A Guidebook of Introduced Marine Species in Hawaii

Edited by
L. G. Eldredge and C. M. Smith






Bishop Museum Technical Report 21
August 2001

Sponsored by grants from the Packard Foundation, U.S. Fish and Wildlife Service, and National Marine Fisheries Service to B.P. Bishop Museum and the University of Hawai'i

A Guidebook of Introduced Marine Species in Hawai'i

Edited by
L. G. Eldredge and C. M. Smith

Bishop Museum Technical Report 21
August 2001

SPECIAL THANKS

Special thanks are extended to the David and Lucile Packard Foundation and the U.S. Fish and Wildlife Service for their generous support of the marine alien species workshop; thanks are also extended to the Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service for support of publication of this guidebook. Much of the work presented here was originally supported by the Hawaii Coral Reef Initiative to Bishop Museum and the Department of Botany, University of Hawaii. This guide could not have been completed without the efforts of the Department of Natural Science, Bishop Museum and the Department of Botany, University of Hawaii-Manoa.

Cover:
Top row, left to right: *Hypnea musciformis*, *Gracilaria salicornia*, *Cladophora sericea*
Bottom row, left to right: *Mycale armata*, *Carijoa riisei*, *Chthamalus proteus*

NONINDIGENOUS MARINE INVERTEBRATES

Ralph C. DeFelice

Lucius G. Eldredge

James T. Carlton

Contribution No. 2001-005 to the Hawai'i Biological Survey

NONINDIGENOUS INVERTEBRATES

Ralph C. DeFelice, Lu G. Eldredge, and James. T Carlton

Introduction

Animals have been introduced throughout the world by humans, either accidentally or intentionally. When in a new environment, introduced animals can compete with native ones for food or space; introduce new pests, parasites, or pathogens; and generally cause a disruption in the native environment.

Through the Hawaii Biological Survey at Bishop Museum, a count of the total number of species in the Archipelago has been compiled. In 1999, the time of the last tally, there were 23,150 known species of terrestrial and aquatic algae, plants and animals, including 5047 nonindigenous species (~ 20%). The total number of marine and brackish water alien species in the Hawaiian Islands is 343, including 287 invertebrates, 24 algae, 20 fish, and 12 flowering plants.

The 287 alien marine invertebrate species make up about 7 % of the known marine and brackish water invertebrate fauna in the Hawaiian Islands (4099 species). Arthropods have been the most successful marine invaders, with 71 suspected alien crustacean species, while 53 alien mollusks have made it to Hawaii. Due to the large number of alien marine invertebrates in Hawaii and the limited amount of information known for most of them, we can highlight only a few of these nonindigenous species in this guidebook.

The greatest number of introduced marine invertebrates have arrived to Hawaii through hull fouling, but many have also arrived with solid ballast and in ballast water. We consider 201 species (70%) to be introduced, and 86 species (30%) cryptogenic (not demonstratively native or introduced). Two hundred forty eight (87%) have become established, 15 (5%) arrived but failed to become established, 6 (2%) were intercepted, and the population status of 18 species (6%) is unknown.

The nonindigenous invertebrate species in the Hawaiian Islands are primarily of Indo-Pacific/Philippines Islands region origin. A surprising number of species from the tropical western Atlantic/Caribbean region have invaded Hawaii as well.

This guide is intended to provide information concerning marine alien species to people who spend time in the coastal waters of Hawaii. Some of the more recent discoveries of alien species have been made by photographers and aquarium collectors. It is hoped that when individuals observe animals not previously seen, they will bring them to the attention of the appropriate people.

List of Nonindigenous Marine Invertebrates included in the guidebook

Sponges
Haliclona (Sigmadocia) caerulea Hechtel, 1965
Gelliodes fibrosa (Wilson, 1925)
Suberites zeteki (de Laubenfels, 1936)
Mycale (Zygomycale) parishii (Bowerbank, 1875)
Mycale armata Thiele, 1900

Jellyfish
Phyllorhiza punctata von Lendenfeld, 1884
Cassiopea andromeda Forskal, 1775

Hydroid
Pennaria disticha (Goldfuss, 1820)

Octocoral
Carijoa riisei (Duchassaing & Michelotti, 1860)

Anemone
Diadumene lineata (Verrill, 1869)

Polychaetes
Chaetopterus sp.
Sabellastarte spectabilis (Grube, 1878)
Salmacina dysteri (Huxley, 1855)

Bivalves
Anomia nobilis Reeve, 1859
Crucibulum spinosum (Sowerby, 1824)
Crassostrea virginica (Gmelin, 1791)
Chama macerophylla (Gmelin, 1791)

Crustaceans
Balanus amphitrite (Darwin, 1854)
Balanus eburneus Gould, 1841
Chthamalus proteus Dando & Southward, 1980
Gonodactylaceus falcatus (Forskal, 1775)
Ligia exotica Roux, 1828
Pachygrapsus fakaravensis (Rathbun, 1907)
Scylla serrata (Forskal, 1775)

Bryozoans
Schizoporella errata (Water, 1878)
Amathia distans Busk, 1886
Bugula neritina (Linnaeus, 1758)

Ascidians
Ascidia sydneiensis Stimpson, 1885
Phallusia nigra Savigny, 1816
Didemnum candidum Savigny, 1816

SPECIMEN HANDLING

The following section provides both general and taxa-specific specimen handling techniques for invertebrates likely to be found on artificial substrates such as docks and pilings.

General Techniques

- All references to formalin below mean formalin stock diluted 1:9 with seawater
- Mix alcohol with de-ionized water to avoid percipitates
- Always completely submerge specimens in preservative and make sure the specimen is not too large for the jar
- Preserving solutions (both formalin and alcohol) used to fix material rapidly becomes very acidic; if material cannot be processed promptly upon return from the field, it is advisable to change the preserving solution to avoid acidity problems; no material should remain in its initial fixing solution for more than one month
- Sort specimens and groups according to fixing requirements; do not mix hard and soft animals; some fragile specimens may be damaged or destroyed
- Soft-bodied animals or unique specimens should be sorted directly into individual specimen jars
- When labeling specimens during field collection, be aware that some live animals will eat or otherwise destroy paper labels
- Any material that may be required for DNA analysis must be either frozen or fixed in 100% ethanol
- When freezing to relax or store specimens, do not thaw and re-freeze them; defrost one, photograph, if necessary; then fix in preservative
- It is important to cross-reference any photographs to the actual specimen photographed; make sure that field labels record this
- Material which has been fixed properly in formalin can be transported damp without liquid, if it is sealed containers

Labels

Labeling is an important step in collecting any specimen. Labels should include the collectors name, date, exact location, habitat type (e.g., wooden pier piling, floating dock, patch reef, etc.), and depth of collection. Detailed notes regarding the living color of the animal are essential for the positive identification of many invertebrate groups, as most animals lose all color upon preservation. Photographing the living specimen before preservation is ideal. Labels should be placed inside collection bags or bottles as soon as possible, preferably at the time of collection. Specimens should be placed on ice in the field or quickly transported in sea water to a laboratory for sorting and preservation. In most cases, specimens should be narcotized and preserved within eight hours.

Preservation Methods for Specific Taxa

Sponges
If possible, photograph live specimens in situ to record colors and growth form. Some specimens will disintegrate when handled. Preserve in 100% alcohol, or freeze, then preserve.

Sea Anemones
If possible, photograph and relax in the field live specimens before fixing. Put in a jar with enough seawater to allow the specimens to fully expand, then freeze or add menthol or magnesium chloride (epsom salt) and leave overnight; fix in formalin by adding the correct amount to the frozen specimens making sure it mixes as it defrosts.

Hydroids
If possible, photograph live animals; narcotize large hydroids in menthol or magnesium chloride overnight prior to fixation. Fix in formalin; store in formalin or 70% alcohol.

Soft corals
If possible, photograph and relax specimens before fixing. Put in a jar with enough seawater to allow the specimens or expand fully, then freeze or adds menthol or magnesium chloride. Leave until relaxed, fix in formalin for a maximum of 12 hours; rinse thoroughly in water, store in 70% alcohol.

Flat worms [Platyhelminths]
If possible, specimens should be photographed alive. It is important that they are preserved as flat as possible. Specimens can be relaxed using menthol or magnesium chloride overnight; but this is not always successful; specimens often disintegrate. The best method is to freeze a small amount of formal in a jar; then place the specimen on top when it will freeze onto the surface of the formalin, die flat and be fixed at the same time. Add an appropriate amount of seawater to make up the solution.

Polychaete worms
These specimens can be fixed directly in formalin. Some larger species may need to be relaxed using menthol or magnesium chloride prior to fixing. Try to remove tube-dwelling species from their tubes to allow proper fixation; always retain the tubes. Many species will fragment; all fragments should be retained. Fix in formalin and store in formalin or 70% alcohol. In the case of species with calcareous tubes, transfer from formal to 70% alcohol within 24 hours of fixing.

Ectoprocts/Bryozoans
If possible, photograph alive as living colors can be useful identification features. Fix hard species in formalin, if possible, then dry; store dried. Soft or lightly calcified species should be fixed in formalin (not more than a few days); store in 70% alcohol.

Mollusks
General: Most mollusks can simply be put directly into formalin to fix and are usually stored in formalin. It can be helpful to relax snails (gastropods) specimens.

Opisthobranchs (and other reduced-shell gastropods): Specimens must be photographed alive as form and color patterns are very important diagnostic features. Specimens must be relaxed before fixing. The best method for relaxing is to put specimen in a jar with enough seawater for it to crawl around with rhinophores, gills, etc. fully extended; freeze overnight. Add enough stock formalin to frozen to make up solution of appropriate strength, make sure it is mixed as the seawater thaws. If freezing is impractical, use menthol, magnesium chloride in seawater, or iced seawater, overnight, to relax specimens. Fix in formalin; do not leave specimens in formalin for more than one week; store in 70% alcohol.

Bivalves: For species with shells that seal tightly, place a match stick or similar object between valves prior to fixation to insure that fixative reaches internal tissues. To get bivalves to gape, either warm until they relax enough or freeze them. Fix in formalin, store in formalin (except for species with very thin shells).

Crustaceans
If possible, photograph living specimens, particularly shrimps. Specimens are best fixed alive. Remove hermit crabs from their shells and tube-dwelling species from the tubes prior to fixing. Avoid putting specimens with large claws in with other animals as they may grab and damage more fragile species. It is sometimes preferable to kill large crabs individually and them put them in a communal container to fix. Fix in formalin and store in formalin or 70% alcohol. Do not freeze crustaceans unless there is no other option, as they do no fix as well after having been frozen.

Echinoderms
Echinoderms are not usually among introduced species and rarely found on docks and pilings. At any rate they should be photographed while alive. Asteroids, ophiuroids, and echinoids should be fixed in formalin and most can be dried; otherwise they should be stored in 70% alcohol. Sea cucumbers can be fixed in 100% alcohol and stored in 70% alcohol

Tunicates [Ascidians]
Compound, colonial, or other gelatinous ascidians should be photographed alive as form and color patterns are very important diagnostic features. Large solitary ascidians should be relaxed before fixing; menthol or magnesium chloride in seawater overnight is usually effective. Large solitary ascidians may also need to have preservatives injected into them to insure adequate fixation; fix in formalin; store in 70% alcohol.

[Specimen handling information modified from: Hewitt, C.L. and R.B Martin. 2001. Revised protocols for baseline port surveys for introduced marine species - Survey design, sampling protocols, and specimen handling. Centre for Research on Introduced Marine Pests, Hobart, Tasmania. Technical Report 22.]

Sigmadocia caerulea

Hechtel, 1965

Blue Caribbean sponge

Phylum	Porifera
Class	Demospongiae
Subclass	Ceractinomorpha
Order	Haplosclerida
Family	Chalinidae

Photo by R. DeFelice

Description

Growth Form

Thickly encrusting or massive (irregular, solid form) sponge with raised thick-walled volcano-shaped oscules, up to several centimeters in height.

Color

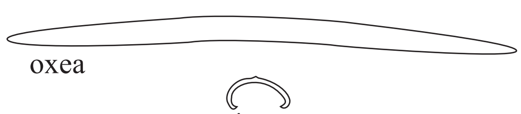
Exterior is pale blue-green, interior color is a dirty yellow.

Texture and Surface Features

Specimens are soft and easily torn. Surface is even, somewhat smooth, like fine sandpaper.

Spicules

Megascleres: bent oxeas (170-230 µm). Microscleres: sharply curved C-shaped sigmas (25 µm).



Spicules of *Sigmadocia caerulea*.

Habitat

In the Hawaiian Islands, *S. caerulea* is mainly restricted to shallow-water fouling communities (i.e. pier pilings, floating docks) of the major harbors on Oahu or associated disturbed habitats (i.e. dredged channels and artificial lagoons). It is also found on the roots of the nonindigenous Red Mangrove, *Rhizophora mangle*, native to Florida, West Indies, and South America, which is abundant in Pearl Harbor and Keehi Lagoon. In Kaneohe Bay, *S. caerulea* is found on patch reefs in southeast corner of the bay as well as the fouling community on Coconut Island floating docks.

Distribution

Hawaiian Islands

Oahu – Pearl Harbor, Honolulu Harbor, Keehi Lagoon, Kewalo Basin, Ala Wai Harbor, and Kaneohe Bay.
Kauai – Nawiliwili Harbor.
Midway Atoll – main harbor.

Mechanism of Introduction

Unintentional introduction, most likely as fouling on ships' hull.

Native Range

Caribbean or Eastern Pacific (Panama)

Present Distribution

Caribbean, eastern Pacific at Panama, main Hawaiian Islands, and Guam.

Impact

Fouling organism. Ecological impact unstudied, but probably some competition for space with native species.

Ecology

Feeding

Like all shallow-water sponges, *S. caerulea* is a filter feeder, continuously circulating water through their bodies. Microscopic food particles are removed from water by specialized collar cells. Digestion is intracellular.

Reproduction

S. caerulea is capable of asexual reproduction by fragmentation of the adult. Details regarding sexual reproduction of this species are unstudied. Many sponges are sequentially hermaphroditic. These sponges reproduce sexually by capturing sperm that has been released into the water column by adjacent individuals and transporting it to an awaiting egg deep within the sponges aquiferous system. The embryo may be released shortly after fertilization or held for further development. The embryo released is typically a motile larva, which after a time in the plankton, settles to the bottom and develops into a young sponge.

Remarks

This sponge is considered to be a recently unintentionally introduced species due to its sudden appearance in the islands and widespread disjunct geographic distribution (Caribbean and Hawaiian Islands). De Laubenfels (1950) and Bergquist (1967) both conducted sponge surveys on the floating docks on Coconut Island in Kaneohe Bay, Oahu where *S. caerulea* is now abundant. It is unlikely that this conspicuous species was present but overlooked by these researchers.

Sigmadocia caerulea from the Caribbean, was first described from Jamaica by Hechtel (1965). He reports this species as common on pilings and mangrove roots, as well as in a sandy turtle grass bed. Van Soest (1980) reports the species from mangrove roots and intertidal rocks in the Caribbean. Wulff (1996) also collected *S. caerulea* from mangrove roots in the Caribbean, but noted that eastern Pacific specimens were only found associated with the bases of branching pocilloporid corals.

Introduction to Hawaii was most likely by means of fouling on a ship's hull. *S. caerulea* was previously only known from the Caribbean and the eastern Pacific at Panama. The initial inoculation point was probably Honolulu or Pearl Harbor on Oahu. It now also occurs in the main harbor on Kauai, but was not found on any other neighboring main islands when surveys were conducted in 1997. *S. caerulea* was recently transported from Pearl Harbor to Guam on the hull of a floating dry dock. It remains to be seen whether this sponge will become established there.

References

Bergquist, P. R. 1967. Additions to the sponge fauna of the Hawaiian Islands. Micronesica. 3: 159-174.

Hechtel, G. J. 1965. A systematic study of the Demospongiae of Port Royal, Jamaica. Peabody Mus. Nat. Hist. Bull. 20: 1-103.

Laubenfels, M. W. de. 1950. The sponges of Kaneohe Bay, Oahu. Pac. Sci. 4(1): 3-36.

Soest, R.W.M. van. 1980. Marine sponges from Curacao and other Caribbean localities. Part II. Haplosclerida. Stud. Fauna Curacao. 62(191): 1-173.

Wulff, J. 1996. Do the same species of sponges live on both sides of the isthmus of Panama? in Recent Advances in Sponge Biodiversity and Inventory and Documentation, Bull. Inst. Royal Sci. Nat. Belgique. 66: 165-173.

Gelliodes fibrosa

(Wilson, 1925)

Gray encrusting sponge

Phylum	Porifera
Class	Demospongiae
Order	Haplosclerida
Family	Niphatidae

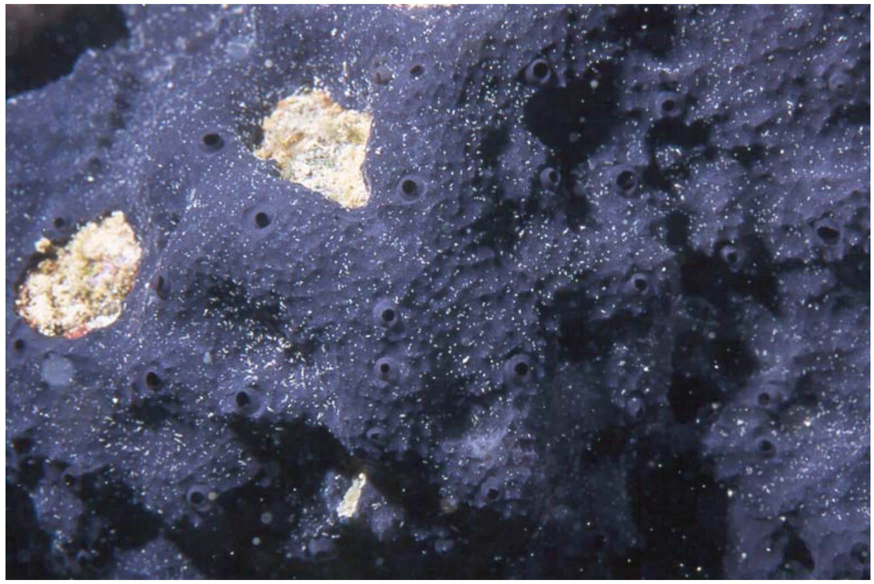


Photo by R. DeFelice

Description

Growth Form

Most commonly occurring morphology is a thickly encrusting mat with anastomosing and meandering branches, some branches may be erect.

Color

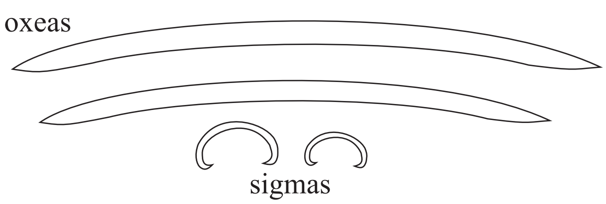
Exterior color is blue-gray, interior grayish beige.

Texture and Surface Features

Spongy, fibrous, elastic, tough. Surface is variable, smooth to irregularly conulose, with protruding tufts of fibers.

Spicules

Megascleres: curved oxeas (160-180 µm)
Microscleres: small sigmas (15 µm)



Spicules of *Gelliodes fibrosa*

Habitat

In the Hawaiian Islands, *G. fibrosa* is mainly restricted to shallow-water fouling communities (i.e. pier pilings, floating docks) of the major harbors or associated disturbed habitats (i.e. dredged channels and artificial lagoons) on Oahu, Kauai and Maui. In Kaneohe Bay, *G. fibrosa* is found on patch reefs in southeast corner of the Bay as well as the fouling community on Coconut Island floating docks. On patch reefs, it is typically found encrusting the shaded underside of plate corals.

Branching morphology of *Gelliodes fibrosa* (photo R. DeFelice).

Gelliodes fibrosa

Distribution

Hawaiian Islands

Oahu - leeward coast harbors, and Kaneohe Bay
Maui - Kahului Harbor
Kauai - Nawiliwili Harbor

Native Range

Philippines

Present Distribution

Philippines, main Hawaiian Islands, and possibly Guam

Mechanism of introduction

Unintentional introduction, as fouling on ships' hulls

Impact

Fouling organism. Ecological impact unstudied, but observations suggest competition for space with native invertebrates. Possible threat to corals in protected habitats, such as Kaneohe Bay.

Ecology

Feeding

Sponges are filter feeders, continuously circulating water through their bodies. Microscopic food particles are removed from water by specialized collar cells. Digestion is intracellular (phagocytosis and pinocytosis).

Reproduction

Like most sponges, *G. fibrosa* is probably capable of asexual reproduction by fragmentation of the adult. Details regarding sexual reproduction of this species are unknown. (See **Reproduction** of *Sigmadocia caerulea* for general description of sponge reproduction.)

Remarks

Although the holotype remains to be examined, spiculation and skeletal details of the Hawaiian specimens agree well with *Gelliodes fibrosa* (Wilson 1925) first described from the Philippines and then later by de Laubenfels (1935). This species is not recorded elsewhere to date in the Indo-Pacific except the Philippines. This sponge was found to be abundant in 1997 on hull of a floating dry-dock in Pearl Harbor, Oahu brought from the Philippines in 1992. *G. fibrosa* was also recently transported to Guam (1999) on the hull of the very same dry-dock, but it's current population status there is unknown.

We consider this abundant and conspicuous species to be nonindigenous and it's presence in the Hawaiian Islands to be the result of a recent unintentional introduction, probably as fouling on the hull of a ship or floating dry-dock. It currently occurs in areas that have been extensively surveyed by sponge experts de Laubenfels (1940s and 50s) and Bergquist (1960s), and could not have been overlooked. It has become established in Pearl and Honolulu Harbors and Kaneohe Bay (Oahu), Kahului Harbor (Maui), and Nawiliwili Harbors (Kauai). It was not yet present in harbors on the island of Hawaii when surveys were conducted there in 1996.

References

De Laubenfels, M.W. 1935. A collection of sponges from Puerto Galera, Mindoro, Philippine Islands. Phil. J. Sci. 156(3):327-336.

Suberites zeteki

(de Laubenfels, 1936)

Lobate sponge

Phylum Porifera
Class Demospongiae
Order Hadromerida
Family Suberitidae

Photo by J. Hoover

Description

Growth Form

Encrusting to massive, usually with large lobate or digitate projections.

Color

External color variable, usually red or red-orange, but also yellow, dark green, greenish purple, or turquoise; internal color always yellow-ochre.

Texture and Surface Features

Texture dense, flexible, rubbery, but easy to tear; like cheese. Surface generally smooth, some specimens with goose-bumps

Spicules

Straight sharply pointed tylostyles, large variation in size 300-700 µm, some smaller ones with irregularly shaped or lumpy heads; although ectosome consists of brushes of smaller tylostyles of nearly uniform size (300 µm), no distinct size classes are evident

Spicules of *Suberites zeteki.*

Habitat

Common as fouling in harbors, especially those with some estuarine conditions, and in Kaneohe Bay, primarily on floating docks, dock pilings and mangrove roots, also on hulls of ships.

Distribution

Hawaiian Islands

Oahu – all leeward harbors and Kaneohe Bay
Kauai – Nawiliwili Boat Harbor

Native Range

Caribbean or west coast Panama

Present Distribution

Caribbean, Panama, Hawaiian Islands, Guam

Mechanism of Introduction

Unintentional introduction, most likely as fouling on ships' hull.

Impact

Fouling organism. Ecological impact unstudied, some competition for space with native species likely.

Ecology

Reproduction

Like all sponges, *S. zeteki* is capable of asexual reproduction by fragmentation of the adult. Details regarding sexual reproduction of this species are unknown. (See **Reproduction** of *Sigmadocia caerulea* for general description of sponge reproduction.)

Feeding

Sponges are filter feeders, continuously circulating water through their bodies. Microscopic food particles are removed from water by specialized collar cells. Digestion is intracellular.

Remarks

De Laubenfels (1950) thought *S. zeteki* to be the most abundant in Hawaii, especially in shallow-water protected environments such as boat harbors and embayments. Recent observations of sponge populations in these habitats around Oahu, suggest that the more recently introduced sponge, *Mycale armata*, not present during de Laubenfels' time, is now more abundant and widespread.

De Laubenfels (1950) considered the Hawaiian specimens to be identical to *Laxosuberites zeteki* which he described in 1936, found at both ends of the Panama Canal. We have examined the holotype of *L. zeteki* and concur with de Laubenfels' determination.

Mycale cecilia de Laubenfels 1936, a common West Indian species, is also very common in shallow water locations such as Honolulu and Pearl Harbors, leading him to speculate that: "The 2 Panamanian forms conceivably may have been bought to Hawaii on ship bottoms, one being abundant on those [ships] dry-docked at Pearl Harbor, or conversely, they may have been taken from Hawaii to Panama."

References

De Laubenfels, M.W. 1950. The sponges of Kaneohe Bay, Oahu. *Pac. Sci*. 4(1): 3-36.

Mycale (Zygomycale) parishii

(Bowerbank, 1875)

Red-brown branching sponge

Phylum Porifera
Class Demospongiae
Order Poecilosclerida
Family Mycalidae

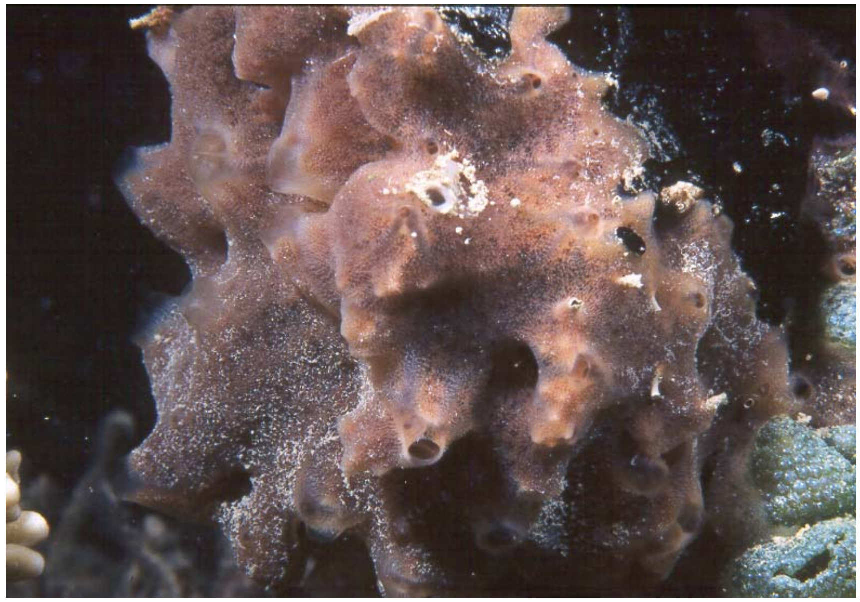


Photo by R. DeFelice

Description

Growth Form

Thin encrusting to large arborescent, cylindrical digitate branches, few bifurcations, attached to substrate with basal holdfast.

Color

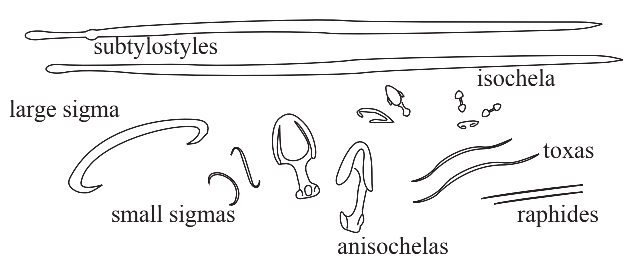
Color red-brown (most common), brownish purple, or dirty yellow (encrusting form).

Texture and Surface Features

Soft, spongy, elastic. Surface smooth to uneven with with tangential spicule skeleton.

Spicules

Megascleres: subtylostyles (320 µm)
Microscleres: sigmas (2 sizes, 25 and 80 µm), toxas, raphides, palmate anisochelae (2 sizes, 20 and 45 µm), and palmate isochelae (10 µm).



Spicules of *Zygomycale parishii*

Habitat

In the Hawaiian Islands, this sponge is mainly restricted to shallow-water fouling communities (i.e. pier pilings, floating docks) of the major harbors on Oahu or associated disturbed habitats (i.e. dredged channels and artificial lagoons). In Kaneohe Bay, is found on patch reefs in southeast corner of the bay as well as the fouling community on Coconut Island floating docks.

Distribution

Hawaiian Islands

Oahu – Pearl Harbor, Honolulu Harbor, Keehi Lagoon, Barber's Point, and Kaneohe Bay.
Maui – Kahului Harbor.

Native Range

Caribbean

Present Distribution

Caribbean, Brazil, eastern Pacific at Panama, main Hawaiian Islands, Indo-Malay Region, Australia, Indian Ocean.

Mechanism of Introduction

Unintentional introduction, most likely as fouling on ships' hull.

Impact

Fouling organism. Ecological impact unstudied, but observations suggests competition for space with native species.

Ecology

Reproduction

Like all sponges, *M. parishii* is capable of asexual reproduction by fragmentation of the adult. Details regarding sexual reproduction of this species are unknown. (See **Reproduction** of *Sigmadocia caerulea* for general description of sponge reproduction.)

Feeding

Sponges are filter feeders, continuously circulating water through their bodies. Microscopic food particles are removed from water by specialized collar cells. Digestion is intracellular.

Remarks

De Laubenfels (1950) recorded this species first from Kaneohe Bay in 1947, and further noted that it was abundant on the hulls of vessels that remained for a year or more in Pearl Harbor. He considered it to be a native species providing a biogeographical link to East Indian fauna. At the time, *M. parishii* was previously known from the Indian Ocean, Indonesia, and Australia. It has since been reported in New Caledonia, Jamaica and Brazil (Hechtel 1965). Bergquist (1967) again recorded it from the floating docks on Coconut Island, Oahu and considered it to be introduced.

This species is considered to be an unintentionally introduced species to Hawaii due to its widespread distribution and affinity for the fouling community and associated disturbed habitats.

References

Bergquist, P. R. 1967. Additions to the sponge fauna of the Hawaiian Islands. Micronesica. 3: 159-174.

de Laubenfels, M. W. 1950. The sponges of Kaneohe Bay, Oahu. Pac. Sci. 4(1): 3-36.

Hechtel, G.J. 1965. A systematic study of the Demospongiae of Port Royal, Jamaica. Peabody Mus. Nat. Hist. Yale. Bull. 20.

Mycale armata

Thiele, 1900

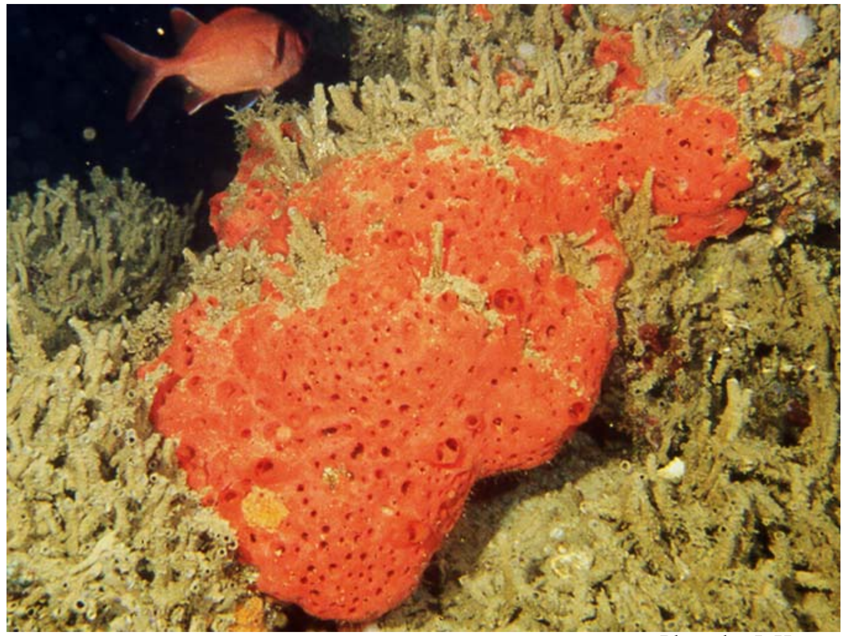


Photo by J. Hoover

Orange sponge

Phylum Porifera
Class Demospongiae
Order Poecilosclerida
Family Mycalidae

Description

Growth Morphology

Thickly encrusting, cushions to lobate-massive. Individuals can grow quite large, up to 1 m diameter and 0.5m thick or larger.

Color

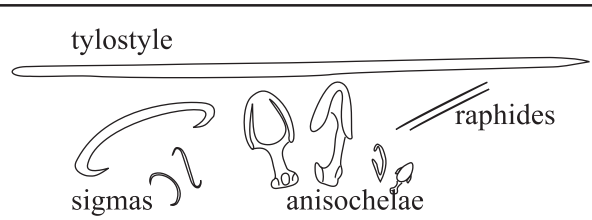
External color bright red-orange, internal same.

Texture and Surface Features

Sponge is firm, but compressible, tearing easily. Oscules are large and conspicuous with raised membranous lip, scattered evenly over surface. Surface is uneven, but smooth with large "keyhole" ostia. The interior is cavernous, and often packed with small ophiuroids (*Ophiactis* cf. *savignyi*).

Spicules

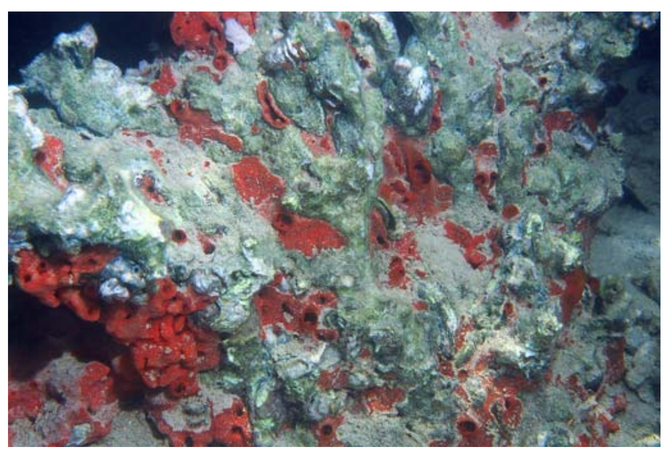
Megascleres: tylostyles
Microscleres: sigmas (2 sizes), palmate anisochelae (2 sizes), and raphides.



Spicules of *Mycale armata*

Habitat

In the Hawaiian Islands, *M. armata* is mainly restricted to shallow-water fouling communities (i.e. pier pilings, floating docks) of the major harbors on Oahu or associated disturbed habitats (i.e. dredged channels and artificial lagoons). In Kaneohe Bay, *M. armata* is found on patch reefs in southeast corner of the bay as well as the fouling community on Coconut Island floating docks.



Mycale armata in Kaneohe Bay permeating dead *Porites compressa* head (photo R. DeFelice)

Distribution

Hawaiian Islands

Oahu – Pearl Harbor, Honolulu Harbor, Keehi Lagoon, Barber's Point Harbor, and Kaneohe Bay.
Maui – Kahului Harbor.

Native Range

Australia (GBR); Torres Straits; Indo-Malay region

Present Distribution

Native range, and main Hawaiian Islands

Mechanism of Introduction

Unintentional introduction, most likely as fouling on ships' hull.

Impact

Fouling organism. Ecological impact unstudied, but observations suggests competition for space with native sponge and coral species. In Kaneohe Bay, this sponge appears to be overgrowing some coral on patch reefs, especially *Porites compressa.*

Ecology

Feeding

Sponges are filter feeders, continuously circulating water through their bodies. Microscopic food particles are removed from water by specialized collar cells. Digestion is intracellular.

Reproduction

Like most sponges, *M. armata* is probably capable of asexual reproduction by fragmentation. Details regarding sexual reproduction of this species are unstudied.

Remarks

Mycale armata is considered to be a recently unintentionally introduced species to Hawaii due to its sudden appearance in the islands. This bright orange sponge is the largest, most conspicuous sponge in the harbors of Oahu and in Kaneohe Bay, where the most extensive surveys of sponges in the Hawaiian Islands were conducted. It is very difficult to imagine this species could have been overlooked by these experienced researchers.

Unlike the other alien sponges reported here, which appear to be relatively benign introductions, this species may present a real threat to the lagoon-patch reef communities of Kaneohe Bay (see Impact).

Refereces

Bergquist, P. R. 1967. Additions to the sponge fauna of the Hawaiian Islands. Micronesica. 3: 159-174.

de Laubenfels, M. W. 1950. The sponges of Kaneohe Bay, Oahu. Pac. Sci. 4(1): 3-36.

Phyllorhiza punctata

von Lendenfeld, 1884

White-spotted jellyfish

Phylum Cnidaria
Class Scyphozoa
Order Rhizostomeae
Family Magistiidae

Photo J. Grovhoug

Description

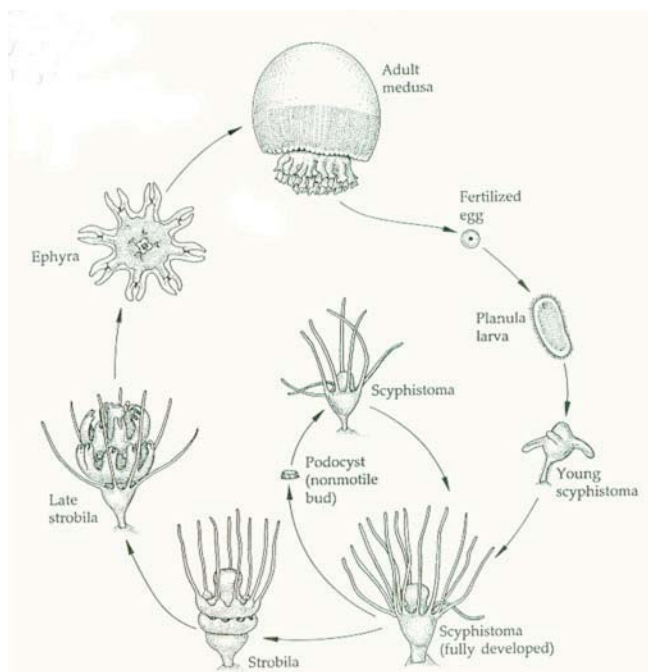
The bell of this large jellyfish may reach 50 cm in diameter. It is typically bluish-brown with many evenly distributed opaque white spots. It has eight thick transparent branching oral arms which terminate with large brown bundles of stinging cells. From each oral arm hangs a longer ribbon-like transparent appendage.

A superficially similar, but smaller species of jellyfish, *Mastigias* sp. (pictured below), is also thought to be an alien.

The similar, and also alien, species *Mastigias* sp. (photo T. Kelly)

Habitat

In Hawaii these jellyfish are found swimming near the surface in the murky waters near estuaries in harbors and embayments. Nothing is known about the habitat of the tiny benthic stages of this species in Hawaii.



The life-cycle of a typical jellyfish. Note the pelagic stages (ephyra, medusa and larva) and the benthic stages (scyphistoma and strobila). These different stages allow the jellyfish to be introduced by different mechanisms (e.g., pelagic stages transported in ballst water, or benthic stages transported as fouling on a ships' hull.). (from Brusca and Brusca 1990.)

Phyllorhiza punctata

Distribution

Hawaiian Islands

Oahu – Pearl and Honolulu Harbors, Ala Wai Canal and Yacht Harbor, Kaneohe Bay.

Native Range

Australia

Present Distribution

Australia, Hawaiian Islands, Caribbean, Gulf of Mexico.

Mechanism of Introduction

Unintentional, as ship-fouling scyphistomae or as ephyrae in ballast water.

Impact

Ecological impact unstudied in Hawaiian Islands, but these jellyfish are known to eat planktonic crustaceans and fish eggs and larvae elsewhere. A population explosion of *P. punctata* in the Gulf of Mexico, where it is an alien species, appeared to threaten the local fish populations and other commercially important species such as shrimp, menhaden, anchovies, and crabs. No comparable population fluctuations are known to occur in Hawaiian waters, but it has been reported that this jellyfish appears to be more common in winter months.

Ecology

Feeding

Phyllorhiza has stinging cells or nematocysts in its tentacles, which are used for protection and capturing plankton.

Reproduction

Basic cnidarian reproduction (see figure on previous page) involves an asexually reproducing polyp stage, alternating with a sexually reproducing medusoid stage. This reproductive strategy is known as "*alternation of generations*". The scyphozoan reproductive cycle is typically dominated by the medusoid stage. The adult planktonic **medusa** is commonly referred to as a jellyfish. The planktonic **planula** larvae of the sexually reproducing medusa typically settles to the bottom where it attaches and grows (**scyphistoma** stage). It may then either directly form additional scyphistoma via a process of budding, and/or develop into a **strobila**, a benthic form which asexually produces and releases young medusa known as **ephyrae**. This alternation of generations may facilitate the transport of jellyfish by shipping through ballast water (planktonic planula, ephyrae or medusa) or fouling (benthic scyphistoma or strobila).

Remarks

Under the name *Cotylorhizoides pacificus*, Cutress (1961) indicated that this Indo-Pacific jellyfish was introduced from the Philippine Islands, as ship-fouling scyphistomae, into Pearl Harbor between 1941-1945. It was restricted to Pearl Harbor until about 1950, but then in 1953-54 it appeared in Kaneohe Bay (Cutress, 1961). Devaney and Eldredge (1977) noted that this rhizostomid "certainly appears to be *P. punctata"*. Wrobel and Mills (1998), regard it as an Indo-Pacific species also found in Hawaii and as introduced to the western tropical Atlantic Ocean. Cooke (1984) felt that the taxonomy of the Hawaiian population was unresolved, and that it should be referred to simply as a "mastigid". We tentatively retain the name *Phyllorhiza punctata* for convinience.

References

Cooke, W.J. 1984. New scyphozoan records for Hawaii: *Anomalorhiza shawi* Light, 1921, and *Thysanostoma loriferum* (Ehrenberg, 1835); with notes on several other rhizostomes. Proc. Biol. Soc. Wash. 97:583-588.

Cutress, C.E. 1961. [Comment on introduced jellyfish in Hawaii] in: Doty, M.S., 1961, *Acanthophora*, a possible invader of the marine flora of hawaii. Pacific Science. 15(4): 547-552.

Devaney, D.M. and L.G. Eldredge. 1977. Class Scyphozoan. in Reef and Shore Fauna of Hawaii. Section 1: Protozoa through Ctenophora. Bishop Museum Spec. Pub. 64(1).

Wrobel, D. and C. Mills. 1998. Pacific Coast Pelagic Invertebrates. Sea Challengers, Monterey. 108 p.

Cassiopea andromeda

Forskal, 1775

Upside-down jellyfish

Phylum Cnidaria
Class Scyphozoa
Order Rhizostomeae
Family Cassiopeidae

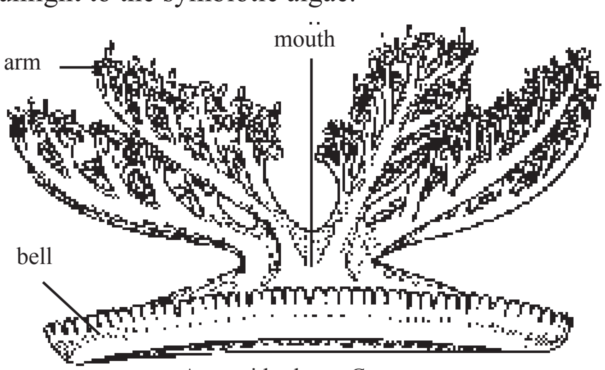
Photo by J. Hoover

Description

This jellyfish usually lies mouth upward on the bottom, in calm shallow water, gently pulsating its bell to create water flow over it's arms. The bell of *Cassiopea* is yellow-brown with white or pale spots and streaks. The outstretched arms are also brownish with extended frilly tentacles. Adults can grow to 30 cm in diameter. They are often mistaken as sea anemones.

Habitat

Cassiopea are typically found in shallow lagoons, intertidal sand or mud flats, and around mangroves. *Cassiopea* feed on drifting zooplankton. Individuals also harbors photosynthetic dinoflagellate algae that provides food to the jellyfish. The zooxanthellae live in the tissues on the ventral surface of the jellyfish, and the jellyfish sits on the bottom upside-down to provide sunlight to the symbiotic algae.



An upside-down *Cassiopea*.

Distribution

Hawaiian Islands

Throughout main Hawaiian Islands.

Native Range

Indo-Pacific

Present Distribution

Indo-Pacific and Hawaiian Islands

Mechanism of Introduction

Unintentional introduction, juvenile benthic stage in ships' hull-fouling or pelagic stage in ballast water.

Impact

A nuisance species, which can sting people. Ecological impact unstudied.

Ecology

Feeding

Like other jellyfish, *Cassiopea* has stinging cells or nematocysts in both its epidermis and gastrodermis, which is used for protection and capturing food. A sting from *Cassiopea* may result in skin welts, skin rash, itching, vomiting and skeletal pains depending on the individuals sensitivity to the toxin of the nemato-cysts.

Reproduction

Basic cnidarian reproduction involves an asexually reproducing polyp stage, alternating with a sexually reproducing medusoid stage, as described for *Phyllorhiza punctata*. This jellyfish is dioecious; an adult female jellyfish produces eggs and holds them until a male jellyfish releases sperm into the water. The female uses her arms and tentacles to gather sperm from the water to fertilize the eggs.

Remarks

Pacific basin *Cassiopea* are currently placed in the one species *C. andromeda* (Hummelinck, 1968), but have been reported from Hawaii under two separate names, *Cassiopea medusa* Light 1914 and *Cassiopea mertensii* Brandt 1835. Cooke (1984) noted that these *Cassiopea*, with "their pseudobenthic habits are the most improbable adult immigrants." As *C. medusa*, Chu and Cutress (1954) note that it was "common the year round in bays and salt-water canals."

Cutress (1961) considered it to be introduced from the Philippines by ships as hull-fouling scyphistome to Pearl Harbor between 1941-1945. It was restricted to Pearl Harbor until about 1950, when it appeared in Honolulu Harbor and Ala Wai Canal. As *C. mertensii* Brandt, Uchida (1970) reported it from "the sandy bottom at a depth of 2 feet from Kaneohe Bay." Under the name *C. mertensii*, it was previously known from only several locations in the South Pacific Ocean, especially the Caroline Islands. *Cassiopea* were seen in the early 1990s in fishponds on Molokai and in fishponds in Waikaloa area of the island of Hawaii .

References

Chu, G.W. and C.E. Cutress. 1954. Human dermatitis caused by marine organisms in Hawaii. Proc. Haw. Acad. Sci. 1953-54: 9.

Cooke, W.J. 1984. New scyphozoan records for Hawaii: *Anomalorhiza shawi* Light 1921 and *Thysanostoma loriferum* (Ehrenberg 1835); with notes on several other rhizostomes. Proc. Biol. Soc. Wash. 97: 583-588.

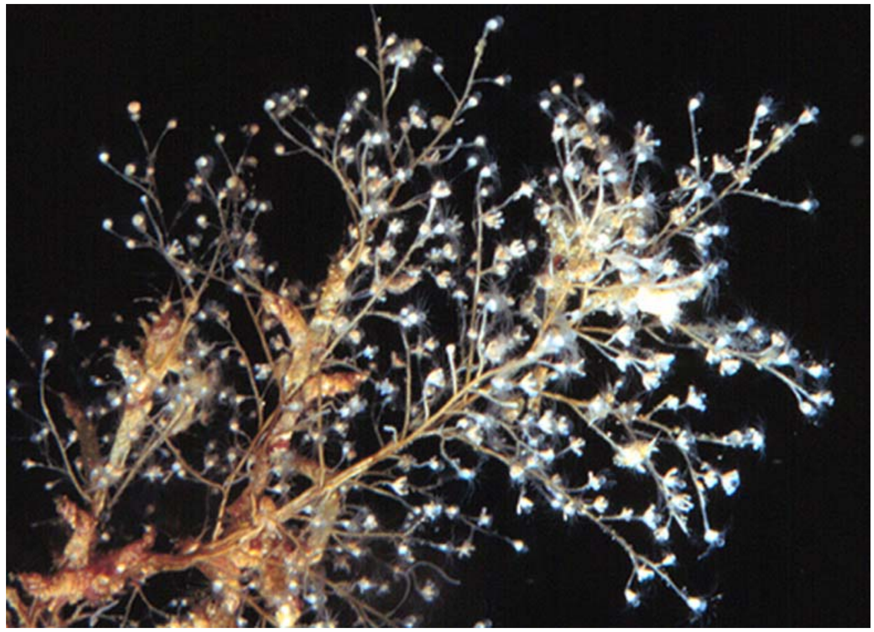
Cutress, C.E. 1961. [Comment on introduced jellyfish in Hawaii] p. 549, in: Doty, M.S. 1961. *Acanthophora*, a possible invader of the marine flora of Hawaii. Pac. Sci. 15(4): 547-552.

Hummelinck, P. W. 1968. Caribbean Scyphomedusae of the genus *Cassiopea*. Studies on the Fauna of Curacao and other Caribbean Islands. 25: 1-57.

Uchida, T. 1970. Occurrence of a rhizostome medusa, *Cassiopea mertensii* Brandt from the Hawaiian Islands. Annotat. Zool. Jap. 43:102-104.

Pennaria disticha

(Goldfuss, 1820)



Christmas tree hydroid

Phylum Cnidaria
Class Hydrozoa
Order Hydroida
Family Halocordylidae

Description

Colonies are large, as tall as 30 cm, with a dark brown to black perisarc, a protein-chitin exoskeleton which surrounds the stem and branches. This perisarc is usually overgrown with diatoms and algae, making the branches of the hydroid appear muddy brown. Branching is alternate. The polyp has a circle of 10 to 18 filiform tentacles at the base and as many as 12 capitate tentacles on the upper part of the hydranth. The polyps are white with a reddish tinge. Annulations occur on the branches which bear the polyps, and on the main stem and side branches.

Large colony of *Pennaria* in Pearl Harbor (photo J. Hoover)

Habitat

Attached to artificial and natural hard substrates where there is some water movement. Very common as fouling in harbors throughout the main islands, and commonly found on reefs usually in more protected areas or in cracks and crevices.

Distribution

Hawaiian Islands

All main Hawaiian Islands

Native Range

Western Atlantic

Present Distribution

World-wide in warm seas

Mechanism of Introduction

Unintentional, as fouling on ships' hull

Impact

Fouling organism. Ecological impact unstudied, but some competition for space with other invertebrates likely. This hydroid will sting humans, causing a mild irritation.

Ecology

Feeding

The hydroid is a carnivore, using the stinging cells in its tentacles to capture small plankton which drifts by in the currents. The feeding tentacles carry the prey to the mouth region where it is ingested whole.

Reproduction

Hydrozoan polyps can reproduce asexually by budding. The medusa (gonophores) bud off singly from the hydranth body just above the proximal tentacles. A single colony bears gonophores of one sex only. The mature medusae are similar in the two sexes; they have an elongate bell, a velum, four radial canals and four rudimentary tentacles. *Pennaria* medusae generally break away from the colony and swim about during the discharge of the sex products, but depending on environmental conditions, they may remain attached. At the onset of spawning, the ripe medusae gradually begin a rhythmic twitching. The males emit puffs of white sperm, the females eject three to six eggs. The spent medusae finally drop off, swim feebly if at all, and shrivel and die in a few hours.

Fertilization is external. In about a day, developing embryo becomes a young free-swimming planula, which will eventually settle and develop into a young hydroid colony.

Remarks

We regard this common fouling hydroid as introduced with ship fouling. It is reported, with various synonyms, from warm-water seas worldwide. Edmondson (1933) reported it (as *Pennaria tiarella*) in Pearl Harbor and Kaneohe Bay, attached to stones, pilings of old wharves, buoys, and other floats. He noted that it appeared to be identical to the Atlantic Ocean *P. tiarella* McCrady, and may have been transported to Hawaii on the bottoms of ships.

Boone (1938) redescribed *P. disticha* as a new species, *Corydendrium splendidum*, from Kaneohe Bay (later synonymized by Cooke, 1977), collected as a single large colony in 2 meters of water at low tide, in 1928. It has been widely reported by numerous authors throughout the main Hawaiian islands.

References

Boone, L. 1938. Family Clavidae. Bull. Vand. Mar. Mus. 7: 33-34.

Cooke, W.J. 1977. Order Hydroida. in: D.M. Devaney and L.G. Eldredge (eds), Reef and Shore Fauna of Hawaii, Section 1:Protozoa through Ctenophora. Bishop Mus. Spec. Pub. 64(10): 71-104.

Edmondson, C.H. 1933. Reef and Shore Fauna of Hawaii, Bishop Museum, Spec. Pub. 22.

OCTOCORAL

Carijoa riisei

(Duchassaing & Michelotti, 1860)

Snowflake coral

Phylum	Cnidaria
Class	Anthozoa
Subclass	Octocorallia
Order	Telestacea
Family	Telestidae

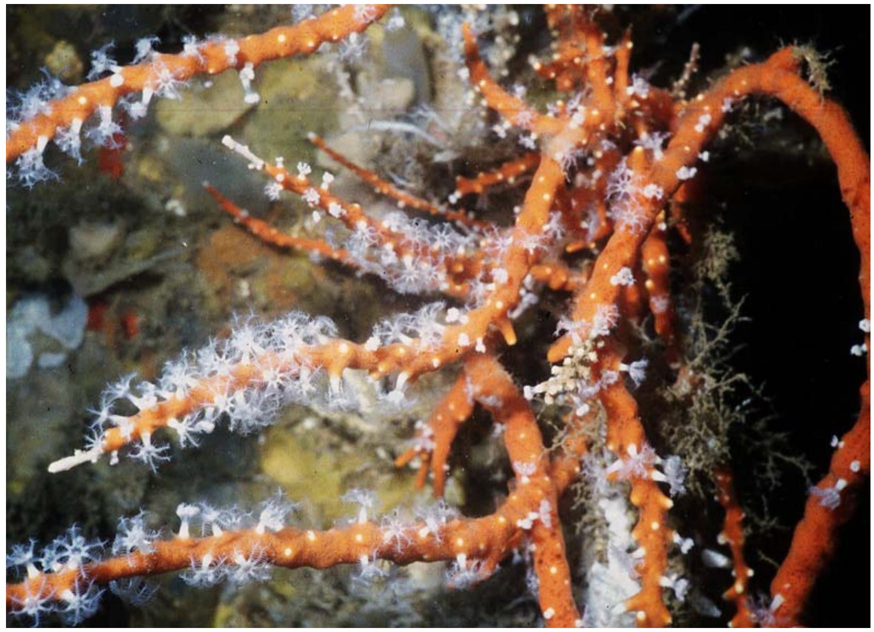
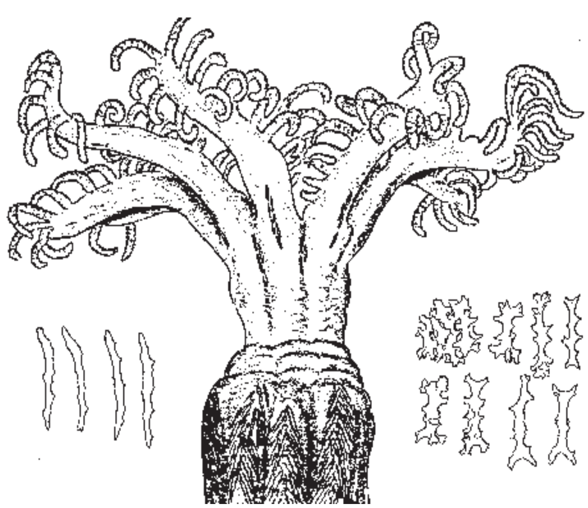


Photo S.Coles

Description

The species forms erect, branching colonies with flexible stems. Each tall axial polyp has many short lateral polyps. Polyps, when extended, have eight white frilly tentacles, like the rays of a snowflake. The long stems or branches of the octocoral are a dirty white color, but they are almost always covered with a very thinly encrusting orange-red sponge, yet to be identified. Two types of sclerites occur in the body wall.



Polyp of *Carijoa riisei* and some sclerites from body wall (from Devaney and Eldredge 1977).

Habitat

Most commonly found in the fouling community of harbors, usually on pier pilings or wrecks which are not exposed to direct sunlight. It is found outside of harbors, especially along the leeward coast of Oahu, on shipwrecks or in sheltered and shaded crevices or shallow caves on the deeper reefs.

Distribution

Hawaiian Islands

Throughout the main Islands

Native Range

Western Atlantic, from Florida to Brazil

Present Distribution

Western Atlantic, Hawaiian Islands, possibly now widespread in the Indo-Pacific (see Remarks)

Mechanism of Introduction

Unintentional, most likely as fouling on ships' hull

Impact

Fouling organism. Ecological impact unstudied, but probably some competition for space with other invertebrates.

Ecology

Feeding

Like all cnidarians, *C. riisei* has tiny stinging cells in their tentacles which enable the capture of motile zooplankton.

Reproduction

Polyps may reproduce asexually by simply splitting in two, or sexually by release and fertilization of gametes into the water column. The resulting planula larvae settle to the bottom and develop directly into young polyps.

Remarks

This orange soft coral or "snowflake coral" native to the western Atlantic Ocean from Florida to Brazil, was first found in 1972 in the fouling community in Pearl Harbor (Thomas, 1979, as *Telesto riisei*). Muzik (pers. comm.) noted that a species of *Carijoa* is now also known from Chuuk, Palau, the Philippines, "Indonesia", Australia, and Thailand: whether some of these also represent the species *riisei* is not known, although it could certainly have achieved such a wide distribution in more than 20 years of ship-mediated dispersal if it were first introduced to the Hawaiian Islands in the late 1960s or early 1970s. Colin and Arneson (1995) published photographs of *Carijoa* sp. from Chuuk, in Micronesia, and from a cement ship in Enewetak, Marshall Islands, noting that "it is a very common fouling organism found on buoys, wharves and ship bottoms, plus turbid water reefs."

References

Colin, P.L. and L.Arneson. 1995. Tropical Marine Invertebrates. Coral Reef Press, Beverly Hills. 296 pp.

Thomas, W.J. 1979. Aspects of the micro-community associated with *Telesto riisei*, an introduced alcyonarian species. MS Thesis, Zoology Dept., University of Hawaii.

Diadumene lineata

(Verrill, 1869)

Orange-striped sea anemone

Phylum	Cnidaria
Class	Anthozoa
Order	Actinaria
Family	Diadumenidae

Photo R. Manuel

Description

Small anemone with tentacular crown to 3.5 cm in diameter, 3 cm in height; column cylindrical, smooth green-gray or brown, with or without vertical orange or white stripes. Tentacles 50 to 100 in number, slender tapering, fully retractile, usually transparent, sometimes gray or light green flecked with white.

Habitat

On solid substrates (undersides of stones or shells, on pilings or floating docks) in intertidal pools or shallow-water protected areas such as harbors and embayments, often associated with mussels or oysters. May occur in brackish water.

Distribution

Hawaiian Islands

Known only from Kaneohe Bay, Oahu

Native Range

Western Pacific (Japan, China, and Hong Kong)

Present Distribution

Western Pacific, Indonesia, New Zealand, Hawaiian Islands, Pacific Coast of North America, North Atlantic

Mechanism of Introduction

Unintentional, as fouling on ships' hulls or with commercial oysters

Impact

Fouling organism. Ecological impact unstudied, but presumed minimal.

Ecology

Feeding

The anemone is a carnivore, using the stinging cells in its tentacles to capture plankton which drifts by in the currents. The feeding tentacles carry the prey to the mouth region where it is ingested whole.

Reproduction

Anemones can reproduce asexually by simply splitting themselves in half (longitudinal fission). Sexual reproduction is most likely achieved through the release of gametes by both sexes followed by external fertilization and embryonic development.

Remarks

A population of this distinctive orange-striped sea anemone was discovered on a piling on the south shore of Kaneohe Bay on February 15, 1999. Native to the Western Pacific (Japan, China, and Hong Kong), it was introduced to the North Atlantic Ocean in the 1890s and to the Pacific coast of North America in the early 1900s (Carlton, 1979). It is also known from New Zealand and Dobo in Indonesia (D. Fautin, pers. comm., 1999).

D. lineata apparently shows extreme tolerance towards abiotic factors, e.g. salinity, temperature, (Gollasch & Riemann-Zürneck 1996), which undoubtedly has contributed to its success as an invading species. It is difficult to imagine that Edmondson would have missed this species in his explorations around Oahu, and thus it may be a relatively recent (1960s and later) introduction, most likely in ship fouling.

References

Carlton, J.T. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific coast of North America. Ph.D. Dissertation, University of California, Davis. 904 pp.

Gollasch, S., & Riemann-Zürneck, K. 1996. Transoceanic dispersal of benthic macrofauna: Haliplanella lineata (Verrill, 1898) (Anthozoa, Actinaria) found on a ship's hull in a ship yard dock in Hamburg Harbour, Germany. Helgoländer Meeresuntersuchungen, 50: 253-258.

Chaetopterus sp.

Parchment worm

Phylum Annelida
Class Polychaeta
Family Chaetopteridae

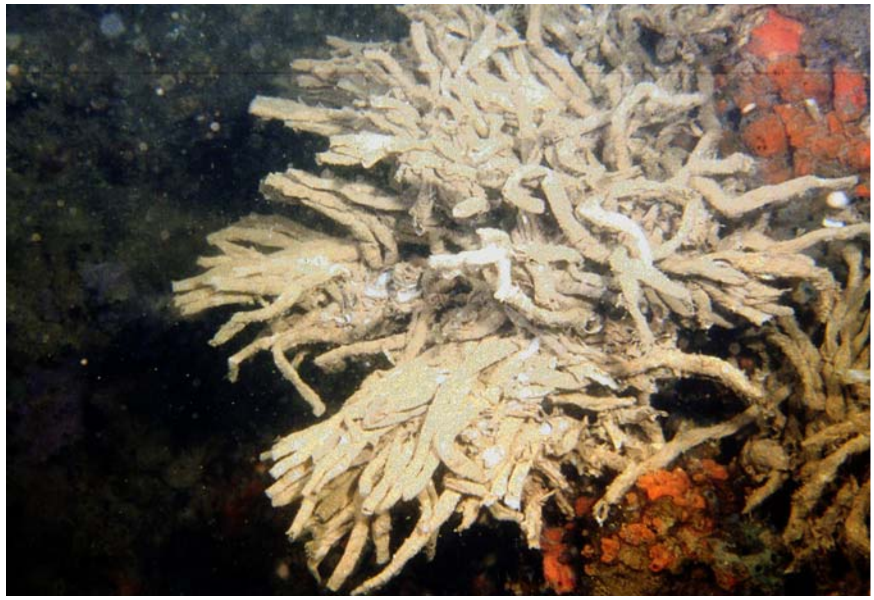
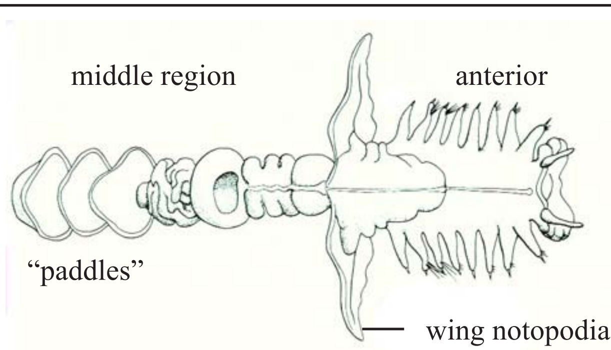


Photo J. Hoover

Description

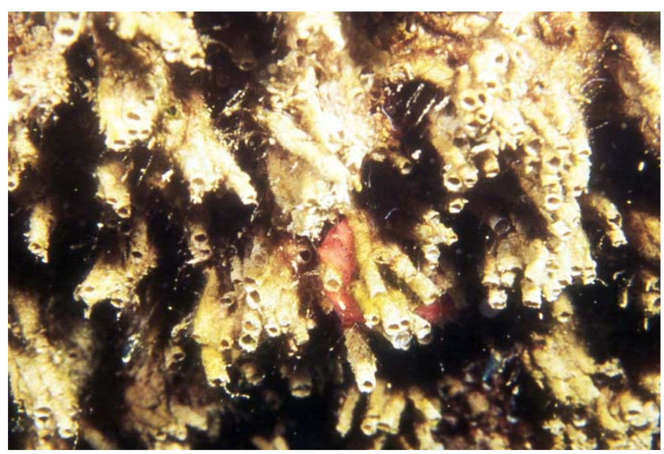
These large worms live in tough tubes (often described as parchment-like) that are usually coated with fine mud. The body of this species is divided into 3 regions. The anterior region has 8 to 12 segments and a pair of short, tapered palps and a pair of eyes. The middle region is made up of segments, the second of which has a pair of winglike notopodia; the third, fourth and fifth have fan-shaped paddles. The posterior region has 9 to 20 or more segments bearing sticklike notopodia with knobbed ends. The middle and posterior regions are green or black. Tubes are are approximately 8 to 12 cm long and 0.5 cm to 1 cm wide (from Bailey-Brock 1987).



Anterior and middles regions of *Chaetopterus* sp. (from Bailey-Brock 1987).

Habitat

Aggregations typically occur in shallow, silty water attached to solid substrates such as rock, coral rubble, and pier pilings, but can occasionally be found in a variety of reef habitats. Clumps of worms tubes are also found partially buried in sediments in protected areas.



Close-up of *Chaetopterus* tubes (photo J. Hoover).

Chaetopterus sp.

Distribution

Hawaiian Islands

Throughout main Hawaiian Islands, especially in harbors and embayments

Native Range

Unknown

Present Distribution

Probably worldwide in warm and temperate seas

Mechanism of Introduction

Unintentional, as fouling on ships' hulls or planktonic larvae in ballast water

Impact

Fouling organism. Ecological impact unstudied, but observations suggest competition for space with other invertebrates. In some areas (e.g., Pearl Harbor), *Chaetopterus* can form dense monospecific aggregations which undoubtedly affect the abundance and distribution of animals in the habitat.

Ecology

Feeding

Chaetopterus live in irregularly U-shaped tubes through which they pump water, filtering out organic particles with a mucus bag that acts as a sieve. Nodopodial paddles create the water current through the tube, while other segments bear suckers to help anchor the worm in position. When the mucus bag becomes clogged with particles, it is rolled into a ball, passed to the mouth by a ciliary tract and ingested, then a new bag is produced.

Reproduction

Certainly contributing to its success as an invader is the chaetopterids power of regeneration. Any single segment from among the first 14 can regenerate anteriorly and posteriorly to produce a complete worm. Chaetopterid worms are dioecious (having separate sexes). Gametes arise from proliferation of cells from the peritoneum, these cells are released into the coelom where they mature, before being released. After a short time in the plankton, the trochophore larvae settle and mature.

Remarks

Bailey-Brock (1976) noted that *Chaetopterus* sp. was abundant in Kaneohe Bay on the alga *Dictyosphaeria cavernosa*. Bailey-Brock (1987, as *C. variopedatus*) noted it was also "a frequent component of fouling communities". Coles et al. (1999) record its continued presence in Pearl Harbor (1996 collections). It was not, curiously, reported in Hartman (1966) nor in the works of Edmondson, covering the biota of the Islands up to the 1940s. It may have been introduced during or after World War 11, or indeed even much later in the 1960s or early 1970s. We regard it as cryptogenic.

References

Bailey-Brock, J.H. 1976. Habitats of tubicolous polychaetes from the Hawaiian Islands. Pacific Science. 30:69-81.

Bailey-Brock, J.H. 1987. Phylum Annelida. in: Reef and Shore Fauna of Hawaii, Section 2: Platyhelminthes through Phoronida and Section 3: Sipuncula through Annelida, D.M. Devaney and L.G. Eldredge (eds). Bish. Mus. Spec. Pub. 64(2 and 3): 216-454.

Coles, S.L., R.C. DeFelice, L.G. Eldredge, and J.T. Carlton. 1999. Historical and recent introduction of nonindigenous marine species into Pearl Harbor, Oahu, Hawaiian Islands. Marine Biology. 135:147-158.

Hartman, O. 1966. Polychaetous annelids of the Hawaiian Islands. Occ. Pap. B.P. Bish. Mus. 33(11): 163-252.

Sabellastarte spectabilis

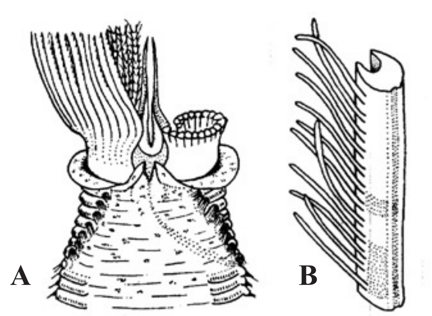
(Grube, 1878)

Featherduster worm, Fan worm

Phylum Annelida
Class Polychaeta
Family Sabellidae

Description

This large species attains 80 mm or more in length and 10 to 12 mm in width. The entire body of the worm is buff colored with flecks of purple pigment. These worms inhabit tough, leathery tubes covered with fine mud. Radioles (branched tentacles) lack stylodes (small finger-like projections on the tentacles of some sabellids) and eyespots and are patterned with dark brown and buff bands. There is a pair of long, slender palps and a 4-lobed collar. These worms are very conspicuous on reef flats and harbor structures because of their large size and banded pattern of the branchial crowns (from Bailey-Brock, 1987).



Sabellistarte spectabilis. (A) Dorsal view of collar region. (B) Part of radiole. (from Day, 1967)

Habitat

Abundant on Oahu's south shore reefs, and in Pearl Harbor and Kaneohe Bay at shallow depths, especially in dredged areas that receive silt-laden waters. Also found in pockets and crevices in the reef flat. It is especially abundant along the edges of reefs that have been dredged, as at Ala Moana and Fort Kamehameha, Oahu; it may be an indicator of waters with high sediment content (Bailey-Brock, 1976). Reported from a wide variety of coastal habitats (e.g., in holes, crevices, and matted algae at outer reef edges of rocky shores, from interstices of the coral *Pocillopora meandrina*; from under boulders in quiet water, in crevices in lava, in open coast tide pools, and from tidal channels exposed to heavy surf).

Distribution

Hawaiian Islands

Shallow water throughout main islands

Native Range

Red Sea and Indo-Pacific

Present Distribution

Western Africa, Red Sea, India, Indo-Pacific, Japan, New Caledonia, Hawaiian Islands

Mechanism of Introduction

Unintentional, probably as fouling on ships hull.

Impact

Fouling organism and popular aquarium species. Ecological impact unstudied, but most likely minimal.

Ecology

Feeding

Sabellids are suspension feeders. Cilia on the tentacles create a current that draws water and food particles to the worm. The particles are captured, sorted, and carried with mucus along a series of tracts and grooves to the mouth. Large particles are stored for use in tube building.

Reproduction

Sabellid worms can reproduce asexually by fragmentation, and can also regenerate lost body parts, including the large branchial crown. These worms are dioecious (having separate sexes). Gametes arise from proliferation of cells from the peritoneum, these cells are released into the coelom where they mature, before being released. Fertilization is external, and after a short time in the plankton, the trochophore larva settles and matures.

Remarks

This large and distinctive sabellid, has had a complex taxonomic history. It is not noted in the Hawaiian biota until after World War II. There is no material in Bishop Museum collections prior to 1946, nor is there any mention of it in the literature until 1966. It does not appear (either by name or by description) in Edmondson's books (1933, 1946), nor is it mentioned in the early fouling studies of Pearl Harbor, an environment with which Edmondson was very familiar.

On the assumption that such a large fouling species would not be overlooked, we treat it here as introduced. Since 1966, it has been treated in the Hawaiian literature as *Sabellastarte sanctijosephi* , a species originally described from the Red Sea and regarded as occurring from western Africa to the Indo-Pacific and up to Japan (Day, 1967). Hartman (1966) also synonymized *S. punctata* under *S. sanctijosephi*, the former species having been collected during the Albatross expedition in 1902 at Puata Bay and Waialea, Oahu (Hartman, 1966, as *S. indica*). Hartman (1966) noted that R. W. Hiatt collected it in 1946 at Halape, Hawaii, from a wide variety of coastal habitats. It has since been widely reported throughout the main islands.

Knight-Jones (pers. comm.) has revised the taxonomy of this worm as shown above, assigning the name *S. spectabilis* (originally described from the Philippines) to the large Hawaiian worm and resurrecting *S. punctata* as a distinct, smaller species. With this resolution, the 1902 records dissolve; in addition, it is not clear which of the above records — which range from harbor fouling habitats to open coast reef sites — would be reassignable to which species. We tentatively interpret the harbor and dredged channel populations, at least, to represent *S. spectabilis*.

References

Bailey-Brock, J.H. 1976. Habitats of tubicolous polychaetes from the Hawaiian Islands. Pacific Science. 30:69-81.

Bailey-Brock, J.H. 1987. Phylum Annelida. in: Reef and Shore Fauna of Hawaii, Section 2: Platyhelminthes through Phoronida and Section 3: Sipuncula through Annelida, D.M. Devaney and L.G. Eldredge (eds). Bishop Mus. Spec. Pub. 64(1 and 3): 216-454.

Day, J.H. 1967. A monograph of the Polychaeta of Southern Africa. Part 1 and 2. British Mus. Nat. Hist, London.

Edmondson, C.H. 1933. Reef and Shore Fauna of Hawaii. B.P. Bishop Mus. Spec. Pub. 22.

Edmondson, C.H. 1946. Reef and Shore Fauna of Hawaii, 2nd ed. B.P. Bishop Mus. Spec. Pub. 22.

Hartman, O. 1966. Polychaetous annelids of the Hawaiian Islands. Occ. Pap. B.P. Bishop Mus. 33(11): 163-252.

Salmacina dysteri

(Huxley, 1855)

Serpulid worm

Phylum Annelida
Class Polychaeta
Family Serpulidae

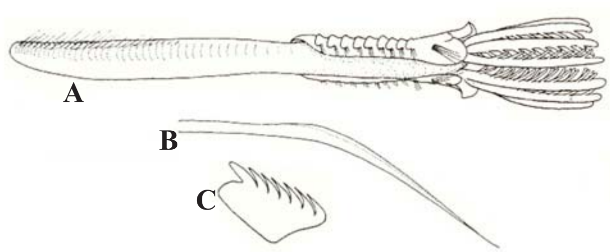
Photo by R. DeFelice

Description

This small gregarious species is characterized by having very slender, white tubes, 15 mm long and 0.5 mm wide. Aggregations of this species can form thick anastomosing bundles of tubes. The branchial crown is composed of 8 radioles, 4 on each side. Species in this genus lack an operculum. There are 7 to 9 thoracic segments; fin and blade setae occur on the first setiger and simple wingless setae and sickle setae are present on the remaining setigers (from Bailey-Brock 1987).

Habitat

Most common on hard substrates or overgrowing other fouling invertebrates in sheltered waters, especially harbors and embayments, but can be found in a variety of shallow and deep reef habitats.



Salmacina dysteri.
(A) Entire worm. (B) Collar setae. (C) Thoracic uncinus. (Day 1967)

Distribution

Hawaiian Islands

Throughout the main islands, especially in harbors.

Native Range

Unknown

Present Distribution

Cosmopolitan in warm seas

Mechanism of Introduction

Unintentional, most likely as fouling on ships hulls

Impact

Fouling organism. Ecological impact unstudied, but assumed to be minimal.

Ecology

Reproduction

These worms may reproduce asexually by transverse division. They are also hermaphroditic, and fertilization and subsequent larval development are external.

Feeding

Serpulids are suspension feeders. Cilia on the tentacles create a current that draws water and food particles to the worm. The particles are captured, sorted, and carried with mucus along a series of tracts and grooves to the mouth.

Remarks

Although nomenclatural problems surround this now-global species, we tentatively retain this name. This signature fouling harbor species is also reported in Hawaiian waters at depths to 200-600 meters and as being found across a wide variety of habitat facies in the Islands, for example, rocky intertidal, reef flats on algae, anchialine lava ponds, and reef slopes to depth (Bailey-Brock, 1976). While it may thus be that more than one species is involved, this range of habitats tentatively places this tubeworm in the cryptogenic category.

Edmondson and Ingram (1939) found it in fouling beginning in 1935 in Kaneohe Bay. Long (1974) reported it on "offshore" and Pearl Harbor fouling panels (1968), and Hartman (1966) noted that it occurred as "massed tubes fouling harbor installations during summer and fall months at Pearl Harbor and Kaneohe Bay". It's continued presence has been widely reported throughout the main islands by numerous authors.

References

Bailey-Brock, J.H. 1976. Habitats of tubicolous polychaetes from the Hawaiian Islands. Pacific Science. 30:69-81.

Edmondson, C.H. and Ingram, W.H. Fouling organisms in Hawaii. B.P. Bishop Mus. Occ. Pap. 14(14):251-300.

Hartman, O. 1966. Polychaetous annelids of the Hawaiian Islands. Occ. Pap. B.P. Bishop Mus. 33(11): 163-252.

Long, E.R. 1974. Marine fouling studies off Oahu, Hawaii. Veliger. 17: 23-39.

Anomia nobilis

Reeve, 1859

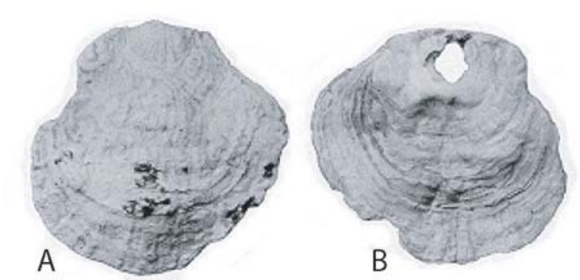
Jingle shell, Saddle oyster

Phylum Mollusca
Class Bivalvia
Family Anomiidae

Photo by R. DeFelice

Description

Jingle shells superficially resemble true oysters, but their mode of attachment, a byssal plug passing through an opening in the right (lower) valve, and their delicate translucent shells distinguish them. Shells are orbicular, irregular and distorted, and thin. The upper shell (left valve) is somewhat convex and milk-white, beige or pale green. The shells have scalelike, concentric lamellae sculpturing with slanting radiating threads. Many individuals are commonly found piled one on top of the other in the fouling community (from Kay, 1979).



Right and left valves of *Anomia nobilis*. (from Dall et al. 1938)

Habitat

A very common fouling organism, typically found on pier pilings and floating docks in harbors in characteristic stacks (one on top of the other). Also found intertidally on the under surface of flat stones.

Distribution

Hawaiian Islands

In harbors throughout the main islands

Native Range

Indo-Pacific

Present Distribution

Widespread Indo-Pacific and Hawaiian Islands

Mechanism of Introduction

Unintentional, most likely as fouling on ships' hulls

Impact

Fouling organism. Ecological impact unstudied, but observations suggest competition for space with other fouling invertebrates

Ecology

Feeding

Bivalves are suspension feeders. Water is moved through an incurrent siphon into the mantle cavity by cilia on the ctenidia (gills). Water passes over the ctenidia, food particles are extracted by the cilia, and water is expelled through an exhalent siphon.

Reproduction

Bivalves are typically gonochoristic (having separate male and female individuals), fertilization is external, and the developing larva (veliger) settles to the bottom after a time in the plankton.

Remarks

Although this brackish-water jingle shell was described from the Hawaiian Islands, it is thought to be an early ship-fouling introduction. Unlike the endemic oyster *Ostrea sandvicensis*, with which this species is often found, *Anomia nobilis* is found throughout the lndo-West Pacific (Kay, 1979). It is unlikely to have been missed in collections of some two or three decades earlier. It is thus another example of a species being first described from the site of introduction. It has been widely reported in Hawaiian waters by numerous authors.

References

Kay, E.A. 1979. Hawaiian Marine Shells. Reef and Shore Fauna of Hawaii, Section 4: Mollusca. B.P. Bishop Mus. Spec. Pub. 64(4), 653 pp.

GASTROPOD

Crucibulum spinosum

(Sowerby, 1824)

Spiny cup-and-saucer shell

Phylum	Mollusca
Class	Gastropoda
Subclass	Prosobranchia
Order	Neotaenioglossa
Family	Calyptraeidae

Photo R. DeFelice

Description

Low conical limpet-like shell with apex spirally coiled. Dorsal surface of shell ray-white with spirally arranged spines or knobby projections. Ventral surface of shell purple or black and smooth with a distinct cup-like projection (from Kay 1979).

Another introduced intertidal gastropod, *Crepidula aculeata* (Gmelin, 1791), is superficially similar to Crucibulum when viewed dorsally. The ventral is smooth with similar coloration, but with a shelf or deck, rather than than a cup.

Another alien gastropod, *Crepidula aculeata*. (Photo R.DeFelice)

Habitat

In harbors and embayments, on pier pilings, coral rubble and basalt rocks from the intertidal to 8 m.

Distribution

Hawaiian Islands

Throughout the main islands

Native Range

Southern California to Chile

Present Distribution

World-wide in warm seas

Mechanism of Introduction

Unintentional, as fouling on ships' hulls

Impact

Fouling organism. Ecological impact unstudied, some competition for space with native intertidal species likely.

Ecology

Feeding

Crucibulum spinosum is a ciliary feeder.

Reproduction

These gastropods are protandrous hermaphrodites, changing during the course of their life from a small male into a full-grown female (Kay 1979). They spawn throughout the year in Kaneohe Bay and can account for 90 percent of the veliger component in the Bay in certain areas (Taylor 1975).

Remarks

Like many nonindigenous species, this small fouling gastropod species appeared in the Hawaiian fauna soon after World War II. Keen (1971) noted an Eastern Pacific distribution from California to the Gulf to Tomé, Chile. Springsteen and Leobrera (1986) report it as introduced to the Philippines. Given the volume of ship traffic between Pearl and Honolulu Harbors and the Philippines, the appearance of *C. spinosum* in other Pacific harbors is not a surprise. It is probably now much more widespread, but goes unreported.

Edmondson (1946) appears to have been the first to remark on its presence in Honolulu Harbor. By the late 1950s it was widespread around Oahu (Burgess 1959). Ulbrick (1969) reported that it occurred on pieces of dead coral or basalt rocks dredged from sand and rock bottom at 5 to 8 meters in Kaneohe Bay and that it was also found on seawalls and experimental trays put out for oyster spat. It is now a common intertidal and shallow water throughout the main islands, and continues to be reported in the literature.

References

Burgess, C.M. 1959. Where did this shell come from? Hawaiian Shell News. 7(8): 73.

Edmondson, C.H. 1946. Report of the Zoologist for 1946. B.P. Bishop Museum.

Kay, E.A. 1979. Hawaiian Marine Shells. Reef and Shore Fauna of Hawaii, Section 4: Mollusca. B.P. Bishop Mus. Spec. Pub. 64(4), 653 pp.

Keen, A. 1971. Seashells of Tropical Western America. Stanford University Press. 1064 pp.

Springsteen, F.J. and F.M. Leobrera. 1986. Shells of the Philippines. Carfel Seashell Museum, Manila. 377 pp.

Ulbrick, M.L. 1969. Studies on *Crucibulum spinosum* (Sowerby). Proc. Malacol. Soc. London 38: 431-438.

Crassostrea virginica

(Gmelin, 1791)

Photo by R. DeFelice

American Oyster

Virginia Oyster, Atlantic Oyster, Eastern Oyster, Common Oyster

Phylum Mollusca
Class Bivalvia
Family Ostreidae

Description

Oysters are sedentary with their lower valve firmly cemented to hard objects. Their flattened, distorted shells are extremely variable in shape. The shells of *Crassostrea virginica* are typically broadly oval and thick, and grow to about 10-15 cm in length. The lower valve is convex and upper valve flat, usually with concentric ridges and lines. Exterior color is dirty white to gray. The interior is bright white with a deep purple or red-brown muscle scar (from Kay 1979).

Habitat

Oysters favor estuaries and embayments with low salinities and are intolerant of prolonged exposure to fresh water or marine conditions. They are found in shallow water of tidal to subtidal depth of fairly constant turbidity and salinity, but are able to withstand a wide range of temperatures. Oysters usually colonize in beds. Competition for space is an important source of mortality. Uncrowded, oysters can live to be 20 years old.

Distribution

Hawaiian Islands

Throughout the main islands in estuarine areas

Native Range

Gulf of St. Lawrence to Brazil

Present Distribution

Gulf of St. Lawrence to Brazil, British Columbia, and Hawaiian Islands

Mechanism of Introduction

Intentional, for commercial oyster fishery. First plantings in 1866 in Pearl Harbor.

Impact

Fouling organism. Ecological impact in Hawaiian Islands unstudied. Before a die-off in the early 1970s, these oyster formed extensive dense beds in the estuarine areas of Pearl Harbor which undoubtedly affected the native benthic communities there.

Ecology

Feeding

Bivalves are suspension feeders. Water is moved through an incurrent siphon into the mantle cavity by cilia on the ctenidia (gills). Water passes over the ctenidia, food particles are extracted by the cilia, and water is expelled through an exhalent siphon.

Reproduction

These bivalves are gonochoristic (having separate male and female individuals), fertilization is external, and the developing larvae (veliger) settle to the bottom after a time in the plankton. The first spawning usually occurs when the oyster is around two years of age.

Remarks

Crassostrea virginica remains established in Pearl Harbor (Coles et al., 1999), as a result of what is widely regarded as large plantings made in 1866. The history of plantings of this oyster in Hawaii are given by Kay (1979), and it is reported that there were 150,000 square yards of *C. virginica* beds in Pearl Harbor, with an estimated 35 million oysters.

In the early 1970s, *C. virginica* is recorded as having suffered extensive mortalities in Pearl Harbor. In July, 1972 it was reported that 34 million oysters were killed in West Loch, Pearl Harbor (Anonymous, 1972). Three reasons for this mortality have been suggested by various authors; disease, pollution, and sedimentation.

Crassostrea virginica apparently recovered over the next quarter century and is now common in West Loch, Pearl Harbor. Whether the population now in Pearl Harbor resulted from the original 1866 planting or from the later plantings in the 1920s is not known. Also now present in Pearl Harbor is the introduced Australian oyster *Saccostrea cucullata*.

References

Anonymous. 1972. Pearl Harbor oyster kill! Hawaiian Shell News. 20(8): 2.

Coles, S.L., R.C. DeFelice, L.G. Eldredge and J.T. Carlton. 1999. Historical and recent introductions of nonindigenous marine species into Pearl Harbor, Oahu, Hawaiian Islands. Marine Biology. 135: 147-158.

Kay, E.A. 1979. Hawaiian Marine Shells. Reef and Shore Fauna of Hawaii, Section 4: Mollusca. B.P. Bishop Mus. Spec. Pub. 64(4), 653 pp.

Chama macerophylla

(Gmelin, 1791)

Rock oyster

Phylum Mollusca
Class Bivalvia
Family Chamidae

Description

Brightly colored, heavy shelled bivalve with long, ribbed, leafy projections in radiating rows. Most commonly, yellow or orange, but some pinkish individuals may be found. Inside is white. May grow to about 10 cm in diameter. This species lives fixed to the substrate with one shell valve cemented in place. They are highly variable in form, with the lower valve conforming to the shape of the substrate and upper, exposed valve becoming very worn losing color and sculpture.

Chama living on the hull of a ship in Pearl Harbor (Photo R. DeFelice)

Habitat

Individuals always live attached to hard substrate, adults can only be removed with hammer and chisel. In Hawaii, this species was found to be abundant on the hull of a floating dry-dock in Pearl Harbor, and two nearby collecting statiions. So far it has not been reported outside od Pearl Harbor.

Distribution

Hawaiian Islands

Known only from Pearl Harbor, Oahu

Native Range

Caribbean

Present Distribution

Caribbean and Pearl Harbor, Oahu

Mechanism of Introduction

Unintentional, as fouling on ships' hull

Impact

A stubborn fouling species; adult bivalves are very difficult to remove from ships hulls. Ecological impact unstudied, but presumed minimal.

Ecology

Feeding

Bivalves are suspension feeders. Water is moved through an incurrent siphon into the mantle cavity by cilia on the ctenidia (gills). Water passes over the ctenidia, food particles are extracted by the cilia, and water is expelled through an exhalent siphon.

Reproduction

Reproduction in this species is unstudied. Bivalves are typically gonochoristic (having separate male and female individuals), fertilization is external, and the developing larvae (veliger) settle to the bottom after a time in the plankton.

Remarks

The variability in the form of the shell is the primary cause of the confused systematics within the Chamoidea. First reported in Hawaii as the Red Sea species, *Chama elatensis* Delsaerdt, 1986, by Coles et al. (1999) in Pearl Harbor, we now tentatively apply the name *C. macerophylla* to these specimens (G. Paulay, pers. comm.). This species was previously known only from the Caribbean.

References

Coles, S.L., R.C. DeFelice, L.G. Eldredge and J.T. Carlton. 1999. Historical and recent introductions of nonindigenous marine species into Pearl Harbor, Oahu, Hawaiian Islands. Marine Biology. 135: 147-158.

Balanus amphitrite

(Darwin, 1854)

Striped barnacle

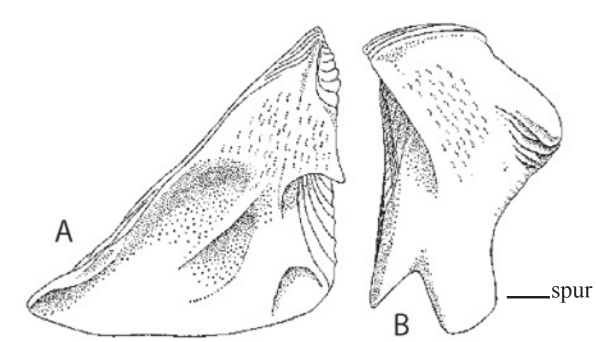
Phylum	Arthropoda
Subphylum	Crustacea
Class	Maxillopoda
Subclass	Cirripedia
Order	Thoracica
Family	Balanidae

Photo by R. DeFelice

Description

Balanus amphitrite is a small, conical, sessile barnacle (to about 1.5 cm diameter). Color is whitish with purple or brown longitudinal stripes. Surface of test plates are longitudinally ribbed. The interlocking tergum and scutum, the paired structures which cover the animal inside are as pictured below.

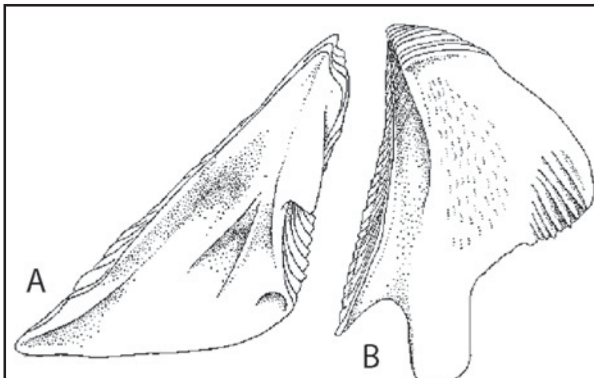
A similar species, *Balanus reticulatus* Utinomi, is also an introduced species and commonly occurs with *B. amphitrite*. It also has longitudinal purple or brown stripes, but these stripes are intersected by horizontal grooves, giving the surface of the test plates a rough reticulated striation, unlike *B. amphitrite*. It can also be distinguished by examination of the tergum and scutum pictured below. Note the more sharply pointed apex of the tergum and the elongated and narrower tergum spur of *B. reticulatus*.



Balanus amphitrite. (A) Scutum. (B) Tergum.

Habitat

Very common in the intertidal fouling communities of harbors and protected embayments. The live attached to any available hard surface, including rocks, pier pilings, ship hull, oyster shells, and mangrove roots.



Balanus retculatus. (A) Scutum. (B) Tergum.

Distribution

Hawaiian Islands

Throughout the main Hawaiian Islands

Native Range

Southwestern Pacific and Indian Ocean

Present Distribution

World-wide in warm and temperate seas

Mechanism of Introduction

Unintentional, as fouling on ships hulls

Impact

Barnacles are a serious fouling problem on ship bottoms, buoys, and pilings. The ecological impact of this barnacle in Hawaii is unstudied.

Ecology

Feeding

Barnacles have specialized paired appendages, called cirri, that they use as a scoop net, reaching out into the water and extracting food particles. When they cirri are drawn back, food is scraped off into the mouth.

Reproduction

These barnacles are hermaphrodites, but cross-fertilization occurs in dense populations. In such cases, males deposit sperm directly into the mantle cavity of adjacent functional females via a long tube. Fertilized eggs are brooded in the mantle cavity, and it may be several months before the free-swimming planktonic larvae are released.

Remarks

This now widespread barnacle of southern hemisphere origins was first collected in 1902 in Honolulu Harbor. Edmondson (1933, as *Balanus amphitrite hawaiiensis*) noted that it was very common in Pearl Harbor on piling and shore rocks. Both *B. amphitrite* and *B. reticulatus* are well established in Hawaii and have been widely reported by many authors throughout the main Islands.

References

Edmondson, C.H. 1933. Reef and Shore Fauna of Hawaii. B.P. Bishop Mus. Spec. Pub. 22.

Balanus eburneus

Gould, 1841

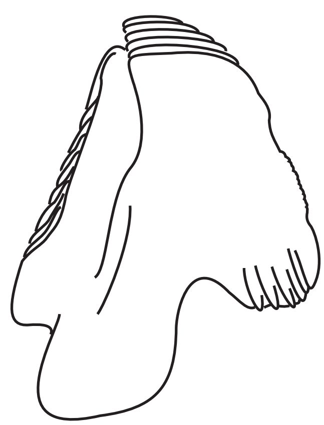
Ivory barnacle

Phylum Arthropoda
Subphylum Crustacea
Class Maxillopoda
Subclass Cirripedia
Order Thoracica
Family Balanidae

Photo by R. DeFelice

Description

A small, white, conical barnacle, without the longitudinal stripes of *Balanus amphitrite* and *B. reticulatus* previously discussed. Large adults approach 2 cm in diameter. Surface of the test plates generally smooth or with shallow horizontal grooves. The tergum (pictured below) has a short broad spur with a rounded tip, quite distinct from both *B. amphitrite* and *B. reticulatus*.



Tergum of *Balanus eburneus*.

Habitat

Common in the low intertidal fouling community. Found on ship hulls, buoys, pilings, oysters and mangrove roots.

Distribution

Hawaiian Islands

Throughout the main islands

Native Range

Atlantic coast of North America and Caribbean to northern South America

Present Distribution

Worlwide in warm and tropical seas

Mechanism of Introduction

An early unintentional introduction, as fouling on ships' hulls

Impact

Nuisance fouling species. Ecological impact unstudied, most likely some competition for space with other intertidal species.

Ecology

Feeding

Barnacles have specialized paired appendages, called cirri, that they use as a scoop net, reaching out into the water and extracting food particles. When they cirri are drawn back, food is scraped off into the mouth.

Reproduction

These barnacles are hermaphrodites, but cross-fertilization occurs in dense populations. In such cases, males deposit sperm directly into the mantle cavity of adjacent functional females via a long tube. Fertilized eggs are brooded in the mantle cavity, and it may be several months before the free-swimming planktonic larvae are released.

Remarks

This western Atlantic Ocean "ivory barnacle" was first collected in 1929 in Pearl Harbor. Edmondson (1931) wrote that *Balanus eburneus* is a typical species of the east coast of the United States, which is suggestive of the view that the barnacle may have been transported to Hawaii through shipments of oysters or on the bottoms of ships. Edmondson (1933) noted that it was in Pearl Harbor, on buoys, floats, and oyster shells. It is now abundant and has been reported throughout the main Islands.

References

Edmondson, C.H. 1931. New crustacea from Kauai, Oahu and Maui. Occ. Pap. B.P. Bishop Mus. 9(17): 18.

Edmondson, C.H. 1933. Reef and Shore Fauna of Hawaii. B.P. Bishop Mus. Spec. Pub. 22.

Chthamalus proteus

Dando & Southward, 1980

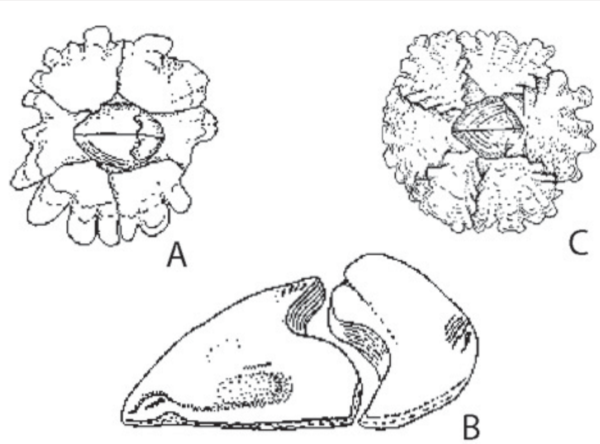
Caribbean barnacle

Phylum Arthropoda
Subphylum Crustacea
Class Maxillopoda
Subclass Cirripedia
Order Thoracica
Family Chthamalidae

Photo by J. Hoover

Description

Chthamalus proteus is a small light brown or gray-white barnacle (to about 1 cm diameter). Its conical shell is variable in external appearance depending on age, crowding, and degree of weathering. Shell plates may be smooth or ribbed. The photo above is of relatively uncrowded older individuals. Older weatherd individuals of *C. proteus* superficially resemble *Nesochthamalus intertextus*, a native intertidal species (pictured below). The interleaving teeth between the shell plates differentiates *N. intertextus* (see illustration below), and it tends to be dull purple.



Chthamalus proteus. (A) Dorsal view. (B) Tergum and scutum. *Nesochthamalus intertextus*. (C) Dorsal view.

Habitat

In the Hawaiian Islands, *C. proteus* inhabits the high or supra-tidal zones of protected harbors and embayments, growing on pilings and other surfaces. The native barnacle, *N. intertextus* inhabits a similar zone, but only along exposed coasts. *C. proteus* is commonly seen growing above the water line on ships' hulls in Hawaii.

A similar, but native, species of high-intertidal barnacle in Hawaii, *Nesochthamalus intertextus* (photo J. Hoover).

Distribution

Hawaiian Islands

Oahu – all South Shore harbors, and Kaneohe Bay
Kauai – Nawiliwili Harbor
Maui – Kahului Harbor
Hawaii – Hilo Harbor
Midway Atoll – main harbor

Native Range

Gulf of Mexico to Trinidad and north east Brazil

Present Distribution

Western Atlantic, Hawaiian Islands and Midway Atoll, and Guam.

Mechanism of Introduction

Unintentional, as fouling on ships' hulls.

Impact

Serious nuisance fouling organism. Ecological impact unstudied, but probably some competition for space with native and nonindigenous invertebrates in the high intertidal.

Dense population of *Chthamalus proteus* in the high-intertidal on a pier piling in Hilo Harbor in 1997 (photo by R. DeFelice).

Ecology

Feeding and Reproduction

(see comments for previous barnacle species)

Remarks

This Caribbean barnacle probably appeared on Oahu sometime between 1973 and 1994. It was first observed on March, 1995 in Kaneohe Bay, but the point of inoculation was most likely Pearl or Honolulu Harbor. When surveys were undertaken in 1996, it was found to be widespread around Oahu, including Pearl Harbor (Southward et al., 1998), and by 1996-1998 it had been found on Kauai, Maui, Hawaii, Midway Island, and Guam. Southward et al. (1998) noted that the date of introduction was after 1973 (the last thorough barnacle surveys of Oahu) and it could have been as recently as 1994 or 1995. However, considering the present distribution of *C. proteus* in the islands and the usual lag time between an introduction and notable abundance, it was possibly earlier. Its abundance and widespread distribution by 1995-1996 certainly suggests an inoculation in the 1980s.

Introduction could have been either on ships' hulls or as larvae in ballast water. Southward et al. suggest that ballast water is less likely than transport of adults since a dense settlement is needed to establish a breeding population of such obligate cross-fertilizing sessile animals. The barnacle is now common on many ship and barge hulls in Hawaii, and on some which travel throughout the Pacific. It seems only a matter of time until this barnacle further invades the Pacific region.

The ecological impacts of this barnacle are not yet known. Southward et al. (1998) suggests this barnacle has established itself by exploiting a largely "vacant niche" (i.e. supratidal zone) and that this introduction may be relatively benign. *C. proteus* does, however, settle on a large number of living substrates in the higher intertidal zone (such as introduced oysters and mangroves on the south shore of Kaneohe Bay). The appearance of *C. proteus* in the Hawaiian Islands adds another Caribbean element to the nonindigenous marine fauna of the Hawaiian Islands.

References

Southward, A.J., R.S. Burton, S.L. Coles, P.R. Dando, R.C. DeFelice, J. Hoover, P.E. Parnell, T. Yamaguchi, and W.A. Newman. 1998. Invasion of Hawaiian shores by an Atlantic barnacle. Mar. Ecol. Prog. Ser. 165: 119-126.

Gonodactylaceus falcatus

(Forskal, 1775)

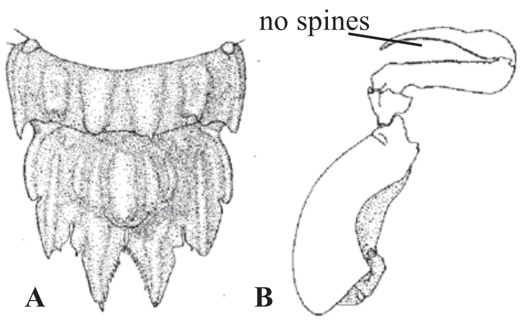
Philippine mantis shrimp

Phylum Arthropoda
Subphylum Crustacea
Class Malacostraca
Order Stomatopoda
Family Gonodactylidae

Photo by J. Hoover

Description

Individuals may grow to about 6 cm in length and are generally dark green (males) or reddish brown (females). This species can be distinguished from other Hawaiian stomatopods by examination of the last (sixth) abdominal segment and telson (pictured below). The sixth abdominal segment has six inflated carinae or lobes. The telson also with inflated carinae and three pairs of marginal teeth and one pair of accessory teeth. Memebers of the genus *Gonodactylaceus* do not have spines on dactylus. Another smaller species, *G. hendersoni*, is also found in Hawaii and is considered also to be introduced. It is typically a mottled beige with some white spots.



Gonodactylaceus falcatus. (A) Sixth abdominal segment and telson. (B) Dactylus.

Habitat

Dead branching coral heads, clumps of coralline algae, or crevices and small holes in solid reef substrate.

Distribution

Hawaiian Islands

Shallow reefs of Oahu, especially Kaneohe Bay and Waikiki

Native Range

Indo-Pacific

Present Distribution

Indo-Pacific and Hawaiian Islands

Mechanism of Introduction

Unintentional, most likely with fouling on ships' hulls

Impact

An aggressive species, *G. falcatus* has been shown to drive out the native stomatopod, *Pseudosquilla ciliata*, from dead coral heads. Since it's introduction, *G. falcatus* has almost completely replaced the once common *P. ciliata* in the coral heads on the shallow reefs of Oahu (Kinzie, 1968).

Ecology

Feeding

Stomatopods are generally carnivorous predators, using their powerful raptorial claws to snap up live prey.

Reproduction

Stomatopods have separate sexes. Fertilized eggs are carried by the female until hatching. The free-swimming planktonic larvae undergo several stages of development before settlement in shallow water. *G. falcatus* appears to reproduce twice a year (see Kinzie, 1968)

Remarks

Kinzie (1968) argued that an lndo-Pacific species of mantis shrimp (which he discussed under the name *Gonodactylus falcatus*) was introduced to the Hawaiian Islands. Manning and Reaka (1981) subsequently described the same Hawaiian population as a new species, *Gonodactylus aloha*, and considered it endemic. Kinzie (1984) examined their arguments in detail and concluded that at the least the species was cryptogenic. Barber and Erdmann (2000) proposed that *G. aloha* is a synonym of *G. mutatus*, but recently Ahyong (pers. comm.) has synonymized *G. mutatus* back to *G. falcatus*.

The first specimens of *G. falcatus* were observed in 1954 in dead coral heads in Kaneohe Bay. Kinzie (1968) suggested that it was introduced onto Oahu with concrete barges towed back at the end of World War II, particularly from the area of the Philippines and the South China Sea. Kinzie demonstrated experimentally that the more aggressive *G. falcatus* had displaced the native stomatopod *Pseudosquilia ciliata* from coral head habitats in Kaneohe Bay. It's continued presence around Oahu has been reported by a number of authors.

References

Barber, P.H. and M.E. Erdmann. 2000. Molecular systematics of the Gonodactilidae (Stomatopoda) using mitochondrial cytochrome oxidase C (subunit 1) DNA sequence data. J. Crust. Biol. 20: 20-36.

Kinzie, R.A. 1968. The ecology of the replacement of Pseudosquilla ciliata by *Gonodactylus falcatus* (Crustacea: Stomatopoda) recently introduced into the Hawaiian Islands. Pac. Sci. 22: 465-475.

Kinzie, R.A. 1984. Aloha also means goodbye: a cryptogenic stomatopod in Hawaii. Pac. Sci. 38: 298-311.

Manning, R.B. and M.L. Reaka. 1981. *Gonodactylus aloha*, a new stomatopod crustacean from the Hawaiian Islands. J. Crust. Biol. 1: 190-200.

Ligia exotica

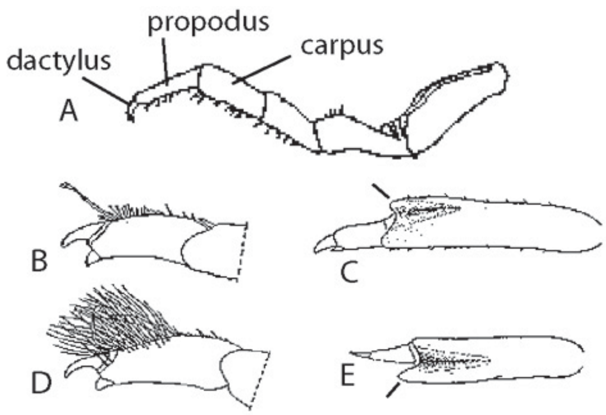
Roux, 1828

Wharf Roach

Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Superorder	Peracarida
Order	Isopoda
Family	Ligiidae

Description

This large gray-brown isopods can grow to about 3 cm. It has large bulging eyes and long antennae and uropoda. Smaller individuals can be confused with *Ligia hawaiiensis*, an endemic species. They can be distinguished by an examination of the last leg (seventh pereopod). The dactylus of *L. hawaiiensis* has long setae, while that of *L. exotica* does not. Also the carpus of *L. hawaiiensis* has a process which extends past the distal margin of the appendage (Tahiti and Howarth, in prep.).



Ligia exotica. (B) Dactylus. (C) Carpus.
Ligia hawaiiensis. (D) Dactylus. (E) Carpus.

Habitat

Found scurrying on rocks and pilings above the water line in harbors.

Distribution

Hawaiian Islands

Honolulu Harbor, Oahu and Hilo Harbor, Hawaii

Native Range

Northeastern Atlantic and Mediterranean

Present Distribution

In harbors of warm and temperate seas worldwide.

Mechanism of Introduction

Unintentional, carried by ships.

Impact

Ecological impact unstudied, but competition with the native *Ligia hawaiiensis* is likely.

Ecology

Feeding

Ligia exotica is a scavenger, feeding on detritus and plant debris.

Reproduction

With separate sexes. Fertilization is internal. Females lay eggs in in cracks and crevices in the intertidal zone.

Remarks

A recent (1996) collection of this species at Hilo represents the first valid record of *L. exotica* from the Hawaiian Islands. The specimens were examined and identified by Stephano Taiti. Previous records of *L. exotica* from Hawaii by Robertson, Edmondson, Van Name, and others, are all based on *Ligia hawaiiensis*, an endemic species (Taiti, pers comm.)

References

Taiti, S. and F. Howarth (in prep.) A key to the terrestrial isopods of Hawaii.

Pachygrapsus fakaravensis

(Rathbun, 1907)

Polynesian grapsid crab

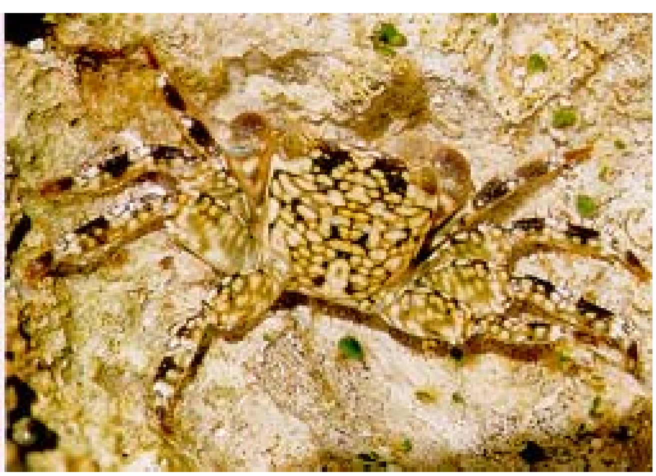
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Infraorder	Brachyura
Family	Grapsidae

Photo by P. Ng

Description

Medium-sized crab, to about 5 cm carapce width. Carapace almost square (9/10 as long as wide), with its whole surface crossed by prominent, granulated lines, fringed by hairs lying flat on the carapace. Middle pair of suprafrontal lobes very prominent and elongate, separated from each other and from the lateral lobes by broad, deep, hairy furrows.

Rathbun (1907) notes that this species is near *P. plicatus* (a native Hawaiian species, pictured below), but is distinguished by its parallel sides, coarse striation, and great hairiness.



A similar, but native, grapsid crab, *Pachygrapsus plicatus* (photo J. Hoover).

Habitat

Intertidal, on rocky shores.

Distribution

Hawaiian Islands

Only known from leeward harbors on Oahu

Present Distribution

French Polynesia, Japan, and Hawaii

Native Range

French Polynesia

Mechanism of Introduction

Unintentional, perhaps as larvae in ballast water.

Impact

Ecological impact unstudied, but probably competes with native intertidal grapsid crabs for food and shelter.

Ecology

Feeding

This crab is a scavenger, feeding on plant and animal debris in the intertidal zone.

Reproduction

With separate sexes. Fertilization is external, with planktonic larval stage.

Pachygrapsus fakaravensis

Remarks

This rocky intertidal crab, previously known from French Polynesia (the type locality is Tuamotu) and Japan, was collected in 1996 from Barbers Point Harbor (Davie, 1998). Peter Ng (pers. comm.) found it to be common at Kewalo, Oahu, in February 2000. Sakai (1976) notes the habitat as "coral reef, at high tidal mark", but in Hawaii, so far it seems to be rescricted to harbors and adjacent areas. We regard it as introduced by ballast water.

References

Davie, P. 1998. New records of crabs in Hawaii (Crustacea: Decapoda: Brachyura). Bishop Mus. Occ. Pap. 56: 63-64.

Sakai, T. 1976. Crabs of Japan and adjacent seas. Kodansha Ltd., Tokyo. 773 pp.

Rathbun, M.J. 1907. The Brachyura. Mem. Mus. Comp. Zool. 35(2): 21-74.

Scylla serrata

(Forskal, 1775)

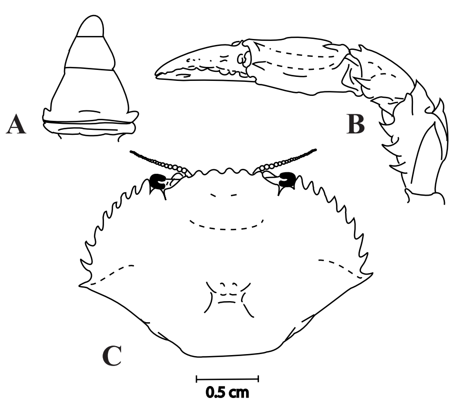
Samoan Crab

Mangrove Crab, Mud Crab

Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Infraorder	Brachyura
Family	Portunidae

Description

This is the largest portunid in Hawaii, exceeding 18 cm in width of carapce. The carapce is smooth, the front bearing four blunt teeth and along the anterolateral border nine sharp teeth of about equal size. The claws of the males become very large. It is either entirely grayish green or purplish brown in color.



Scylla serrata. (A) Telson. (B) Cheliped. (C) Carapace.

Habitat

This crab inhabits muddy bottoms in brackish water along the shoreline, mangrove areas, and river mouths.

Distribution

Hawaiian Islands

All main islands

Native Range

Indo-Pacific, from South Africa to Tahiti, north to Okinawa, and south to Port Hacking, Australia and the Bay of Islands, New Zealand.

Present Distribution

Throughout the Indo-Pacific, from Japan, China, Philippines, and Hawaiian Islands to Australia, Indonesia, East and South Africa, and the Red Sea. Also introduced to Gulf of Mexico (Florida), status unknown.

Mechanism of Introduction

Intentional, to establish a commercial crab fishery. Crabs from Samoa released on Oahu, Molokai, and Hawaii.

Impact

Prized, sought-after commercial species. Ecological impact unstudied in Hawaii, but it is a large, active and aggressive carnivorous species that undoubtedly feeds on native invertebrate species.

Ecology

Feeding

S. serrata is primarily a carnivore, eating mollusks, crustaceans, and polychaetes, as well as small amounts of plants and debris.

Reproduction

Crabs are gonochoristic (having male and female individuals in the same population). Mating of *S. serrata* take place as early as the first year of life after the female undergoes a precopulatory molt. Recent studies in northern Australia, have shown that the transition of immature crabs to physiological maturity probably occurs between 90-110 mm carapace width (Knuckey, 1996). During copulation, a male approaching a female in premolting condition climbs over her, clasps her with his chelipeds and the anterior pair of walking legs, and carries her around. They may remain so paired for 3 to 4 days until the female molts. The male then turns the female over for copulation, which usually lasts 7 to 12 hours. Although the spermatozoa of *S. serrata* are non-motile, sperm can be retained by the female, and fertilization may not take place for many weeks or even months after spawnings (Chen, 1976). While most of the life cycle of *S. serrata* is spent in inshore waters, especially estuaries, the females migrate offshore with the fertilized eggs attached to the pleopods, where they hatch in a few weeks (Hill, 1996).

Remarks

The Samoan crab was first introduced into Kaneohe Bay, in order to start a fishery in 1926. Between 1926 and 1935, 98 crabs were released on Oahu, Hawaii, and Molokai, all from Samoa (Brock, 1960). By 1940 it had "already become thoroughly established about our shores, entering estuaries of streams and ascending far up some of the larger rivers" (Edmondson and Wilson, 1940). Edmondson (1954) noted that large specimens may exceed 20 cm in breadth and weigh several pounds. Maciolek and Timbol (1981) reported it from the Kahana Estuary, Oahu, based on collections made from 1969 to 1971. Eldredge (1994) noted that as of 1992 it was one of the major species collected in certain areas of the island of Hawaii. Brock (1960) attributed part of the success of the crab, in light of the relatively few individuals released, as being due in part to the fact that some of the estuarine areas where this species was released have a low rate of tidal flushing, a situation which may be conducive to the rapid growth of a population within the estuarine area.

References

Brock, V. 1960. The introduction of aquatic animals into Hawaiian water. Int. Revue Hydrobiol. 45: 463-480.

Chen, T. P. 1976. Aquaculture Practices in Taiwan. Fishing News Books Limited, Surrey, England. 162 pp.

Edmondson, C.H. and I.H. Wilson. 1940. The shellfish resources of Hawaii. Sixth Pac. Sci. Congress, Univ. Calif. Press, Berkeley. pp. 241-243.

Edmondson, C.H. 1954. Hawaiian Portunidae. B.P. Bishop Mus. Occ. Pap. 21(12): 217-274.

Eldredge, L.G. 1994. Introductions of commercially significant aquatic organisms to the Pacific Islands. South Pacific Commission (Noumea, New Caledonia), Inshore Fisheries Research Project, Tech. Rept. 7.

Hill, B. J. 1996. Offshore spawning by the portunid crab *Scylla serrata* (Crustacea: Decapoda). Marine Biology 120: 379-384.

Knuckey, I. A. 1996. Maturity in male mud crabs, Scylla serrata, and the use of mating scars as a functional indicator. Journal of Crustacean Biology 16(3): 487-495.

Maciolek,J.A. and A.S. Timbol. 1981. Environmental features and macrofauna of Kahana Estuary, Oahu, Hawaii. Bull. Mar. Sci. 31: 712-722.

Schizoporella errata

(Waters, 1878)

Branching bryozoan

Phylum Ectoprocta
Class Gymnolaemata
Order Cheilostomata
Family Schizoporellidae

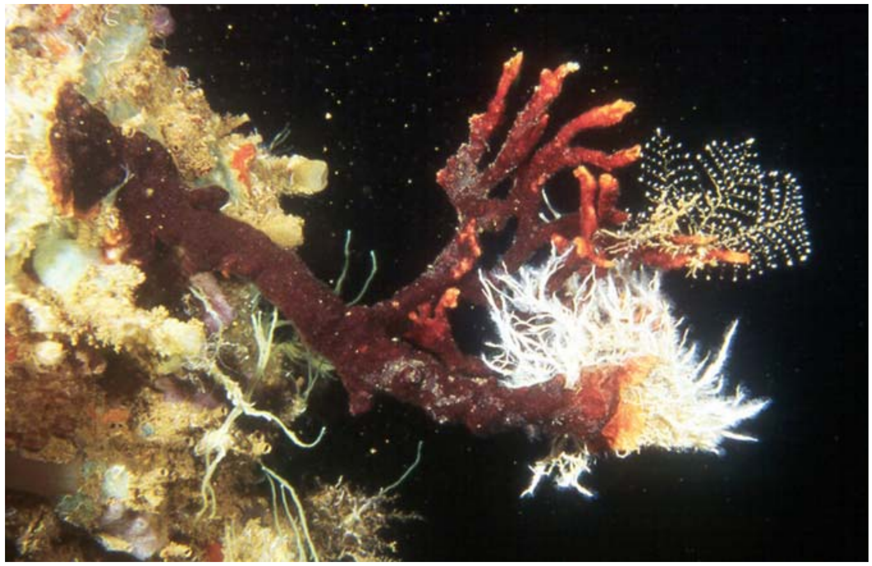
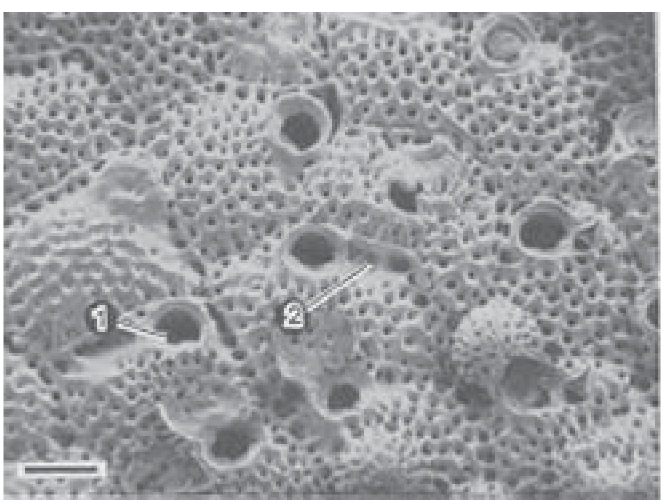


Photo J. Hoover

Description

This heavily calcified encrusting bryozoan is typically dark brick red with orange-red growing margins. It assumes the shape of whatever it overgrows. This species may form heavy knobby incrustations on flexible surfaces such as algae or worm tubes, turning them into solid, sometimes erect branching structures. The thickness of the growth is dependent upon the age of the colony. Multilaminar encrustations of 1 cm thick are common. The frontal surface of the zoecium (secreted exoskeleton housing of individual zooids) is porous with a wide semicircular aperture and proximal sinus. Also with single avicularia on right or left side of aperture sinus.



SEM of *Schizoporella errata*, showing (1) aperture, and (2) avicularia (from Soule et al. 1987).

Habitat

As fouling in shallow water on hard substrates (pilings, hulls, coral rubble, etc.) in harbors and embayments. Occasionally found on the reef, especially in Kaneohe Bay.

Distribution

Hawaiian Islands

Throughout the main islands and Midway Atoll.

Native Range

Mediterranean

Present Distribution

Probably worldwide in warm temperate-subtropical seas (reported from West Africa, Red Sea, Persian Gulf, South Australia, New Zealand, Hawaiian Islands, Pacific Coast of North America, East Coast North America through Caribbean to Brazil, and Mediterranean).

Mechanism of Introduction

Unintentional, as fouling on ships' hulls

Impact

Fouling organism. Ecological impact unstudied, but observations suggest some competition for space with other fouling invertebrates.

Schizoporella errata

Ecology

Feeding

The bryozoan is a suspension feeder. It has a retractable U-shaped crown of tentacles (lophophore) which bear cilia that create a current, bringing food particles toward the animal. Particles are then guided into the mouth by action of the tentacles and cilia.

Reproduction

Each bryozoan colony begins from a single, sexually produced, primary zooid. This zooid undergoes asexual budding to produce a group of daughter cells, which themselves form buds, and so on. Most bryozoans are hermaphroditic, each zooid capable of producing sperm and eggs. Sperm is released into the coelom and the fertilized eggs are retained and brooded for a time before being released.

Remarks

Edmondson (1933) was the first to remark upon an "undetermined orange species" forming encrustitng and branching colonies in Pearl Harbor. *S. errata* is now a common fouling species, found throughout the main Islands.

References

Soule, J.D., D.F. Soule, and H.W.Chaney. 1987. Phylum Ectoprocta. *in* Reef and Shore Fauna of Hawaii. Section 2: Platyhelminthes through Phoronida, and Section 3: Sipuncula through Annelida, D.M. Devaney and L.G. Eldredge (eds). Bishop Mus. Spec. Pub. 64(2 and 3): 83-166.

Edmonson, C.H. 1933. Reef and Shore Fauna of Hawaii. B.P. Bishop Mus. Spec. Pub. 22.

Amathia distans

Busk, 1886

Photo by J. Hoover

Bushy bryozoan

Phylum Ectoprocta
Class Gymnolaemata
Order Ctenostomata
Family Vesiculariidae

Description

This bryozoan forms soft, bushy growths, 5-20 cm in diameter. The flexible stolons (branches) are usually coated with silt and diatoms which gives the colonies a muddy brown color. The colonies consist of short, erect zooids (individuals) arranged biserially in a spiral around each stolon segment.

Amathia distans, stolon with spiraling zooids (from Grodon & Mawatari, 1992)

Habitat

Primarily as fouling in shallow water on hard substrates (pilings, hulls, coral rubble, etc.) in harbors and embayments. Occasionally found on the reef in more protected areas.

Distribution

Hawaiian Islands

Throughout main Hawaiian Islands and also Midway Atoll.

Native Range

Caribbean

Present Distribution

North Carolina to Brazil, Mediterranean and Red Sea, Puget Sound to the Gulf of California, Australia, New Zealand, Java, Japan, and Hawaiian Islands.

Mechanism of Introduction

Unintentional, as fouling on ships' hull or as larvae in ballast water.

Impact

Fouling organism. Ecological impact unstudied, but presumed minimal.

Ecology

Feeding

The bryozoan is a suspension feeder. It has a retractable U-shaped crown of tentacles (lophophore) which bear cilia that create a current, bringing food particles toward the animal. Particles are then guided into the mouth by action of the tentacles and cilia.

Reproduction

Each bryozoan colony begins from a single, sexually produced, primary zooid. This zooid undergoes asexual budding to produce a group of daughter cells, which themselves form buds, and so on. Most bryozoans are hermaphroditic, each zooid capable of producing sperm and eggs. Sperm is released into the coelom and the fertilized eggs are retained and brooded for a time before being released.

Remarks

First reported from Kaneohe Bay by Edmondson and Ingram (1939, based on 1935 collections), this bushy broyozoan is now a well established fouling species, reported throughout the main Islands. It was also one of the few alien marine invertebrates found at Midway Atoll when surveys were conducted there in 1998 (DeFelice et al. 1998).

References

Edmondson, C.H. and W.M. Ingram. 1939. Fouling organisms in Hawaii. Occ. Pap. B.P. Bishop Museum. 14(14): 251-300.

DeFelice, R.C., S.L. Coles, D. Muir, and L.G. Eldredge. 1998. Investigation of the marine communities of Midway Harbor and adjacent lagoon, Midway Atoll, Northwestern Hawaiian Islands. Hawaii Biol. Survey, Bishop Museum (HBS Contrib. No. 1998-014).

Bugula neritina

(Linnaeus, 1758)

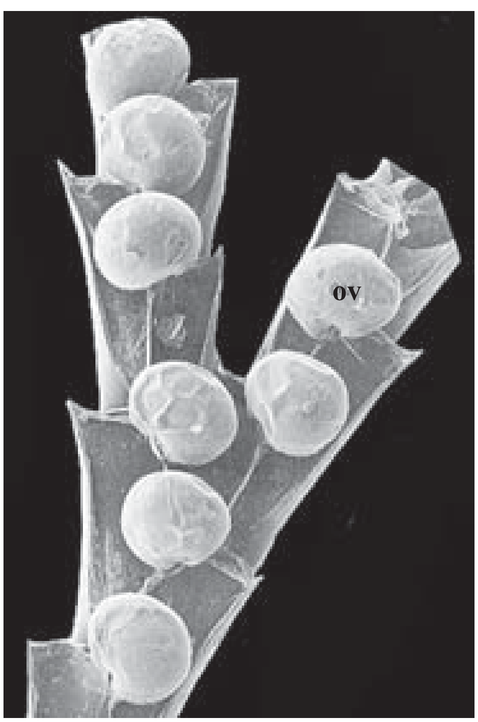
Brown bryozoan

Phylum Ectoprocta
Class Gymnolaemata
Order Cheilostomata
Family Bugulidae

Photo by S. Davidson

Description

Flexible bushy colonies, branching biserial, to about 10 cm high. Color is purplish-brown. Zooids alternating, with the outer corner pointed, but not spined. No avicularia, ovicell large, white, and globular (from Gordon & Mawatari, 1992).



SEM of Bugula neritina, (ov) globular ovicell (from Gordon & Mawatari, 1992).

Habitat

Typically found in harbors and embayments, especially Pearl Harbor, intertidal to 5 m, attached to any available hard substrate.

Individual colony of *Bugula neritina* (photo S. Davidson)

Distribution

Hawaiian Islands

Throughout the main islands, in harbors, embayments, and shallow reef areas.

Bugula neritina

Native Range

Unknown, perhaps the Mediterranean

Present Distribution

Worldwide in tropical and temperate seas

Mechanism of Introduction

Unintentional, most likely as fouling on ships' hulls.

Impact

Fouling organism. Ecological impact unstudied, likely some competition for space with native species.

Ecology

(see Feeding and Reproduction for previous bryozoan species)

Remarks

A common fouling organism worldwide, reported from all seas except subarctic and subantarctic regions, this species is most likely a suite of very similar species. It's presence in Hawaii was first reported by Edmondson (1933). He noted that it was one of the most common fouling species in harbors and bays around Oahu. It has since been widely reported throughout the main Islands by a number of authors.

Recently, *B. neritina* has been a subject of a great deal of biochemical research. It is the source of a novel chemical, bryostatin, which has been shown been effective against leukemia.

There are three additional alien species of *Bugula* reported in Hawaii; *B. dentata*, *B. robusta*, and *B. stolonifera* (Zabin, 1999).

References

Edmondson, C.H. 1933. Reef and Shore Fauna of Hawaii. B.P. Bishop Museum Spec. Pub. 22.

Gordon, D.P. and S.F. Mawatari. 1992. Atlas of marine-fouling Bryozoa of New Zealand ports and harbours. New Zealand Oceanographic Institute, Pub. 107: 1- 52.

Zabin, C.J. 1999. New records of introduced fouling Bryozoa from Oahu, Hawaii. Occ. Pap. Bishop Mus. 59: 46-47.

Ascidia sydneiensis

Stimpson, 1885

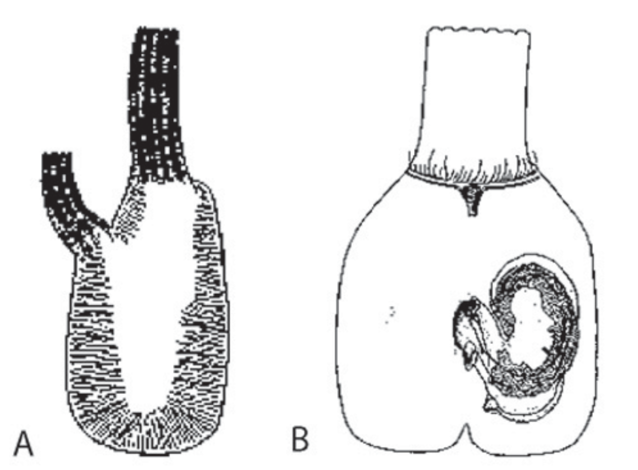
Gray sea squirt

Phylum	Chordata
Subphylum	Urochordata
Class	Ascidiacea
Order	Enterogona
Family	Ascidiidae

Photo by R. DeFelice

Description

This very common large solitary ascidian has a translucent gray membranous tunic. It is finely wrinkled with minute hairs and clear enough to let the brown, orange or reddish body show through. With the tunic removed, the right side displays a prominent fringe of short, stout muscles fibers set perpendicular to the margin of the body, with the central region almost devoid of musculature. A large specimen will have more than 100 oral tentacles. The S-shaped gut loop is deeply recurved, and the hindgut is typically grossly swollen and packed with silt (from Abbott et al. 1997).



Ascidia sydneiensis. (A) With tunic removed, showing musculature. (B) Opened, showing gut loop (from Abbott et al. 1997).

Habitat

Common in harbors and embayments, it lives in shallow water attached to any available hard substrate such as dead coral, pier pilings, boat hulls or floats.

Distribution

Hawaiian Islands

Throughout the main islands and Midway Atoll in harbors and embayments.

Native Range

Most likely Indo-Pacific

Present Distribution

Warm and temperate seas of the Southern Hemisphere

Mechanism of Introduction

Unintentional, as fouling on ships' hulls

Impact

Fouling organism. Ecological impact unstudied, but probably competes with other shallow-water invertebrates for space, especially in the fouling community.

Ecology

Feeding

Ascidians are suspension feeders that use a mucous net to filter plankton from the water. Ciliary action moves water into the oral siphon and to the pharynx which resembles a basket. As water is pumped through slits in the pharyngeal basket, out the atrial siphon, it passes through a layer of mucous coating the inside. When the mucous sheet is clogged with food, special structures pass it to a short esophagus and into the stomach.

Reproduction

This species is hermaphrodite, with a simple reproductive system. Fertilization is external, and after a time in the plankton the free-swimming tadpole larvae will settle and metamorphose.

Remarks

Ascidia sydneiensis is probably the most common large ascidian in calm waters in Hawaii. It was first recorded in 1940-1941 from Oahu. Abbott et al. (1997) note that it "exploits docks, floats, boat hulls, solid debris on mudflats, and other firm substrates in calm habitats such as Kaneohe Bay, Pearl Harbor, and the Keehi boat harbor."

Although described as "virtually worldwide", "cosmopolitan" and "widely distributed in the warmer regions of the world" (Van Name, 1945), *Ascidia sydneiensis* likely originates in the Australian - Indo-Pacific region. First described from Port Jackson, Australia, from material collected intertidally, most of its many synonyms were described from Indonesia, Sri Lanka, or Australia. It is also known from lagoons in Tahiti and Moorea, New Caledonia, Palau Island, Japan, and the Indian Ocean (Seychelles, Isles Maurice, and eastern Africa) (Kott, 1985). It may be introduced to Japan (where it was first recorded by 1906 [Kott, 1985]).

By 1878 it was recorded from South Africa and by 1881 it was reported from the Caribbean, at St. Thomas in the West Indies. In the tropical western Atlantic, it is more restricted in its distribution, being known from the West Indies and other Caribbean regions, Colombia, and Brazil (Van Name, 1945), as well as from the "Atlantic coast of Africa", suggestive of introduction from the Pacific by ship fouling in the 19th century.

References

Abbott, D.P., A.T. Newberry, and K.M. Morris. 1997. Reef and Shore Fauna of Hawaii. Section 6B: Ascidians (Urochordata). Bishop Mus. Spec. Pub. 64(6B).

Kott, P. 1985. The Australian Ascidiacea Part 1, Phlebobranchia and Stolidobranchia. Mem. Queensland Mus. 23: 1-440.

Van Name, W.G. 1945. The North and South American ascidians. Bull. Amer. Mus. Nat. Hist. 84: 1-476.

Phallusia nigra

Savigny, 1816

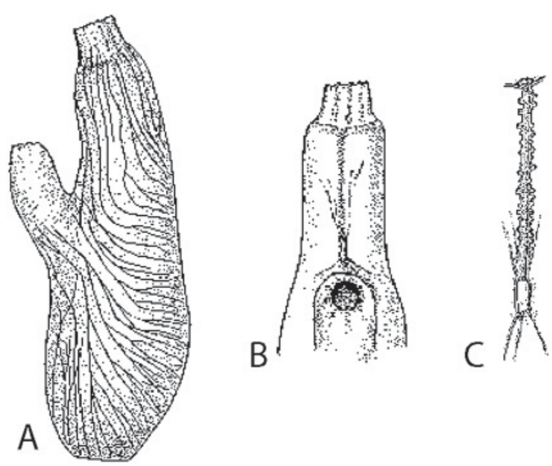
Photo R. DeFelice

Black sea squirt

Phylum Chordata
Subphylum Urochordata
Class Ascidiacea
Order Enterogona
Family Ascidiidae

Description

This common large solitary ascidian is typically a velvety black or dark brown. Small specimens or individuals growing in shaded areas may be a translucent gray with scattered spots of blank pigment. *P. nigra* adheres to the substrate by it's posterior left region. It's right has a thick, cartilagenous, smooth tunic with prominent blood vessels. The siphons are separated by a third to half the body length. Removing the tunic reveals evenly distributed musculature on the right mantle. A large individual will have around 50 oral tentacles (from Abbott et al. 1997).



Phallusia nigra. (A) With tunic removed (B) Dorsal view of siphon region (C) Neural duct (from Abbott et al 1997).

Habitat

Common in harbors and embayments, *P. nigra* lives in shallow water attached to any available hard substrate such as dead coral, pier pilings, or floats.

Distribution

Hawaiian Islands

Throughout the main islands, primarily in harbors.

Native Range

Tropical western Atlantic

Present Distribution

Tropical western Atlantic, Mediterranean, Indian Ocean, Micronesia, and Hawaiian Islands

Mechanism of Introduction

Unintentional, as fouling on ships' hulls

Impact

Fouling organism. Ecological impact unstudied, probably competes for space with other fouling and shallow-water invertebrates.

Ecology

Reproduction

This species is hermaphrodite, with a simple reproductive system. Fertilization is external, and after a time in the plankton the free-swimming tadpole larvae will settle and metamorphose.

Feeding

Ascidians are suspension feeders that use a mucous net to filter plankton from the water. Ciliary action moves water into the oral siphon and to the pharynx which resembles a basket. As water is pumped through slits in the pharyngeal basket, out the atrial siphon, it passes through a layer of mucous coating the inside. When the mucous sheet is clogged with food, special structures pass it to a short esophagus and into the stomach.

Remarks

The first records of this common large (to 9 - 10 cm) dark solitary ascidian, appear to date from 1968-1972, with the report of "*Ascidia melanostoma*" from fouling panels off of Oahu at 15 meters depth and in Pearl Harbor at 9 meters by Long (1974); Abbott et al. (1997) consider it probable that these records represent morphological variants of *P. nigra* (*Ascidia melanostoma* being otherwise unknown from the Islands).

Abbott et al. (1997) noted that *P. nigra* "lives on rocks and dead coral on barely subtidal mudflats in Kaneohe Bay and on floats and pilings there and in Pearl Harbor and in the Keehi boat harbor". They further note that the color of *P. nigra*, while a consistent velvety black in the tropical western Atlantic Ocean, varies in the Hawaiian Islands, with individuals in shady places having translucent gray tunics.

The origin of *Phallusia nigra* is unclear; it may be native to the Red Sea (its type locality) and the Indian Ocean area, or to the tropical western Atlantic Ocean, where it occurs from Florida to Brazil (Abbott et al., 1997). It also occurs in Micronesia. Earlier records from Australia are now referred to other *Phallusia* species

References

Abbott, D.P., A.T. Newberry, and K.M. Morris. 1997. Section 6B: Ascidians (Urochordata). Reef and Shore Fauna of Hawaii. Bishop Museum Special Publ. 64 (6B).

Long, E.R. 1974. Marine fouling studies off Oahu, Hawaii. Veliger. 17: 23-39.

Didemnum candidum

Savigny, 1816

White didemnid

Phylum Chordata
Subphylum Urochordata
Class Ascidiacea
Order Enterogona
Family Didemnidae

Photo by R. DeFelice

Description

Didemnum candidum is a common white or gray colonial ascidian that forms patches or mounds. These patches can be quite extensive, overgrowing worm tubes, sponges, ascidians, and algae in the fouling community.

Didemnids are very difficult to identify, even for an expert. They can not be identified in the field. The tiny zooids must be extracted from the tunic, which is nearly impossible, and this has led to the confusion of didemnid taxonomy. *Didemnum candidum* is one of 4 or 5 white or gray species in this Family in Hawaii, and examination of a taxonomic key (e.g. Abbott et al. 1997) is required for positive identification.

Habitat

In shallow water, primarily in the fouling community of protected harbors and embayment, but also on the reefs in Kaneohe Bay. Grows on all substrates, even living animals and algae.

Distribution

Hawaiian Islands

Throughout the main Islands, and possibly Northwestern Hawaiian Islands

Native Range

Unclear, perhaps Indo-Pacific

Present Distribution

Worldwide in warm seas

Mechanism of Introduction

Unintentional, as fouling on ships' hulls.

Impact

Fouling species. Ecological impact unstudied in Hawaii, observations suggest some competition for space with other shallow-water species in harbors and embayments.

Ecology

(see Feeding and Reproduction for previously discussed ascidians)

Remarks

The name *Didemnum candidum* has been applied to a staggering number of populations of a similar-looking taxon around the world; the species may be one of the most widely-recorded ascidians in the world (Van Name, 1945; Eldredge, 1966). Its cosmopolitan nature recalls Van Name's (1945) famous statement regarding this species: "I am far from being able to overcome the fear that I am confusing more than one species...". More than 50 years later, the species is still in need of revision.

Records from Hawaii commence with Paul Galtsoff's collections in 1930 from Pearl and Hermes Reefs (Tokioka, 1967). Eldredge (1967) reported it from several stations on Oahu (Kaneohe Bay, Ala Wai Yacht Harbor, Pearl Harbor, and off Barber's Point) based upon collections from 1961 to 1963. Long (1974) and Hurlbut (1991) further reported upon Pearl Harbor populations.

Hurlbut (1991) examined patterns of larval abundance, settlement, and juvenile mortality in Pearl Harbor. *Didemnum candidum*'s greater abundance at shallow depths on floats as compared to greater depths on pilings is due to greater larval settlement near the water surface directly related to the surface location of larvae-producing adults, and to the larvae being photopositive and geonegative. She also noted that colonies of *Didemnum candidum* on settling plates at 0.5 meter depth are capable of releasing larvae at 6 to 8 weeks of age.

Originally described from the Red Sea, it was reported in the 1880s and 1890s from stations as far spread as Brazil, New Zealand, the Antilles, and off Mozambique indicating that some measure of wide-spread dispersal by ships had already been achieved. It now also occurs in Australia and New Zealand, the western Pacific Ocean, Indian Ocean, the western Atlantic Ocean, and the Mediterranean , as well as western Europe, and the Philippines, Gilbert, Palau, and Galapagos Islands (Tokioka, 1967). Whether it originated in the Indo-Pacific, or elsewhere, is not clear.

References

Abbott, D.P., A.T. Newberry, and K.M. Morris. 1997. Section 6B: Ascidians (Urochordata). Reef and Shore Fauna of Hawaii. Bishop Museum Special Publ. 64 (6B).

Eldredge, L.G. 1967. A taxonomic review of the Indo-Pacific didemnid ascidians and descriptions of twenty-three Central Pacific species. Micronesica. 2: 161-261.

Hurlbut, C.J. 1991. The effects of larval abundance, settlement and juvenile mortality on depth distribution of a colonial ascidian. J. Exp. Mar. Biol. Ecol. 150: 183-202.

Long, E.R. 1974. Marine fouling studies off Oahu, Hawaii. Veliger. 17: 23-39.

Tokioka, T. 1967. Pacific Tunicata of the United States National Museum. U.S. Natl. Mus. Bull. 251: 1-247.

Van Name, W.G. 1945. The North and South American ascidians. Bull. Amer. Mus. Nat. Hist. 84: 1-476.