Nonindigenous and Invasive Species

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INTRODUCTION

The Northwestern Hawaiian Islands (NWHI) represents a relatively pristine marine ecosystem with few nonindigenous and invasive species. Of the 343 nonindigenous species (NIS) found in the water's of the Main Hawaiian Islands (MHI), only 13 have been detected in the NWHI (Eldredge and Carlton, 2002; Godwin et al., 2006; Godwin et al., 2008). This difference is likely due to the NWHI's extreme remoteness, relatively low rates of visitation and concerted management efforts. Still, the threat of nonindigenous species spreading from the MHI to the NWHI and becoming invasive is a serious concern. The terms nonindigenous and invasive are both used to refer to species that are living outside of their historic native range. The difference is that invasive species have been shown to cause environmental or economic harm, while NIS have not. Most NIS currently found in the NWHI are in few locations and in low abundances. There is debate as to whether any are invasive, but this is an active area of research (Schumacher and Parrish, 2005).

A total of 13 nonindigenous species have been authoritatively detected in the NWHI (Figure 8.1; Table 8.1). These species range from invertebrates to fish, and have a wide variety of life histories, likely modes of introduction and potential impacts. Some species have been found in only one or two locations (e.g., the red alga *Hypnea musciformis*), whereas others are widely distributed throughout most of the atolls and shoals (e.g., the blueline snapper *Lutjanus kasmira*). The difference in their distributions is related to their movement speeds, transport methods, ecological success and probability of detection.

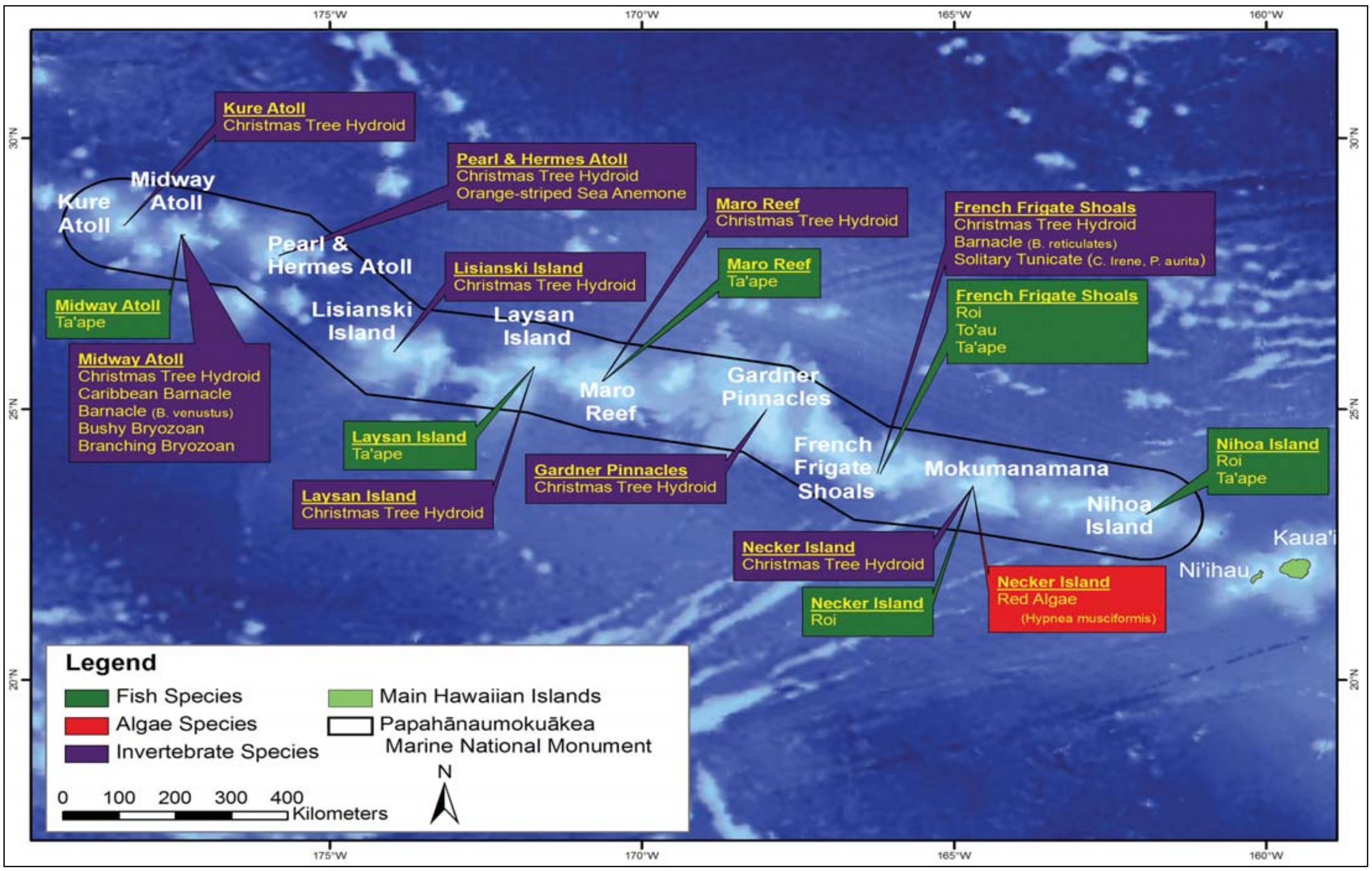

Figure 8.1. Documented distribution of nonindigenous and invasive species in the NWHI. Map: K. Keller.

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Table 8.1. Marine nonindigenous and invasive species in the Northwest Hawaiian Islands. The table also includes information on their native range, where they have been seen in the NWHI, present population status and potential impacts. Sources: Abbott, pers comm; DeFelice et al., 1998; DeFelice et al., 2002; Godwin et al., 2004; Godwin, 2008; Godwin, pers comm; Waddell et al., 2008; Zabin et al., 2004.

SCIENTIFIC NAME	COMMON NAME	TAXA	NATIVE RANGE	PRESENT STATUS	SIGHTINGS	POTENTIAL IMPACT
Hypnea musciformis	Red alga	Algae	Unknown; Cosmopolitan	Unknown; in drift and on lobster traps	MMM	Change community structure and diversity of benthic habitat, including overgrowing coral. Currently forms large blooms, up to 7,465 kg (or 20,000 lbs), off the coast of Maui.
Diadumene lineata	Orange-striped sea anemone	Anemone	Japan	Unknown; on derelict net only	PHR	Fouling organism. Ecological impact is unstudied but presumed minimal.
Pennaria disticha	Christmas tree hydroid	Hydroid	Unknown; Cosmopolitan	Established	MMM, FFS, GAR, MAR, LAY, LIS, PHR, MID, KUR	Competition for space with other invertebrates. Also stings humans, causing a mild irritation.
						the potential to overgrow coral reefs.
Schizoporella errata	Branching bryozoan	Bryozoan	Mediterranean	Established	MID	Fouling organism. Ecological impact unstudied, but observations suggest some competition for space with other fouling invertebrates.
Balanus reticulatus	Barnacle	Barnacle	Atlantic	Established on seawall	FFS	Fouling organism. Ecological impact is unstudied but presumed minimal.
Balanus venustus	Barnacle	Barnacle	Atlantic and Caribbean	Not established; on vessel hull only	MID	Fouling organism. Ecological impact is unstudied but presumed minimal.
Chthamalus proteus	Caribbean barnacle	Barnacle	Caribbean	Established in harbor	MID	Serious nuisance fouling organism. Competes for space and food resources with native species. Grows in such densities that it could exclude algal grazers such as opihi.
Polycarpa aurita	Styelidae, solitary tunicate	Tunicate	Indo-Pacific, Western Atlantic	ARMS	FFS	This species has the capacity to become an aggressive component of a fouling community on man-made surfaces, and the potential for recruitment to natural habitats is always a possibility.
Lutjanus fulvus	Toau or Blackline Snapper	Fish	Indo-Pacific	Established	FFS	Could out-compete native species for resources, but current densities may be too low to see these effects.
Lutjanus kasmira	Taape or Blueline snapper	Fish	Indo-Pacific	Established	NIH, FFS, MAR, LAY, MID	Could prey on or out-compete desirable fishery species. May also exclude more desirable species from fishing gear through competition. Scientific research into these effects is currently lacking.
Cephalopholis argus	Roi or Peacock grouper	Fish	Indo-Pacific	Established	NIH, MMM, FFS	May predate on native species that are targeted by aquariums, dive tours and fishermen. Scientific research into these effects is currently lacking.
Carijoa riisei	Snowflake coral	Octocoral	Indo-Pacific	Has not been seen in NWHI yet	Five Fathom Pinnacle	Overgrows black corals, killing them. Competes for space with other invertebrates.
Acanthophora spicifera	Red alga	Algae	Indo-Pacific	Has not been seen in NWHI yet	Kauai	Change community structure and diversity of benthic habitat, including overgrowing coral.

Island/atoll abbreviations found throughout this chapter: NIH = Nihoa, MMM = Mokumanamana, FFS = French Frigate Shoals, GAR = Gardner Pinnacles, MAR = Maro Reef, LAY = Laysan Island, LIS = Lisianski Island, PHR = Pearl and Hermes Atoll, MID = Midway Atoll, KUR = Kure Atoll

All of the atolls and islands have at least one nonindigenous species, but several such as Midway Atoll (six species) and French Frigate Shoals (five species) have numerous. These two locations have been the foci of human activity for many years, especially during World War II when they were used as military bases. This activity probably meant greater ship traffic and food imports, both of which are considered principal NIS vectors. They are also two of the most studied locations and thus present NIS have a greater probability of detection.

In addition to confirmed NIS observations in the NWHI, several unconfirmed reports of sightings exist and two other species (i.e., *Carijoa riseii* and *Acanthophora Spicifera*) have proven to be extremely successful invaders of the MHI, and therefore pose a serious threat to the NWHI. The red algae *Hypnea musciformis* and *Acanthophora spicifera* may have been sighted drifting on Maro Reef and sighted near Midway Atoll, respectively. The blackline snapper (*Lutjanus fulvus*) may have been spotted off Nihoa Island, and blueline snapper (*L. kasmira*) may have been seen off Mokumanamana, Lisianski Island, and Pearl and Hermes Atoll (Godwin et al., 2006, Draft Environmental Impact Statement, Draft Management Plan for the NWHI Proposed National Marine Sanctuary 2006, R. Kosaki, pers. comm.).

Vectors

Populations of nonindigenous marine species that have already colonized areas of the MHI represent the most likely source of nonindigenous species in the NWHI. This deduction is based on the proximity and pattern of ship movements among these two areas (Godwin et al., 2006). It is difficult to conclusively determine vectors of movement, but the most likely are: hull fouling, ballast water discharge and natural water currents. Recently, marine debris has been suggested as a vector and has shown the ability to transport nonindigenous species to the NWHI (Godwin et al., 2006). To date no records show any species were purposefully introduced into the NWHI, although they most certainly were to the MHI (e.g., blueline and blackline snapper, Peacock grouper).

Data Collection

To deal with the threat of NIS and invasive species, information about their biology and spatial distribution is critical. Sightings of marine invasive species in the NWHI come from a variety of sources (Table 8.2). Sources are typically biological inventories of particular areas (e.g., Midway Harbor Survey, French Frigate Shoals Survey) or are opportunistic (e.g., derelict fishing net removal project) and thus are limited in temporal and spatial scope. These types of data are useful for determining if a particular location has been invaded, or if a potential vector is acting as an invasive pathway. However, these data do not provide any indication of the severity of an invasion, whether an invasive population is growing or shrinking or the ability to complete a rigorous statistical comparison among locations.

Currently, there is no systematic survey which covers all habitats likely to harbor NIS and invasive species. Most data are collected or informed by conventional SCUBA or snorkeling. As a result, most data are collected at depths shallower than 35 m. This is a concern since several nonindigenous species already detected in the NWHI or in the MHI have been detected well below this limit (e.g., blueline snapper – 256 m). To fill this gap Papahanaumokuakea Marine National Monument (PMNM) has begun assessing deep water survey technologies (C. Menza, pers. comm.).

The NWHI Coral Reef Assessment and Monitoring Program (NOWRAMP) and lobster trap monitoring programs provide quantitative abundance data of NIS and can monitor changes over time (see Table 8.2 for details); however sampling is spatially biased. For example, NOWRAMP surveys are completed at permanent sites and thus may not be representative of larger populations and may not detect NIS that occur in unsampled habitats. Similarly, hull, net and trap inspections are tied to the distribution of invasive species and may provide biased population estimates of attached species. More intensive surveys in specific areas (e.g., Midway Harbor Survey) offer detailed fine spatial scale data and taxonomic resolution, but are time intensive and costly.

Table 8.2. Marine invasive species monitoring programs in the NWHI.

PROGRAM	OBJECTIVES	TIME PERIOD	ISLANDS OR ATOLLS	AGENCIES
NOWRAMP	Monitor fish, algae, coral and other invertebrates	2000-2007	NIH, MMM, FFS, GAR, MAR, LAY, LIS, PHR, MID, KUR	NOAA-PMNM, PIFSC
Midway Harbor Survey	Survey the invertebrates on artificial substrates in and around Midway Harbor	1998	MID	USFWS, Bishop Museum
French Frigate Shoals Survey	Survey the seawall at Tern Island for nonindigenous species	2002	FFS	USFWS, Bishop Museum
Derelict Fishing Net Removal Project	Remove derelict fishing nets on Kure, Pearl and Hermes, Midway and Lisianski and determine if any nets contained nonindigenous species	2000	LIS, PHR, MID, KUR	NOAA-NMFS
Derelict Fishing Net Removal Project	Remove derelict fishing nets on French Frigate Shoals and determine if any nets contained nonindigenous species	2007	FFS	NOAA-NMFS
Census of Coral Reefs	Characterize invertebrate communities	2007	FFS	NOAA-NMFS
Hull Fouling Project	Assess hull fouling as a mechanism for the dispersal of nonindigenous species	2003	MHI, MID	HCRI-RP, HI-DLNR
Lobster Trap Monitoring	Monitor the population of spiny lobsters, and identify any algae that is growing on the lobster traps	1985-2007	MMM, MAR	NOAA-PIFSC

Abbreviations: NOWRAMP = Northwest Hawaiian Islands Rapid Assessment and Monitoring Program, MHI = Main Hawaiian Islands, NOAA = National Oceanic and Atmospheric Administration, PMNM = Papahanaumokuakea Marine National Monument, USFWS = U.S. Fish and Wildlife Service, NMFS = National Marine Fisheries Service, HI DLNR = Hawaii Department of Land and Natural Resources, PIFSC = Pacific Islands Fisheries Science Center, HCRI-RP = Hawaii Coral Reef Initiative Research Program

MARINE ALGAE

Nonindigenous algae in the NWHI are a major concern, because of the mobility of propagules, fast growth rate, potential ecological impacts to the native benthic community and presence in the MHI. One species of red algae, *Hypnea musciformis*, has been detected in the NWHI and another species, *Acanthophora spicifera*, is of particular concern because of its aggressive growth rate. Both species are present in the MHI and *H. musciformis* probably originated there.

At least 19 species of macroalgae have been intentionally or passively introduced in Hawaii since the mid 1950s (Doty, 1961; Brostoff, 1989; Rodgers and Cox, 1999; Russell, 1987, 1992; Woo, 1999; Smith et al., 2002; Smith et al., in press) and at least five have successfully established themselves. These species are capable of moving to the NWHI.

Red Algae, Spiny Algae (*Acanthophora spicifera*)

This species of red algae has not yet been authoritatively recorded in the NWHI, but there has been one unconfirmed sighting at Midway and due to its success in the MHI, it is a species of particular concern. It is widely distributed among the MHI and throughout the tropics and subtropics. Introduction likely originated in Honolulu Harbor in the 1950s via a fouled barge originating in Guam (Doty, 1961). It has since spread to all the MHI, and is the most widespread invasive algae in the archipelago and is now a common component of the intertidal community (Smith et al., 2002).

Movement and associated range extensions occur naturally through water movement, or anthropogenically through hull fouling. Fragments or spores move through advection and are likely the means of local dispersal in Hawaii (Kilar and McLachlan, 1986). Branches are brittle that often results in fragmentation. Fragments can accumulate forming large, free-floating populations and can drift for potentially long distances before settling and establishing new colonies. It is also frequently spotted fouling hulls throughout the MHI (Smith et al., 2002).

A. spicifera can adapt to a variety of habitats and environmental conditions, and this is one of the reasons of its success throughout tropical and subtropical ecosystems. In Hawaii, it is abundant in protected areas where it is not exposed to high-energy wave action, such as rocky intertidal beaches, tide-pools and shallow reef-flats. It attaches to hard substrates and is often found growing with the native algae species of *Laurencia nidifica* and *Hypnea cervicornis* (Botany UH, 2001). In other areas it has been found as an epiphyte on other algae species and as a free living drift alga.

Potential impacts are poorly studied. It likely impacts the community structure and diversity of the benthic habitat through competition and smothering (Preskitt, 2002; Eldrege 2003), but these effects have not been well quantified (Shluker, 2003). *A. spicifera* can outcompete native algae such as *L. nidifica* and *H. cervicornis* (Russell, 1992). In the eastern tropical Pacific, blooms of *A. spicifera* covered by cyanobacterial epiphytes have been observed at several reefs and were associated with widespread coral mortality.

Red Algae (*Hypnea musciformis*)

In 2005, international press coverage drew attention to the potential spread of the red, invasive alga, *Hypnea musciformis* when large quantities were found entangled in lobster traps at depths from 30 to 90 m near Mokumanamana (Godwin et al., 2006; Figure 8.2). The species was first recorded from deep water (>30 m) at Mokumanamana in 2002, and one small individual was found as part of a drift assemblage at Maro Reef (Friedlander et al., 2008). From 2002 through 2004, small sprigs of the alga were commonly recorded on lobster traps at Mokumanamana. In spring to early summer of 2005, pounds of *H. musciformis* began to appear on lobster traps at Mokumanamana, generating concern about a large-scale epidemic of this nuisance alga. Later that year a special cruise was organized by PMNM to investigate the problem. Interestingly, no *H. musciformis* was discovered at Mokumanamana during the cruise, and continued investigations of algae associated with lobster traps in 2006 have failed to find any significant population blooms other than a few small individuals similar to those documented in 2002 through 2004 (Friedlander et al., 2008).

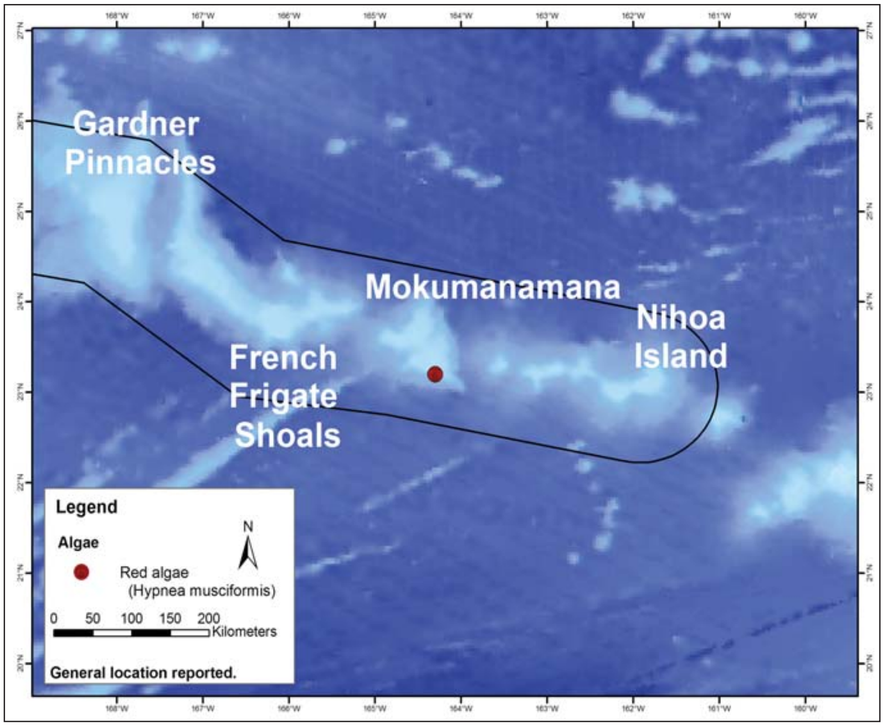

Figure 8.2. General location of the red algae Hypnea musciformis *from NOAA/PIFSC lobster trap monitoring.*

H. musciformis was intentionally introduced from its native range in Florida to Kaneohe Bay on Oahu in 1974 for mariculture. It is commercially cultivated as a food source and for kappa carrageenan, a common food additive. Like *A. spicifera*, it spreads quickly and is distributed widely throughout the MHI where it is now found on Kauai, Oahu, Molokai and Maui, with the most abundant populations occurring on Maui (Botany UH, 2001). Populations are often found on calm intertidal and shallow subtidal reef-flats where it either attaches to sandy flat rocks or is found as an epiphyte on other algae species, often on *A. spicifera*, *Laurencia nidifica*, *Sargassum echinocarpum*, and *S. polyphyllum* (http://hawaii.edu/reefalgae/invasive_algae/index.htm).

Principal reasons for this species success are its high growth rate, ability to epiphytize other algae and frequent fragmentation. Russell (1992) estimated a growth rate between 10-50% per day. Drifting fragments can attach to other floating algae, like *S. echinocarpum* or *S. polyphyllum*, and float long distances before establishing new colonies. Attachment is aided by the presence of apical hooks (Figure 8.3). Fragments as small as 5 mm proved viable, growing at a rate of 200% a week (Smith et al., 2002). Besides fragmentation, *H. musciformis* also spreads through hull fouling.

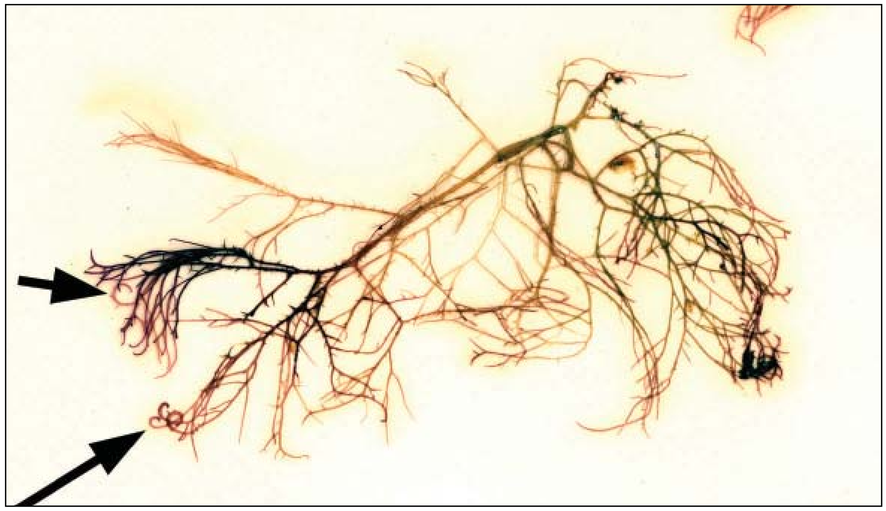

Figure 8.3. H. musciformis*. The arrows point to the species' distinctive hooks. Photo: P. Vroom.*

Potential impacts include competition with native algae and the creation of large dense surface mats. Like other invasive algae, it probably impacts the community structure and diversity of the benthic habitat, but these effects have not yet been quantified (Shluker, 2003). Russell (1992) found *H. musciformis* can outcompete the native algae *H. cervicornis*, especially in the presence of *A. spicifera*. *H. musciformis* can form large dense mats, which have been correlated with high levels of nutrient inputs from the coast. Similar nutrient inputs are not present in the NWHI, but mats located around the MHI are capable of supplying propagules for distribution to the NWHI. The presence of dense mats are also a concern, because in peak blooms tens of thousands of pounds of algae can wash ashore forming windrows 0.5 m high. The effect of these windrows on local biota like the Hawaiian monk seal or green sea turtle is unknown.

H. musciformis now makes up a significant portion of the diet for the green sea turtle, sometimes composing as much as 99-100% of the seaweed mass in their stomachs. However, the nutritional value of *H. musciformis* has not yet been determined and so the long-term impact of incorporating this alga into the sea turtles' diet is unknown (Botany UH, 2001).

INVERTEBRATES

Out of the all the different taxonomic groups of NIS, invertebrates represent the most species and are the least studied. Nine invertebrate species (one anemone, one hydroid, two bryozoans, three barnacles and two tunicates) have been detected in the NWHI. These invertebrates are typically cryptic and have been detected with the help of fine-scale surveys in targeted areas (e.g., Defelice et al., 1998, 2002). Most nonindigenous invertebrates have been detected at Midway Atoll and French Frigate Shoals, the two locations with the lion's shares of survey effort and human activity. A tenth invertebrate species, the snowflake coral (*Carijoa riseii)*, which has not been detected in the NWHI is described herein because it is a species of particular concern.

Orange-striped Sea Anemone (*Diadumene lineata)*

The orange-striped sea anemone is native to Japan, but has spread throughout the Pacific, Atlantic, Caribbean, the North Sea and the Mediterranean (Zabin et al., 2004). In 2000, about 100 individuals were identified in the lagoon at Pearl and Hermes Atoll attached to a derelict fishing net (Zabin et al., 2004; Figure 8.4). To date, no established adults have been seen in the NWHI.

Although it can reproduce sexually, it likely spreads through asexual reproduction and hull fouling in the NWHI (Zabin et al., 2004). It exhibits a wide tolerance of temperature and salinity and is generally found on solid substrates, in intertidal pools or protected shallow waters such as bays and harbors. The orange-striped sea anemone is often found with mussels and oysters in other parts of its range (DeFelice et al., 2001), and could have been transported to Hawaii in an oyster shipment (Zabin et al., 2004). The impacts of this species in the NWHI remain unknown and unstudied.

Christmas Tree Hydroid *(Pennaria disticha)*

The Chrismas tree hydroid is native to the western Atlantic and has been reported in all of the NWHI except Nihoa (Godwin et al., 2006). It also is widely distributed among the MHI (DeFelice et al., 2001). It was first reported in the region during a survey of Pearl Harbor in 1929 (DeFelice et al., 2001).

It attaches to natural and artificial hard substrates where there is some water movement. It is very common in harbors in all the MHI and is often found in more protected areas such as cracks and crevices on reefs, at depths of 0–50 m. The impacts of the Christmas tree hydroid are unstudied, but it is likely that it competes for space with other invertebrates. It also can sting humans, resulting in minor irritation (DeFelice et al., 2001).

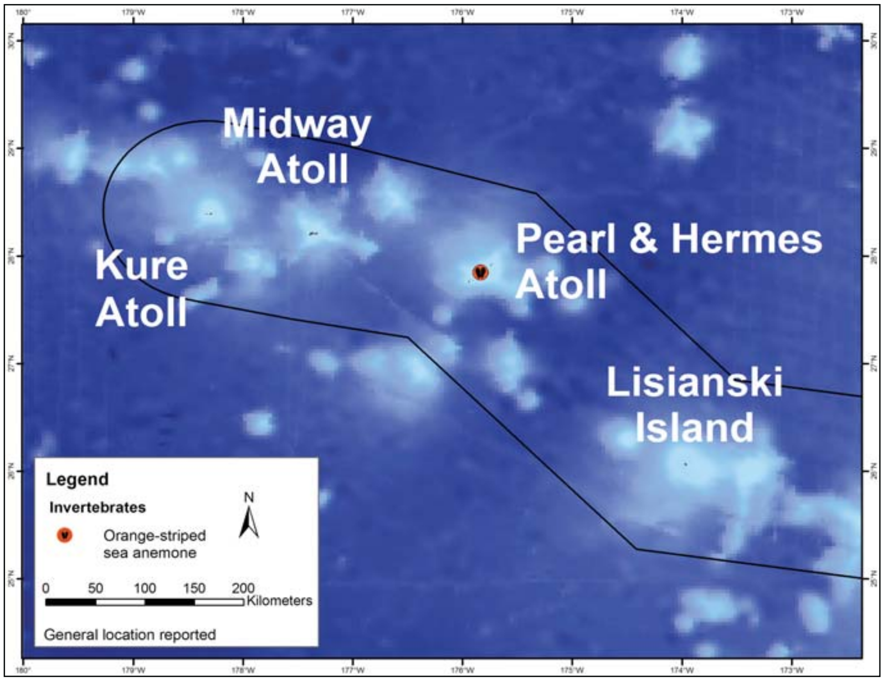

*Figure 8.4. General location of the orange-striped sea anemone (*Diadumene lineata*) from NOAA/PIFSC/CRED Marine Debris Program.*

Bushy Bryozoan (*Amathia distans*)

In 1997 the bushy bryozoan was found at Midway Harbor, dominating many of the manmade structures that were surveyed (Figure 8.5). It formed large colonies on wood, concrete and metal pilings, as it does in harbors in the MHI (DeFelice et al., 1998). To date, this is the only location in the NWHI where it has been sighted. Its native range is the Caribbean, but it has spread over much of the tropics and subtropics including the western Atlantic, Mediterranean and Red Seas, eastern Pacific and coastal waters of Australia, New Zealand, Java and Japan (DeFelice et al., 2001). Movement is considered to be aided by hull fouling, ballast water discharge (larvae) or natural water movement (Shluker, 2003).

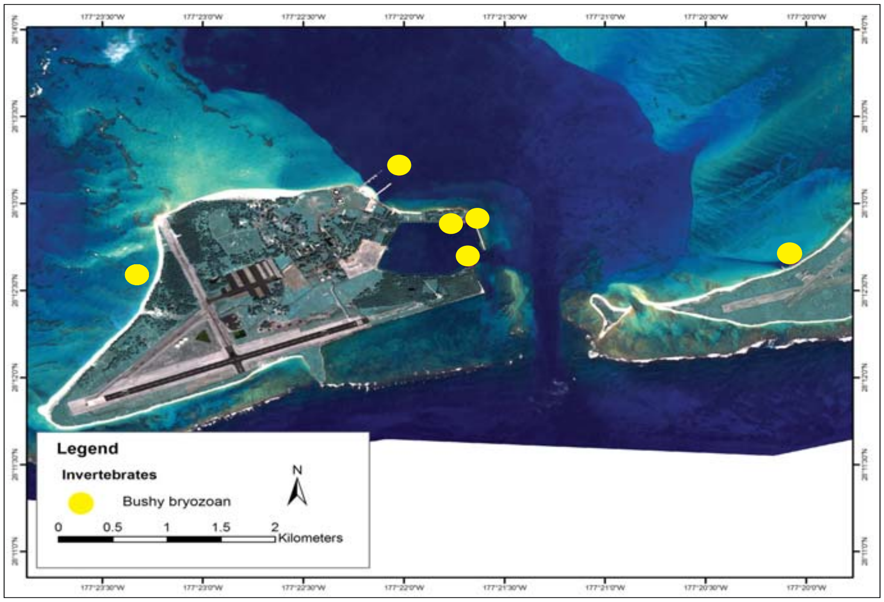

*Figure 8.5. General locations of the bushy bryozoan (*Amathia distans*) at Midway Atoll.*

The bushy bryozoan was first spotted in the region at Kaneohe Bay in 1935, and has since spread to all the MHI (Shluker, 2003; Coles et al., 2004). It can be found in shallow water on hard anthropogenic substrates such as pilings and vessel hulls and natural substrates such as coral rubble. It is usually found inside harbors or embayments, or occasionally in more protected areas of the reef. The impacts of the bushy bryozoan are unknown and presumed minimal (DeFelice et al., 2001), probably including competition for space (Shluker, 2003).

Branching Bryozoan (*Schizoporella errata*)

The branching bryozoan was recorded at Midway Harbor in 1997, where it was found occupying many of the same locations as the bushy brozoan, although not as abundant (DeFelice et al., 1998) (Figure 8.6). It is usually found inside harbors or embayments on man-made substrates, or occasionally in more protected areas of coral reefs (DeFelice et al., 2001). Its native range is the Mediterranean, but is now found worldwide, including all the MHI (DeFelice et al., 2001) where it was first described at Pearl Harbor in 1933. It can be transported anthropogenically through hull fouling, which is likely how it was unintentionally transported to so many locations around the globe (Shluker, 2003). The impacts of this species are unknown, but likely include competition for space (DeFelice et al., 2001).

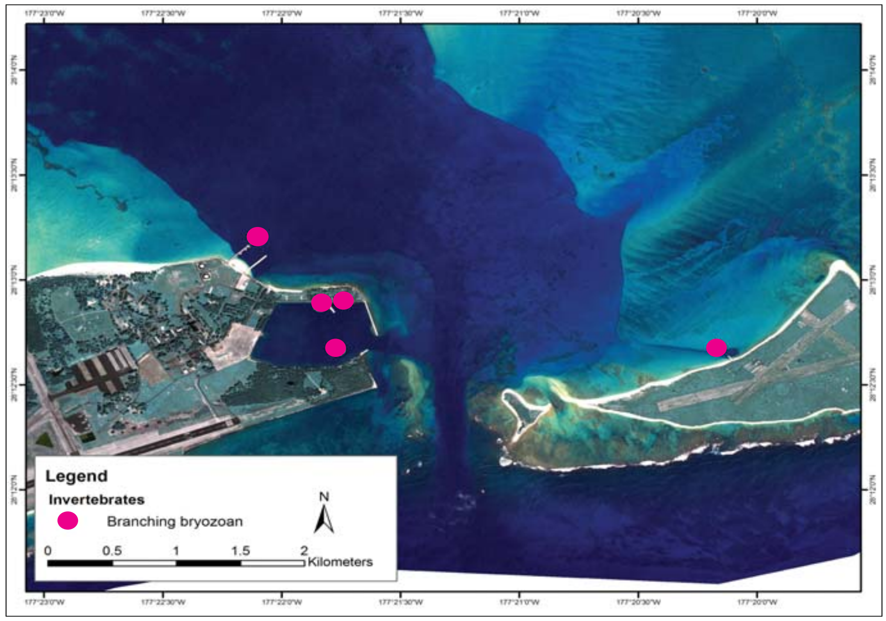

*Figure 8.6. General locations of the branching bryozoan (*Schizoporella errata*) at Midway Atoll.*

Barnacle (*Balanus reticulates*)

Although this species of barnacle has been found in the MHI on Kauai, Oahu, Maui and Hawaii (Coles et al., 2004), and was found on about 25% of the ship hulls in one hull fouling study (Godwin et al., 2004), it has only been spotted once in the NWHI, on a seawall at Tern Island in French Frigate Shoals in 2002 (DeFelice et al., 2002; Figure 8.7). It is a fouling organism. Its ecological impact is presumed to be minimal, although there is little research to confirm this assumption.

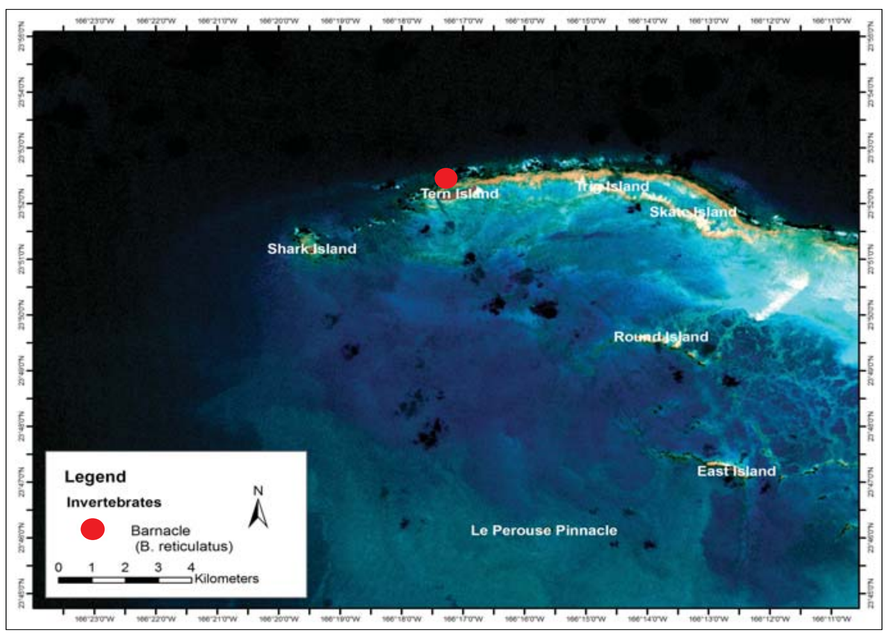

Figure 8.7. General location of the barnacle Balanus reticulatus *at Tern Island, French Frigate Shoals.*

Barnacle (*Balanus venustus*)

This barnacle, native to the Atlantic and Caribbean oceans, has been seen once on a hull of a ship anchored at Midway Harbor in 2003 (Godwin et al., 2004), demonstrating this species' ability to be transported through hull fouling. However, an established adult has never been seen in the NWHI. Its ecological impact is presumed to be minimal.

Caribbean Barnacle (*Chthamalus proteus*)

This barnacle from the Caribbean was found in Midway Harbor attached to pier pilings in 1997 (DeFelice et al., 1998; Figure 8.8). It likely arrived in the region between 1973 and 1994, since it was first noticed at Kaneohe Bay, Oahu in 1995 and was not found during a comprehensive intertidal survey of Oahu in 1972.

It was probably introduced through either hull fouling or ballast water, although Southward et al. (1998) argues that hull fouling is more likely. It is commonly seen above the waterline on inter-island ships (Zabin, 2007). Larval dispersal could also be a natural vector for spread between the islands of the Hawaiian archipelago, now that it is established there. Although there may be some peaks of larval production, larvae are found in the water column year-round.

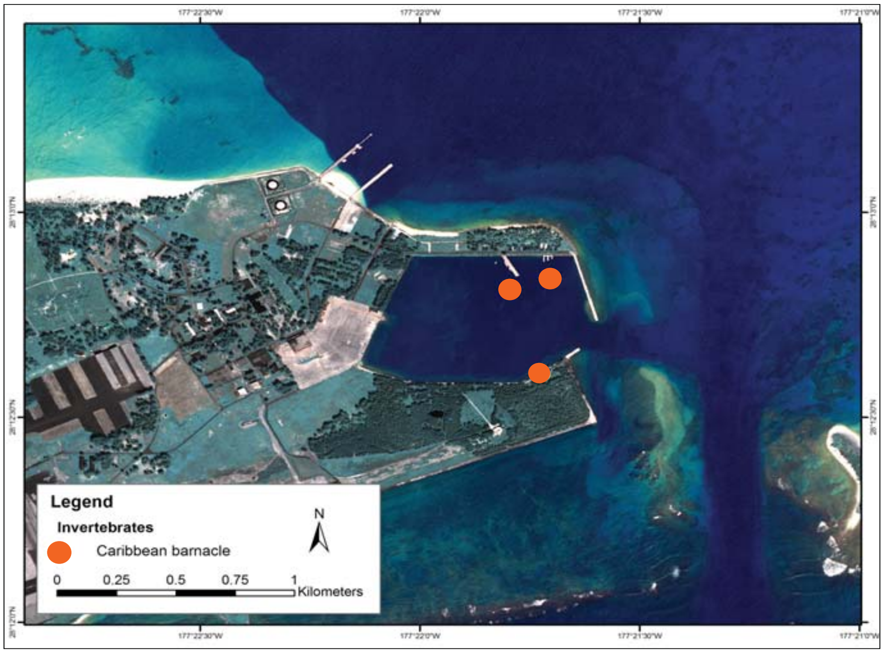

*Figure 8.8. General locations of the Caribbean barnacle (*Chthamalus proteus*) at Midway Atoll.*

Surveys of MHI have found Caribbean barnacles around Kauai, Maui and Hawaii (DeFelice et al., 2001). It usually colonizes supratidal anthropogenic structures such as pier pilings and sea walls, although some individuals have been observed on intertidal boulders in the MHI. It is generally found in protected embayments and harbors, but small colonies have been found at one high energy site in Kaneohe Bay. This finding is a concern, because this species may be moving into habitat used by the native barnacle *Nesochthamalus intertextus*. At the moment, it seems the Caribbean barnacle is not competing with *N. intertextus*, but rather growing next to it. In addition, Caribbean barnacle individuals were quite small, so it was unclear whether there was an established population.

The Caribbean barnacle has been implicated in displacing another nonindigenous barnacle, *Balanus amphitrite*, in the MHI demonstrating its competitive ability (Shluker, 2003). Its rapid proliferation may reflect that it is filling an unexploited niche in the Hawaiian archipelago, in the high intertidal and splash zones. The density of colonies and the rapid pace of reproduction make the Caribbean barnacle a good competitor for space. This proliferation could alter the community structure and potentially exclude algal grazers such as protected Hawaiian limpets (e.g., *Cellana exarata, C. melanostoma, C. sandwicensis, C. talcosa*).

Styelidae, Solitary Tunicate *(Cnemidocarpa Irene)*

This species is a widespread Indo-Pacific tunicate found in Japan, the Philippines, Australia, Micronesia and Melanesia. Large specimens may reach a length of 4 cm and have a dark brown to whitish tunic with deep wrinkles that are arranged to create irregularly shaped raised areas. This species is commonly associated with fouling communities located within man-made harbors and shallow benthic habitats with rubble substrate from Kauai to the island of Hawaii (Abbott et al., 1997).

The larval stage of most solitary tunicates is brief; the larva does not feed, but concentrates on finding an appropriate place for the adult to live. The actual larvae are tadpole shaped and the muscular tail comprises two-thirds of the larval body; it is supported by a notochord and contains a nerve cord. Gravity and light-sensitive sensory vesicles along the dorsal surface of the larval body orient the animal as it swims. After a period of up to a few days, the larva will settle and attach itself to a surface using three anterior adhesive papillae. As the larva metamorphoses into an adult, the tail reabsorbs, providing food reserves for the developing animal.

This species has only been recorded from French Frigate Shoals in the Monument, where it was collected from an Autonomous Reef Monitoring Structures (ARMS) installed in 2006 (Godwin et al., 2008; Figure 8.9). Due to the short larval duration of tunicates, this species was likely transported to French Frigate Shoals by some anthropogenic means from a source location in the southeastern portion of the archipelago. Therefore this record represents recruitment to the ARMS from an undocumented established population at French Frigate Shoals.

The impacts of this species are unknown but it has the capacity to become a dominant fouling organism on any man-made substrate.

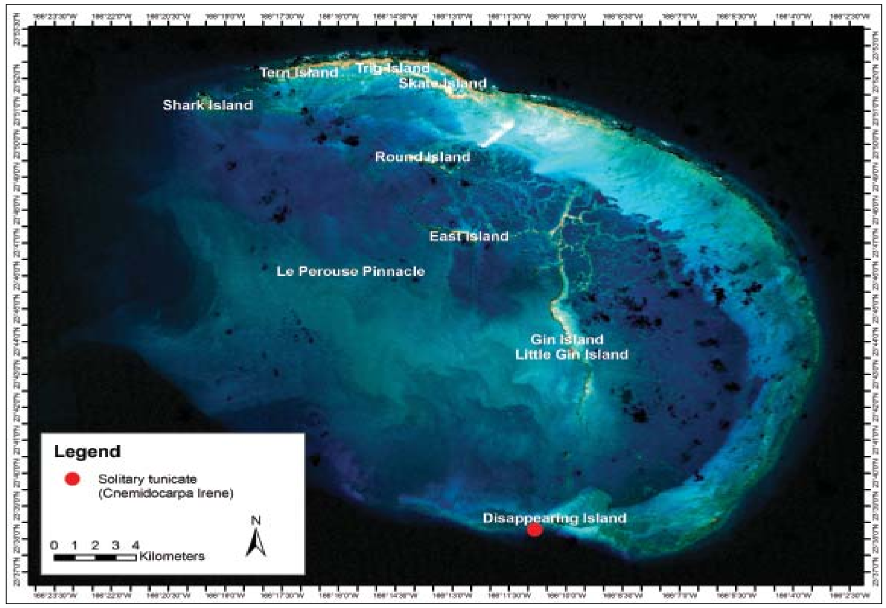

Figure 8.9. Documented location of C. irene *at French Frigate Shoals.*

Styelidae, Solitary Tunicate (*Polycarpa aurita)*

This solitary tunicate is pale brown with a tough and leathery tunic that is generally encrusted with worm tubes, sponges and other fouling organisms. Specimens in Hawaii only reach up to 4 cm in length but this species attains greater lengths (10-12 cm) in other areas of its Indo-Pacific range. This species is also found in the western Atlantic (Caribbean and Gulf of Mexico). It is established in the southeastern portion of the archipelago as a common species in fouling communities located within man-made harbors and the shallow and intertidal habitats of natural embayments (Abbott et al., 1997).

The larval cycle described under *C. irene* also applies to this species. Therefore, a larval cycle of only a few days exists. It was recently recorded from French Frigate Shoals from the same collections in which *C. irene* was identified (Godwin et al., 2008). These collections were part of an effort by the Coral Reef Ecosystem Division (CRED) of the Pacific Islands Fisheries Science Center in Honolulu in 2007. The focus of the efforts was to expand a 2000 project, which examined fouling organisms associated with derelict fishing gear in the NWHI (Godwin, 2000; Figure 8.10) and retrieve and quantify the organisms collected by an ARMS deployed in 2006 at French Frigate Shoals. As with *C. irene*, anthropogenic transport to French Frigate Shoals is assumed and a scenario of opportunistic recruitment to the ARMS from some established population in the lagoon is likely.

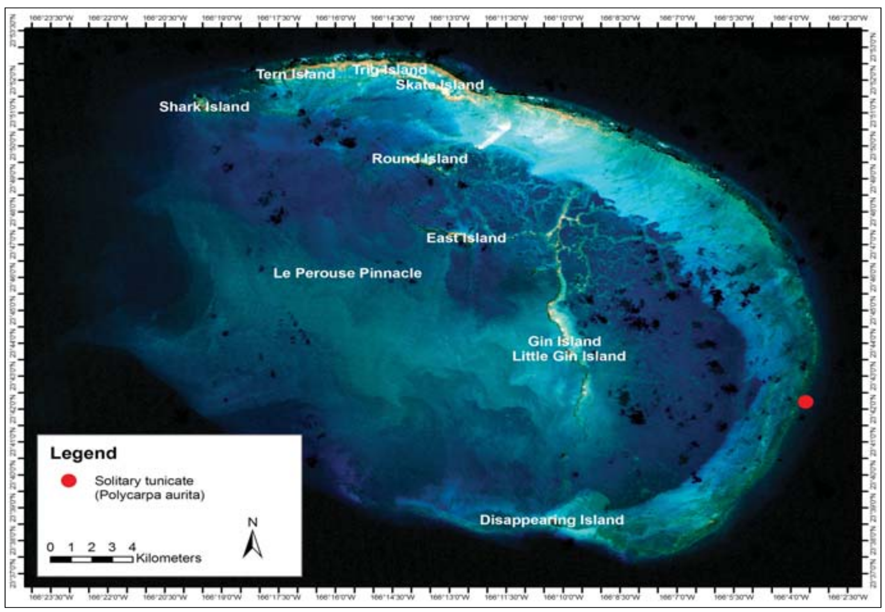

Figure 8.10. Documented location of P. aurita *at French Frigate Shoals.*

This species has the capacity to become an aggressive component of a fouling community on man-made surfaces, and the potential for recruitment to natural habitats is always a possibility. Recent incidences of natural tunicate populations acting invasively and overgrowing remote coral reef areas demonstrates the potential of this group of organisms to cause damage to coral reefs without direct human influence (Littler and Littler, 1995; Vargas-Angel et al., 2008)

Snowflake Coral (*Carijoa riisei*)

The snowflake coral has not been detected in the NWHI, but is a species of particular concern. It was first spotted in Pearl Harbor in 1972 (DeFelice et al., 2001), and by 1990 had been recorded around all of the MHI. Of the 343 nonindigenous marine species that have been introduced to the Hawaiian Islands, the snowflake coral may be the most successful at proliferation, as demonstrated by its distribution among the MHI, and it may exhibit some of the highest invasive potential (Grigg, 2003). It has not been sighted in the NWHI to date, but in 2007 a colony was found at Five Fathom Pinnacle (Kahng, per comm.), approximately 200 km from Nihoa Island which is the southeastern-most point of the NWHI.

This species was originally thought to be native to the Caribbean, but recent research has shown it to be more likely indigenous to the Indo-Pacific. It is likely that several slightly different species have reached the Hawaiian archipelago (Kahng, 2006).

The snowflake coral is very light sensitive; it thrives in spots that receive 10–30% ambient light, and avoids well-lit habitats. Therefore in shallow water (10–30 m), where light levels are high, it attaches to dark cracks, shaded walls or pilings, the underside of ledges and corals, lava tubes and other shaded areas. As it moves into deeper water and light levels diminish, it is found on a wider variety of habitats. At depths of 75–110 m, it has been found to explode into patches as large as 200 km^2 (Grigg, 2003). It generally attaches to hard substrates such as rocks, corals or anthropogenic structures. It does need to be positioned above the benthic layer, and away from stagnant water, as it requires some wave energy to continuously transport the zooplankton that it filters from the water for food (Godwin et al., 2006).

The snowflake coral reproduces both asexually and sexually. The polyps can split in two, allowing clones to spread and cover an entire habitable patch within several years. It can also release gametes into the water column, which once fertilized, can survive for up to 90 days (Kahng, 2006) and thus are capable of travelling long distances. This species can also spread through hull fouling, although this may not be common.

At shallow depths, the snowflake coral seems to occupy an unutilized habitat niche in Hawaii (Shluker, 2003). However at depth, it has overgrown entire beds of black coral, killing 90% of the coral surveyed in the Maui Black Coral Bed in 2001 (Grigg, 2003). Black coral harvesting generates $15 million a year in the state of Hawaiian, and the spread of the snowflake coral represents a serious threat to this industry (Godwin et al., 2006). Beyond the economic impacts, it has shown the potential to severely reduce biodiversity by blanketing entire areas.

FISHES

Three species of nonindigenous fish have been observed in the NWHI, blackline snapper (*Lutjanus fulvus)*, blueline snapper (*L. kasmira)* and Peacock grouper (*Cephalopholis argus).* All three species were purposefully introduced to the MHI between 1955 and 1961 along with eight other species of groupers (Serranidae), snappers (Lujanidae) and emperor breams (Lethrinidae) from Moorea in French Polynesia. All were introduced as potential commercial species (Brock, 1960; Randall, 1987). Of the three species, blueline snapper have been the most successful in terms of distribution and abundance (Shluker, 2003).

Blackline Snapper (*Lutjanus fulvus* or Toau)

Intentionally introduced in 1956, blackline snapper has spread to all of the MHI, and into the southeastern end of the NWHI. It has been spotted at Nihoa and French Frigate Shoals (Shluker, 2003; Figure 8.11). It has fairly low abundance, possibly due to its exploitation for food (Shluker, 2003). Blueline snapper (*L. kasmira*) was introduced around the same time, but it has spread much faster than blackline snapper, despite the many biological similarities between the two species. Scientists are unsure how to explain the difference in range expansion.

Blackline snapper is a reef fish, generally found in the lagoons or outer reef slopes and usually at depths of 1–40 m, but it has been seen as deep as 75 m. It has a temperature tolerance of 20–28°C and spawns year-round (http://www.larvalbase.org), increasing its chances of larval dispersal. Ecological impacts are unstudied.

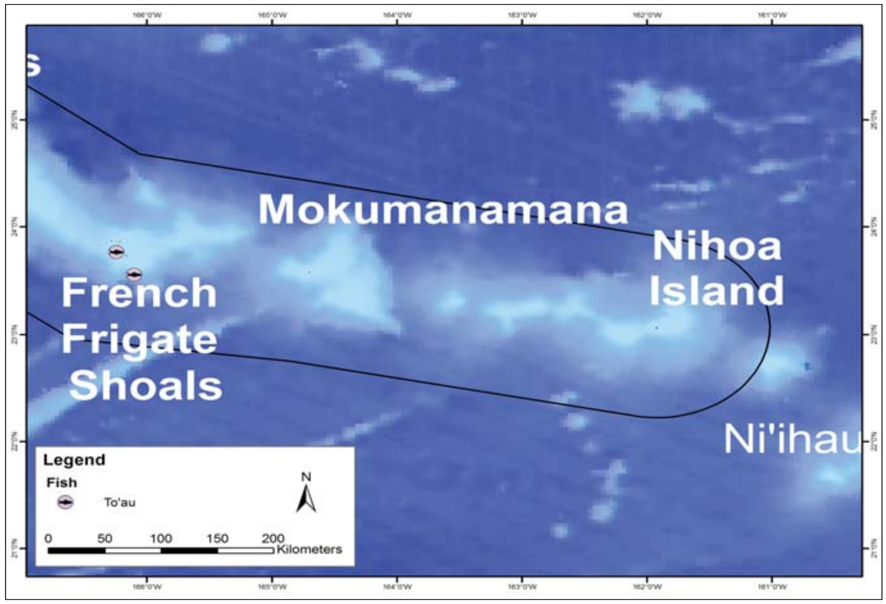

Figure 8.11. *Documented distribution of blackline snapper (*Lutjanus fulvus*) in the NWHI.*

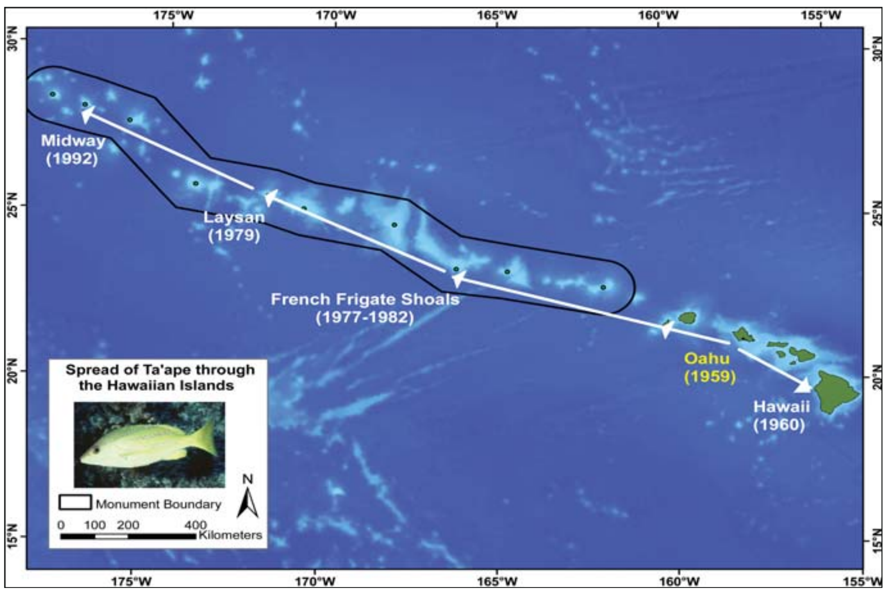

*Figure 8.12. Documented distribution of blueline snapper (*Lutjanus kasmira*) in the NWHI. Source: Sladek Nowlis and Friedlander, 2004.*

Blueline Snapper
(Lutjanus kasmira or Taape)

Blueline snapper has been detected throughout the NWHI, including Nihoa, Mokumanamana, French Frigate Shoals, Maro Reef, Laysan Island and Midway Atoll (Friedlander et al., 2005). It likely migrated from the MHI where it was intentionally introduced to Oahu in 1955. From the initial population of 3,200 individuals brought from French Polynesia, the fish has spread throughout the full length of the Hawaiian archipelago (Oda and Parrish, 1982; Randall et al., 1993; Figure 8.12) and is now one of the most conspicuous and abundant species in the fish community. Friedlander et al. (2002) found blueline snapper was the second most abundant species by number and biomass over hard substrate in Hanalei Bay, Kauai.

Due to its abundance and the concern that blueline snapper might impact native fish, more effort has been spent studying its ecology compared to other similar nonindigenous species. Blueline snapper is generally found in lagoons and outer reef slopes at depths from 2-70 m, but it has been seen as deep as 256 m. Friedlander et al. (2002) found the species to be abundant over habitats like deep slope, spur and groove and shallow slope, but it was also found in lesser quantities in the complex back reef. A more recent report indicated that blueline snapper is also common among algal plain habitats (C. Menza, pers. comm.). These low relief habitats dominated by algae (macroalgae and crustose coralline algae), may make up a considerable proportion of the deeper benthic habitats in the NWHI where coral are rare. Friedlander et al. (2002) have also shown that blueline snapper utilize sand habitats for feeding and the species may undergo an ontogenetic habitat shift.

The blueline snapper was never accepted into the local diet, and many fishermen believe it out competes native fish for resources and fishing bait. There is little scientific evidence to back this conclusion (but see Schumacher and Parrish, 2005), which leads to disagreement and debate between scientists and fishermen as to the effects of the blueline snapper on native species (Shluker, 2003).

Peacock Grouper (*Cephalopholis argus* or Roi)

The Peacock grouper was introduced from French Polynesia in 1956 as a food species. Since then, it has spread throughout the MHI, and has been seen at Nihoa, Mokumanamana and French Frigate Shoals in the NWHI (Shluker, 2003; Godwin et al., 2006; Figure 8.13).

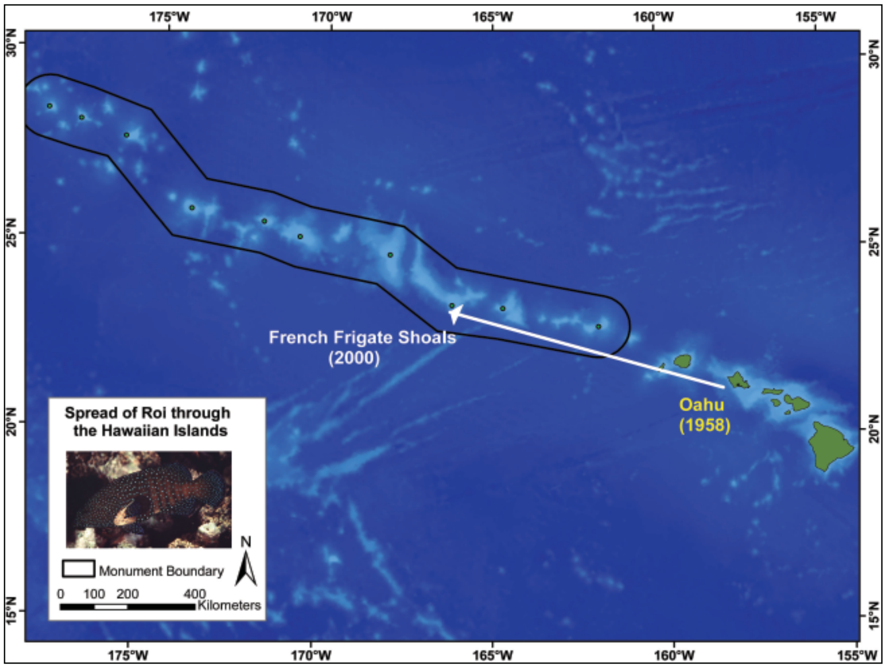

*Figure 8.13. Documented distribution of the Peacock grouper (*Cephalopholis argus*) in the NWHI. Source: Sladek Nowlis and Friedlander, 2004.*

It is found in lagoons and seaward reef habitats, at depths of 1–40 m, although it generally prefers depths of 10 m or less (Godwin et al., 2006).

Although originally sought by fishermen, its popularity declined after incidences of ciguatera poisoning increased and is now considered by many fishermen as unsafe to eat (Godwin et al., 2006). Without fishing pressure, the Peacock grouper has grown abundant and could impact native reef fishes through predation as well as competition for space and resources. However, there is little scientific research on the effects due to Peacock grouper, and thus no conclusive evidence has been gathered.

MANAGEMENT

PMNM has taken active steps to mitigate the threats of NIS, including ballast discharge prohibition, hull inspections and cleaning, snorkel/dive gear treatment and luggage inspection of air passengers. Action plans consisting of multiple strategies and activities address PMNM priority management needs. One of the PMNM's 22 action plans is "to detect, control, eradicate where possible, and prevent the introduction of alien species into the Monument". PMNM has also undertaken research to develop knowledge of baseline conditions and detect NIS introductions. Early detection greatly increases the probability of NIS control and possibly eradication (e.g., Pyne, 1999).

EXISTING DATA GAPS

The primary data gap for nonindigenous and invasive species in the NWHI is a complete survey of nonindigenous species across habitats. Surveys need to have a greater spatial distribution to have a more complete picture of the nonindigenous and invasive species populations. The following are key datasets needed for management and future research efforts:

- Species inventory;
- Population size;
- Rate of spread;
- Spatial distribution; and
- Habitat requirements and natural history information for established populations to use in habitat suitability models.

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