey polyps (Veron, 1986; Barnes 1987).

Age, Growth, Longevity

Asexual growth by budding from the solenial canals. Linking of polyps by outward growth from the body wall. The secondary stolon are platform-like and the scerites fuse producing hard massive colonies.

Distribution

Extends from the Red Sea and west Africa, east to Fiji and the Marshall Is. Southerly distribution from south of Madagascar and south Western Australia, north to the Kyushu Is., Japan. Not present in Hawaii, though in Guam and the CNMI.

Feeding and Food

Heterotrophic, autotroph with zooxanthellae

Reproductive Strategies

Sexual and asexual. Sexual reproduction is unknown in *Tubipora musica.* An example of other genera within the family may provide an analogous understanding. Morphologically similar, *Briareum stechei, Pachyclavularia violacea* was found to be dioecious external brooder with the developing planulae residing just beside the mouth. The reddish-brown planulae were released between 11 and 13 days after the full moon in November (Alino and Coll, 1989). The colour of the planulae suggests the presence of zooxanthellae.

References

Alino, P.M. and Coll, J.C. 1989. Observations of the synchronized mass spawning and post-settlement activity of octocorals on the Great Barrier Reef, Australia: Biological aspects. Bull. Mar. Sci. 45:697-707.

Barnes, R. D. (1987). Invertebrate zoology. Saunders Colledge, Philadelphia.

Sprung, J. & J. C. Delbeek 1997. The Reef Aquarium, vol. 2. Ricordea Publishing, Miami, USA.

Veron J. E. N. 1986. *Coral of Australia and the Indo-Pacific.* Angus and Robertson. ISBN 0 207 15116 4.