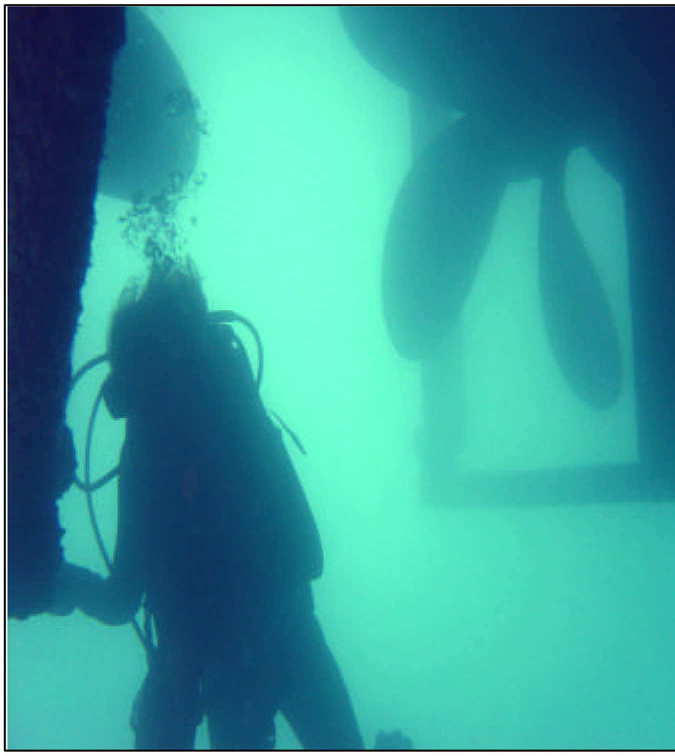

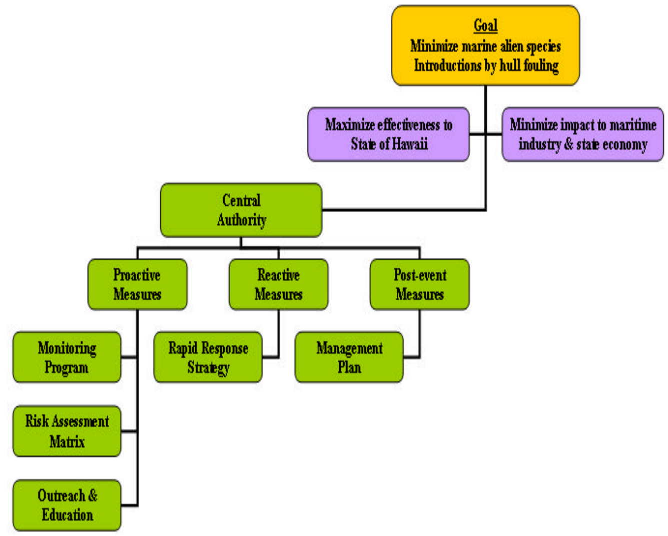

THE ASSESSMENT OF HULL FOULING AS A MECHANISM FOR THE INTRODUCTION AND DISPERSAL OF MARINE ALIEN SPECIES IN THE MAIN HAWAIIAN ISLANDS

August 2004

COVER

Survey of fouling community on a vessel in Honolulu Harbor and initial framework for goal and criteria for management of hull fouling as a marine AIS transport mechanism.

Images by L.S. Godwin

THE ASSESSMENT OF HULL FOULING AS A MECHANISM FOR THE INTRODUCTION AND DISPERSAL OF MARINE ALIEN SPECIES IN THE MAIN HAWAIIAN ISLANDS

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EXECUTIVE SUMMARY

The goals and objectives of this Hawai‘i Coral Reef Initiative-Research Program 2003 funded project dealt with both a field component and collaboration with an assembled group of stakeholders concerned with formulating management strategies for hull fouling as a marine aquatic invasive species (AIS) transport mechanism.

The field component surveyed potential mechanisms for introducing marine AIS through hull fouling. The focus was on a broad range qualitative survey of these mechanisms to allow for greater coverage during the period of the project. The specific mechanisms were a particular set of vessels types and the operations conducted by local shipyards. A total of 35 vessels were surveyed, which yielded 112 species from 10 different phyla. There were 48 species identified as AIS and 12 as cryptogenic. Within the total for AIS and cryptogenic records, 49 of the species had already been documented as established in Hawai‘i, 1 species was not established, 9 were confirmed new records and a single species had an unknown status. The potential effect of shipyard operations was assessed through an interview process and on-site evaluations. It was determined that the regulations for the control of toxic waste at shipyards indirectly minimize the likelihood of marine AIS exposure to local harbors.

Ballast water has been dealt with as a management issue in the United States and throughout the world. Hull fouling is a new management issue and required expert opinions from various stakeholders representing the maritime industry, state and federal aquatic resource managers, and the research community. Since this was a new issue for all stakeholders involved, the focus of the working group was to determine the goal, major criteria and potential alternatives for management. An initial framework for the management of hull fouling, through a series of pro-active, reactive and post-event measures, was developed through a collaborative process. In addition, a workshop geared towards outreach and education of all involved stakeholders was conducted in the early stages of the project.

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I. Introduction

Biological invasions brought about by anthropogenic influences have occurred throughout the world through a variety of mechanisms including maritime shipping, live seafood and bait shipments, aquaculture, shipments of commercial and institutional aquarium species, and the activities of education and research institutions. The primary pathway identified for marine aquatic invasive species (AIS) introductions has been maritime vessel traffic to ports around the world through ballast water discharge (Williams et al. 1988; Carlton & Geller 1993; Ruiz et al. 2000a). Although this pathway is blamed for the majority of marine AIS introductions around the United States, the amount of ballast water being released varies among ports (Carlton et al. 1995; Smith et al. 1996; Godwin and Eldredge 2001). There are other pathways associated with maritime vessel activity that can be responsible for introductions.

Maritime vessel activity acting a mechanism for the transport of marine AIS is a complex issue involving more than just ballast water. Ocean-going vessels can be thought of as biological islands for species that dwell in harbors and estuaries around the world. These vessels have substrate for the settlement of species associated with fouling communities, provide protected recesses that can be occupied by both sessile and mobile fauna, and possess enclosed spaces that hold water in which everything from plankton to fish can become entrained (Wonham et al. 2000). The vectors associated with ocean-going vessels are ballast water, sediments, and hull fouling, and should be thought of as a collective unit.

I.A. Marine AIS Invasions

Marine habitats can be considered robust when dealing with disturbances such as climate change and glaciation measured over millions of years. When disturbances are more intense over shorter time scales, the marine environment can be considered to be fragile. It is these short time frames and intense disturbances that are relevant to human society and the anthropogenic effects induced on marine habitats. The introduction of marine AIS can cause irreversible alterations to marine communities and is an anthropogenic disturbance that has become of great concern.

In the terrestrial environment the issue of invasive species and their control has been dealt with as a management issue for some time but the concept of marine AIS is a relatively new issue (Office of Technology Assessment 1993). In the United States, awareness of marine AIS in the federal government and the scientific community has increased more since the late 1980s than in the past 30 years (Carlton 1993). This can be attributed to the invasion of the Eurasian zebra mussel *Dreissena polymorpha*, which was first collected in the Great Lakes, in 1988 (Nalepa and Schloesser 1993). The zebra mussel has overwhelmed the benthic communities of the Great Lakes, but the economic impacts and not the ecological ramifications are what brought it to the attention of public officials. The zebra mussel is a prolific fouling organism in its new environment - the Great Lakes - and one of the consequences is the clogging of cooling intakes of power plants. The cost of control of the zebra mussel was expected to reach US$500 million by the year 2000 (USA Ballast Book 1998).

Marine AIS are a worldwide problem with economic and ecological consequences. Table 1 gives a few examples of marine AIS worldwide and includes potential and proven impacts. These marine AIS demonstrate the variety of organisms that have invaded coastal habitats due to anthropogenic facilitation. Maritime shipping activity is blamed for the introduction of all the species listed, with the exception of *Caulerpa taxifola*, which was accidentally released from the Monaco Aquarium (Meinesz 1997). Incidentally, *Rapana venosa*, which was discovered in the southern Chesapeake Bay in 1998 (Harding and Mann 1999), was likely introduced from the Black Sea, where it is and alien species introduced from Japan. *Carcinus maenus* and *Asterias amurensis* both are likely to cause ecological changes, as epibenthic predators, in the areas in which they have been introduced (Grosholz and Ruiz 1995; Grannum et al. 1996). *Potamocorbula amurensis* has become the most numerous benthic invertebrate in its new habitat in San Francisco Bay and could cause drastic changes due to its ability to filter out large quantities of plankton from the water column, thus changing the base of the food chain in this habitat (Cohen and Carlton 1995).

The species listed in Table 2 are examples of marine AIS that have invaded Hawaiʻi. The macroalgae *Kappaphycus* spp. and the snapper *Lutjanus kasmira* were both intentionally introduced and appear to have effects on the communities in which they are present. *Chthamalus proteus* and *Gelliodes fibrosa* have both been reported recently, and are likely to have been present in Hawaiʻi for some time (Southward et al. 1997; DeFelice 1999). These last two species are most likely introductions by commercial or military maritime shipping activities. Since *Chthamalus proteus* is native to the Caribbean, it is unlikely its larvae would have survived the journey to Hawaiʻi in the ballast tank of a commercial vessel and instead was probably introduced as a fouling species on a vessel hull. *Gelliodes fibrosa* is only known from the Philippines (DeFelice 1999) and was found on the hull of a floating drydock brought to Pearl Harbor from Subic Bay in the Philippines in 1992.

Table 1. Examples of marine NIS introductions worldwide

Species	Area(s) and Date of Introduction	Native Range	Impacts
Asterias amurensis (starfish)	Australia(1980s)	Japan, Korea	Negative impacts on the shellfish industry and local coastal ecology
Carcinus maenus (crab)	North America (late 1800s-Atlantic coast, 1990s-Pacific coast), South Africa(1990s), Japan(1980s), Australia(early 20th century)	Western Europe, British Isles	Negative impacts on shellfish industry and local coastal ecology
Caulerpa taxifola (macroalgae)	Mediterranean(1980s)	West Indies	Overgrowth of local species and habitats with impacts on local ecology
Potamocorbula amurensis (clam)	San Francisco Bay(1980s)	Asia	Drastic change in local ecosystem with unknown long term effects
Rapana venosa (snail)	North America-Atlantic coast(1990s)	Japan	Potential impacts to shellfish industry with unknown long-term ecosystem impacts

Table 2. Examples of marine NIS introductions in Hawai‘i

Species	Area(s) and Date of introduction	Native Range	Impacts
Chthamalus proteus (barnacle)	Main Hawaiian Islands (after 1973)	Tropical Western Atlantic	Impacts unknown
Gelliodes fibrosa (sponge)	Pearl harbor, O‘ahu (recorded in 1996)	Phillipines	Impacts unknown
Chama macerophylla (mollusk)	Pearl Harbor, O‘ahu (recorded in 1996)	Red Sea	Impacts unknown
Kappaphycus sp. (macroalgae)	Kane‘ohe Bay (1970s)	Philippines	Overgrowth of coral reefs
Lutjanus kasmira (fish)	O‘ahu, Intentionally introduced (1950s)	Marquesas	Competition with native reef fish

I.B. Vectors for Marine AIS Associated with Maritime Vessels

1. Ballast Water

From the early history of seafaring to the present, ocean-going vessels needed ballast. All vessels before the middle of the 19th century used solid ballast in the form of sand, rocks, and other heavy materials. As ships became larger it became necessary to design ballast systems into vessels that took the form of dedicated tanks that could be filled with water. The need to use the aquatic environment for a transportation medium in the growing global economy has lead to the increases in vessel size and ballast water volume. This increased ballast water volume combined with faster ship speeds allows the uptake and survival of an increased number of organisms.

Organisms that are associated with marine plankton communities can be pulled into the ballast tanks of vessels during ballasting operations. These organisms are characterized as holoplankton, meroplankton, and tychoplankton. The holoplankton are the species that live entirely in the water column their entire life. Holoplankton are further divided into the phytoplankton, which includes unicellular algae and various bacteria, and the zooplankton. This latter grouping includes small crustaceans, gelatinous species, and a variety of other organisms. Meroplankton are the larval forms of marine species that use the water column to feed and disperse before becoming adult organisms. The larvae and eggs of crabs, barnacles, snails, clams, starfish, worms, fish, and many other species are present in meroplankton and represent a large part of the biomass of plankton communities. Tychoplankton are species that normally live in bottom communities and become suspended in the water column temporarily. Additionally, adult organisms of animals such as fish and crabs can become entrained in ballast tanks by being in close proximity to sea chest intakes or as attached organisms on debris.

Bacteria that have the potential for causing human health problems can also be found in ballast water. In the early 1990s shellfish beds in the southeastern United States along the Gulf of Mexico had to be closed because of the presence of cholera bacteria (*Vibrio cholerae*). This occurrence of *Vibrio cholerae* was traced back to ballast water discharges from vessels arriving from South America. The strain present in the Gulf of Mexico was the same that triggered an epidemic in South America that caused 10,000 deaths. The vibrios are waterborne bacteria that cause cholera when humans ingest contaminated water or raw or poorly cooked seafood taken from contaminated areas. There are 139 serogroups of *Vibrio cholerae* but only two - (01 and 0139) - cause cholera of epidemic proportions. The association of cholera bacteria with ballast water began to be realized more widely following the study of McCarthy & Khambaty (1994) in the Gulf of Mexico. Further research has detected both 01 and 0139 serogroups in ballast water being discharged in the United States Mid-Atlantic ports of Baltimore and Norfolk in the Chesapeake Bay (Ruiz et al. 2000b).

2. Sediments

Vessels generally ballast in coastal areas or ports that have a great deal of particulate matter suspended in the water column. This suspended matter is made up of organic and inorganic detritus and plankton. After ballast water is pumped into tanks particles begin to settle to the bottom and form a sediment layer. These layers can be up to eight centimeters thick (Godwin pers. observ.) and can provide a habitat for benthic fauna. A portion of the sediments can become re-suspended and discharged during ballasting and deballasting operations. Ballast tanks will always retain water and sediments in unpumpable sections of the tank until it is re-suspended by ballasting operations or movement of the vessel during transit. This material is removed from the tank periodically to prevent damage to pumps and is undertaken by members of the crew during port visits and sea transits or by shipyard workers during service periods. In both cases the material can be either intentionally or unintentionally dumped overboard.

These ballast water sediments can harbor communities of adult organisms that result from the settlement of larvae and eggs from the meroplankton. These organisms can mature and become a source for new larvae that become suspended within the water column of the ballast tank. Another common component of the sediment is the resting stages of phytoplankton species such as dinoflagellates and diatoms. Only a few researchers have dealt with ballast sediments. The most notable are the studies by Hallegraeff et al. (1990), Hallegraeff & Bolch (1992), and Kelly et al. (1993) that demonstrated the presence of viable resting stages of phytoplankton species in ballast sediments. These studies connected the introduction of the toxic dinoflagellates that are transported as cysts to ballast sediments. In the first two studies, the toxic dinoflagellates *Gymnodinium catenatum* and *Alexandrium catenella*, which cause paralytic shellfish poisoning, were identified from ballast sediments sampled from commercial cargo vessels arriving to Southern Australia. These sediments can also harbor bacterial communities that can flourish by deriving nutrients from the abundant organic matter settling out to the bottom of the ballast tank.

There is sediment accumulation associated with maritime vessel activity that is not due to ballast water operations. A source common to any type of vessel is the sediment found on anchors and anchor chains, which can accumulate in the chain locker compartment. These areas of the vessel can provide a sheltered habitat for a variety of animals that are adapted to an intertidal existence along coastlines and others that can exist in an encysted stage, such as the dinoflagellates mentioned earlier. Vessels that conduct unique operations such as dredging and those that function as work platforms (i.e., barges, floating dry docks) have to be considered as well. These vessels can transport sediments associated with deck surfaces and the gear associated with their unique operations. Very little has been done to survey this type of sediment transport due to the random nature of these arrivals to port systems.

3. Hull Fouling

Ballast water is the pathway that has been the major focus of investigation as a marine invasion vector, and the biofouling that occurs on the surfaces of vessel hulls has been given less attention. Historically, wooden sailing ships provided an ideal surface to which marine fouling organisms could attach. Common fouling organisms on these vessels were the wood-boring shipworms (*Teredo* sp.). The cosmopolitan range of this organism is thought to have resulted from worldwide spread by wooden vessels, especially as trade routes opened up between the Atlantic and the Pacific. Hull fouling has been dramatically reduced with the advent of steel hulls and anti-fouling coatings. The steps taken by large ocean going vessels and personal craft to eliminate hull fouling are not completely effective though, and organisms are still being transported by this means.

The organisms that generally foul vessel hulls are the typical species found in natural marine intertidal and subtidal fouling communities. The typical invertebrate organisms associated with marine fouling communities are arthropods (barnacles, amphipods, and crabs), molluscs (mussels, clams, and sea slugs), sponges, bryozoans, coelenterates (hydroids and anemones), protozoans, annelids (marine worms), and chordates (sea squirts and fish), as well as macroalgae (seaweed). If these fouling communities become very developed they can also provide micro-habitats for mobile organisms such as fish. Initial settlement of fouling organisms tends to be in sheltered areas of the hull, such as sea chest intakes and rudder posts, and develop in areas where anti-fouling coatings have been compromised (Ranier 1995; Coutts 1999; James and Hayden 2000; Godwin 2003). Anti-fouling coatings wear off along the bilge keel and weld seams, and are inadequately applied in some cases, all which make the surfaces susceptible to settlement by fouling organisms. Further work has focused on the transport of hull fouling organisms on personal craft throughout the tropical Pacific (Floerl and Inglis 2001).

Two recent marine AIS introductions to Hawai‘i are directly attributed to hull fouling. The bivalve mollusk *Chama macerophylla* and the sponge *Gelliodes fibrosa* both were introduced from the fouling community on the hull of a floating drydock towed to Hawai‘i from the Philippines in 1992 (DeFelice 1999). The barnacle *Chthamalus proteus*, which is listed in Table 2, is native to the Caribbean, was not recorded in Hawai‘i before 1973 (Southward et al, 1997). The larvae of *C. proteus* would not have a good chance at surviving the journey from the Caribbean in a ballast tank and were likely introduced by larvae spawned from adults that were part of a vessel hull fouling community. Apte et al. (2000) recorded such a scenario with blue mussels (*Mytilus galloprovincialis*), which were part of the fouling community on the hull of the U.S.S. Missouri, which was towed to Pearl Harbor from Bremerton, Washington. These mussels, which are AIS to Hawai‘i, were observed spawning upon arrival to Pearl Harbor; three months later, settled juveniles were recorded in the harbor, and identified as *M. galloprovincialis* through molecular techniques.

I.C. Minimizing the Effects Through Management

In the aquatic environment it is considered unrealistic to be able to eradicate an AIS once it has become established. The best strategy is to minimize the likelihood of initial introduction through prevention and outreach efforts. The most common approach for prevention is to target individual species that are potentially invasive to an area. This is a method proven to be effective in terrestrial systems, however, a more comprehensive approach in aquatic environments is to identify major pathways that can expose habitats to AIS and determine ways to control their potential effects. There are many pathways that can transport AIS to aquatic systems and a variety of management tools and treatment options aimed at prevention. This section briefly covers efforts aimed at prevention of AIS introductions associated with maritime vessels.

Due to the impacts documented by the invasion of the zebra mussel to the Great Lakes, Congress passed the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA). The NANPCA legislation created mandatory ballast water management guidelines that applied only to the Great Lakes. A reauthorization of NANPCA in 1996 created the National Invasive Species Act of 1996 (NISA), which expanded the legislation to cover all U.S. ports. Under NISA, the U.S. Coast Guard (USCG) developed voluntary ballast water management guidelines and mandatory ballast water management reporting and record keeping. NISA required the USCG to submit a report to Congress to evaluate the effectiveness of the voluntary ballast water management program. This report was submitted in June 2002 and concluded that compliance was too low to allow for an accurate assessment and proposed regulations that would make the voluntary guidelines mandatory. The proposed mandatory guidelines would require all vessels equipped with ballast water tanks entering U.S. waters after operating beyond the Exclusive Economic Zone (EEZ) to use one of the following approaches:

- Complete exchange of ballast water intended for discharge in U.S. waters. This exchange must take place no less than 200 nautical miles from any shore.
- Retain ballast water on board the vessel
- Prior to entry into U.S waters, use an environmentally sound ballast water management method that has been approved by the USCG
- Discharge ballast water to an approved reception facility.

In conjunction with this proposed rulemaking there are other aspects that are in development that involve the setting of standards and an approval process for experimental technologies for the purpose of ballast water treatment. This approval process will be designed to encourage vessel owners to participate with the experimental process of developing effective technologies for ballast water treatment. Also in development will be penalty provisions that will be attached to the new legislation. A public comment phase for this effort began in January 2003 and is scheduled to proceed until October 2003.

Presently, the NISA 1996 legislation is being reauthorized as the National Aquatic Invasive Species Act 2003 (NAISA). This is expanded legislation that seeks to provide tools and coordination to manage AIS threats more broadly. The NAISA legislation will implement a framework for an effective AIS management program. The components of this framework will be coordinated between all levels of government in partnership with private sector stakeholders. The components of the framework are:

- Prevention – Increased efforts focused on ballast water, sediments and hull fouling of maritime vessels arriving from outside the EEZ and domestic coastwise traffic inside the EEZ. Pursuit of environmentally sound treatment and prevention methods for all high risk pathways.

- Public Outreach and Education – Provisions to provide support for education and outreach to states, industry, and tribes that focus on high risk pathways and measures to minimize introduction and spread of AIS.
- Early Detection and Response – Coordination with state, local, and tribal governments to establish monitoring and rapid response program for AIS.
- Research and Risk Analysis – research to determine predictive guidelines for AIS introduction and establishment and risk assessment activities to develop management strategies to minimize introductions.
- Control and Management – Strategies directed towards management guidelines for AIS that have become established.

I.D. Hawai‘i Case Study

The native species of the marine and terrestrial environments of Hawai‘i arrived as natural biological invasions through historical time and through evolution and adaptation became the present communities associated with the archipelago. The islands of Hawai‘i are one of the most isolated areas in the world and all native plants and animals exist due to the pioneering species that settled here originally. The advent of modern history has created new human-mediated, or anthropogenic, biological invasion by AIS through non-natural mechanisms. Recent compilations of marine alien species in Hawai‘i (Eldredge and Carlton 2002) include some 343 species—287 invertebrates, 24 algae, 20 fish, and 12 flowering plants. Based on recent species inventories and a survey of historical literature the likely pathways for some of these introductions have been determined (Table 3).

The Hawai‘i Coral Reef Initiative-Research Program (HCRI-RP) 2003 project: “The assessment of hull fouling as a mechanism for the introduction and dispersal of marine introduced species in the main Hawaiian Islands” coincided with the development of management efforts in the state of Hawai‘i concerning marine AIS. The principal investigators were involved many aspects of these efforts, which included eliciting and structuring information for future development of administrative rules concerning hull fouling.

1. Hawai‘i AIS Management Efforts

In 2003 the development of administrative rules dealing with the vectors of ballast water and ballast sediments were drafted by the State of Hawai‘i and pending rules for hull fouling are in development. The administrative rules for ballast water and ballast sediments were based on a rules and regulations from the International Maritime Organization resolution A.868(20) within MEPC 47, and State of California Assembly Bill 703. The rules were developed, reviewed and agreed upon by a multiple stakeholder task force.

Table 3. Hawai'i marine AIS introduction mechanisms (Eldredge and Carlton 2002)

Mechanism	Species Number	Percent Established
Hull fouling	212	90
Solid ballast	21	90
Ballast water	18	89
Intentional release: Fishery	18	28
Parasites associated AIS	8	88
Organisms associated with commercial oyster shipments	7	100
Aquarium release	3	67

2. Administrative Rules for Ballast Water and Ballast Sediments

In the Session Laws of Hawai'i 2000, the Legislature established Act 134, which subsequently became Chapter 187A-31, Hawai'i Revised Statues (HRS), titled Alien Aquatic Organisms. Chapter 187A-31, HRS, designated the Department of Land and Natural Resources (DLNR) as the lead agency for preventing the introductions and carrying out the eradication of alien aquatic organisms through the regulation of ballast water discharges and hull fouling. It also gives DLNR the authority to establish an interagency task force to address concerns relating to alien aquatic organisms and adopt administrative rules, including penalties, to carry out the intent of this law.

The administrative rules for ballast water mirror the rules generated by the USCG for mandatory ballast water management and reporting. In the case of ballast sediments all vessels (including vessels at dry dock) are required to dispose of ballast sediment in a proper manner. Ballast sediment is defined as any settling particulate matter (organic or inorganic) that is found inside a ballast tank.

3. Hull Fouling

Hull fouling is a new management issue, and requires expert opinions from various stakeholders connected to maritime shipping, marine resource management, and marine alien species problems. This HCRI-RP 2003 funded component was focused on collaboration with an assembled group of stakeholders concerned with formulating a framework of information that will assist future management efforts for hull fouling.

The collaborative effort on hull fouling was begun with stakeholders from the Hawai'i maritime industry, state and federal aquatic resource managers, the scientific community, and a single non-governmental organization. To familiarize the stakeholders with the issue and concerns there was a two-day workshop involving researchers from outside of Hawai'i that study hull fouling introductions of marine AIS. This workshop was followed by monthly meetings to elicit criteria and concerns relating to managing hull fouling as a mechanism for marine AIS introductions.

II. Project Component: Field Survey

II.A. Introduction

The field component of the HCRI-RP project had multiple goals with the purpose of surveying the potential mechanisms for the introduction and dispersal of marine AIS through vessel fouling. These goals and objectives were as follows:

- **Goal: Surveys of hull fouling**

SCUBA Surveys

1. Commercial barges operating within Hawai‘i
   - ♦ Arrivals from overseas ports
   - ♦ Inter-island traffic
   - ♦ Intra-island traffic
2. Motor yachts/sailboats arriving from overseas destinations
3. Foreign fishing boats

Shipyard Surveys

1. When the opportunity presents itself the hulls of vessels being serviced in dry docks and boat yards were surveyed, including:
   - ♦ Commercial barges
   - ♦ Foreign fishing boats
   - ♦ Other commercial vessels

Objective: Identify the organisms present and create a list of species and determine if marine alien species are present

- **Goal: Survey of bio-fouling waste disposal practices for commercial hull cleaning facilities**

Objective: Determine if local shipyard practices are contributing to the introduction of marine alien species

- **Goal: Compile arrival patterns and vessel operation dynamics for:**
   - ♦ Commercial barges
   - ♦ Foreign fishing boats
   - ♦ Motor yachts/sailboats

Objective: Create a profile for last port (or region) of call for overseas arrivals to determine the potential sources for marine alien species. A compilation of the various operations in Hawai‘i of these vessels will provide insight to the potential dispersal of marine alien organisms.

II.B. Surveys of Hull Fouling

1. Introduction

Surveys for adult invertebrates that were part of the hull fouling communities were conducted to determine to what extent marine AIS are being transported in this fashion. The focus was to perform a qualitative analysis that created a species inventory.

The organisms that generally foul vessel hulls are the typical species found in natural marine intertidal and subtidal fouling communities. These organisms are usually associated with one of the following groups: sponges, coelenterates (hydroids, corals, and anemones), mollusks (mussels, clams, and sea slugs), annelids (marine worms), arthropods (barnacles, amphipods, and crabs), bryozoans (moss animals), chordates (sea squirts and fish), as well as macroalgae (seaweed).

Through collaboration with state and private industry representatives, arrivals notification for various vessel types was received. This arrivals information was used to schedule field survey activities throughout the study.

2. Methodology

Port Arrivals

1) Identify vessel for survey
   - Commercial vessel – consult vessel arrival schedules maintained by State of Hawai'i Department of Transportation, Harbors Division
   - Personal Craft – consult with harbor master of public or privately owned marinas to provide arrivals information

     Public marinas: State of Hawai'i Department of Land and Natural Resources, Division of Boating and Ocean Resources
     Private marinas: consult marinas listing in Hawai'i Ocean Industry and Shipping News publication
2) Contact vessel owner/operator to obtain particulars (i.e., last port, vessel maintenance records….) and permission to conduct hull survey
   - Commercial vessel – either directly or through the shipping agent
   - Personal Craft – speak directly to owner/operator
3) Survey entire hull from bow to stern on port and starboard sides with scuba and collect a representative sample of all taxonomic groups present
4) Record the overall percent cover of fouling in each of the following sections of the vessel:
   - Bow
   - Midship
   - Stern
   - Prop and rudder
   - Above the water line
   - Drydock support strips (DDSS) and zinc block

Shipyard Hull Surveys

1) Identify point of contact local shipyard facilities
2) Establish time of vessel entry into dry-dock and access
3) Survey entire hull from bow to stern on port and starboard sides with scuba and collect a representative sample of all taxonomic groups present
4) Record the overall percent cover of fouling in each of the following sections of the vessel:
   - Bow
   - Midship
   - Stern
   - Prop and rudder
   - Above the water line

All samples were analyzed upon return to the laboratory to determine if organisms were live or dead, and each taxonomic group was recorded on a standardized data sheet. Hard-shelled organisms were preserved in 75% Ethanol, tunicates and cnidarians were relaxed and fixed in 10% Formalin then transferred to 75% Ethanol, and macroalgae was preserved in 2% Formalin. Organisms were then identified at a later date.

3. Results

Diving and Shipyard Surveys

A total of 35 vessels were surveyed during the field component of the study. Diving surveys were done on 34 vessels and a single vessel was surveyed within a shipyard. Appendix A contains the metadata for each vessel sampled, and Table 4 below provides a simplified compilation. The single vessel sampled in the ship yard was an inter-island barge. The inter-island barges were combined together for analysis in the results section.

Table 4. The number of vessel types sampled during field component

Vessel Type	# Sampled
Foreign Fishing Boat	3
Inter-island Barge	9
Inter-island Tug	5
Overseas Barge	3
Overseas Personal Craft	12
Overseas Research Vessel	1
Intra-island Floating Dry Dock	1
Other	1

All vessels were part of the originally intended focus group, with the exception of the last two vessels in the list. The floating dry dock is described by the qualifier, intra-island, due to the fact that it was transported from Pearl Harbor to Kalaeloa Barber's Point Harbor. This vessel was in the Pearl Harbor inactive shipyard for over ten years and was purchased by Marisco Shipyard at Kalaeloa Barber's Point Harbor. Pearl Harbor is a highly invaded area with many marine alien species. This was a unique opportunity to document the intra-island movement of species on Oáhu. The vessel labeled “other” was a U.S. Navy work vessel involved in the salvage operations for the Ehime Maru in 2001.

Organisms Identified from Field Component

A diverse group of organisms was collected and identified from the diving and shipyard sample efforts. The following table presents the ten phyla recorded.

Table 5. Marine species represented in field samples across all vessels sampled (n=35)

Phylum	Representatives in field samples
Plantae	macroalgae
Porifera	sponges
Cnidaria	hydroids (hydrozoan), anemones and coral (anthozoans)
Annelida	free-living and tube dwelling worms
Mollusca	bivalves, worm shells (Vermetidae) and snails (Gastropoda)
Crustacea	crabs, mantis shrimp, pericarids and barnacles (Cirripedia)
Pycnogonida	sea spiders
Bryozoa	moss animals
Echinodermata	brittle stars
Urochordata	sea squirts

The mean percent occurrence across all vessels sampled is presented in Figures 1-4. The Plantae are represented exclusively by macroalgae, which are distinguished by their representative classes; Chlorophyceae, Phaeophyceae, and Rhodophyceae. Porifera, Pycnogonida, Bryozoa, Echinodermata, and Urochordata are presented as all-inclusive categories when demonstrating percent occurrence. The representatives of the cnidarians are the hydrozoans and anthozoans, while annelids are broken down into tube dwelling species, which includes sabellids, serpulids, and spirorbids, and a free-living species category, which is comprised of a number of different families. The molluscs are divided into gastropods, vermetids (worm shells), and bivalves. The crustaceans are presented as four categories that range from specific groupings such as cirripedia (barnacles), stomatopods (mantis shrimp), and brachyuran (crabs) to the broader category peracarids (amphipods, isopods, and caprellid shrimp).

The species data is initially presented in this way to demonstrate the taxonomic groups present in the hull fouling communities of vessels sampled. Other studies on hull fouling have found a similar suite of organisms on a variety of commercial vessels (Yan and Huang 1993; Rainer 1995; Coutts 1999; James and Hayden 2000) and personal craft (Floerl and Inglis 2001).

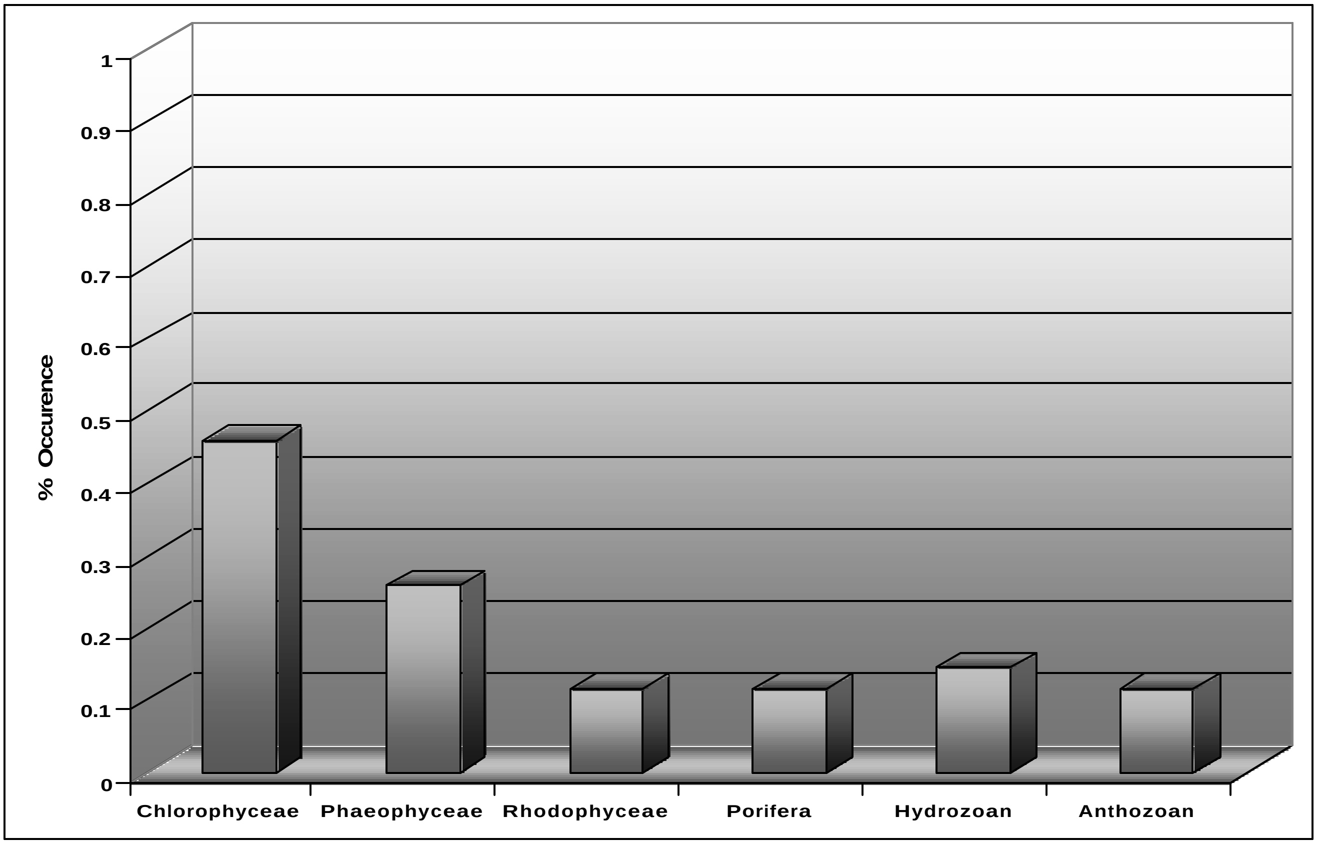

Figure 1. Mean percent occurrence across all vessels for Plantae, Porifera, and cnidarians

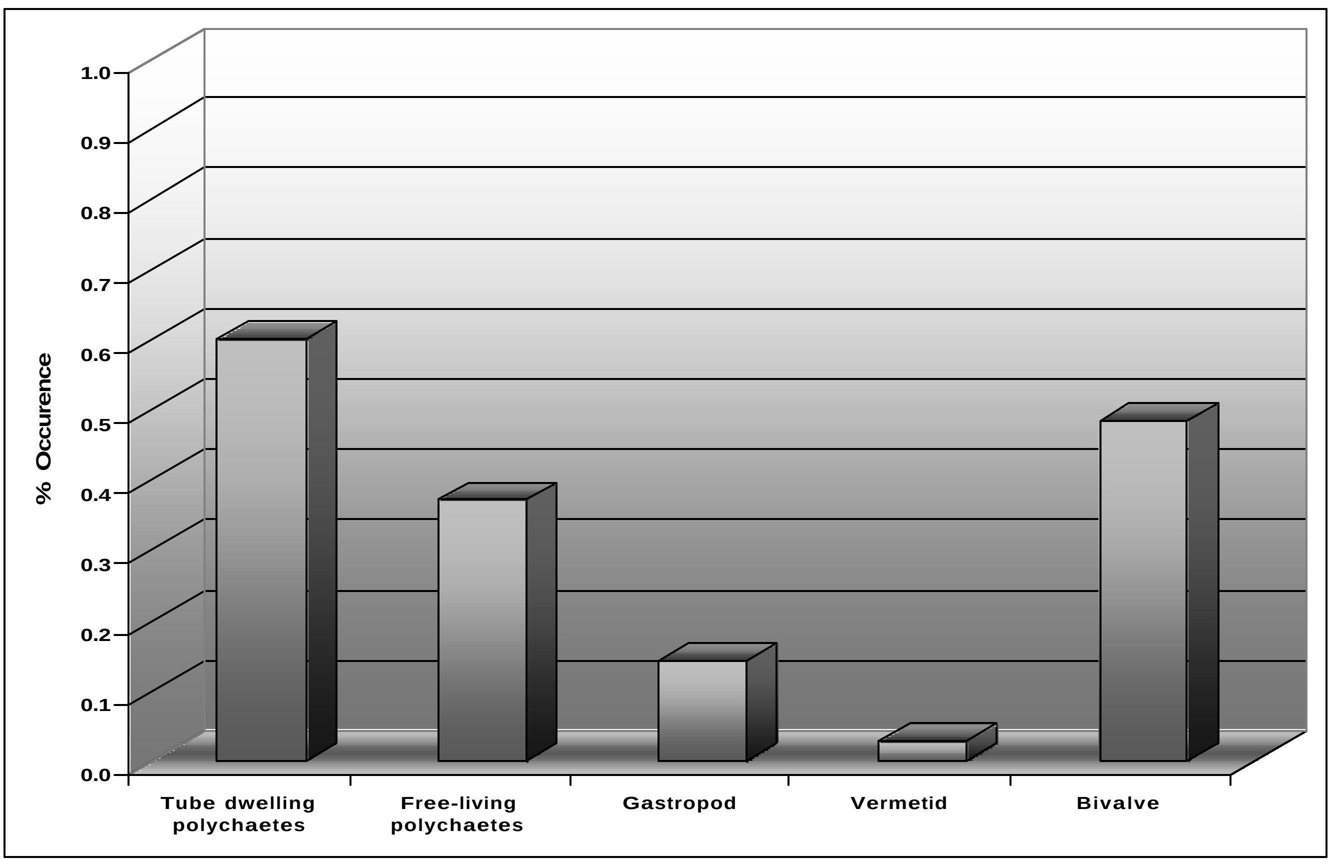

Figure 2. Mean percent occurrence across all vessels for annelids and molluscs

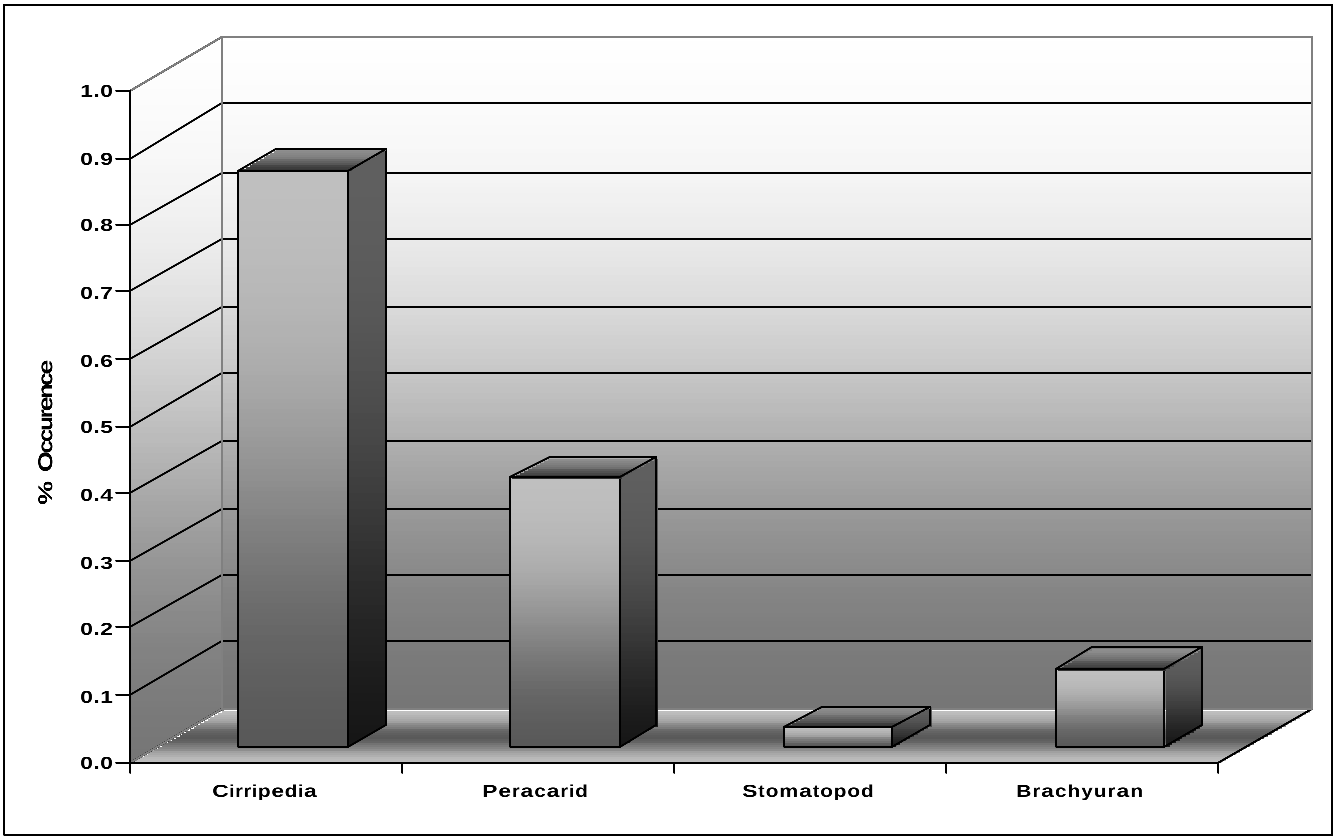

Figure 3. Mean percent occurrence across all vessels for crustaceans

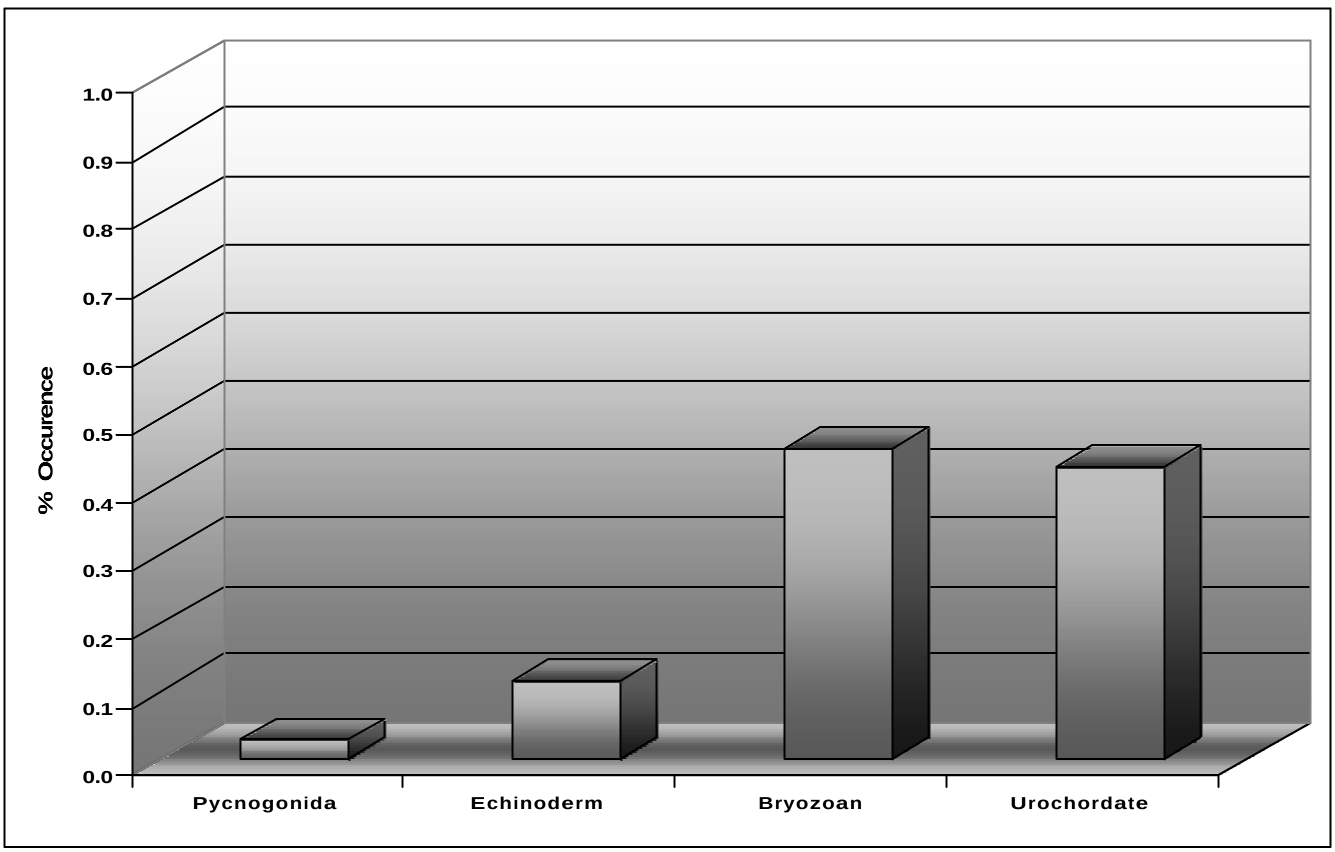

Figure 4. Mean percent occurrence across all vessels for pycnogonids, echinoderms, bryozoans, and urochordates

The following section will present specific results based on vessel types. A complete inventory of the species recorded on each vessel sampled during the course of the field component can be found in Appendix B. These data were analyzed to show the mean percent occurrence of specific species categories on the particular locations on the hulls described in the methods; referred to as coverage data in this report. A unique category was included which denoted species associated with the patches left by dry dock supports and with the zinc blocks. This was due to the fact that on some vessels the majority of fouling recorded was associated with these regions and was not uniform over the entire hull. All large commercial vessels have zinc blocks of some type for control of corrosion, but the strips of fouling associated with the patches created by dry dock support blocks are not always present. In Coutts (1999), these areas are referred to as dry dock support strips (DDSS). The category created for data recording was DDSS/Zinc, which refers to organisms only associated with the DDSS and zinc blocks.

The species categories for vessel coverage data were based on the organisms that could be identified in the field, which in most cases were either on phylum or generic morphotype (see Table 6 below). The lowest level of identification in the field was to the family level. This coverage data will be presented for each vessel type. An accompanying table will show the presence of AIS or cryptogenic species, and if they are considered new records. The information in this final table was determined through laboratory analysis and was based on a different species status category list (see Table 6 below). The differences between the category lists are based on the level of resolution capable in the field and the finalization of taxonomy in the laboratory.

Table 6. Categories for vessel coverage and species status data

Coverage data categories		Species status categories
PLANTAE		PORIFERA
Chlorophyceae		CNIDARIA
Phaeophyceae		Class Hydrozoa
Rhodophyceae		Class Anthozoa
PORIFERA		ANNELIDA
CNIDARIA		Family Sabellidae
Class Hydrozoa		Family Serpulidae
Class Anthozoa		Family Spirorbidae
ANNELIDA		MOLLUSCA
Family Sabellidae		Class Polyplacophora
Family Serpulidae		Class Gastropoda
Family Spirorbidae		Family Vermetidae
MOLLUSCA		Class Bivalvia
Class Polyplacophora		CRUSTACEA
Class Gastropoda		Class Cirripedia (Balanomorph only)
Family Vermetidae		Class Amphipoda
Class Bivalvia		Class Isopoda
CRUSTACEA		Class Stomatopoda
Balanomorpha barnacle		PYCNOGONIDA
Lepadimorpha barnacle		ECHINODERMATA
ECHINODERMATA		Class Ophiuroidea
Class Ophiuroidea		BRYOZOA
BRYOZOA		UROCHORDATA
UROCHORDATA		

The macrolagae are omitted from the species status list due to the fact that the taxonomy of these species was incomplete. The crustacean category in the species status list added amphipods, isopods, and stomatopods and deleted the lepadimorph barnacle category. The additions were for species that could be identified in the laboratory but not in the field. The lepadomorph barnacles seen in the field were cosmopolitan species and did not fall into either a marine AIS or cryptogenic category. The phylum Pycnogonida was added to the species status category. A complete formal list of all species, which includes free-living polychaete worms and other cryptic fauna with their status designations can be found in Appendix C.

Foreign Fishing Boats

Vessel Information

ID	Vessel Type	Home Port	Vessel Journey Record
027	Foreign Fishing Boat	Japan	Peru>Marshall Islands>Honolulu
028	Foreign Fishing Boat	Japan	Japan>Pusan, Korea>Honolulu
029	Foreign Fishing Boat	Japan	Japan>Marshall Islands>Honolulu

Fishing vessel 027 was the only one of the group to have a high level of fouling but all the species were cosmopolitan open ocean species. The other two vessels were almost completely devoid of fouling species. There were no alien species recorded in the laboratory and a species status table is not included for these vessels. The coverage data is shown in Figures 5 and 6.

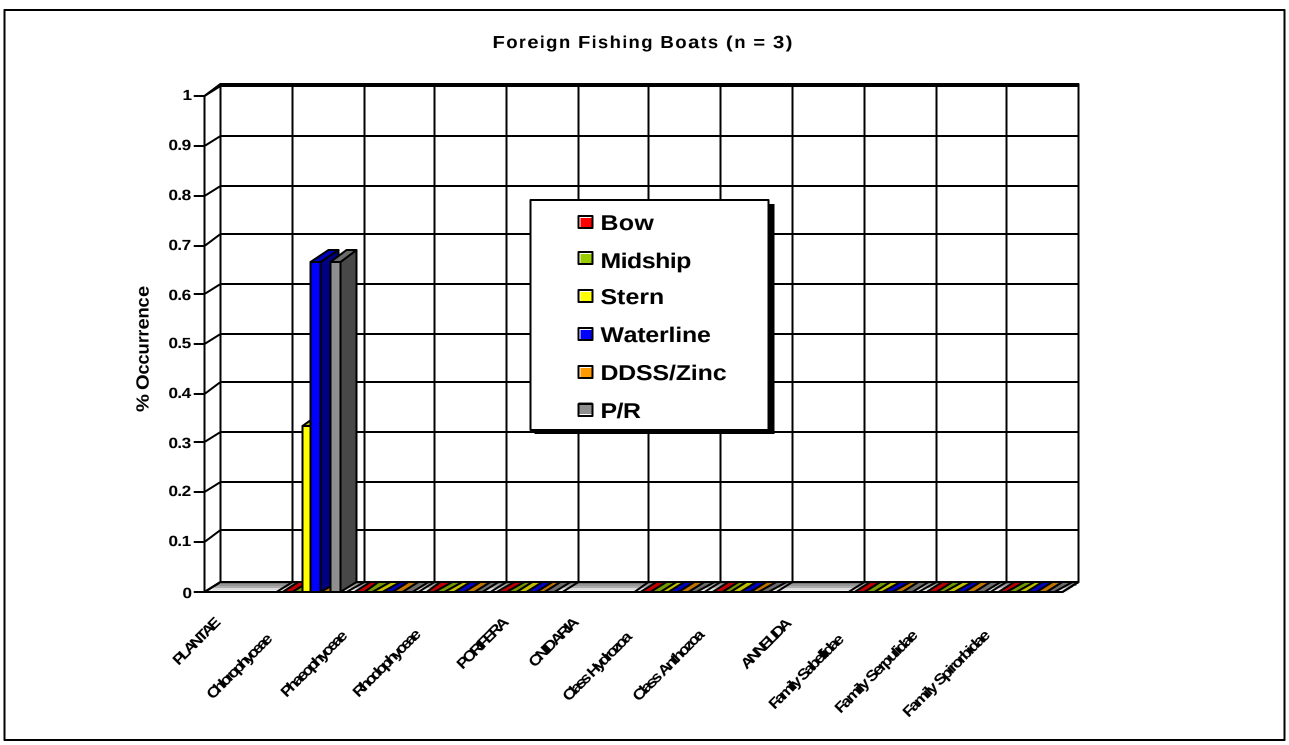

Figure 5. Mean percent occurrence of Plantae, Porifera, cnidarians, and annelids on particular hull locations for foreign fishing boats

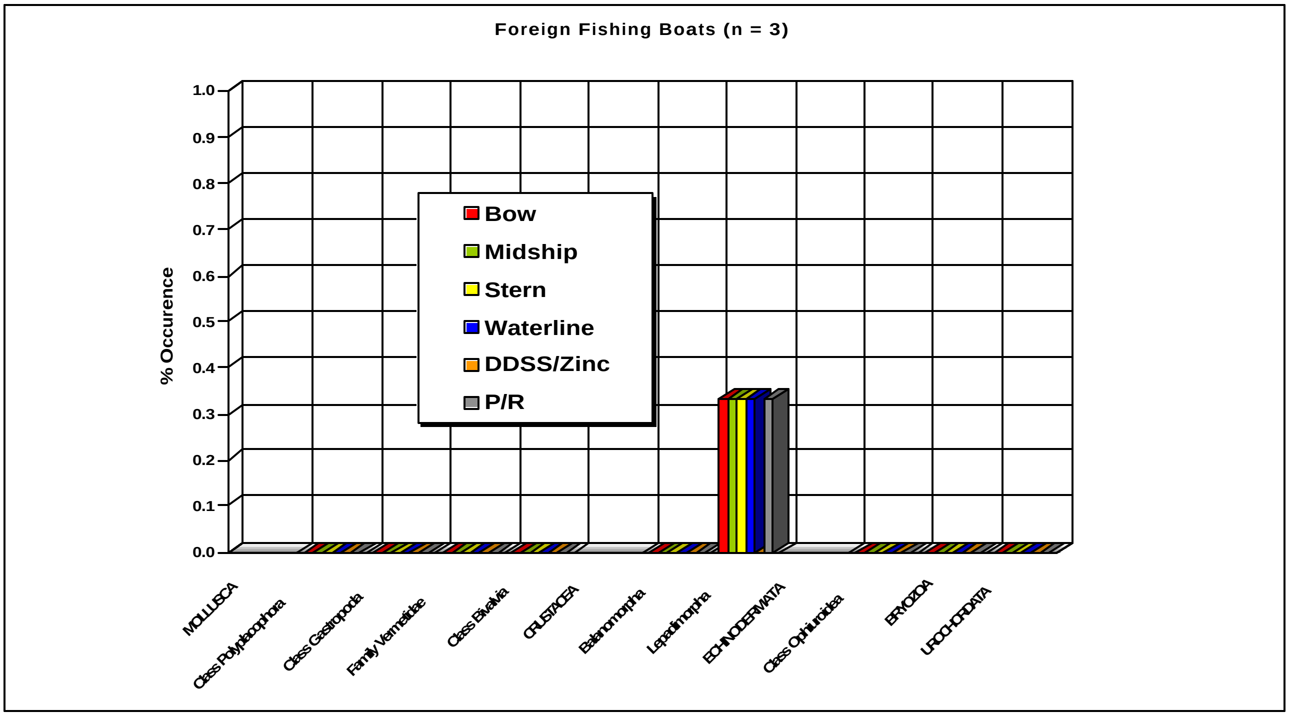

Figure 6. Mean percent occurrence of molluscs, crustaceans, echinoderms, bryozoans, and urochordates on particular hull locations for foreign fishing boats

<u>Inter-island Barges</u>

Vessel Information

ID	Vessel Type	Home Port	Vessel Journey Record
020	Interisland Barge	Honolulu	Interisland>Honolulu
014	Interisland Barge	Honolulu	Interisland>Honolulu
013	Interisland Barge	Honolulu	Interisland>Honolulu
012	Interisland Barge	Honolulu	Interisland>Honolulu
011	Interisland Barge	Honolulu	Interisland>Honolulu
010	Interisland Barge	Honolulu	Interisland>Honolulu
016	Interisland Barge	Honolulu	Interisland>Honolulu
023	Interisland Barge	Honolulu	Interisland>Honolulu
015	Interisland Barge	Honolulu	Interisland>Honolulu

All of the inter-island barges, with the exception of 011, solely operated in the Main Hawaiian Islands. Vessel 011 had been operating in the Pacific Northwest six months prior to the sampling event. This vessel had been dry-docked and cleaned before its arrival to Hawaiʻi and had no fauna from the previous region. All inter-island cargo barges were heavily fouled and marine AIS were associated with each. These marine AIS were organisms already recorded from Hawaiʻi and are established in all commercial harbors throughout the Main Hawaiian Islands. The exception was the record of the serpulid polychaete worm *Salmacina tribranchiata* from a few of the hulls. This species was initially recorded in the field as *Salmacina disteria*, which is another serpulid polychaete said to be an established marine AIS in the harbors of Hawaiʻi. A renowned expert on serpulid worms identified the *S. tribranchiata*, but more specimens have to be obtained for confirmation. The identification for *S. tribranchiata* will be retained for this report and considered a new record. All other species considered as congeners were reported as *Salmacina* sp. during the processing of samples. The compliment of phyla and morphotypes with their status is shown in Table 7. The data for fouling coverage on all inter-island barges is shown in Figures 7 and 8.

Table 7. Species status for inter-island barges

Interisland Barges	Total	AIS	Cryptogenic	New Records
PORIFERA	0	0	0	0
CNIDARIA				
Class Hydrozoa	1	1	0	0
Class Anthozoa	2	1	0	0
ANNELIDA				
Family Sabellidae	1	0	1	0
Family Serpulidae	6	5	1	1
Family Spirorbidae	7	1	0	0
MOLLUSCA				
Class Polyplacophora	2	0	0	0
Class Gastropoda	2	0	0	0
Family Vermetidae	0	0	0	0
Class Bivalvia	2	1	0	0
CRUSTACEA				
Balanomorpha	4	3	0	0
Class Amphipoda	4	0	0	0
Class Isopoda	2	0	0	0
Class Stomatopoda	0	0	0	0
PYCNOGONIDA	0	0	0	0
ECHINODERMATA				
Class Ophiuroidea	1	0	0	0
BRYOZOA	10	4	1	0
UROCHORDATA	4	3	0	0
Totals	48	19	3	1

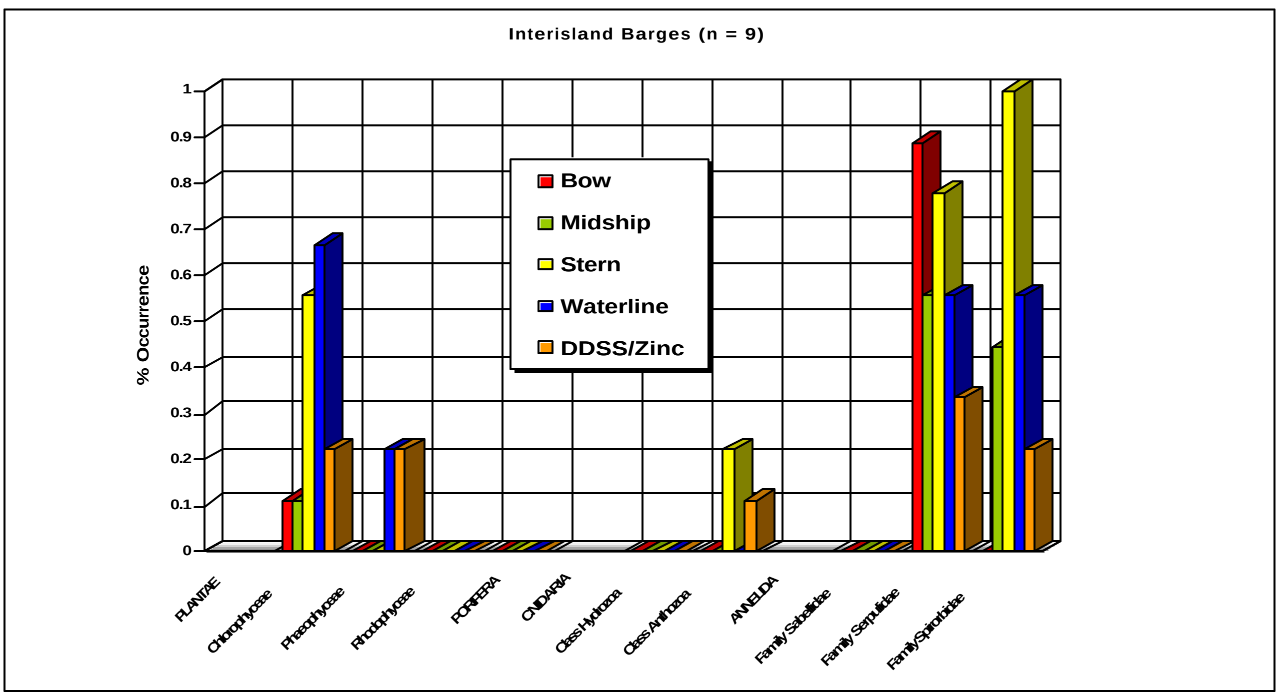

Figure 7. Mean percent occurrence of Plantae, Porifera, cnidarians, and annelids on particular hull locations for inter-island barges

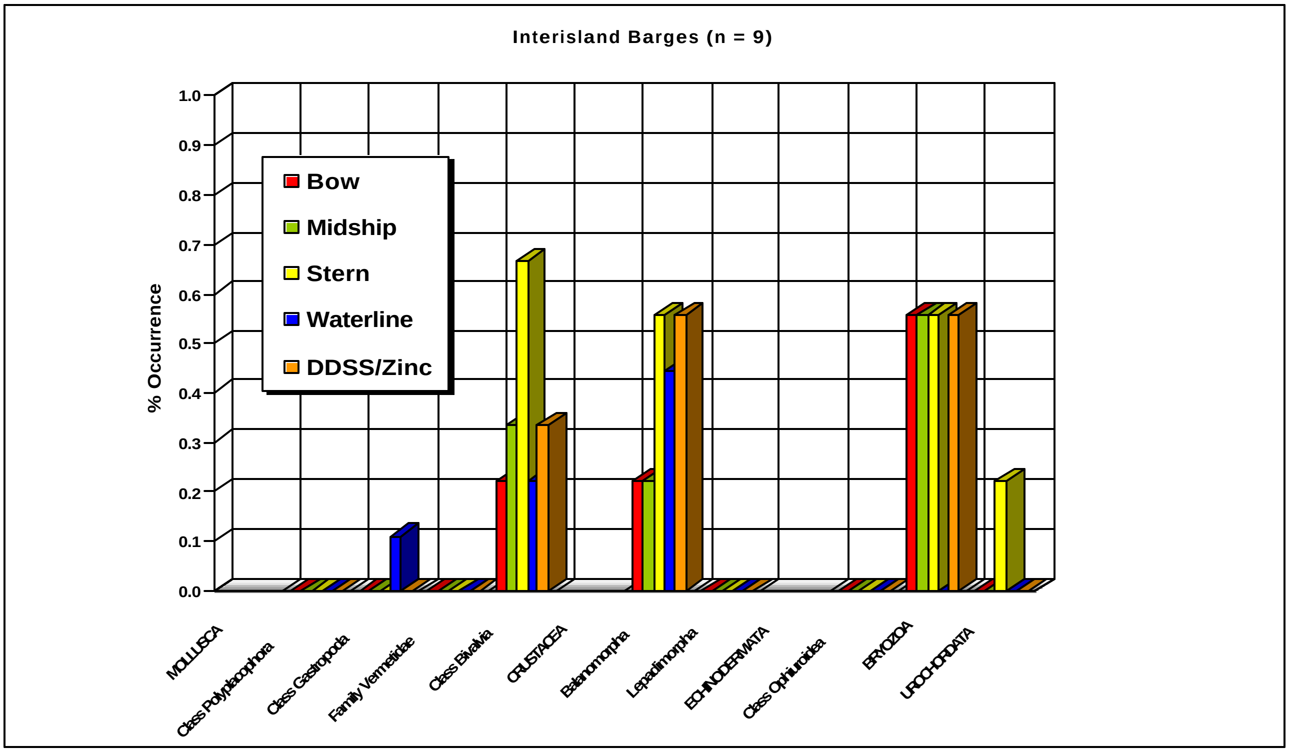

Figure 8. Mean percent occurrence of molluscs, crustaceans, echinoderms, bryozoans, and urochordates on particular hull locations for inter-island barges

Inter-island Tugs

Vessel Information

ID	Vessel Type	Home Port	Vessel Journey Record
030	Interisland Tug	Honolulu	Interisland>Honolulu
031	Interisland Tug	Honolulu	Interisland>Honolulu
021	Interisland Tug	Honolulu	Interisland>Honolulu
032	Interisland Tug	Honolulu	Interisland>Honolulu
022	Interisland Tug	Honolulu	Interisland>Honolulu

These vessels are part of the fleet of tugs that tow the inter-island cargo barges to all the Main Hawaiian Islands. The tug fleet was not initially considered for sampling at the beginning of the study. A high level of fouling was recorded for the majority of the five vessels surveyed. There were many marine AIS, all of which were established species in Hawai‘i, recorded from the hulls of these vessels. The fouling communities on some of these vessels were developed beyond the pioneer settlers, such as balanomorph barnacles and tubeworms, and were dominated by an extensive crust of the bryozoans *Schizoporella errata* and *Watersipora edmondsoni* which are marine AIS. The data for fouling coverage is presented in Figures 9 and 10 and the species status list for inter-island tugs is in Table 8.

Table 8. Species status for inter-island tugs

Interisland Tug	Total	AIS	Cryptogenic	New Records
PORIFERA	3	3	0	0
CNIDARIA				
Class Hydrozoa	2	1	1	0
Class Anthozoa	0	0	0	0
ANNELIDA				
Family Sabellidae	2	1	1	0
Family Serpulidae	6	4	2	0
Family Spirorbidae	5	2	3	0
MOLLUSCA				
Class Polyplacophora	0	0	0	0
Class Gastropoda	2	0	0	0
Family Vermetidae	2	0	0	0
Class Bivalvia	2	0	0	0
CRUSTACEA				
Balanomorpha	6	3	0	0
Class Amphipoda	2	0	0	0
Class Isopoda	2	0	0	0
Class Stomatopoda	0	0	0	0
PYCNOGONIDA	1	0	0	0
ECHINODERMATA				
Class Ophiuroidea	1	0	0	0
BRYOZOA	5	3	1	0
UROCHORDATA	9	7	0	0
Totals	50	26	8	0

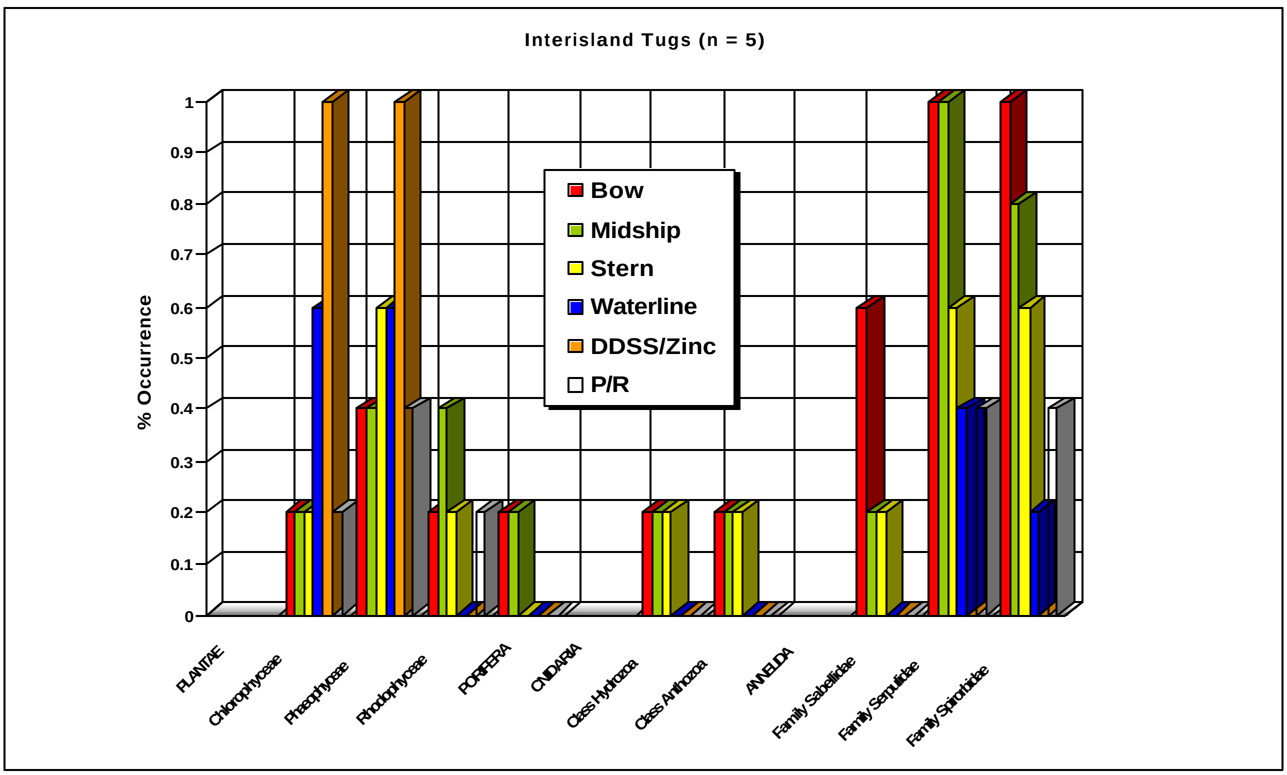

Figure 9. Mean percent occurrence of Plantae, Porifera, cnidarians, and annelids on particular hull locations for inter-island tugs

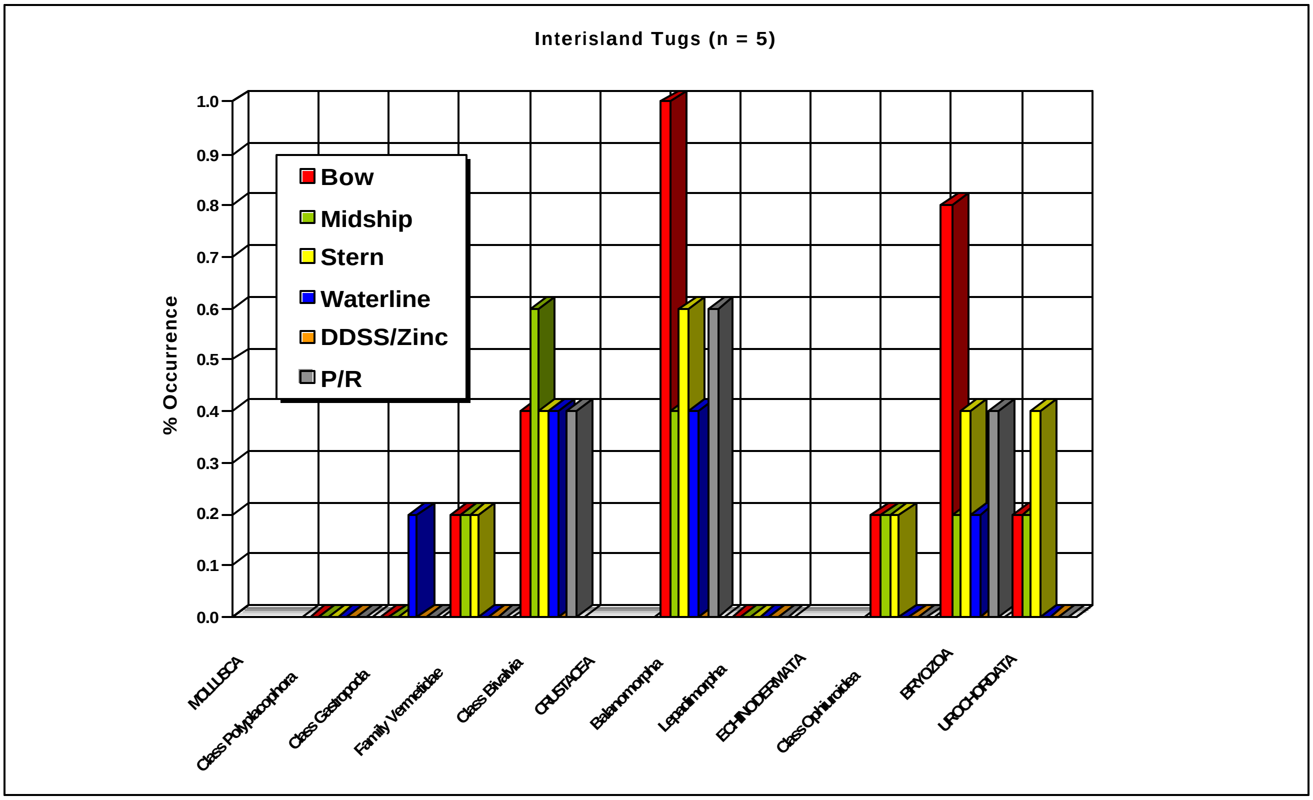

Figure 10. Mean percent occurrence of molluscs, crustacea, echinoderms, bryozoans, and urochordates on particular hull locations for inter-island tugs

<u>Overseas Barges</u>

Vessel Information

ID	Vessel Type	Home Port	Vessel Journey Record
004	Overseas Barge	Honolulu	Marshall Islands>Honolulu
005	Overseas Barge	Long View, Washington	Long View>Coos Bay, Oregon>Honolulu
006	Overseas Barge	Long View, Washington	Long View>Coos Bay, Oregon>Honolulu

A total of three overseas barges were surveyed during the course of the field component. The level of fouling on all of these vessels was quite low, and no alien species were recorded. No species status table will be presented but Figures 11 and 12 present the fouling species coverage data for all the vessels surveyed.

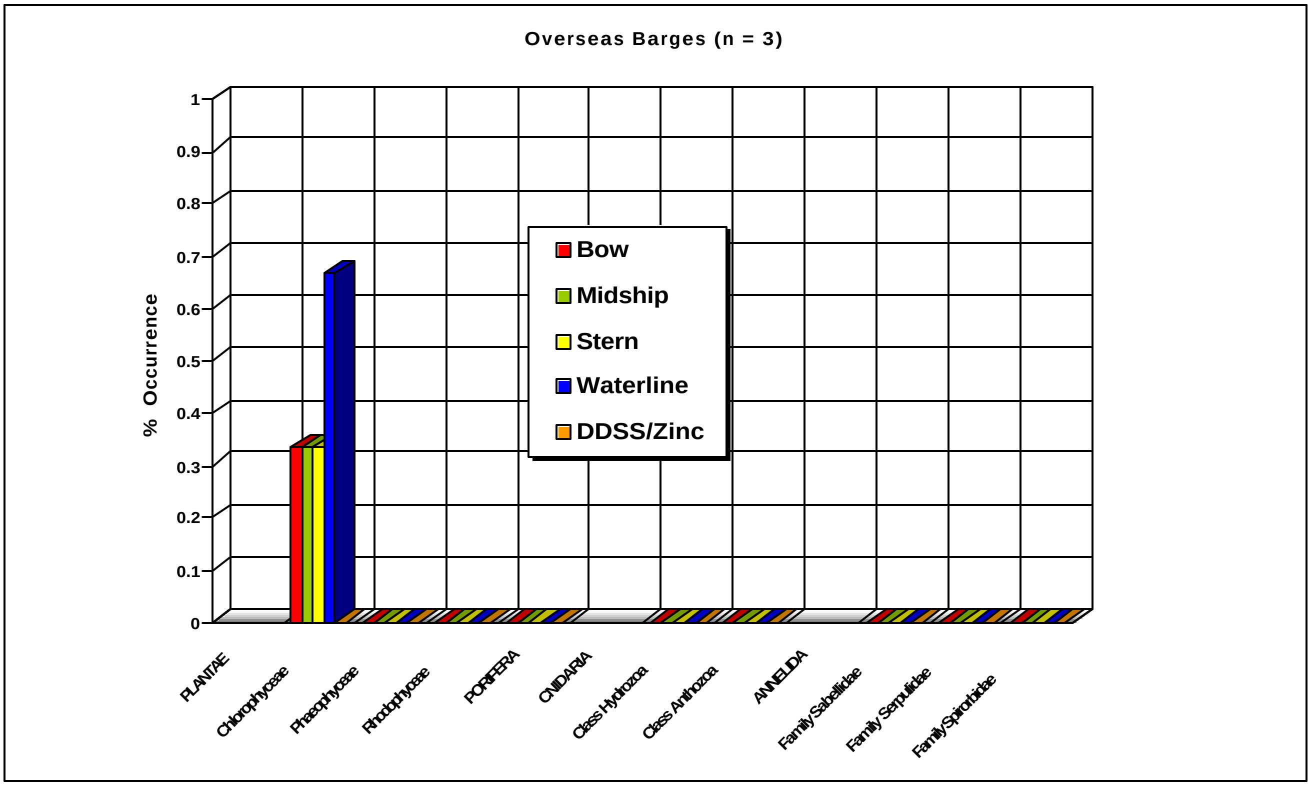

Figure 11. Mean percent occurrence of Plantae, Porifera, cnidarians, and annelids on particular hull locations for overseas barges

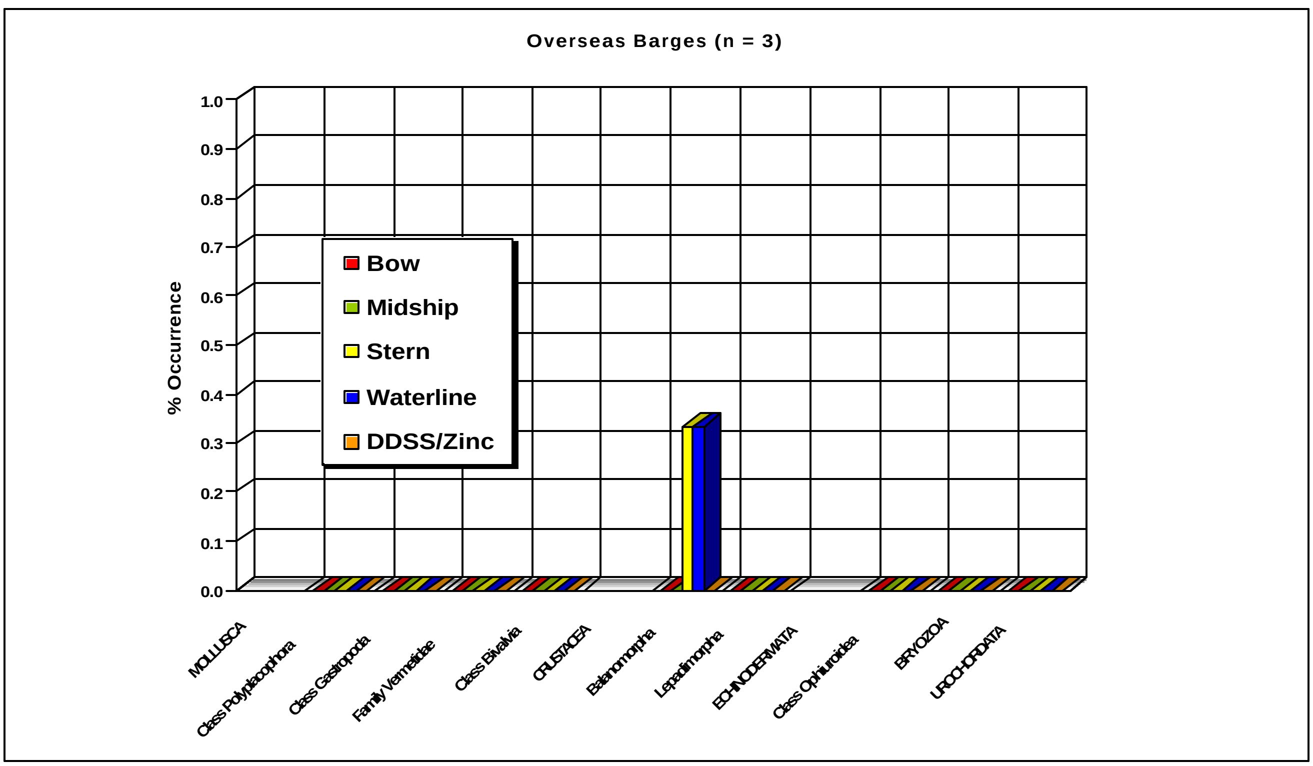

Figure 12. Mean percent occurrence of molluscs, crustaceans, echinoderms, bryozoans, and urochordates on particular hull locations for overseas barges

<u>Overseas Personal Craft</u>

Vessel Information

ID	Vessel Type	Home Port	Vessel Journey Record
019	Overseas Personal Craft	San Francisco	San Francisco>Mexico>Maui>Honolulu
018	Overseas Personal Craft	San Francisco	San Francisco>Mexico>Hilo>Honolulu
017	Overseas Personal Craft	Unknown	South Pacific>Honolulu
026	Overseas Personal Craft	Unknown	South Pacific>Honolulu
034	Overseas Personal Craft	San Francisco	San Francisco>Mexico>Honolulu
001	Overseas Personal Craft	Haifa, Israel	Haifa>Cyprus>Greece>Italy>France>Spain>Caribbean>Florida>New York>Florida>Panama(Canal Transit) >Costa Rica>Mexico>San Diego>Hilo>Lahaina>Honolulu
002	Overseas Personal Craft	Meiken, Japan	Meiken>Honolulu
003	Overseas Personal Craft	Norfolk, Virginia	Norfolk>Florida>Caribbean>Panama(Canal Transit)>Mexico>Hilo>Honolulu
007	Overseas Personal Craft	Southhampton, England	Liverpool>Portugal>Cuba>Panama (Canal Transit)>Galapagos>Honolulu
008	Overseas Personal Craft	Cape Town, South Africa	Liverpool>Portugal>Cuba>Panama (Canal Transit)>Galapagos>Honolulu
009	Overseas Personal Craft	Glasgow, Scotland	Liverpool>Portugal>Cuba>Panama (Canal Transit)>Galapagos>Honolulu
033	Overseas Personal Craft	Vancouver, Canada	Vancouver>Hilo>Honolulu

The vessel information above demonstrates the variety of locations from which personal craft are arriving from outside of Hawai‘i. Despite the small sample size it is clear that the journey records are more complex than the commercial cargo traffic arriving to Hawai‘i. Table 9 shows a large number of marine AIS associated with these vessels, but only one new record was recorded. The majority of the marine AIS recorded were species already established that had recruited to the hulls while the vessels had been operating within Hawaiian waters. The new record column in Table 9 shows one confirmed and one unconfirmed species. The confirmed new record was for the barnacle *Megabalanus peninsularis* Pilsbry found on vessels 007, 008, and 009, which were part of a twelve vessel regatta transiting through Hawai‘i. The last port of call for all these vessels was the Galapagos Islands. *Megabalanus peninsularis* is a common species in this location and was likely picked up while in port at this location. The species record that is unconfirmed is for a barnacle of the genus *Chthamalus*. One of the more common marine AIS established in Hawai‘i is the Caribbean barnacle *Chthamalus proteus* Dando and Southward. This *Chthamalus* species was found on vessel 026, which was surveyed on the day of its arrival from the southern Pacific. This would discount the species being one that settled on the vessel while it was in Hawaiian waters. At the time of the writing of this report the specific species of this *Chthamalus* was not yet determined, hence its status as an unconfirmed new record. The coverage data for all the overseas personal craft surveyed is presented in Figures 13 and 14.

Table 9. Species status for overseas personal craft

Overseas Personal Craft	Total	AIS	Cryptogenic	New Records
PORIFERA	0	0	0	0
CNIDARIA				
Class Hydrozoa	1	0	0	0
Class Anthozoa	0	0	0	0
ANNELIDA				
Family Sabellidae	1	0	1	0
Family Serpulidae	4	3	1	0
Family Spirorbidae	1	1	0	0
MOLLUSCA				
Class Polyplacophora	0	0	0	0
Class Gastropoda	0	0	0	0
Family Vermetidae	0	0	0	0
Class Bivalvia	0	0	0	0
CRUSTACEA				
Balanomorpha	8	8	0	1+1(?)
Amphipoda	9	3	0	0
Isopoda	2	0	0	0
Stomatopoda	0	0	0	0
PYCNOGONIDA	1	1	0	0
ECHINODERMATA				
Class Ophiuroidea	0	0	0	0
BRYOZOA	2	1	0	0
UROCHORDATA	4	4	0	0
Totals	33	21	2	1

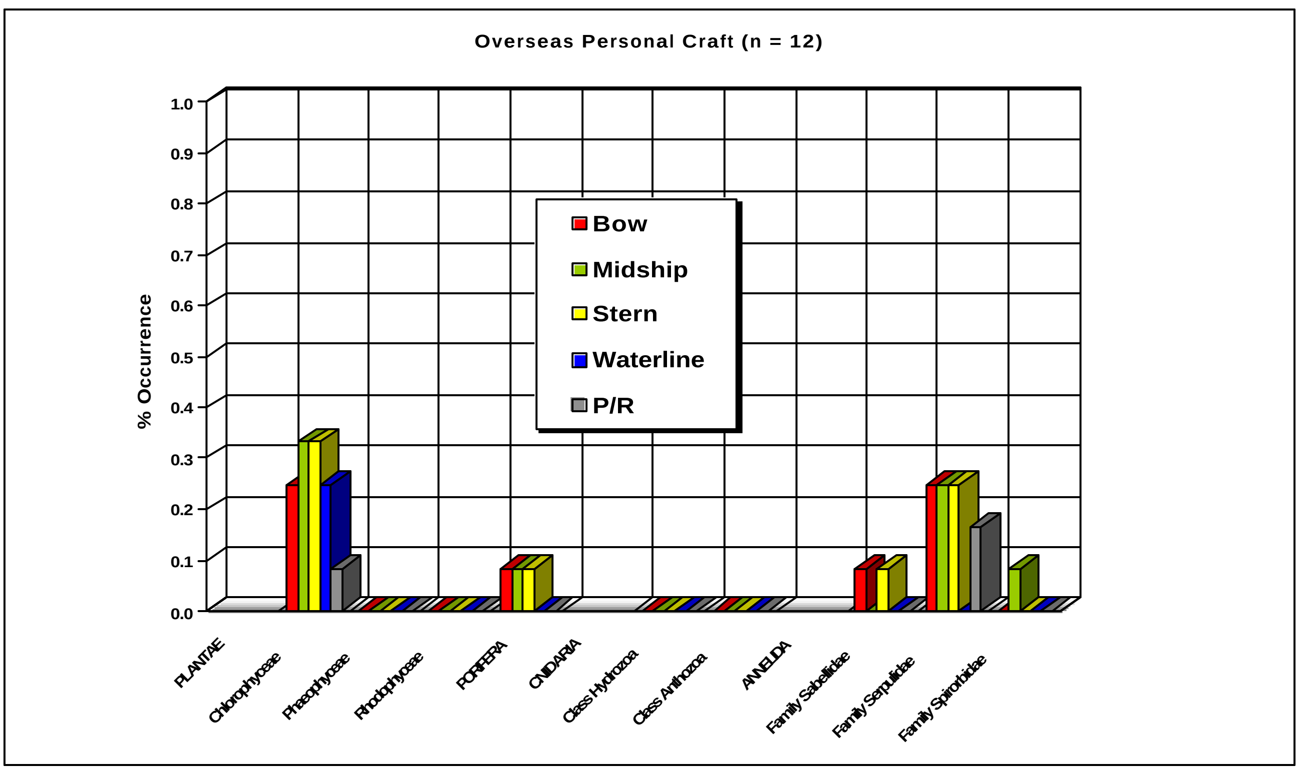

Figure 13. Mean percent occurrence of Plantae, Porifera, and annelids on particular hull locations for overseas personal craft

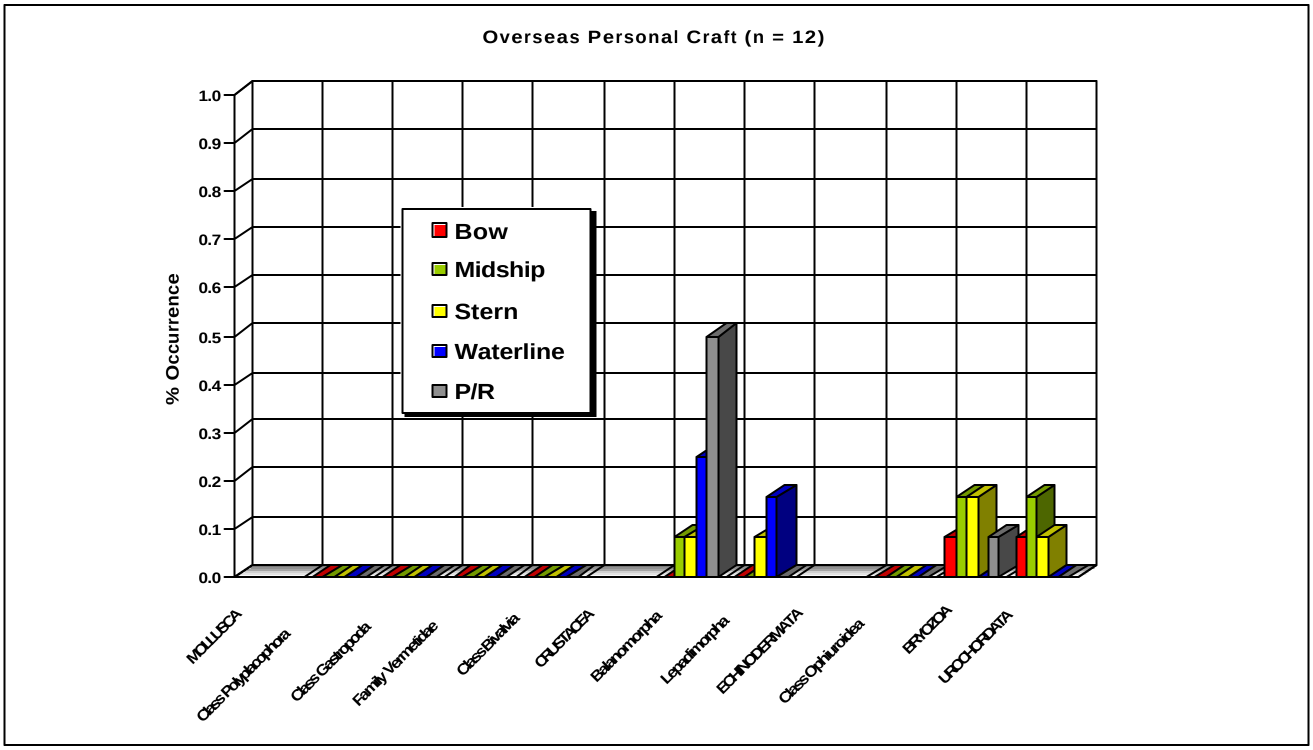

Figure 14. Mean percent occurrence of molluscs, crustaceans, echinoderms, bryozoans, and urochordates on particular hull locations for overseas personal craft

<u>Other Vessels</u>

Vessel Information

ID	Vessel Type	Home Port	Vessel Journey Record
024	U.S. Navy Salvage Vessel	Los Angeles	Los Angeles>Honolulu
025	Intra-island floating dry dock	Pearl Harbor	Pearl Harbor>Barber's Point Harbor
035	NOAA Research Vessel	Honolulu	Jacksonville, FL>Panama (Canal Transit)>Honolulu

This was a component representing more stochastic events that are not part of standard vessel movements in Hawai‘i. The U.S. Navy salvage vessel (024) was sampled during an effort prior to the beginning of the HCRI-RP project but both the intra-island floating dry dock and research vessel were sampled during the course of this project. Table 10 presents the species status of organisms associated with these three vessels. Due to the fact there is only one of each type of vessel there were no calculations on coverage. The two overseas arrivals (024 and 035) accounted for the four new records for marine AIS. Three of the new records were on vessel 024, which was the barnacle species *Megabalanus californicus* and the two urochordate species *Styela clava*, and *Styela plicata.* These are all common species within the area of the last port of call for this vessel. A single new record for a barnacle species was recorded from vessel 035. This species was *Balanus venustus*, which is native in the region of the last port of call from which this vessel arrived to Hawai‘i.

Table 10. Species status for other vessels

Other Vessels	Total	AIS	Cryptogenic	New Records
PORIFERA	10	1	5	0
CNIDARIA				
Class Hydrozoa	0	0	0	0
Class Anthozoa	1	1	0	0
ANNELIDA				
Family Sabellidae	2	1	1	0
Family Serpulidae	2	2	0	0
Family Spirorbidae	0	0	0	0
MOLLUSCA				
Class Polyplacophora	0	0	0	0
Class Gastropoda	0	0	0	0
Family Vermetidae	0	0	0	0
Class Bivalvia	4	2	0	0
CRUSTACEA				
Balanomorpha	7	5	0	2
Class Amphipoda	1	0	0	0
Class Isopoda	0	0	0	0
Class Stomatopoda	1	1	0	0
PYCNOGONIDA	0	0	0	0
ECHINODERMATA				
Class Ophiuroidea	1	0	0	0
BRYOZOA	1	1	0	0
UROCHORDATA	8	6	0	2
Total	38	19	6	4

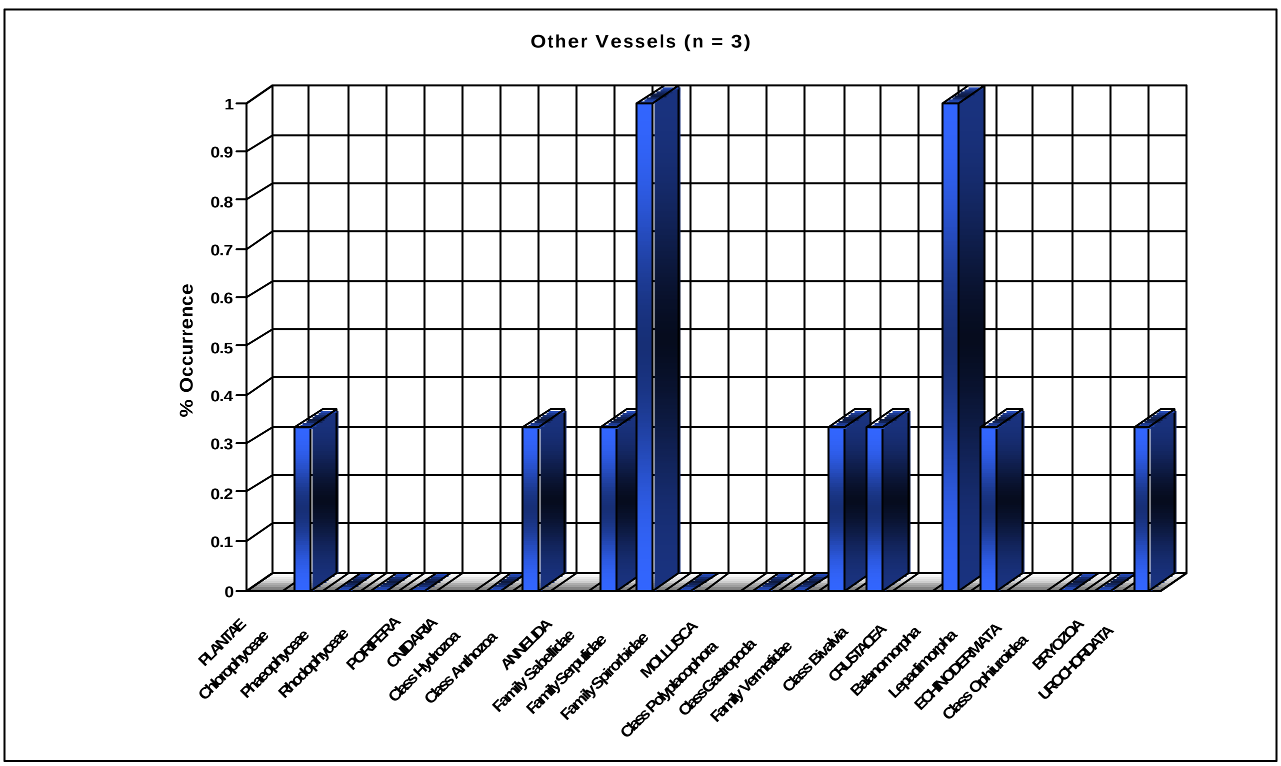

Figure 15. Mean percent occurrence of all species for other vessels

Shipyard Hull Surveys

It was stated at the beginning of this section that only a single inter-island barge was surveyed within a shipyard setting. The results of this survey were combined with the inter-island barge component previously covered.

4. Discussion

The hull surveys conducted during this project are just a small picture of the various vessel types involved. It would require an extended effort to draw final conclusions concerning the level of risk associated with each vessel type. The vessels that were targeted during this effort were chosen for their differences in operation compared to standard commercial cargo carriers.

The level of operation by overseas and inter-island barges in Hawai'i is different from other port systems on the mainland United States. Towed barges are not as major of a component in coastal ocean ports on the mainland United States as they are in Hawai'i. The inter-island cargo barge system creates issues and situations that are unique to Hawai í.

There are also quite a significant number of foreign flagged fishing vessels that use the port facilities in Hawai'i. The geographic position of Hawai'i makes it an ideal port for standard fueling and supply operations and mechanical and medical emergencies for these vessels. The potential for poorly maintained vessels of this type entering port in Hawai'i for these reasons should always be considered by those monitoring arrivals.

Personal craft arriving from overseas locations are a vessel component that has just recently been considered from the standpoint of marine AIS transport. Again, the desirability of Hawai'i as a port of call for regular services and emergencies attracts many vessels of this type. These craft also tend to have longer port stays in Hawai'i than any other of the vessels surveyed in this study. The arrival of these vessels to marinas is not as closely monitored as arrivals to commercial ports. There is rarely pre-arrival notice of these vessels, with the exception being organized races. Hull maintenance varies between owner/operators and ports like Hawai'i are often used as in-water cleaning stations for small scale needs.

A brief synopsis of findings for each vessel type and vessel coverage data is as follows:

Overseas cargo barges

There are regular monthly arrivals of these vessels. The vast majority of these originate from Washington, Oregon, and California. Cargo barges home-ported in Hawai'i are on a regular circuit from the Marshall Islands, where they conduct loading and unloading of commercial cargo. These barges and the regular arrivals from California have the potential for transporting nonindigenous organisms that have the capacity to recruit and survive in coastal areas of Hawai'i. There are rare events in which cargo barges that are not part of these regular arrivals could expose Hawaii's marine environments to nonindigenous organisms. Although this study showed only a small amount of fouling with these vessels, the operational characteristics will always make them a threat for hull fouling transport. The combination of slow speed and lengthy residency times at overseas ports provides a greater opportunity for recruitment, and regular and irregular arrivals should always be monitored.

Inter-island cargo barges and tugs

The fouling on these inter-island vessels was quite abundant and diverse on average. A majority of the fouling organisms were both confirmed alien species and those considered cryptogenic. These organisms made up 46% of the fouling community on inter-island barges and 68% on the inter-island tugs. The established marine AIS barnacle *Chthamalus proteus* was found on the hull of every inter-island barge surveyed. The affinity of this and other marine AIS for the hulls of the vessels that conduct inter-island cargo transport could explain the homogenous distribution of many marine AIS to the commercial harbors in the Main Hawaiian Islands.

Foreign fishing boats

Three vessels were surveyed, and only one had any fouling to record. Two of the vessels were new arrivals preparing to embark on commercial fishing operations. These vessels tend to have clean hull due to the fact that they are serviced in their homeports prior to leaving for long-term fishing operations. This saves money in fuel and allows structural inspection before work begins in the harsh open-ocean environment. This is standard procedure for vessels home-ported in Japan but is variable for Korean and Taiwanese vessels. The one vessel with hull fouling had been at sea for a long period and the growth was composed of cosmopolitan open-ocean species. Foreign fishing boats have predictable arrival patterns since there are local vessel agents that support their operations. These agents, local harbor authorities, and the U.S. Coast Guard are the first line of defense in minimizing the impact of poorly maintained fishing vessels that could expose Hawaii's marine environments to nonindigenous fouling organisms. Foreign fishing vessels intent on using the local port system for regular operations or emergency situations need be monitored from the standpoint of marine AIS issues so that their impacts can be minimized.

Overseas personal craft

There are many unknown characteristics concerning the arrival of these vessels and their potential for exposing Hawaii's marine environments to nonindigenous fouling organisms. There is no pre-arrival notification for the majority of these craft, and this creates quite a problem in monitoring arrivals. The solution to this problem would be tasking state personnel at the ports of entry on O'áhu and the island of Hawai'i to conduct a visual assessment of vessels upon arrival. This visual assessment would then be used to determine if action must be taken. Lack of pre-arrival notification is one problem and the practice of in-water hull cleaning in another. If a vessel arrives with a growth of organisms that settled at an overseas location, then the potential to introduce these organisms is increased by in-water cleaning immediately after arrival. Efforts need to be made to educate the owners/operators of these craft relating to the concerns of the State of Hawai'i about the transport of non-indigenous species on their vessel hulls and post-arrival activities that could increase the likelihood of introduction.

Other vessels

The vessels in this category had the highest percentage of marine AIS of all the vessels surveyed. Also the majority of new records for marine AIS were associated with this category. Two vessels were from overseas locations and were not part of the normal vessel arrival pattern in Hawai'i. Both overseas arrivals were associated with special cases that required their transit to Hawai'i for long or permanent port stays. The other vessel in this group was an interesting case of intra-island transport of species to a location in which most did not previously exist. This floating dry dock, which was inactive in Pearl Harbor for an extended period, was covered with a variety of established marine AIS found only in Pearl Harbor. The intra-island movement of this vessel to Kalaeloha Barber's Point Harbor has served to extend the range of species once contained in Pearl Harbor.

Vessel Coverage Data

The analysis of vessel coverage involved the mean percentage coverage of various species categories at pre-determined hull locations. An additional location was added during the course of the study that included dry dock support strips (DDSS) and zinc blocks. The DDSS locations are areas were dry dock supports blocked the application of antifouling coatings during shipyard service. These create perfect squares that tend to become heavily fouled while the rest of the vessel remains clean. Zinc blocks are secured to the hull at a variety of locations for the purpose of slowing the corrosive activities of sea water. These were combined to represent a separate category because their impact was considered important. The DDSS/Zinc block areas were noted to be colonized heavily by fouling organisms on most vessels, even those recently repainted (see Appendix D).

The most commonly encountered species overall were chlorophyte macroalgae, tube-dwelling polychaetes, barnacles, and bryozoans. The chlorophyte macroalgae tended to colonize all exposed and submerged surfaces equally well but tended to most common at the waterline and on the zinc blocks. The serpulid and spirorbid families of tube dwelling polychaetes colonized all submerged surfaces but tended to be dense in the stern and prop/rudder locations. These two families were common primary settlers, while the other tube dwelling family, sabellids, only existed within areas of the hull with well developed fouling growth. Barnacles could be found in all locations, but across all vessels they were most common along the waterline, in the prop/rudder area, and the DDSS/Zinc block surfaces. Finally, bryozoans were common as pioneer colonizers but also as components of fully developed fouling communities. On heavily fouled vessels a crust of live and dead bryozoans formed a solid substrate for other fouling organisms such as sabellid worms and tunicates.

As would be expected, fouling organisms on vessel hulls will make use of any characteristic that allows then to recruit and develop with greater ease. The stern hull and prop/rudder regions are protected from the laminar flows that can shear off organisms and tend to be the colonized more easily. Unique locations and surfaces also tend to provide an advantage to fouling growth. The DDSS locations have older and more compromised anti-fouling coatings and can show quite stark differential fouling (see Appendix D). The complex structure and unique surface of zinc blocks was a desirable location for macroalgal and barnacle growth (Appendix D)

II.C. Survey of biofouling waste disposal practices for commercial hull cleaning facilities

<u>1. Introduction</u>

There are two large commercial shipyard facilities that operate within the State of Hawai'i commercial harbor system. There is also the military shipyard at Pearl Harbor, which is the largest in Hawai'i but is not included in the scope of this project. There are a variety of smaller commercial facilities that cater to personal craft, which operate in the vicinity of marinas operated by the State of Hawai'i.

2. Methodology

The Hawai‘i Ocean Industry and Shipping News, Ports Directory 2003 was consulted to determine what facilities existed within the state of Hawai‘i. Points of contact were set up at each facility identified and either a face-to-face or phone interview was conducted. Further information concerning facilities and operations was obtained during on-site visits and interviews with owners/operators of vessels being serviced.

3. Results

The two large commercial facilities are Marisco Shipyard and Pacific Shipyards. Marisco Shipyard is located a Kalaeloa Barber's Point Harbor on the Wai ánae coast of O áhu. This facility operates one large floating dry dock and a single small floating dry dock. Pacific Shipyards, which is located in Honolulu Harbor, also operates two floating dry docks of comparable size to those operated at Marisco Shipyards. The type of vessels serviced by both of these companies is identical, which are:

- Local inter-island cargo barges and tugs
- Public sector vessels home-ported in Hawai‘i

a) University of Hawai‘i
b) National Oceanic and Atmospheric Administration
c) U.S. Coast Guard

- Local commercial fishing boats
- Local tourist industry vessels
- Foreign fishing boats

Both of these large facilities are regulated by stringent rules and regulations designed to prevent the introduction of chemical wastes into the aquatic environments associated with their operations. Hull cleaning activities, which use high-pressure water sprays, strip away toxic antifouling paints that have to be contained by the facilities. Tarps are hung around vessels to prevent wind dispersion of water droplets, which contain toxic substances. The spray water and all material hydro-blasted from the vessel hull collect on the floor of the dry dock, where it drains into retention areas. Both state and federal regulations require this material to be pumped into holding facilities operated by the shipyard and disposed of by companies licensed to handle toxic waste.

Shipyard facilities catering to small personal craft receive mostly local operated vessels for major service and hull cleaning. The exception would be in the case of emergency repairs needed for any overseas arrivals. Vessel operators/owners from ten of the twelve vessels surveyed were interviewed and all said that they cleaned their vessel hull before arrival to Hawai‘i. All of these owner/operators said that they usually did in-water cleanings both shortly after arrival to a port and before departure, if they were in port a month or more. The in-water cleanings were usually done by the owner/operators using scrub pads and scrapers.

4. Discussion

The two commercial shipyards that exist in Hawai‘i do not have the capacity to service vessels over 400 feet in length, which excludes the majority of modern cargo vessels. These two operations are focused mainly on the service of local vessels that fall within the size limitations.

The only vessels operating outside of Hawai‘i that are serviced by these facilities are commercial foreign fishing boats, overseas cargo barges, and any vessel needing emergency repairs.

This would create a situation in which they could either expose their areas of operation to the small component of overseas fouling organisms associated with these vessels or help to disperse established marine AIS that have recruited to local vessel hulls. Due to the restrictions placed on these facilities concerning toxic waste containment and handling, the chance of such events is reduced.

Facilities that focus on smaller privately owned vessels are located near public and private marinas. These operations deal with locally owned and operated vessels to a greater extent than overseas arrivals. Unless an overseas personal craft has a serious repair, needs a full recoating of anti-fouling paint, or has severe fouling, hull maintenance is dealt with by the owner/operator. In general, all owner/operators of overseas personal craft would clean their hulls thoroughly before embarking on the long voyage to Hawai‘i. The cases in which overseas vessels needed out-of-water hull cleaning in Hawai‘i were due to the fact that the vessel had been in port for many months and had severe growth of local organisms.

Overall, it appears that shipyard operations on all scales do not contribute to the introduction or spread of marine AIS. The potential should not be discounted though, and education and outreach efforts should include all facilities that conduct hull maintenance operations. The information obtained during this study covers a small fraction of time and the possibility for the transport of marine AIS by way of hull fouling on personal craft should always be considered a possibility.

II.D. Compilation of Arrival Patterns and Vessel Operation Dynamics

1. Introduction

The objective of this aspect of the field component was to create a profile for the last port of call for specific overseas arrivals. The specific vessels for which information was gathered were overseas cargo barges, foreign fishing boats, and overseas personal craft.

2. Methodology

There were three separate data sources for these vessel types. The overseas cargo barges and foreign fishing boat arrivals information was obtained through the State of Hawai‘i Department of Transportation, Harbors Division. Overseas personal craft arrivals had to be further divided into those arriving from domestic ports and those arriving from foreign ports. Data for domestic port arrivals exists with the State of Hawai‘i Department of Agriculture, Plant and Animal Quarantine and Inspection Division. The U.S. Customs Service collects information on the arrival of overseas personal craft from foreign ports.

The information for both agencies existed in hand-written logs, and permission was secured to allow access. The logs from May 2001 through June 2003 for both types of arrivals were entered into a spreadsheet format for analysis. The arrivals information for a two-year period of time was analyzed for all the target vessel types. The overseas barges and foreign fishing boat arrivals data was from a data set obtained for the two year period of time from January 1997 through December 1998. This data set was from the daily arrivals logs for Honolulu Harbor and Kalaeloa Barber’s Point Harbor for this period and was entered prior to this project. An analysis of recent data revealed that the arrivals data for this period was still characteristic of both harbors, so this data set was used instead of re-entering a new set. The data for overseas arrivals of personal craft was separated by domestic and foreign arrivals for the purpose of presentation and analysis of temporal trends. A temporal trend analysis was not done for the overseas barges or foreign fishing boats since they are on more regular commercial schedules.

Last port of call information for the overseas barges and foreign fishing boats was non-specific in some case so the presentation scheme to categorize this information was the United Nations Food and Agriculture Organization (FAO) ocean regions. All but a few of the records of personal craft included specifics on last port of call, which allowed more specific data to be presented on last port of call.

Finally, a brief narrative of the spectrum of the operational dynamics of each vessel type was developed. This narrative will examine the activities of each vessel type to qualitatively determine if there are additional concerns that relate the marine AIS

3. Results

Overseas Barges

A total of 135 barge arrivals from overseas locations were recorded for the two-year period. There were only three FAO regions of operation prior to arrival to Hawai‘i (Figure 16), which were:

- West central Pacific (WCP)
- North east Pacific (NEP)
- East central Pacific (ECP)

Overseas Barge Operational Narrative:

The majority of overseas barge traffic originates from the west coast of the mainland United States from port areas in both Washington and Oregon (NEP) and California (ECP). The WCP component originated from both the Marshall Islands and Johnston Atoll.

The barges from the NEP and ECP are arriving each month on set schedules to unload lumber and paper products and break bulk cargo. Three to four days are spent in port unloading cargo before the return trip to home ports in Puget Sound, Washington and Coos Bay, Oregon.

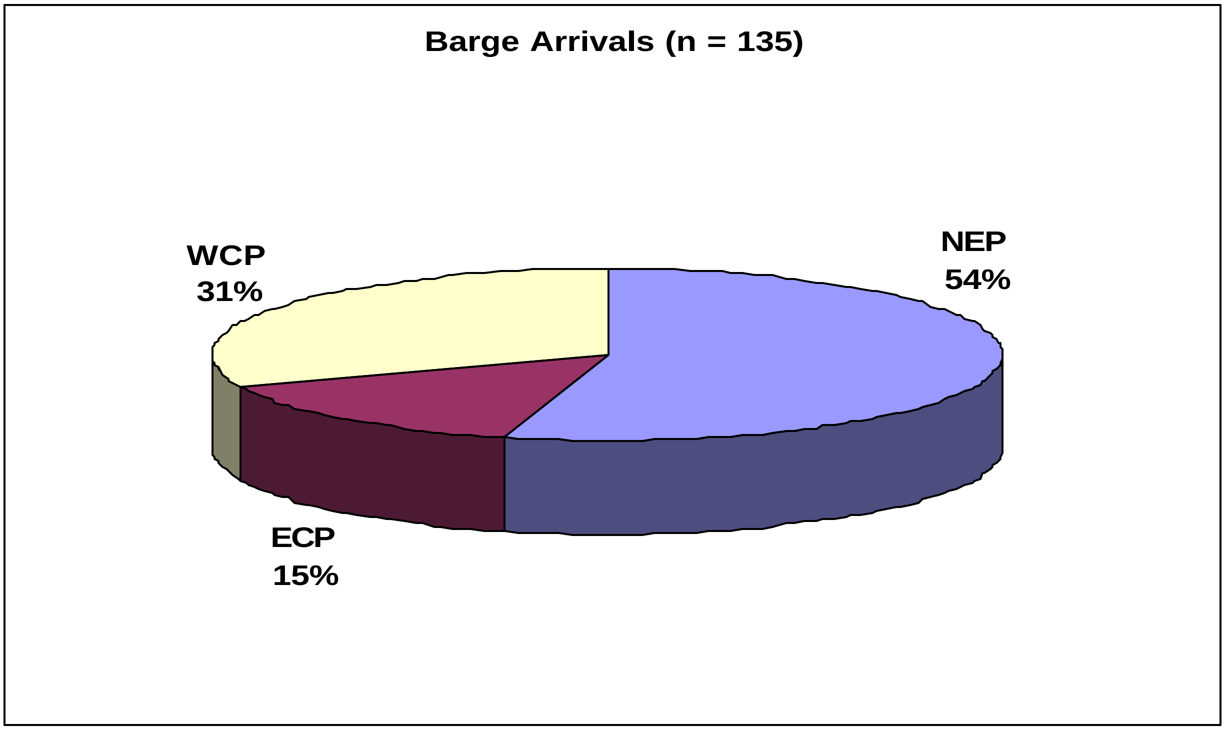

Figure 16. Overseas barge arrivals and FAO last port of call region

Foreign Fishing Boats

A total of 556 foreign fishing boats were recorded during the two-year time period. These foreign fishing boats are Japanese, Korean, or Taiwanese flagged vessels that use Hawai‘i as a port of call for a variety of services. The traffic to Hawai‘i is so great that there are specific vessel agencies in Honolulu that deal only with these arrivals. The vessels were recorded as arriving from seven different FAO regions (see Figure 17). These regions are as follows:

- North eastern Pacific (NEP)
- East central Pacific (ECP)
- South west Pacific (SWP)
- South east Pacific (SEP)
- North west Pacific (NWP)
- South west Atlantic (SWA)
- West central Pacific (WCP)

Foreign Fishing Boat Operational Narrative

Ports in Japan and Korea (NWP) are the most common last ports of call before arrival to Hawai‘i. The SEP and SWA components represent Japanese, Korean, and Taiwanese vessels arriving from fishing grounds near Chile and Argentina.

Vessels will originate in the NWP and transit to Hawai‘i for a port visit before going to fishing grounds outside the sovereign waters of the United States. The vessels may transit to ports in the Marshall Islands (WCP) and other areas to hire on extra crew before arrival to Hawai‘i. Port calls are for the purpose of fueling, purchasing supplies, or to deal with medical emergencies. Vessel will remain in fishing grounds in the ECP, SEP, WCP, and occasionally in the NEP for extended periods and then return to Hawai‘i on the way back to Asian home ports. Vessel owner/operators will generally clean vessel hull before departure from the home port to save on fuel cost.

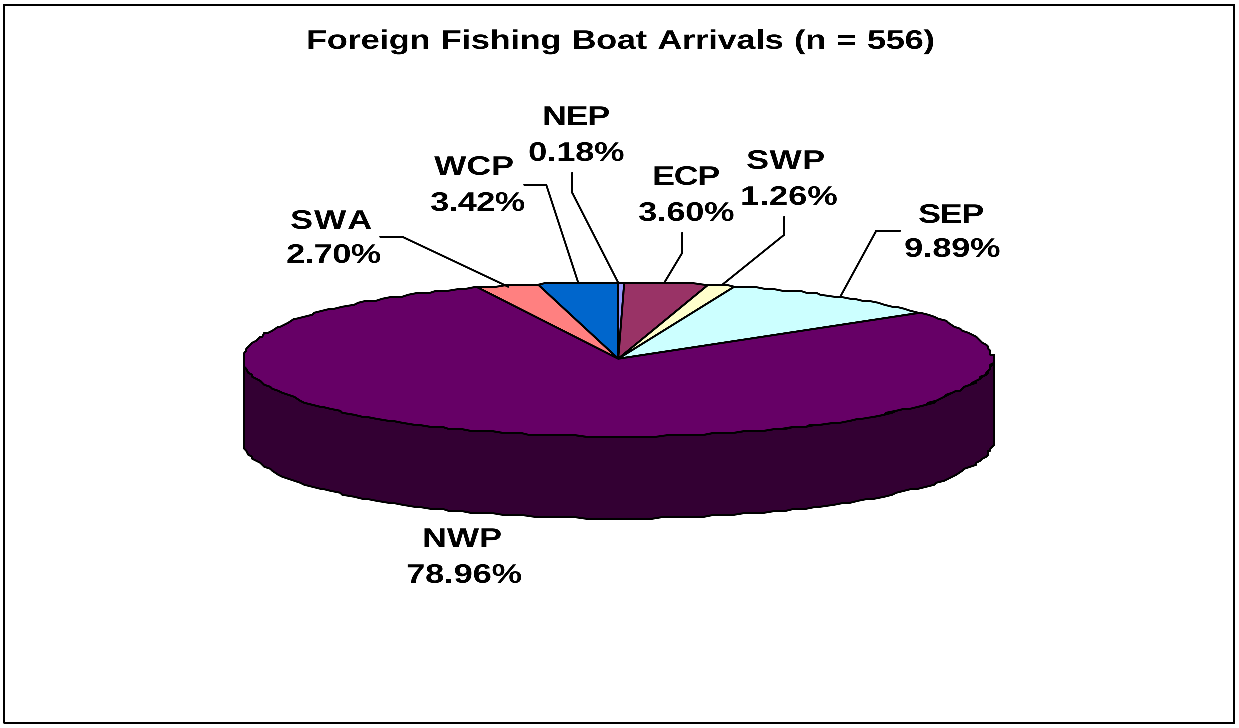

Figure 17. Foreign fishing boat arrivals and FAO last port of call region

Overseas Personal Craft

A total of 161 vessels were recorded that had a foreign last port of call. Records for the arrival of vessels with a domestic last port of call were not complete for the period of May 2001 to June 2003. This being the case, only a qualitative narrative for this data will be provided.

Figure 18 shows the variety of foreign locations in which personal craft made port call before transiting to Hawai‘i. The UF category is for unknown last port of call. The greatest number of arrivals was from French Polynesia, Mexico, and Kiribati, with a considerable number from western Canada. This data is strictly for last port of call and does not provide any insight to a complete voyage record.

The U.S. Customs data set was further analyzed to show temporal trends based on the month of arrival and is shown in Figure 19. One clear trend from this simple analysis is the peaks in arrivals during Hawaii’s winter and summer months.

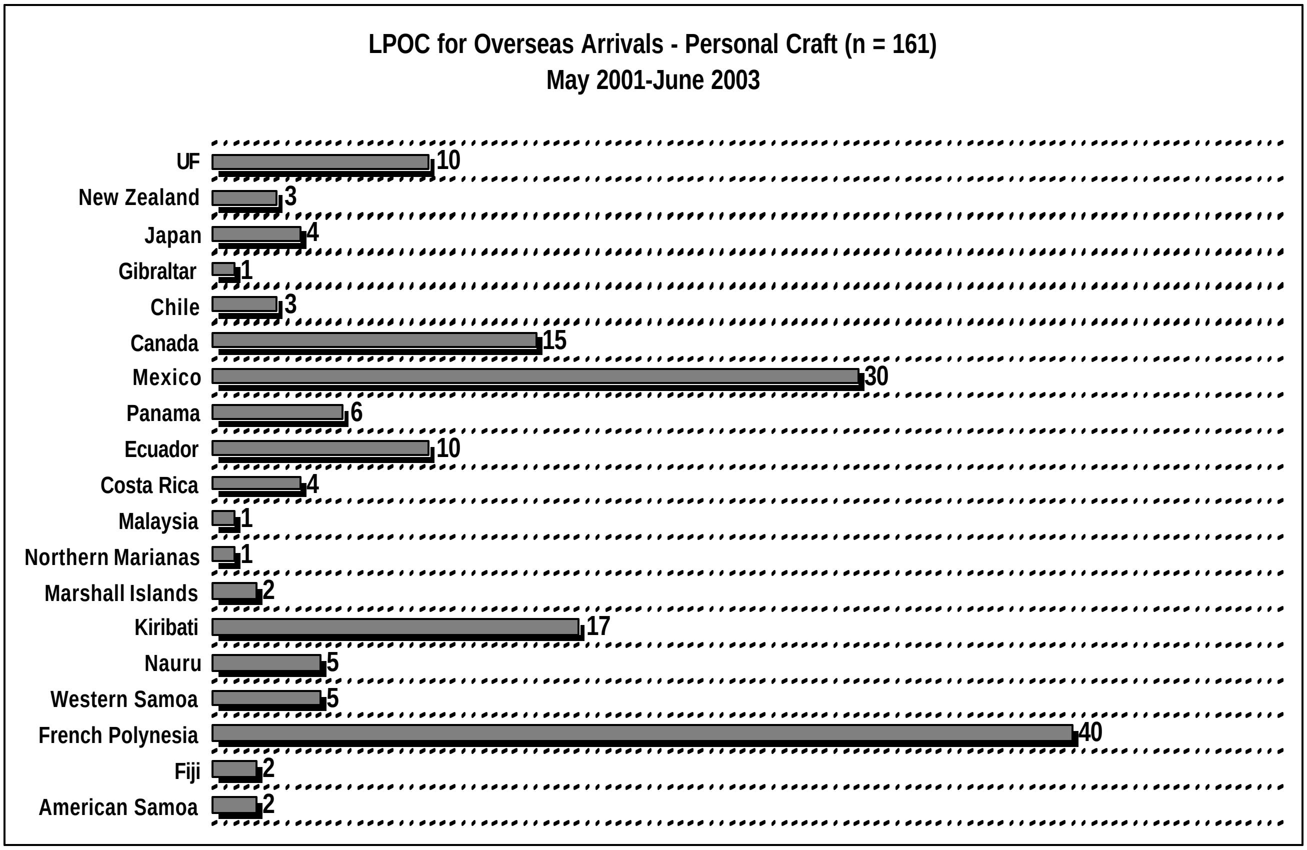

Figure 18. Foreign last port of call for personal craft

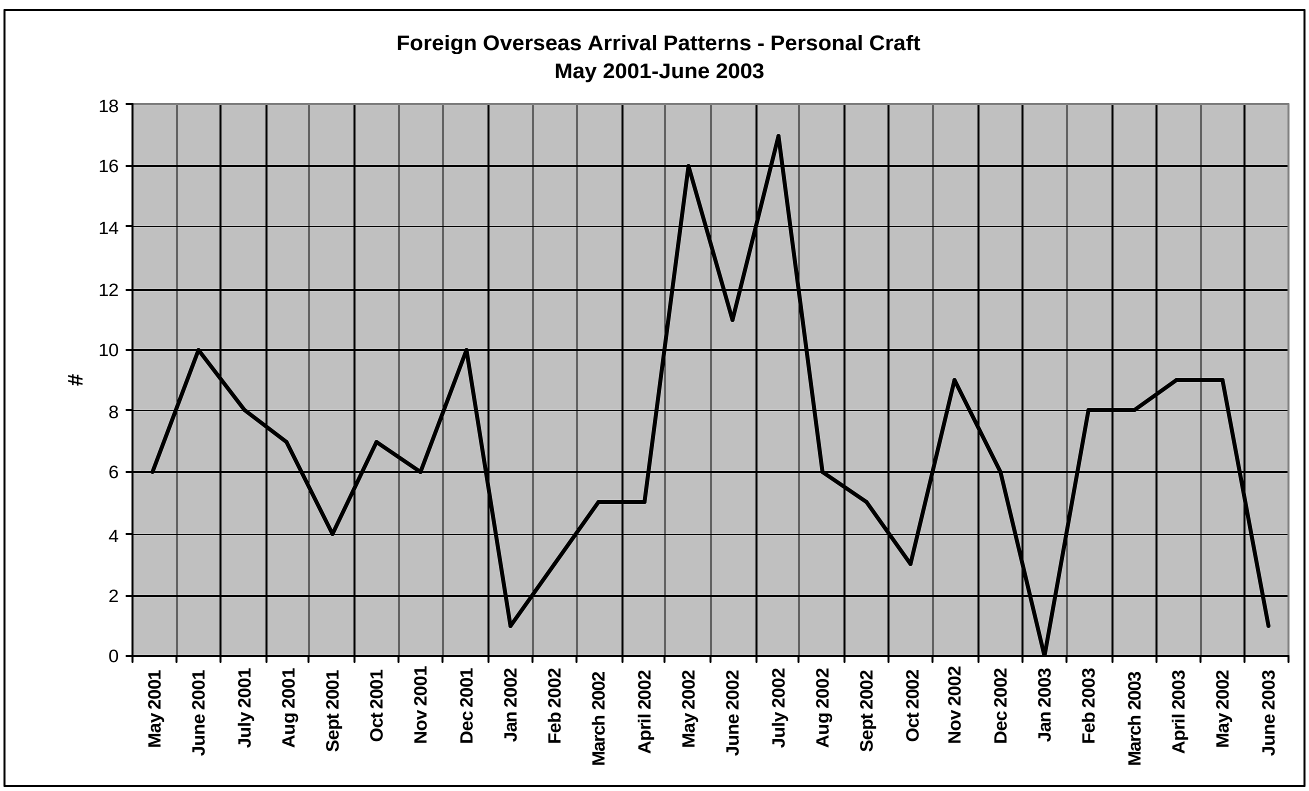

Figure 19. Temporal trends for arrivals from foreign last ports of call

Personal Craft Operational Narrative (Foreign Last Port of Call)

The popular destinations for personal craft in the tropical pacific are based on season and weather trends. Patterns are random overall, but vessels tend to avoid tropical storm seasons in the southern Pacific but will anchor for long periods in ports or a sheltered embayment to ride out harsh weather periods. Vessels will transit from the southern Pacific north to the Line Islands or Mexico for extended or temporary port call before proceeding to Hawai ´ i. During these port stays vessel owners/operators will conduct hull cleanings, either in-water or out-of-water, before departing for Hawaiʻi. This is a common trend due to the extra time gained and fuel savings during the notoriously long trip to Hawaiʻi. Stays in Hawaiʻi vary from a few days to a few months, during which time hull cleaning activities coincide with departure dates.

Personal Craft Operational Narrative (Domestic Last Port of Call)

This vessel component originates from ports in California (San Diego, Long Beach, San Francisco), Oregon (Portland), and Washington (Seattle). Vessels are both home-ported and transitory in these areas. The only predictable component is the Transpac Yacht Race from Long Beach, California to Honolulu, which happens every July and involves around sixty vessels. The remainder of arrivals was random but tended to during Hawaiʻi summer and fall months. These vessels, especially those involved in races, clean their hulls at the last port of call to save on time and fuel consumption

4. Discussion

The vessels focused on for this aspect of the study were chosen for their hypothetical high hull fouling potential. The hypothesized operational aspects of these vessels included slow speeds, longer port residence times, and irregular hull maintenance schedules. This review of arrival patterns has shown that these vessels are a common component of maritime activities in Hawaiʻi. There are regions, in which a fraction of each vessel type operates, that have similar tropical conditions like Hawaiʻi. This would mean that vessels arriving from these regions could potentially have marine fouling organisms suited for introduction and survival. Knowing this type of information is helpful when prioritizing monitoring efforts focused on vessel arrivals. Education and outreach activities could also be focused regionally that inform commercial and private harbor operators about marine AIS issues. Vessel owners/operators could be further informed of any special measures that could be taken to minimize the transport of marine AIS by hull fouling or any other means.

Commercial barges and commercial fishing boats arrive on planned schedules for the most part. This being the case, unscheduled arrivals would be easy to identify and monitored. The arrival of overseas personal craft, excluding organized races, is not as structured and their arrival is usually not known until they tie up to the pier of one of the official ports of entry. The data in Figure 19 shows that there are temporal trends for arrivals though, and extra vigilance during these periods would serve to assist in monitoring vessel arrivals.

III. Project Component: Collaborative Effort to Develop Management Strategies

1. Introduction

The timing of this project was such that it coincided with efforts by the DLNR-DAR to develop the State of Hawai‘i Aquatic Invasive Species Management Plan (AIS Management Plan). Extensive collaboration between all upper level facilitators for this process existed throughout the project. Both principle investigators provided expertise and information that assisted in the development of the AIS Management Plan. The information provided was derived from past marine introduced species research conducted through the Bishop Museum but also directly from the results of the HCRI-RP project. Review of the AIS Management Plan will be covered in greater detail below.

The first step in the collaborative process was to assemble a group of stakeholders in a task force that focused on the issue of the introduction marine AIS through maritime vessel transport. Participation in this process was for the purpose of achieving the goal of this HCRI-RP project component, which was:

- ♦ Creation of a framework of information that could be used as a guide for the development of administrative rules by management professionals at the state level.

The stakeholder group was created by efforts initiated at the DLNR-DAR and was called the Alien Aquatic Organism Task Force (AAOTF). Efforts by the AAOTF were immediately integrated into the State of Hawai‘i AIS Management Plan, which will be described below.

State of Hawai‘i AIS Management Plan

The Division of Aquatic Resources (DAR), under the State Department of Land and Natural Resources (DLNR), initiated the development of the comprehensive AIS Management Plan. DLNR-DAR subsequently contracted with The Nature Conservancy of Hawai‘i (TNC) to coordinate the development of the plan. The efforts for the development of the AIS Management Plan were made possible through a grant from the Hawai‘i Community Foundation.

Many individuals, organizations, and agencies were involved with the development of this plan. The overall organization of individuals and entities involved in the development of the AIS Management Plan is probably easiest described below with a diagrammatic depiction (Figure 20). The diagram in Figure 20 shows the integration of the AAOTF into the strategy for producing the AIS Management Plan. The value of the information concerning issues related to maritime industry was deemed of great importance. Many of the members of the AAOTF volunteered to serve on the various committees involved in drafting the multiple components of the plan. A full list of contributors can be found in Appendix E of the State of Hawai‘i AIS Management Plan.

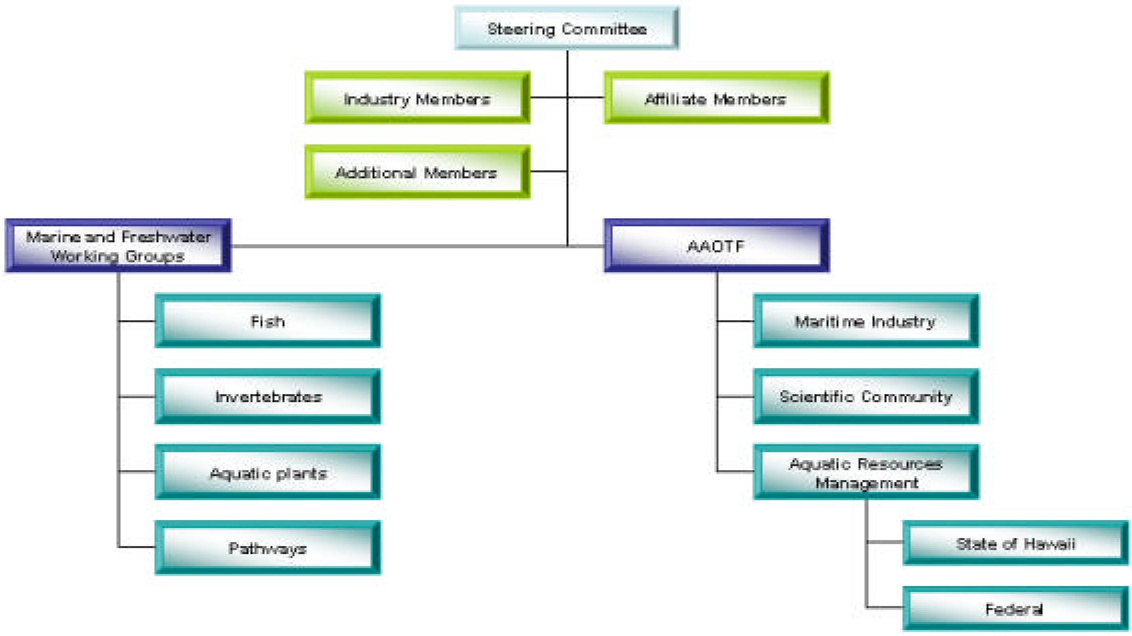

Figure 20. Framework of contributors to State of Hawai'i AIS management plan

2. Methodology

Collaborative process for developing management strategies:

Collaborative efforts were begun with the DLNR-DAR in forming the Alien Aquatic Organism Task Force (AAOTF) made up of stakeholders from the public and private sector to develop a framework for the management of ballast water, ballast sediments and hull fouling. The Aquatic Alien Species Coordinator for the DLNR-DAR worked directly with one of the principle investigators (Godwin) to develop an initial list of stakeholders that were felt to represent the broadest possible expertise and representation for the maritime, scientific and aquatic resource management communities. The AAOTF served as a venue for the elicitation of criteria and concerns that could be used to accomplish the HCRI-RP project goal for the collaborative management component. Information was elicited from stakeholders through series of monthly meetings that began in October 2002 and proceeded through December 2003. In addition to the monthly meetings, a workshop focusing on hull fouling as a mechanism for the transport of marine alien species was scheduled for all stakeholders.

The task force process was structured so that it was a partnership with the DLNR-DAR and The Nature Conservancy. Representatives from the DLNR-DAR were responsible for crafting administrative rules focused on ballast water and ballast sediments, while the principle investigators for the HCRI-RP project were responsible for conducting activities for hull fouling.

These duel activities were conducted at each monthly meeting and active correspondence between meetings was conducted through e-mail and phone contact.

In the case of the HCRI-RP component, the AAOTF was briefed during the first two months of meetings on the reasoning for its inclusion in the task force and what would be involved to elicit information from task force members. Focused efforts for the HCRI-RP component began with a two-day workshop conducted by the principal investigators in collaboration with colleagues from outside of Hawai‘i.

Once the workshop was conducted and AAOTF members became immersed in the issue the following months were an exercise in gathering and structuring information. The methodology used throughout the process with stakeholders involved standard group interview techniques facilitated by one of the principal investigators (Godwin). An assistant recorded information that was elicited during the process on large flip charts. The first step was to establish a goal that is agreed upon by a consensus of stakeholders. This was followed by the elicitation of criteria and concerns that support the goal, through an iterative process that spread over a period of six months. During this process all the criteria and concerns are condensed into a series of generic categories and supporting sub-categories. During each meeting the material covered and recorded was posted at the front of the room on flip chart pages to allow viewing by task force participants. During the interim time between meetings information elicited at previous meetings was continually condensed and categorized for presentation at later meetings. This iterative process allowed constant updating and editing by all task force members as a group. The final process was for the facilitator to form all the information into a framework. A hierarchical framework was chosen to present the information visually but the information was further decomposed into subcategory frameworks with accompanying descriptions. As stated previously, the goal of the process was to elicit information and develop it into a framework that can be used by management professionals to develop administrative rules and management strategies.

3. Results

The AAOTF was successfully formed and began meeting once a month starting in October 2002. These meetings ran monthly, with a few off months, until December 2003. A broad range of stakeholders participated on a regular basis and a cordial working relationship existed throughout the process. The interest and input by the representatives from the maritime community was of particular value. In addition, involvement with the creation of the AIS Management Plan was begun with The Nature Conservancy. Participation in the AIS Management Plan by the principal investigators involved membership on the steering committee and activity in working groups focused on marine invertebrates and commercial shipping vectors. Many members of the AAOTF became interested in the development of the AIS Management Plan and volunteered their time on many of the committees as well.

A workshop was conducted February 12 and 13, 2003 focusing on hull fouling from the perspective of marine alien species transport and potential management strategies. This was accomplished with two invited speakers from New Zealand with research experience in hull fouling transport of marine AIS.

The two guest speakers were:

- Oliver Floerl, National Centre of Marine Biodiversity and Biosecurity, National Institute of Water and Atmospheric Research, Christchurch, New Zealand
- Ashley Coutts, Marine Biosecurity Section, Cawthron Institute, Nelson, New Zealand

The workshop was entitled "Hull Fouling as a Mechanism for Marine Alien Species Introductions." This workshop presented current research and knowledge concerning hull fouling as a mechanism for marine alien species transport and current information concerning management strategies. A series of presentations were given by one of the principal investigators (Godwin) and the guest speakers. The first day of the workshop focused on the introduction of the issue and current research, and the second day was devoted to potential management strategies. During the second day of the workshop an interactive process was begun with stakeholders to create a goal and elicit criteria and concerns. Documentation of the workshop will be done through proceedings that will be published as a Bishop Museum Technical Report in 2004.

Half of each AAOTF meeting from February 2003 through July 2003 was devoted to the hull fouling issue. The overall hierarchy of information is shown in Figure 21. The hierarchy in Figure 21 represents a compilation of the criteria and concerns elicited from AAOTF members and converted to generic terminology. Multiple revisions were necessary to produce this simplified presentation, which includes in-depth information that elaborates on each category. The categories of the hierarchy will be broken down and explained in the remainder of this section.

Generation of a goal

The creation of a goal was the first step in this collaborative process. The challenge was to create a realistic goal that could be used to guide the AAOTF throughout the entire process. This was not attempted until the end of the second day of the workshop and the group agreed upon the following goal:

"Minimize marine alien species introductions by hull fouling"

It was determined by the group that the use of the word "minimize", as opposed to "prevent," created a more realistic goal for the process. This was based on the fact that it is impossible to prevent marine AIS associated with hull fouling with the present status of administrative rules and inspection technologies. This goal was used to guide the process of creating a framework of information that could be used to develop management strategies. The level below the goal displays the criteria that must be satisfied to achieve the goal. These are a generic representation of the concerns voiced by all AAOTF members concerning the impact of any activities that attempt to manage hull fouling as a marine AIS transport mechanism. In general, resource managers were concerned with the level of effectiveness any management strategy but at the same time the maritime industry wanted to minimize the impact to their industry and the economy of the State of Hawai ī

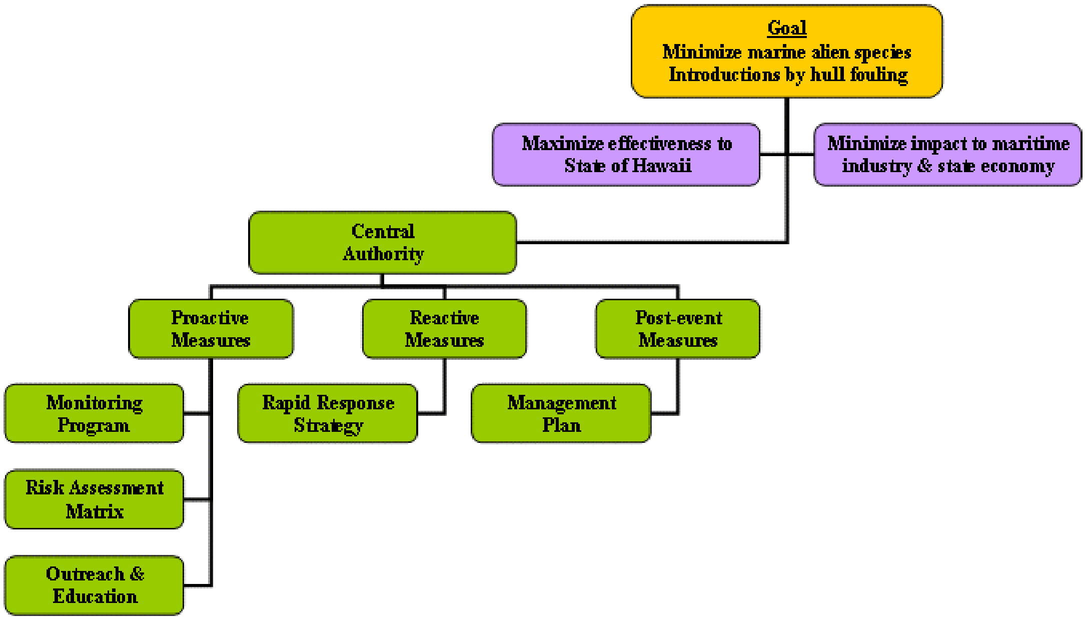

Figure 21. Framework for the management of marine AIS transported by hull fouling

AIS Central Authority

Once a consensus was reach for the goal and its qualifying criteria the task of laying out a management framework was undertaken. The members of the AAOTF were told to assume an environment where monetary and personnel resources were not a limiting factor when suggesting strategies for the management framework. A consistent issue that was brought up was the need for an AIS central authority to carry out the components of any management plan. It was stated many times by the task force that such a central authority was needed to successfully handle AIS from the standpoint of maritime transport mechanisms.

Comments by AAOTF members pertaining to this issue were compiled and reviewed and a picture of a hypothetical AIS central authority took shape. The structure of this hypothetical AIS central authority is shown in Figure 22 According to AAOTF members, if there were no resource constraints, the best approach would be the creation of a new division within the DLNR that deals only with alien species issues (terrestrial and aquatic).

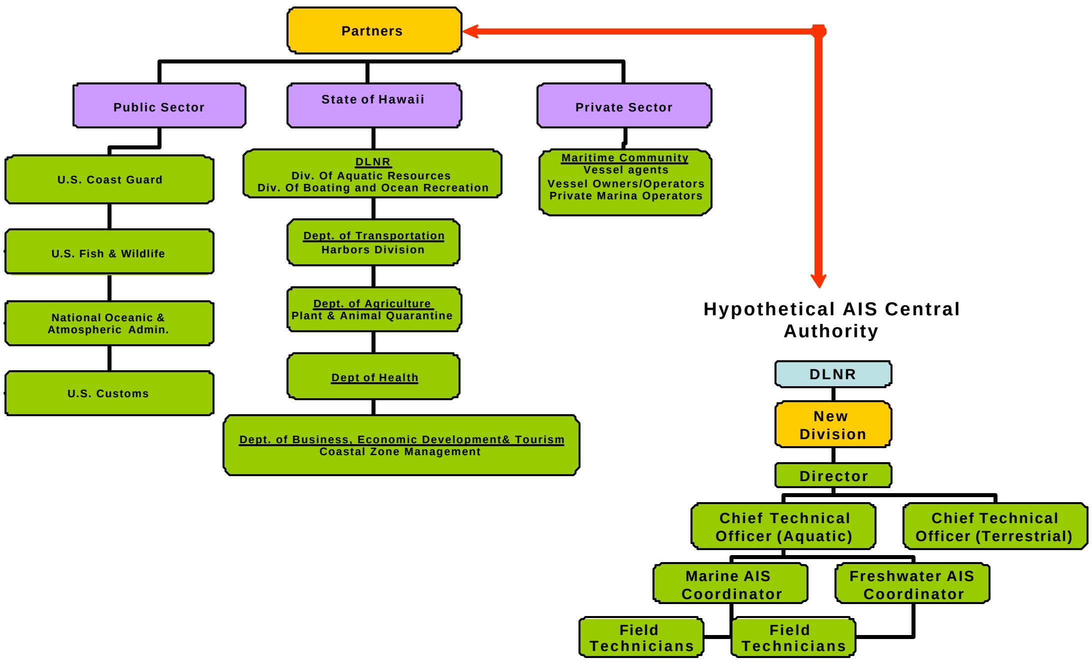

Figure 22. Hypothetical AIS central authority for invasive species activities

Existing personnel, programs and resources from within DLNR presently dealing with alien species in all terrestrial and aquatic environments would be put under the authority of this new division. The issues of AIS transport through maritime activities would be the responsibility of the marine AIS coordinator through federal, state and maritime industry partnerships. A list of organizations needed as partners was developed by the AAOTF and is shown in Figure 22.

Hull fouling is the topic of the management framework being presented here but this scheme would also be applicable to all maritime industry transport mechanisms for AIS. This AIS central authority would use a series of pro-active, reactive and post-event measures to achieve the goal set by the AAOTF.

Pro-active Measures

These measures are geared to the task of minimizing the risk of introduction of marine AIS through hull fouling. The basis of this category is the increase of knowledge and awareness concerning marine AIS by individuals in a variety of stakeholder groups. The majority of resources available to the AIS central authority would be committed to this component. The specific activities included under this category are shown in Figure 23.

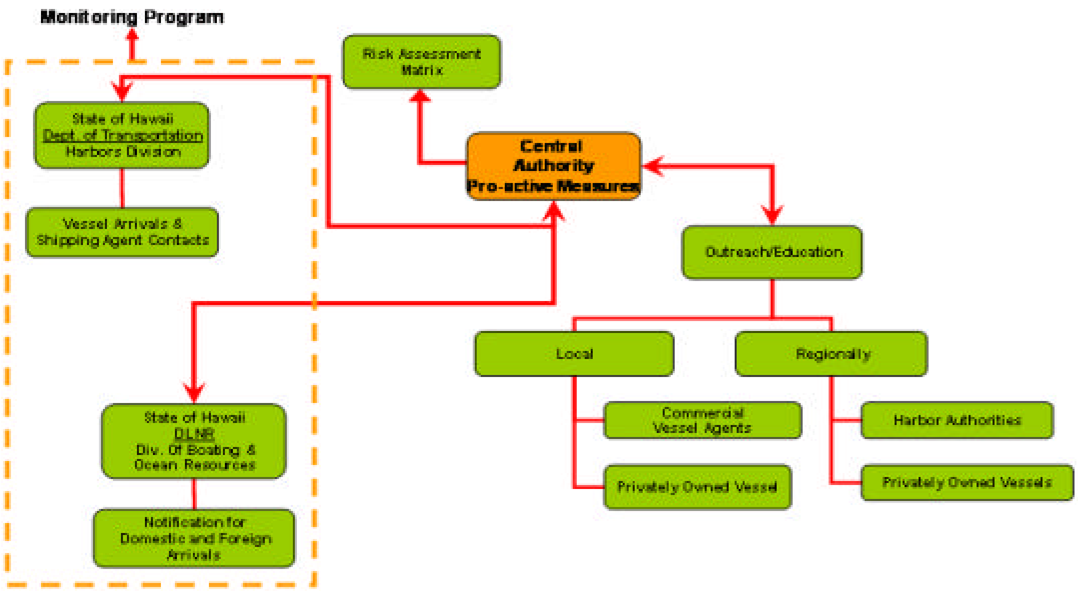

Figure 23. Pro-active measures for management of marine AIS transported by hull fouling

Monitoring Program

The activities included in this component would be focused on monitoring maritime activities for the purpose of identifying and responding to perceived threats. The diagram in Figure 23 shows the partnerships involved in such a monitoring effort. The partners shown in the diagram are required for obtaining vessel arrival data and points of contact for follow-up investigation. The State of Hawai‘i Department of Transportation (DOT), Harbors Division is responsible for managing the daily vessel activities in all commercial harbors and is responsible for keeping logs of scheduled arrivals. Similar duties focused on marinas and personal craft are carried out by the State of Hawai‘i Department of Land and Natural Resources (DLNR), Division of Boating and Ocean Resources (DOBOR). The difference between Harbors Division and DOBOR is that DOBOR rarely receives prior notice to arrivals. If the log of scheduled arrivals is provided regularly to the AIS central authority by the Harbors Division, this would be a first step in managing the risk associated with hull fouling associated with commercial vessel platforms. In the case of DOBOR, notification would be after the vessel has arrived but timely notification to the marine AIS central authority would be valuable to the monitoring program.

In addition to arrivals data from both Harbors Division and DOBOR, further points of contact can also be provided. These points of contact are a necessary step in determining basic information for any vessels. Procedures for this step differ between commercial vessels and personal craft. The point of contact for all commercial arrivals is the local vessel agent, whose job is to handle all aspects of a vessels needs once cleared for arrival to the commercial harbor. All commercial vessels not associated with local operators are required to have a local vessel agent. The identity of the agent for each vessel arrival is recorded by the Harbors Division on the arrivals log. This agent can be contacted by the AIS central authority to acquire information concerning the vessel of interest. A profile of the operations of a vessel before its arrival, and its intentions while in port can be determined through a brief interview. In most cases, the vessel agent will possess enough information on the particulars of the vessel that judgments can be made concerning its risk before its entry into the port.

Although not shown in the diagram in Figure 23, information can also be obtained through collaborative agreements with the partnership agencies listed in Figure 22. Agencies such as the U.S. Coast Guard and U.S. Customs conduct inspections of overseas arrivals and could collaborate by providing on-site information to the AIS central authority. This type of collaboration could provide another layer to monitoring and make the most of limited resources.

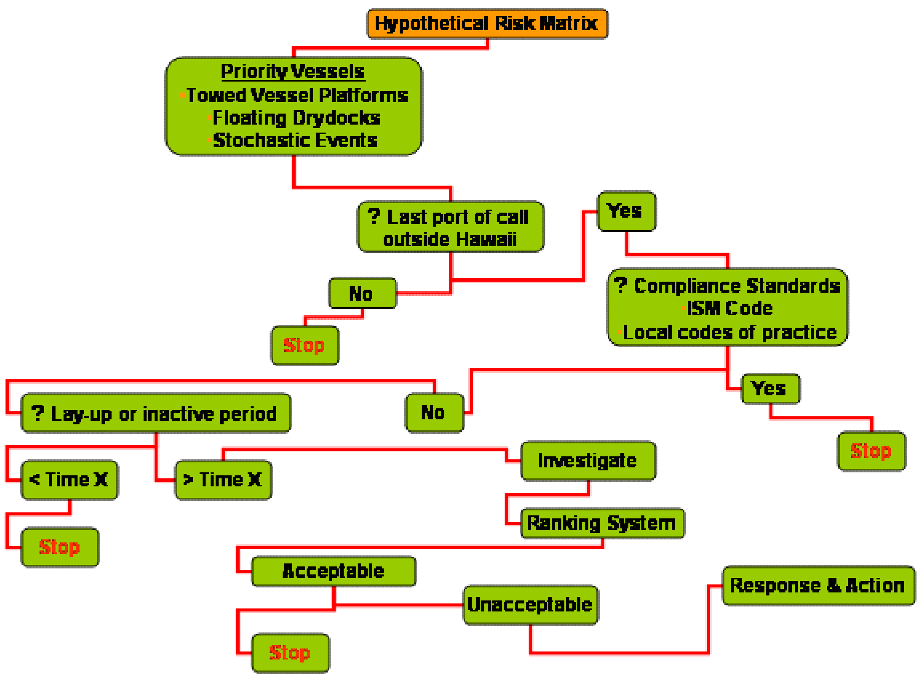

Figure 24. Risk assessment matrix

Risk Assessment Matrix

Throughout the previous section the subject of risk determination is mentioned. It is not realistic to assume that every vessel entering the port system will be considered and investigated, which is reflected in the goal statement of this process (i.e., minimize vs. prevent). To narrow the focus and make the best use of resources it is necessary prioritize. Prioritization is accomplished through the practice of risk assessment, which is guided by a matrix based on simple binary choices. A draft risk matrix was formulated through the collaborative process with AAOTF members and is shown in Figure 24 This matrix is a simple representation based on factors developed by stakeholders and is not considered a final product.

The direction of flow for the matrix represented in Figure 24 is top to bottom. Each step has a binary choice that either directs to process to the next step or instructs the user to stop. If the particulars of a vessel carry the process to the end, further investigation is warranted. Each step will be described in the remainder of this section.

High priority vessels and events

The first task is to form a list of priority vessels that are described below:

1. **Towed vessel platforms:** this category includes a variety of platforms towed by tug boats such as cargo and crane barges, drilling platforms, and pontoon bridges. The tug boats for this and the second category would also be included as high priority vessels for the risk matrix.
2. **Floating Drydocks:** a category of large towed vessel platforms that can change ownership quite frequently and are subsequently moved throughout the oceans of the world. Purchasing and transporting floating dry docks to new locations is a cheaper alternative to constructing new shipyard facilities.
3. **Stochastic Events:** a general category that puts focus on arrivals that are not part of the regular suite of vessel arrivals to a port system. Examples would be unscheduled arrivals for medical and mechanical emergencies, salvaged vessels, and decommissioned military vessels. Personal craft from overseas locations are also included in this category due to the fact that arrivals are quite unpredictable. The exception would be regularly scheduled sailing races that use Hawai‘i as a stop-over or finish point.

The justification for the first two high priority vessel descriptions is that these are slower-moving vessels with long port residence times. These factors create a situation in which the settlement and establishment of fouling organism is more likely. The third category was developed to stress the importance of random events that otherwise might be ignored by port officials and aquatic resource managers.

Step 1: Last port of call outside Hawai‘i

Once a high priority vessel is identified it needs to be determined whether it is arriving from outside of Hawai‘i.

Step 2: Compliance Standards

There are industry standards for the safe operation of vessels, which include maintenance of the overall vessel structure. These standards are stated in the International Management Code for the Safe Operation of Ships and for Pollution Control, referred to as the ISM Code (see ***http://www.imo.org/home.asp?topic_id=182***). The ISM Code addresses the responsibilities of those who operate and manage commercial ships (above 500 gross tonnage). This code provides an international standard for the safe management and operation of these vessels and provisions for pollution prevention. Under the ISM Code ship owners and operators are required to conduct regular safety checks and audits, which include preventative maintenance of ship structures, generically referred to as ship husbandry. The use of this as a prioritization was suggested by AAOTF maritime industry members. The justification is based on the premise that if an owner/operator of a vessel complies with the ISM Code, it is more likely that the vessel has been maintained properly, and therefore is less likely to have extensive fouling growth. The care and maintenance of the hull of a vessel is an important factor in safety and operating cost. A company that is ISM Code compliant will tend to view hull maintenance as a typical cost of operation. The U.S. Coast Guard has access to the database of ISM Code compliant vessels throughout the world and uses the lack of compliance as prioritization criterion for choosing vessels for safety inspections. Collaboration with the U.S. Coast Guard by the AIS central authority would provide access to this information for the risk matrix.

In combination to using ISM Code standards, local industry standards could be developed by the maritime community. These local standards could be disseminated to the regional maritime community to inform mariners on both commercial vessels and personal craft about this issue for Hawai‘i. Personal craft are not covered by ISM Code standards and assumptions cannot be made for hull maintenance practices. Collaboration between maritime community leaders to develop local codes of practice could only bolster international standards and provide guidance to mariners on both commercial vessels and personal craft.

Step 3: Lay-up or inactivity period

This is a step in the matrix that needs further development. The binary choice involves a temporal scale for lay-up or inactivity periods. If the set maximum value is exceeded then the matrix directs the flow to the next step. There was much debate over the maximum temporal value in the AAOTF venue and an actual value was not set. It was decided by the facilitator (Godwin) that a value should be based on research or standards established through experimental means. Much research has been conducted by military and private industry on fouling rates and this should be consulted to develop this step further.

Step 4: Investigate

This step involves actual investigation by the AIS central authority of a vessel determined to be a risk for marine AIS through hull fouling. The approach should be a gradual process that begins with a field ranking system that can be used pier-side or from a boat. This can be accomplished through a visual approach or by use of a remotely operated underwater camera system. The visual approach can be done through a numerical scale that ranks levels of fouling visible from the surface. This ranking system could be adopted by other agencies such as the U.S. Coast Guard or State of Hawai‘i Department of Agriculture, Plant and Animal Quarantine and Inspection to be used by their field personnel if they encounter a suspect vessel. DOBOR staff could also use this system to classify personal craft when communicating with the AIS central authority. This type of visual ranking system has shown promise in New Zealand when used by national inspection officers (Floerl et al. 2004, in press), and can be used to make a quick judgment on whether to conduct more a more rigorous investigation. Another method for on-site judgments would be a remote underwater video camera system. Use of either of these methods would allow the AIS central authority to determine whether the process needs to move from pro-active measures into reactive measures that involve rapid response. Rapid response measures will be covered in a later section.

Outreach and Education

This component is included here since the objective of the pro-active measures is to increase knowledge and awareness of marine AIS transported by maritime vessel activity. The monitoring and risk assessment components increase the knowledge and awareness of a specific group within the aquatic resource community and provide tools for management. An additional tool for management would be an outreach and education initiative broadly aimed at the aquatic resource community, the maritime industry and private citizens. This would allow a relatively new issue such as marine AIS transport by hull fouling to be understood by a greater number of individuals. This understanding empowers a greater pool of individuals to assist managers tasked with carrying out measures to minimize marine AIS. The AIS central authority would benefit from a raised awareness with vessel agents and Harbors Division staff since they would be passing this awareness along to vessel owners and operators that use Hawai‘i as a port of call. This would also be true with DOBOR and private marine facilities, who could inform the operators of personal craft to be more aware of hull maintenance. Outside of Hawai‘i, efforts by the AIS central authority could inform mariners and harbor authorities regionally to be more pro-active concerning hull fouling and other potential mechanisms for marine AIS transport associated with maritime vessel activity. Through the outreach program mariners will also informed of whatever existing administrative rules and penalties exist.

Reactive Measures

This aspect of the management effort would simply involve designing a scheme for reacting to events that are deemed high risk during the pro-active phase. The key to the reactive measures would be partnerships with the agencies shown in Figure 22. A response team (or teams) composed of personnel from these partners would be needed to investigate high risk events and recommend actions to minimize the effects of a high risk vessel.

A preliminary attempt by AAOTF members to compose scenarios and responses is shown in Figure 25. The basic premise behind this effort by the AAOTF was to minimize the time in port for commercial and private vessels. If the vessel identified is a standard cargo vessel or a personal craft arriving from overseas, its time in port would be restricted. A standard cargo vessel would be restricted to cargo operations and then instructed to get underway. If the vessel is a personal craft it would be required to leave port once it has conducted essential activities such as fueling, maintenance, and loading stores. In the case of vessels or vessel platforms intent on a long or permanent port stay, such as the examples in Figure 25, different measures would be required. In these instances the vessel or vessel platform would be subject to quarantine procedures and an out-of-water hull cleaning at the vessel owner’s expense. If such measures are adopted by the State of Hawai‘i, the AIS central authority would use the outreach and education component to inform mariners locally and regionally. The possibility of incurring large costs for hull cleaning would be incentive for preventative measures before arrival to Hawai‘i.

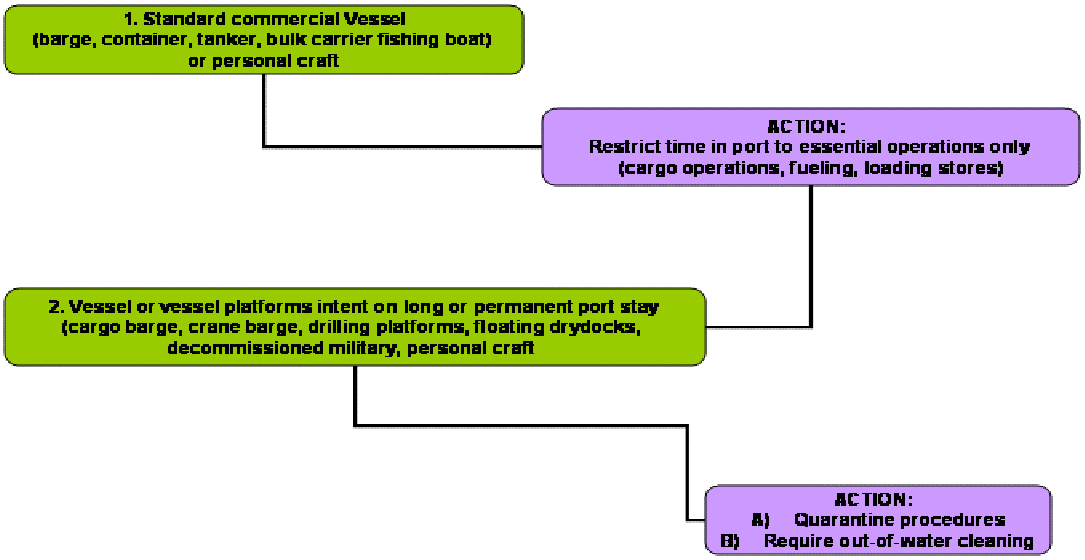

Figure 25. Vessel scenarios and actions for response to high risk event

Post-event Measures

The last category within the draft framework of information is the management aspect. Efforts would move in this direction once it is determined that a long term solution must be put into effect.

The main tool for managing a high risk hull fouling event is to initiate quarantine procedures. This was mentioned in the previous section without elaborating on the particulars. Quarantining would involve steps that would isolate the vessel within a discrete area in a controlled setting. Suggestions for such measures were elicited from AAOTF members.

The only choice for isolating a large vessel is a commercial dry dock within a local shipyard facility. A dry dock would allow safe removal and disposal of fouling organisms. In the case of a personal craft, it could be immediately hauled and cleaned at a local boatyard. For this to be possible the AIS central authority, through authority of the State of Hawai‘i, could designate facilities for such operations and contract their services when the need arises.

Standard in-water cleaning of vessels is not a desired choice because this activity would serve to introduce organisms into the marine environment. This would only be a valid choice if a containment system for material removed from a vessel hull could be designed. Partnering with commercial dive companies and shipyards would be necessary to determine the feasibility of such control measures.

There is much more that needs to be done to develop an effective response to a marine AIS hull fouling event. There are only a few cases in which hull fouling has been dealt with as a management issue (Coutts 2004). Early discovery and quick response is the key to any incursion by an alien species to Hawai‘i. This is only possible through the design of strategies that clearly shown the type of response for various scenarios. This is where the multi-agency rapid response team comes into play. Overall coordination would be handled by the marine AIS central authority, which would have a set of administrative rules for guidance.

4. Discussion

The efforts presented in this section are an initial step towards developing a more concrete strategy to minimize the introduction of marine AIS to Hawai‘i through hull fouling. All information presented was elicited through a collaborative process with multiple stakeholders participating in the AAOTF. The information gathered is intended as a starting point for resource managers tasked with dealing with marine AIS for the State of Hawai‘i.

If hull fouling is viewed in the same way as any other mechanism for the transport of alien species, then the key would be the development of strategies that rely on inter-agency cooperation and partnerships with the private sector. Multi-agency cooperation is the key to present efforts concerning terrestrial alien species in Hawai‘i. The efforts conducted by state and federal agencies concerning early detection and rapid response in terrestrial environments should be used as examples in addition to the information developed in this study.

Awareness of the marine AIS issue and its connection to maritime shipping activities, both domestic and international, is an important component in the future efforts in protecting the marine environment of Hawai‘i in the face of a growing global economy. Outreach to the public sector areas tasked with the management of aquatic resources and private sector interests that conduct operations with the potential for transporting marine AIS is a required component for success. Collaborative efforts between multiple stakeholder groups will continue to be the basis for effective and useful tools to minimize the impact of marine AIS. The mindset of industry and government concerning marine AIS transport by maritime vessel activity is more complex than just regulating obvious vectors such as ballast water, and it will take awareness by both sectors to achieve the maximum positive effect for the environment and minimal impact to industry.

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- Chela Zabin, University of Hawaii, Bryozoa
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Appendix A. Vessel Metadata

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
001	Aliza	Overseas Personal Craft	33	Haifa, Israel

Sample Location	Sample Method	Sample Date
Ala Wai Yacht Harbor	SCUBA	1/10/2003

Vessel Journey Record

Haifa>Cyprus>Greece>Italy>France>
Spain>Caribbean>Florida>
New York>Florida>Panama(Canal Transit)>Costa Rica>Mexico>San Diego>Hilo>Lahaina>Honolulu

Arrival Date

12/24/2002

How long in port (days)

37

Notes

Hauled&Painted- Caribbean, Hauled-New York, Hauled&Painted-Florida

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
5	5	5
Species	**Species**	**Species**
Diatom Film, Chlorophyta, Serpulidae	Diatom Film, Chlorophyta, Serpulidae	Diatom Film, Chlorophyta, Serpulidae

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
100	0
Species	**Species**
Diatom Film, Serpulidae	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
002	Megumi III	Overseas Personal Craft	33	Meiken, Japan

Sample Location	Sample Method	Sample Date
Ala Wai Yacht Harbor	SCUBA	1/13/2004

Vessel Journey Record

Meiken>Honolulu

Arrival Date

10/27/2002

How long in port (days)

73

Notes

Highly fouled with local fauna

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
90	90	90
Species	**Species**	**Species**
Diatom Film, Chlorophyta, Porifera, Serpulidae, Sabellidae, Urochoradata	Diatom Film, Chlorophyta, Porifera, Serpulidae, Sabellidae, Urochoradata	Diatom Film, Chlorophyta, Porifera, Serpulidae, Sabellidae, Urochoradata

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
100	50
Species	**Species**
Diatom Film, Balanomorpha	Chlorophyta, Lepadimorpha, Balanomorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
003	Idle Queen	Overseas Personal Craft	28	Norfolk,Virginia

Sample Location	Sample Method	Sample Date
Ala Wai Yacht Harbor	SCUBA	1/13/2003

Vessel Journey Record

Norfolk>Florida>Caribbean>Panama(Canal Transit)>Mexico>Hilo>Honolulu

Arrival Date

12/29/2002

How long in port (days)

15

Notes

Highly fouled lepadimorpha barnacles

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
15	15	5
Species	**Species**	**Species**
Diatom Film, Chlorophyta	Diatom Film, Chlorophyta	Diatom Film

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
100	30
Species	**Species**
Diatom Film, Balanomorpha	Chlorophyta, Lepadimorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
004	Islander	Overseas Barge	220	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	1/24/2003

Vessel Journey Record

Marshall Islands>Honolulu

Arrival Date

1/23/2003

How long in port (days)

3

Notes

Regular cargo route between Marshall Isl. & Hawaii

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
5	5	5
Species	**Species**	**Species**
Diatom Film, Balanomorpha	Diatom Film	Diatom Film

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	10
Species	**Species**
N/A	Clorophyta, Rodophyta, Balanomorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
005	Tazlina	Overseas Cargo Barge	200	Long View, Washington

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	1/27/2003

Vessel Journey Record

Long View>Coos Bay, Oregon>Honolulu

Arrival Date

1/26/2003

How long in port (days)

3

Notes

Regular cargo route between w. coast and Hawaii

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
0	0	0
Species	**Species**	**Species**
0	0	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	0
Species	**Species**
N/A	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
006	Bandin	Overseas Cargo Barge	200	Long View, Washington

Sample Location	Sample Method	Sample Date
Honolulu, Harbor	SCUBA	1/27/2003

Vessel Journey Record

Long View>Coos Bay, Oregon>Honolulu

Arrival Date

1/26/2003

How long in port (days)

3

Notes

Regular cargo route between w. coast and Hawaii

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
10	10	10
Species	**Species**	**Species**
Diatom Film, Chlorophyta	Diatom Film, Chlorophyta	Diatom Film, Chlorophyta

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	10
Species	**Species**
N/A	Diatom Film, Chlorophyta

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
007	New York	Overseas Personal Craft	35	Southhampton, England (UK)

Sample Location	Sample Method	Sample Date
Koolina Yacht Harbor	SCUBA	2/11/20003

Vessel Journey Record

Liverpool>Portugal>Cuba>Panama (Canal Transit)>Galapagos>Honolulu

Arrival Date

2/3/2003

How long in port (days)

14

Notes

Sailboat race ending in Japan, group of 12 vessels, in-water cleaning in Galapagos

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
0	0	0
Species	**Species**	**Species**
0	0	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
5	0
Species	**Species**
Balanomorpha	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
008	Cape Town	Overseas Personal Craft	35	Cape Town, South Africa

Sample Location	Sample Method	Sample Date
Koolina Yacht Harbor	SCUBA	2/11/2003

Vessel Journey Record

Liverpool>Portugal>Cuba>Panama (Canal Transit)>Galapagos>Honolulu

Arrival Date

2/3/2003

How long in port (days)

14

Notes

Sailboat race ending in Japan, group of 12 vessels, in-water cleaning in Galapagos

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
0	0	0
Species	**Species**	**Species**
0	0	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
5	0
Species	**Species**
Balanomorpha	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
009	Glasgow	Overseas Personal Craft	35	Glasgow, Scotland

Sample Location	Sample Method	Sample Date
Koolina Yacht Harbor	SCUBA	2/11/2003

Vessel Journey Record

Liverpool>Portugal>Cuba>Panama (Canal Transit)>Galapagos>Honolulu

Arrival Date

2/3/2003

How long in port (days)

14

Notes

Sailboat race ending in Japan, group of 12 vessels, in-water cleaning in Galapagos

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
0	0	0
Species	**Species**	**Species**
0	0	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
5	0
Species	
Balanomorpha	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
010	Aukai	Interisland Barge	200	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/2/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/2/2003

How long in port (days)

2

Notes

Regular interisland cargo barge

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
100	100	60
Species	**Species**	**Species**
Chlorophyta, Rodophyta, Serpulidae, Spirorbidae, Bivalvia, Bryozoa	Serpulidae, Spirorbidae, Bivalvia, Bryozoa	Serpulidae, Spirorbidae

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	0
Species	**Species**
N/A	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
011	Pacific Bear	Interisland Barge	200	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/2/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/2/2003

How long in port (days)

1

Notes

Regular interisland cargo barge

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
30	10	5
Species	**Species**	**Species**
Chlorophyta, Serpulidae, Spirorbidae, Bivalvia	Serpulidae, Bryozoa	Bryozoa

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	80
Species	**Species**
N/A	Chlorophyta, Serpulidae, Spirorbidae, Bivalvia, Gastropoda, Balanomorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
012	Waieleleale	Interisland Barge	220	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/3/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/3/2003

How long in port (days)

1

Notes

Regular interisland cargo barge, majority of fouling on zinc blocks

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
10	10	10
Species	**Species**	**Species**
Chlorophyta, Serpulidae, Spirorbidae, Bryozoa	Chlorophyta, Serpulidae, Spirorbidae, Balanomorpha, Bryozoa	Diatom Film, Serpulidae

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	15
Species	**Species**
N/A	Chlorophyta

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
013	Haleakala	Interisland Barge	220	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/3/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/3/2003

How long in port (days)

1

Notes

Regular interisland cargo barge

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
20	20	20
Species	**Species**	**Species**
Serpulidae, Spirorbidae, Balanomorpha, Bryozoa	Serpulidae, Spirorbidae, Bryozoa	Serpulidae, Spirorbidae, Bryozoa

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	5
Species	**Species**
N/A	Chlorophyta, Serpulidae

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
014	Kahoku	Interisland Barge	200	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/5/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/4/2003

How long in port (days)

2

Notes

Regular interisland cargo barge, majority of fouling on zinc blocks

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
10	1	1
Species	**Species**	**Species**
Chlorophyta, Serpulidae, Spirorbidae, Bryozoa	Chlorophyta, Rodophyta, Spirorbidae, Bivalvia	Chlorophyta, Spirorbidae

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	15
Species	**Species**
N/A	Chlorophyta

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
015	Maukana	Interisland Barge	200	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/5/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/4/2003

How long in port (days)

1

Notes

Regular interisland cargo barge, majority of fouling on drydock support strips (DDSS)

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
30	30	10
Species	**Species**	**Species**
Serpulidae, Spirorbidae, Bivalvia, Bryozoa	Serpulidae, Bryozoa	Serpulidae, Spirorbidae, Bryozoa

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	2
Species	**Species**
N/A	Chlorophyta, Serpulidae, Spirorbidae, Balanomorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
016	Kakela	Interisland Barge	200	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/5/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/4/2003

How long in port (days)

1

Notes

Regular interisland cargo barge, majority of fouling on zinc blocks

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
15	15	10
Species	**Species**	**Species**
Chlorophyta, Serpulidae, Spirorbidae, Balanomorpha	Serpulidae, Bivalvia, Balanomorpha	Serpulidae, Spirorbidae, Balanomorpha

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	15
Species	**Species**
N/A	Chlorophyta, Serpulidae, Spirorbidae, Balanomorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
017	Lobo	Overseas Personal Craft	28	Unknown

Sample Location	Sample Method	Sample Date
Ala Wai Yacht Harbor	SCUBA	3/12/2003

Vessel Journey Record

South Pacific>Honolulu

Arrival Date

3/10/2003

How long in port (days)

7

Notes

Highly fouled with green algae only

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
85	75	50
Species	**Species**	**Species**
Chlorophyta	Chlorophyta	Chlorophyta

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
85	25
Species	**Species**
Chlorophyta	Chlorophyta

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
018	Grainne	Overseas Personal Craft	30	San Francisco, California

Sample Location	Sample Method	Sample Date
		3/12/2003

Vessel Journey Record

San Francisco>Mexico>Hilo>Honolulu

Arrival Date

3/5/2003

How long in port (days)

7

Notes

Fouling mostly along keel midship to stern

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
40	20	10
Species	**Species**	**Species**
Serpulidae, Bryozoa	Serpulidae, Bryozoa	Serpulidae, Bryozoa

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
45	5
Species	**Species**
Serpulidae, Bryozoa	Balanomorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
019	Osprey	Overseas Personal Craft	35	San Francisco, California

Sample Location	Sample Method	Sample Date
Ala Wai Yacht Harbor	SCUBA	3/12/2003

Vessel Journey Record

San Francisco>Mexico>Maui>Honolulu

Arrival Date

3/5/2003

How long in port (days)

7

Notes

Completely clean

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
0	0	0
Species	**Species**	**Species**
0	0	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
0	0
Species	**Species**
0	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
020	Kukahi	Interisland Barge	200	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/13/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/12/2003

How long in port (days)

1

Notes

Regular interisland cargo barge, majority of fouling on zinc blocks, dry dock support strips and water intake

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
5	5	5
Species	**Species**	**Species**
Serpulidae, Spirorbidae, Balanomorpha, Bryozoa	Chlorophyta,Cnidaria, Serpulidae, Spirorbidae, Bivalvia, Bryozoa	Serpulidae, Spirorbidae, Bivalvia, Balanomorpha, Bryozoa

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	2
Species	**Species**
N/A	Chlorophyta, Cnidaria, Serpulidae, Spirorbidae, Sabellidae, Bivalvia, Balanomorpha, Urochordata

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
021	Kainani	Interisland Tug	60	Honolulu, Hawaii

Sample Location
Honolulu Harbor

Sample Method
SCUBA

Sample Date
3/13/2003

Vessel Journey Record
Interisland>Honolulu

Arrival Date
3/12/2003

How long in port (days)
1

Notes
Regualr interisland barge tug; high level of fouling on entire hull

Fouling Coverage-Stern (%)
100

Species
Chlorophyta, Rodophyta, Porifera, Cnidaria, Serpulidae, Spirorbidae, Sabellidae, Bivalvia, Vermetidae, Balanomorpha, Bryozoa, Urochordata

Fouling Coverage-Midship (%)
100

Species
Chlorophyta, Rodophyta, Porifera, Cnidaria, Serpulidae, Spirorbidae, Sabellidae, Bivalvia, Balanomorpha, Bryozoa, Urochordata

Fouling Coverage-Bow (%)
100

Species
Chlorophyta, Rodophyta, Porifera, Cnidaria, Serpulidae, Spirorbidae, Sabellidae, Bivalvia, Thoracica, Bryozoa, Urochordata

Fouling Coverage-Prop/Rudder (%)
100

Species
Diatom Film, Chlorophyta, Bivalvia, Bryozoa

Fouling Coverage-Waterline (%)
70

Species
Chlorophyta, Serpulidae, Spirorbidae, Bivalvia

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
022	Mikiala II	Interisland Tug	60	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	3/13/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

3/13/2003

How long in port (days)

1

Notes

Regular interisland barge tug, majority of fouling on intake grates

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
2	1	1
Species	**Species**	**Species**
Serpulidae, Spirorbidae, Balanomorpha, Lepadimorpha	Phaeophyta, Serpulidae, Spirorbidae, Balanomorpha	Serpulidae, Spirorbidae, Balanomorpha

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
40	1
Species	**Species**
Diatom Film, Chlorophyta, Bivalvia, Balanomorpha, Bryozoa	Diatom Film, Chlorophyta

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
023	Aukai	Interisland Barge	200	Honolulu, Hawaii

Sample Location
Honolulu Harbor

Sample Method
Drydock

Sample Date
4/2/2003

Vessel Journey Record
Interisland>Honolulu

Arrival Date
4/1/2003

How long in port (days)
10

Notes
Regular interisland cargo barge, uniform fouling

Fouling Coverage-Stern (%)
100

Species
Cnidaria, Serpulidae, Spirorbidae, Bivalvia, Bryozoa, Urochordata

Fouling Coverage-Midship (%)
100

Species
Serpulidae, Spirorbidae, Bivalvia, Balanomorpha, Bryozoa

Fouling Coverage-Bow (%)
60

Species
Serpulidae, Spirorbidae, Bivalvia, Bryozoa

Fouling Coverage-Prop/Rudder (%)
N/A

Species
N/A

Fouling Coverage-Waterline (%)
50

Species
Chlorophyta, Serpulidae, Spirorbidae,

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
024	Unknown	Other	250	Los Angeles, California

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	7/27/2001

Vessel Journey Record

LA>Honolulu

Arrival Date

7/15/2001

How long in port (days)

12

Notes

U.S. Navy salvage vessel dispatched to assist with Ehime Maru salvage operation in July 2001, sampled by USFWS and not by standard methodology

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
N/A	N/A	N/A
Species	**Species**	**Species**
Serpulidae, Bivalvia, Balanomorpha, Urochordata	Serpulidae, Bivalvia, Balanomorpha, Urochordata	Diatom Film

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	0
Species	**Species**
N/A	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
025	Capable	Floating Drydock	500	Pearl Harbor

Sample Location	Sample Method	Sample Date
Barber's Point Harbor	SCUBA	6/2/2002

Vessel Journey Record

Pearl Harbor>Barber's Point Harbor

Arrival Date

2/10/2002

How long in port (days)

Permanent

Notes

Decomissioned U.S. floating drydock from Pearl Harbor inactive vessel yard (Middle Lock) moved to Barber's Point Harbor for commercial use

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
100	100	100
Species	**Species**	**Species**
Porifera, Serpulidae, Sabellidae, Bivalvia, Balanomorpha, Urochordata	Porifera, Serpulidae, Sabellidae, Bivalvia, Balanomorpha, Urochordata	Porifera, Serpulidae, Sabellidae, Bivalvia, Balanomorpha, Urochordata

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
N/A	25
Species	**Species**
N/A	Chlorophyta

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
026	Tautivy of Hayling	Overseas Personal Craft	30	Unknown

Sample Location	Sample Method	Sample Date
Ala Wai Yacht Harbor	Snorkel	4/9/2003

Vessel Journey Record

South Pacific>Honolulu

Arrival Date

4/5/2003

How long in port (days)

4

Notes

Lightly fouled but with Chthamalus sp. barnacle on hull, unable to contact vessel owner

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
2	1	0
Species	**Species**	**Species**
Lepadimorpha	Diatom Film	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
2	2
Species	**Species**
Diatom Film	Balanomorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
027	Sumiyoshi Maru	Foreign Fishing Boat	60	Japan

Sample Location	Sample Method	Sample Date
Barber's Point Harbor	SCUBA	4/15/2003

Vessel Journey Record

Peru>Marshall Islands>Honolulu

Arrival Date

4/15/2003

How long in port (days)

2

Notes

Japanese fishing boat, highly fouled with open ocean species

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
70	70	60
Species	**Species**	**Species**
Chlorophyta, Lepadimorpha	Lepadimorpha	Lepadimorpha

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
90	95
Species	**Species**
Chlorophyta, Lepadimorpha	Chlorophyta

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
028	Fukutoku Maru	Foreign Fishing Boat	60	Japan

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	5/21/2003

Vessel Journey Record

Japan>Pusan, Korea>Honolulu

Arrival Date

5/21/2003

How long in port (days)

1

Notes

Japanese fishing boat, very clean

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
0	0	0
Species	**Species**	**Species**
0	0	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
0	0
Species	**Species**
0	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
029	Chokyu Maru	Foreign Fishing Boat	60	Japan

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	5/21/2003

Vessel Journey Record

Japan>Marshall Islands>Honolulu

Arrival Date

5/21/2003

How long in port (days)

1

Notes

Japanese fishing boat, very clean

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
0	0	0
Species	**Species**	**Species**
0	0	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
1	1
Species	**Species**
Chlorophyta	Chlorophyta, Lepadimorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
030	Mamo	Interisland Tug	50	Honolulu

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	5/30/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

5/25/2003

How long in port (days)

5

Notes

Regular interisland barge tug, majority of fouling midship on water intakes

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
1	1	3
Species	**Species**	**Species**
Diatom Film	Diatom Film, Chlorophyta, Serpulidae, Bivalvia	Diatom Film, Serpulidae, Spirorbidae, Sabellidae, Bivalvia, Balanomorpha, Bryozoa, Urochordata

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
2	2
Species	**Species**
Diatom Film, Chlorophyta, Serpulidae, Sabellidae, Bryozoa, Urochordata	Chlorophyta, Serpulidae, Bivalvia, Bryozoa

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
031	Moanahele	Interisland Tug	50	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Honolulu Harbor	SCUBA	5/30/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date

5/28/2003

How long in port (days)

2

Notes

Regular interisland barge tug, majority of fouling midship on water intakes

	Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
Coverage	70	70	70
Species	Diatom Film, Chlorophyta, Balanomorpha, Urochordata	Porifera, Serpulidae, Spirorbidae, Sabellidae, Bryozoa, Urochordata	Serpulidae, Spirorbidae

	Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
Coverage	20	10
Species	Rodophyta, Bryozoa	Chlorophyta, Gastropoda, Balanomorpha

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
032	Manuakekai	Interisland Tug	50	Honolulu, Hawaii

Sample Location: Honolulu Harbor

Sample Method: SCUBA

Sample Date: 5/30/2003

Vessel Journey Record

Interisland>Honolulu

Arrival Date: 5/29/2003

How long in port (days): 1

Notes

Regular interisland barge tug, majority of fouling midship on water intakes

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
70	70	70
Species	**Species**	**Species**
Serpulidae, Spirorbidae, Bivalvia, Bryozoa	Porifera, Serpulidae, Spirorbidae, Sabelliae, Bivalvia, Bryozoa, Urochordata	Chlorophyta, Serpulidae, Spirorbidae, Sabellidae, Balanomorpha, Bryozoa

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
30	40
Species	**Species**
Serpulidae, Spirorbidae, Balanomorpha, Bryozoa	Chlorophyta, Balanomorpha, Bryozoa

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
033	Freebase I	Overseas Personal Craft	30	Vancouver, Canada

Sample Location	Sample Method	Sample Date
Ala Wai Yacht Harbor	Snorkel	6/12/2003

Vessel Journey Record

Vancouver>Hilo>Honolulu

Arrival Date

6/10/2003

How long in port (days)

2

Notes

Completely clean, hauled and repainted 2 months before arrival

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
0	0	0
Species	**Species**	**Species**
0	0	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
0	0
Species	**Species**
0	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
034	Passion	Overseas Personal Craft	40	San Francisco, California

Sample Location	Sample Method	Sample Date
Ala Wai Yacht Harbor	Snorkel	6/17/2003

Vessel Journey Record

San Francisco>Mexico>Honolulu

Arrival Date

6/13/2003

How long in port (days)

4

Notes

Minimal fouling, hauled and repainted 6 months before departure from SF

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
1	1	0
Species	**Species**	**Species**
Balanomorpha, Bryozoa	Balanomorpha, Bryozoa	0

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
1	0
Species	**Species**
Diatom Film, Balanomorpha	0

ID	Vessel Name	Vessel Type	Length (ft)	Home Port
035	O.E. Sette	Other	220	Honolulu, Hawaii

Sample Location	Sample Method	Sample Date
Other	SCUBA	8/6/2003

Vessel Journey Record

Jacksonville, Florida>Panama(Canal Transit)>Honolulu

Arrival Date

12/10/2003

How long in port (days)

Permanent

Notes

NOAA research vessel brought from Jacksonville Florida to be homeported in Hawaii, sampled at Midway Atoll, majority of all fouling on bow and midship in drydock support strips

Fouling Coverage-Stern (%)	Fouling Coverage-Midship (%)	Fouling Coverage-Bow (%)
5	1	1
Species	**Species**	**Species**
Serpulidae	Cnidaria, Serpulidae, Balanomorpha, Lepadimorpha	Cnidaria, Serpulidae, Balanomorpha, Lepadimorpha

Fouling Coverage-Prop/Rudder (%)	Fouling Coverage-Waterline (%)
10	1
Species	**Species**
Chlorophyta, Serpulidae, Bivalvia, Balanomorpha	Serpulidae, Lepadimorpha

Appendix B. Formal Hull Fouling Species List with Notes

PHYLUM PORIFERA			
Class Calcarea			
Family Heteropiidae			
	Heteropia glomerosa Bowerbank, 1873	**Cryptogenic**	**Established**
Class Demospongiae			
Order Hadromerida			
Family Suberitidae			
	Suberites zeteki de Laubenfels, 1936	**AIS**	**Established**
Order Haplosclerida			
Family Callyspongiidae			
	Callyspongia sp. Duchassaing & Michelotti, 1864	**Native**	
Family Chalinidae			
	Sigmadocia cf. *caerulea* Hechtel, 1965	**AIS**	**Established**
Family Niphatidae			
	Gelloides fibrosa Wilson, 1925	**AIS**	**Established**
Order Poecilosclerida			
Family Mycalidae			
	Mycale armata Thiele, 1903	**AIS**	**Established**
Family Raspailidae			
	Echinodictyum asperum Ridely & Dendy, 1886	**Cryptogenic**	**Established**
Order Dendroceratida			
Family Dictyodendrillidae			
	Dictyodendrilla sp.	**Native**	
Family Dysideidae			
	Dysidea sp.	**Cryptogenic**	**Established**
PHYLUM CNIDARIA			
Class Hydrozoa			
Family Halocordylidae			
	Pennaria disticha Goldfuss, 1820	**AIS**	**Established**
Family Bougainvilliidae			
	Bougainvillia ramosa (van Beneden, 1844)	**AIS**	**Established**
Family Sertulariidae			
	Dynamena crisioides Lamouroux, 1824	**Cryptogenic**	**Established**
Family Campanularidae			
	Unknown Species	**Unknown**	**Unknown**
Class Anthozoa			
Family Diadumenidae			
	Diadumene leucolena Verrill, 1866	**AIS**	**Established**
	Balanophyllia affinis Semper, 1872	**Native**	

PHYLUM ANNELIDA			
Family Polynoidae			
	Unknown species	**Unknown**	**Unknown**
Family Phyllodocidae			
	Phyllodoce madeirensis Langerhans, 1880	**Native**	
Family Syllidae			
	Typosyllis prolifera Krohn, 1852	**Native**	
	Typosyllis ornata Hartmann-Schroder, 1965	**Native**	
	Haplosyllis sponicola Grube, 1855	**Native**	
Family Nereididae			
	Perinerisis nigropunctata Horst, 1889	**Native**	
Family Eunicidae			
	Eunice filamentosa Grube, 1856	**Native**	
Family Lumbrineridae			
Family Sabellidae			
	Sabellastarte spectabilis (Grube, 1878)	**AIS**	**Established**
	Branchiomma japonica McIntosh, 1883	**Cryptogenic**	**Established**
Family Serpulidae			
	Hydroides elegans Haswell, 1883	**AIS**	**Established**
	Hydroides dirampha Morch, 1863	**AIS**	**Established**
	Hydroides crucigerus Morch 1863	**AIS**	**Established**
	Pomatoleios kraussii (Baird, 1865)	**Cryptogenic**	**Established**
	Pomatoceros cf. *minutus* Rioja, 1941	**AIS**	**New record**
	Salmacina tribranchiata Moore, 1923	**AIS**	**New record**
	Salmacina sp.	**Unknown**	**Unknown**
	Serpula cf. *vermicularis* Linnaeus, 1767	**Cryptogenic**	**Established**
	Serpula cf. *watsoni* Willey, 1905	**AIS**	**New record**
Family Spirorbidae			
	Eulaeospira orientalis Pillai, 1960	**Cryptogenic**	**Established**
	Simplicaria pseudomilitaris Thiriot-Quievreux, 1965	**Cryptogenic**	**Established**
	Janua pagenstecheri Quatrefages, 1865	**AIS**	**Established**
	Neodexiospira preacuta Vine, 1972	**Cryptogenic**	**Established**
	Neodexiospira foraminosa Moore and Bush, 1904	**Cryptogenic**	**Established**
	Pileolaria militaris Claparede, 1868	**AIS**	**Established**
	Circeis cf. *armoricana* Saint-Joseph, 1894	**AIS**	**New record**

PHYLUM MOLLUSCA			
Class Polyplacophora			
Family Chitonidae			
	Rhyssoplax linsleyi Burghardt, 1973	**Native**	
Family Vermetidae			
	Serpulorbis variabilis Hadfield and Kay, 1972	**Native**	
	Petaloconchus keenae Hadfield and Kay, 1972	**Native**	
Class Gastropoda			
	Siphonaria normalis Gould, 1846	**Native**	
	Cymatium intermedium Pease, 1869	**Native**	
	Crepidula aculeata Gmelin, 1791	**Native**	
Class Bivalvia			
	Dendostrea sandvichensis Sowerby, 1871	**Native**	
	Crassostrea gigas (Thunberg, 1793)	**AIS**	**Established**
	Mytilus galloprovincialis Lamarck, 1816	**AIS**	**Not Established**
	Chama macerophylla (Gmelin, 1791)	**AIS**	**Established**
	Brachidontes crebristriatus Conrad, 1837	**Native**	
PHYLUM CRUSTACEA			
Class Cirrepedia			
Order Thoracica			
Family Balanidae			
	Balanus amphitrite Darwin, 1854	**AIS**	**Established**
	Balanus reticulatus Utinomi, 1967	**AIS**	**Established**
	Balanus eburneus Gould, 1841	**AIS**	**Established**
	Balanus venustus Darwin, 1854	**AIS**	**New Record**
	Balanus trigonus Darwin, 1854	**AIS**	**Established**
	Megabalanus californicus Pilsbry, 1916	**AIS**	**New Record**
	Megabalanus tanagrae Pilsbry, 1928	**Native**	
	Megabalanus peninsularis Pilsbry, 1916	**AIS**	**New Record**
Family Chthamalidae			
	Euraphia hembeli Pilsbry, 1928	**Native**	
	Chthamalus proteus Dando & Southward, 1980	**AIS**	**Established**
	Chthamalus sp.Ranzani, 1817	**AIS**	**Unknown**
Family Tetraclitidae			
	Tesseropora pacifica Pilsbry, 1928	**Native**	
Order Lepadodmorpha			
	Lepas anserifera Linnaeus, 1767	**Native**	
	Lepas anatifera Linnaeus, 1758	**Native**	
	Conchoderma virgatum Spengler, 1790	**Native**	
	Conchoderma auritum Linnaeus, 1767	**Native**	

PHYLUM CRUSTACEA			
Order Amphipoda			
Family Amphilochidae			
	Unknown Amphilochidae	**Unknown**	**Unknown**
Family Caprellidae			
	Caprella penantis Leach, 1814	**AIS**	**Established**
Family Gammaridae			
	Elasmopus piikoi Barnard, 1970	**Native**	
	Elasmopus diplonyx Schellenberg, 1938	**Native**	
	Elasmopus pocillimanus Bate, 1862	**Native**	
	Maera pacifica Schellenberg, 1938	**Native**	
	Gammaropsis haliewa Barnard, 1970	**Native**	
	Photis hawaiiensis Barnard, 1955	**Native**	
	Photis aina Barnard, 1970	**Native**	
	Photis kapapa Barnard, 1970	**Native**	
	Ericthonius brasiliensis Dana, 1853	**AIS**	**Established**
	Jassa lilipuna Barnard, 1970	**Native**	
	Jassa falcata Sexton & Reid, 1951	**AIS**	**Established**
Class Isopoda			
Family Sphaeromatidae			
	Unknown Species	**Unknown**	**Unknown**
Tanaidacea			
	Antanais insularis Miller, 1940	**Native**	
	Mesanthuria sp.	**Native**	
Class Decapoda			
Order Brachyura			
Family Dynomenidae			
	Dynomene hispida Guérin, 1832	**Native**	
Family Xanthidae			
	Unknown Xanthidae (Juvenile)	**Unknown**	**Unknown**
Class Stomatopoda			
	Gonodactylaceusus falcatus Lanchester, 1903	**AIS**	**Established**
PHYLUM PYCNOGONA			
	Anoplodactylus sp. Wilson, 1878	**Native**	
PHYLUM ECHINODERMATA			
Class Ophiuroidea			
	Ophiactis savignyi Muller & Troschel, 1842	**Native**	
	Ophiactis modesta Brock, 1888	**Native**	

PHYLUM CRUSTACEA			
Order Amphipoda			
Family Amphilochidae			
	Unknown Amphilochidae	Unknown	Unknown
Family Caprellidae			
	Caprella penantis Leach, 1814	AIS	Established
Family Gammaridae			
	Elasmopus piikoi Barnard, 1970	Native	
	Elasmopus diplonyx Schellenberg, 1938	Native	
	Elasmopus pocillimanus Bate, 1862	Native	
	Maera pacifica Schellenberg, 1938	Native	
	Gammaropsis haliewa Barnard, 1970	Native	
	Photis hawaiiensis Barnard, 1955	Native	
	Photis aina Barnard, 1970	Native	
	Photis kapapa Barnard, 1970	Native	
	Ericthonius brasiliensis Dana, 1853	AIS	Established
	Jassa lilipuna Barnard, 1970	Native	
	Jassa falcata Sexton & Reid, 1951	AIS	Established
Class Isopoda			
Family Sphaeromatidae	Unknown Species	Unknown	Unknown
Tanaidacea			
	Antanais insularis Miller, 1940	Native	
	Mesanthuria sp.	Native	
Class Decapoda			
Order Brachyura			
Family Dynomenidae			
	Dynomene hispida Guerin-Meneville, 1832	Native	
Family Xanthidae			
	Unknown Xanthidae (Juvenile)	Unknown	Unknown
Class Stomatopoda			
	Gonodactylaceusus falcatus Lanchester, 1903	AIS	Established
PHYLUM PYCNOGONA			
	Anoplodactylus sp. Wilson, 1878	Native	
PHYLUM ECHINODERMATA			
Class Ophiuroidea			
	Ophiactis savignyi Muller and Troschel, 1842	Native	
	Ophiactis modesta Brock, 1888	Native	

PHYLUM BRYOZOA			
Class Gymnolaemata			
Family Bugulidae			
	Bugula neritina Linnaeus, 1758	**AIS**	**Established**
	Bugula robusta MacGillivrary, 1869	**AIS**	**Established**
	Holoporella pilaefera Canu & Bassler, 1929	**Unknown**	**Unknown**
Family Chorizoporidae			
	Rhamphostomella argentea Hincks, 1881	**Unknown**	**Unknown**
Family Scrupocellariidae			
	Scrupocellaria cf. *sinuosa* Canu & Bassler, 1927	**Native**	
Family Hippopodinidae			
	Hippopodina feegeensis Busk, 1884	**Cryptogenic**	**Established**
Family Schizoporellidae			
	Schizoporella errata Waters, 1878	**AIS**	**Established**
Family Watersiporidae			
	Watersipora edmondsoni Soule & Soule, 1968	**AIS**	**Established**
Family Cellaporidae			
	Celleporina sp. Gray, 1848	**Unknown**	**Unknown**
Class Stenolaemata			
Family Crisiidae			
	Crisina radians Lamarck, 1816	**Native**	
SUBPHYLUM UROCHORDATA			
Class Ascidiacea			
Suborder Aplousobranchia			
Family Didemnidae			
	Diplosoma listerianum Milne-Edwards, 1841	**AIS**	**Established**
	Didemnum sp.	**Unknown**	**Unknown**
Suborder Phlebobranchia			
Family Ascidiidae			
	Phallusia nigra Savigny, 1816	**AIS**	**Established**
	Ascidia species "A" Abbott et al., 1997	**AIS**	**Established**
Suborder Stolidobranchia			
Family Styelidae			
	Botrylloides simodensis Saito & Watanabe, 1981	**AIS**	**Established**
	Symplegma brakenhielmi Michaelsen, 1904	**AIS**	**Established**
	Polyandrocarpa sagamiensis Tokioka, 1953	**AIS**	**Established**
	Eusynstyela hartmeyeri Michaelson, 1904	**AIS**	**Established**
	Styela plicata Lesueur, 1823	**AIS**	**New Record**
	Styela clava Herdman, 1882	**AIS**	**New Record**
	Polycarpa aurita Sluiter, 1890	**Native**	
Family Pyuridae			
	Microcosmus exasperatus Heller, 1878	**AIS**	**Established**
	Herdmania momus Savigny, 1816	**AIS**	**Established**

Selected Introduced and Cryptogenic Marine Invertebrates

Porifera—[sponges]

Heteropia glomerosa Cryptogenic

First collected in 1955 on test blocks in Honolulu Harbor, this cryptogenic species has more recently been found in Pearl Harbor (1966), Kane òehe Bay (2000), Honolulu Harbor, Ke éhi Lagoon, Ala Wai Harbor, and Kewalo Basin (1999).

Suberites zeteki Introduced

This species was first recorded from O àhu in 1947 and reported as *Terpios zeteki.* It has been more recently found in leeward harbors on O àhu and in Kane òhe Bay, as well as in Nawiliwili Boat Harbor on Kaua `i. It is common in the fouling community with some estuarine conditions, primarily on floating docks, pilings, mangrove roots, and hulls of ships.

Sigmadocia cf. *caerulea* Introduced

This pale blue-green Caribbean sponge was first reported from Pearl Harbor in 1996. It is doubted that it could have been overlooked in previous surveys, since its abundance on floating docks at Coconut Island in Kane óhe Bay. It is common on artificial substrates of all harbors on the main Hawaiian Islands and Midway Atoll.

Gelloides fibrosa Introduced

First reported in 1996 from Pearl Harbor, this blue-gray Philippine sponge was collected from a floating drydock originating from the Philippines. It now occurs around O áhu and at Kaua ´i and Maui.

Mycale armata Introduced

This bright red-orange species was first collected in Pearl Harbor in 1996 and is now known from a number of locations around O áhu and at Kahului Harbor, Maui. The species is known from the Indo-Malayan region from where it may have originated.

Echinodictyum asperum Cryptogenic

This cryptogenic species was first reported from Pearl Harbor in 1997. It is known from the Indo–Pacific region.

*Dysidea sp***.** Cryptogenic

As an undescribed species, *Dysidea* sp. Is similar to an Atlantic Ocean sponge. It has been reported from Honolulu Harbor, Kane óhe Bay, and Ke éhi Lagoon.

Cnidaria: Hydroida—[hydroids]

Pennaria disticha Introduced

As the most common hydroid locally, this species is found throughout the main Hawaiian Islands, as well as at French Frigate Shoals. The earliest record of its occurrence is material collected in 1929 from Pearl Harbor. Additionally, it can grow to 30 cm in protected locations.

Bougainvillia ramosa Introduced

Most likely introduced by ship hull fouling, this species was first reported in 1967. The species, a native of the Atlantic Ocean, has been introduced to ports in Australia, Papua New Guinea, and New Zealand.

Dynamena crisioides Cryptogenic

Specimens of this species were first collected in 1972 in Honolulu Harbor and is now found in Ke éhi Lagoon and Barbers Point Harbor and in Kane óhe Bay.

Cnidaria: Anthozoa—[sea anemones]

Diadumene leucolena Introduced

This species may have arrived from the Caribbean area, since it is more tolerant to warmer waters than it northern Atlantic counterparts. The species was first reported in 1954 and is found along the south shore of O áhu.

Annelida: Polychaeta—[segmented worms]

Sabellastarte spectabilis Introduced

This large and distinctive fanworm was not reported in the literature until 1966 and would not have been overlooked if it has been present. Individuals are widespread around the main Hawaiian Islands.

Branchiomma japonica Introduced

This species is found prominently in the fouling community of boat harbors and lagoons. One of the earliest dates of collection for this species is the early 1940s.

Hydroides elegans, H. dirampha, and *H. crucigerus* Introduced

These three tubeworm species are difficult to differentiate, and all are considered introduced species. Specimens have been reported from collections from the beginning of the 1900s. All the species are found throughout the main Hawaiian Islands.

Pomatoleios kraussi Introduced

There appear to be no records of this species prior to the 1960s. This species is a dominant animal in the intertidal zone and often not found below low tide. Specimens are found in most harbors throughout the main Hawaiian Islands.

Serpula sp. [*S. vermicularis*] Cryptogenic

This species is apparently not common and is usually found only artificial substrates in harbors. Its earliest report was as early as 1936 in Kane óhe Bay.

Spirorbid Tubeworms Cryptogenic

Seven tiny coiled tubeworm species are closely related to human-mediated dispersal vectors: they occur in ship fouling, on commercial oyster shells, as juveniles or adults on small pieces of seagrass or floating debris. The origin of the species in Hawaiian waters is not known.

Mollusca—Bivalvia—[bivalves]

Crassostrea gigas Introduced

This species is well established in Kane óhe Bay. Specimens were initially imported in 1926. Numerous introductions have occurred since.

Mytilus galloprovincialis Not established

The first specimens of this species were reported from the hull of the USS Missouri when it arrived at Pearl Harbor, coming from the Pacific Northwest in June 1998. In 1999 specimens were found in tanks of a submarine, which had been moored in Pearl Harbor for years.

Chama macerophylla Introduced

Originally found on a floating drydock in Pearl Harbor in 1996, its native range is the North Carolina to Brazil. The species is also found in Kane óhe Bay.

Arthropoda: Cirripedia—[barnacles]

Balanid barnacles Introduced

Eight species of balanid barnacles are considered to established. These sessile (rock) barnacles are widely distributed throughout the islands, most likely arriving on ship bottom fouling. This study recognized three new records for the Hawaiian Islands: *Balanus venustus, Megabalanus californicus, M. peninsularis*.

Chthamalus proteus Introduced

This Caribbean barnacle arrived on O áhu sometime between 1973 and 1994. When surveys were begun in 1996, the species was widely distributed around O áhu. By 1998 it had been found on Kaua ´i, Maui, Midway Island, and Guam. Introduction could have been either on ship's hull at the waterline for this is a high intertidal barnacle or as larvae in ballast water.

Arthropoda: Amphipoda—[amphipods]

Caprella penantis Introduced

This small cosmopolitan species is usually associated with the hydroid *Pennaria*. The species was first recorded in 1921 and is considered a ship-fouling introduction.

Ericthonius braziliensis Introduced

This well-known amphipod was first collected in Kane óhe Bay fouling studies in 1936 and is found throughout the Hawaiian Islands. The species often forms masses of silty tubes.

Arthropoda: Stomatopoda—[stomatopods]

Gonodactylaceus falcatus Introduced

The first specimens of this stomatopod were observed in 1954 in dead coral heard in Kane óhe Bay and is thought to have arrived on O áhu with concrete barges towed back at the end of World War II, particularly from the area of the Philippines and the South China Sea. This species has displaced the native stomatopod *Pseudosquilla ciliata* from coral head habitats in Kane óhe Bay.

Bryozoa—[moss animals]

Bugula neritina and *Bugula robusta* Introduced

These very common and abundant bryozoans are widely distributed in the Hawaiian Islands, first being reported in 1921. Their origins remain uncertain, since they are found throughout the world in shallow warm waters.

Hippopodina feegeensis Introduced

This species is known from the Philippines and Queensland to the Red Sea and has been introduced in Florida and the Caribbean. In Hawai‘i, it has been reported from Pearl and Honolulu Harbors, Kane óhe Bay, Kewalo Basin and Ala Wai Harbor.

Watersipora edmondsoni Introduced

This species was described from the hull fouling of houseboats in the Ala Wai Yacht Harbor. It is now reported from Pearl Harbor, Kane óhe Bay, Ke éhi Lagoon, and Waikiki.

Chordata: Ascidiacea—[ascidians]

Ascidians Introduced

Thirteen species of introduced ascidians are reported in this study; one new record for the Hawaiian Islands: *Styela plicata*. They are found throughout the islands attached to a solid substrate. Probably all were introduced ship hull fouling.

Appendix C. Field Data for Hull Surveys

	Vessel #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
PLANTAE																																				
Chlorophyta		X	X	X	X						X	X	X	X	X		X	X				X	X			X		X				X				
Phaeophyta															X		X				X	X	X					X		X	X		X			
Rhodophyta											X											X	X									X				
PORIFERA																																				
Class Calcarea																																				
Family Heteropiidae																																				
	Heteropia glomerosa																									X										
Class Demospongiae																																				
Order Hadromerida																																				
Family Suberitidae																																				
	Suberites zeteki																									X										
Order Haplosclerida																																				
Family Callyspongiidae																																				
	Callyspongia sp.																									X										
Family Chalinidae																																				
	Sigmadocia caerulea																																X			
Family Niphatidae																																				
	Gelloides fibrosa																															X	X			
Order Poecilosclerida																																				
Family Mycalidae																																				
	Mycale armata																					X				X										
Family Raspailidae																																				
	Echinodictyum asperum																									X										
Order Dendroceratida																																				
Family Dictyodendrillidae																																				
	Dictyodendrilla sp.																									X										
Family Dysideidae																																				
	Dysidea sp.																									X										
	Unknown Species 1																									X										
	Unknown Species 2																									X										
	Unknown Species 3																									X										
CNIDARIA																																				
Class Hydrozoa																																				
	Pennaria disticha																					X											X			
	Bougainvillia racemosa																				X															
	Dynamena crisioides																						X										X			
	Unknown Campanularidae																																		X	
Class Anthozoa																																				
	Diadumene leucolena																X				X															X
	Balanophyllia affinis																							X												

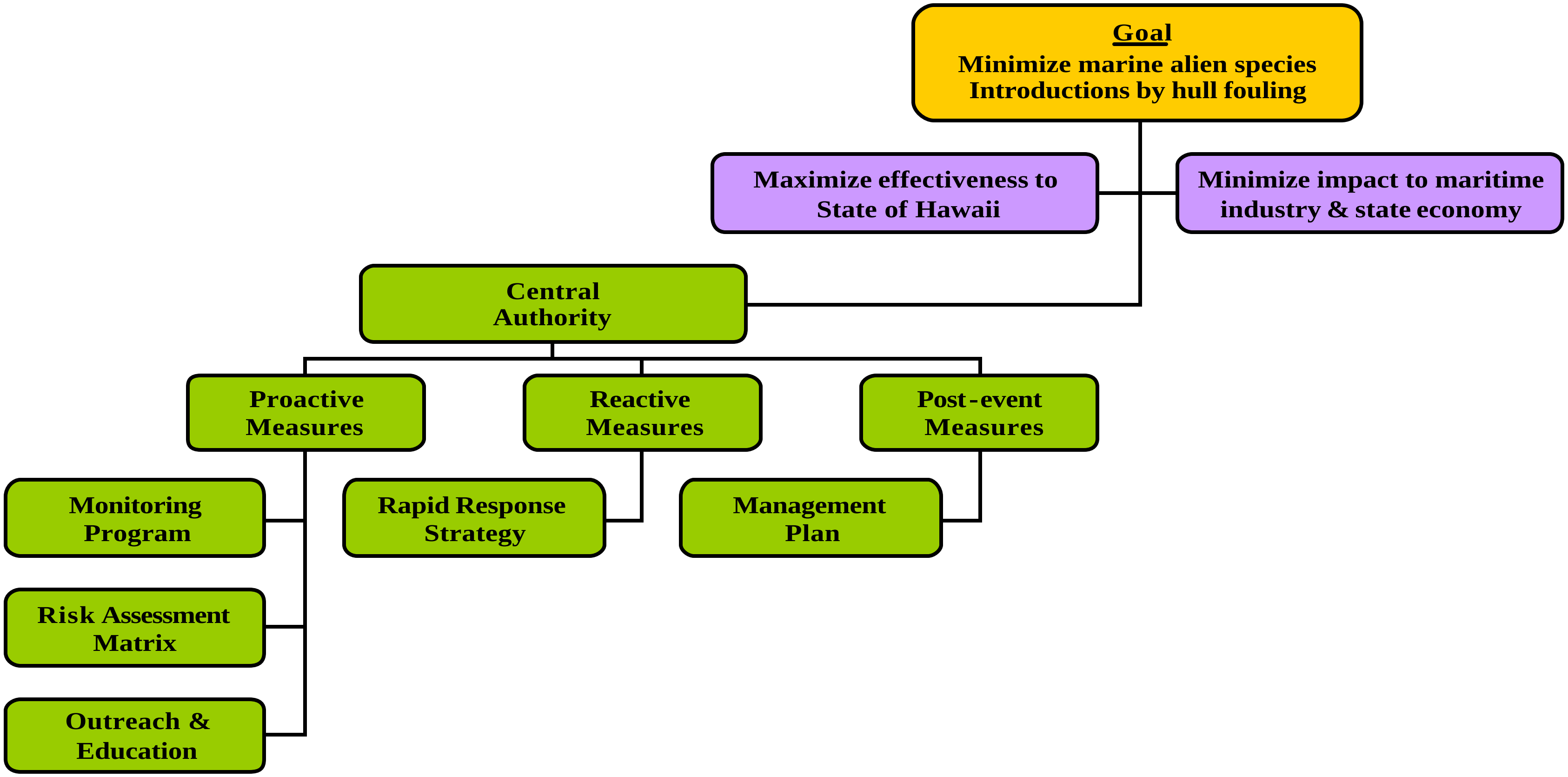
	Vessel #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
ANNELIDA																																				
Family Polynoidae																																				
	Unknown species																		X							X										
Family Phyllodocidae																																				
	Phyllodoce madeirensis																		X																	
Family Syllidae																																				
	Typosyllis prolifera										X											X		X												
	Typosyllis ornata																					X														
	Haplosyllis sponicola																									X						X	X			
Family Nereididae																																				
	Perinerisis nigropunctata		X																				X													
Family Eunicidae																																				
	Eunice filamentosa										X						X				X		X	X								X	X			X
Family Lumbrineridae																																				
	Lumbrineresis heteropoda																					X														
Family Sabellidae	*Sabellastarte spectabilis*																					X				X					X		X			
	Branchiomma japonica		X										X			X					X		X			X						X	X			
Family Serpulidae																																				
	Hydroides elegans	X									X	X	X	X		X	X		X		X	X		X							X	X	X			X
	Hydroides dirampha										X	X	X											X												
	Hydroides crucigera																		X			X														
	Pomatoleios kraussii																X					X														
	Pomatoceros cf. minutus																		X																	
	Salmacina tribranchiata										X																									
	Salmacina sp.															X						X		X	X											
	Serpula vermicularis																					X									X				X	
	Serpula cf. watsoni																							X												
Family Spirorbidae																																				
	Circeis cf. *armoricana*										X	X												X												
	Eulaeospira orientalis													X																						
	Simplicaria pseudomilitaris													X								X														
	Janua pagenstecheri													X	X	X	X				X	X									X				X	
	Neodexiospira preacuta															X																X	X			
	Neodexiospira foraminosa															X					X		X													
	Pileolaria militaris																						X													
	Unknown Species											X	X																							

	Vessel #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MOLLUSCA																																				
Class Polyplacophora																																				
	Rhyssoplax linsleyi										X													X												
	Unknown Species											X																								
Class Gastropoda																																				
	Siphonaria normalis											X				X																X				
	Cymatium sp.																							X												
	Crepidula sp.																					X														
Family Vermetidae																																				
	Serpulorbis variabilis																					X														
	Petaloconchus keenae																					X														
Class Bivalvia																																				
	Ostrea sandvichensis										X	X	X	X	X	X	X				X	X	X	X		X					X		X			X
	Crassostrea gigas																				X															
	Mytilus galloprovincialis																								X											
	Chama macerophylla																									X										
	Brachidontes crebristriatus																					X									X	X	X			X
CRUSTACEA																																				
Class Cirrepedia																																				
	Balanus amphitrite		X								X		X	X		X	X		X			X		X		X					X	X	X		X	
	Balanus reticulatus		X								X				X						X		X	X							X	X	X			X
	Balanus eburneus		X																																	
	Balanus venustus																																			X
	Balanus trigonus																		X							X										
	Euraphia hembeli				X												X																			
	Chthamalus proteus										X	X	X		X	X	X		X		X	X		X								X	X			
	Chthamalus sp.																										X									
	Megabalanus californicus																		X						X											
	Megabalanus tanagrae																																X			X
	Megabalanus peninsularis							X	X	X																										
	Unknown Balanomorpha																						X													
	Tesseropora pacifica				X																										X	X	X			X
	Lepas anserifera																		X		X							X	X	X						
	Lepas anatifera			X				X	X	X																						X				
	Conchoderma virginatum						X	X	X	X				X									X				X	X		X						
	Conchoderma auritum																															X				
Order Amphipoda																																				
Family Caprellidae																																				
	Caprella penantis		X																																	
	Unknown Species																				X															
Stomatopoda																																				
	Gonodactylaceus falcatus																									X										

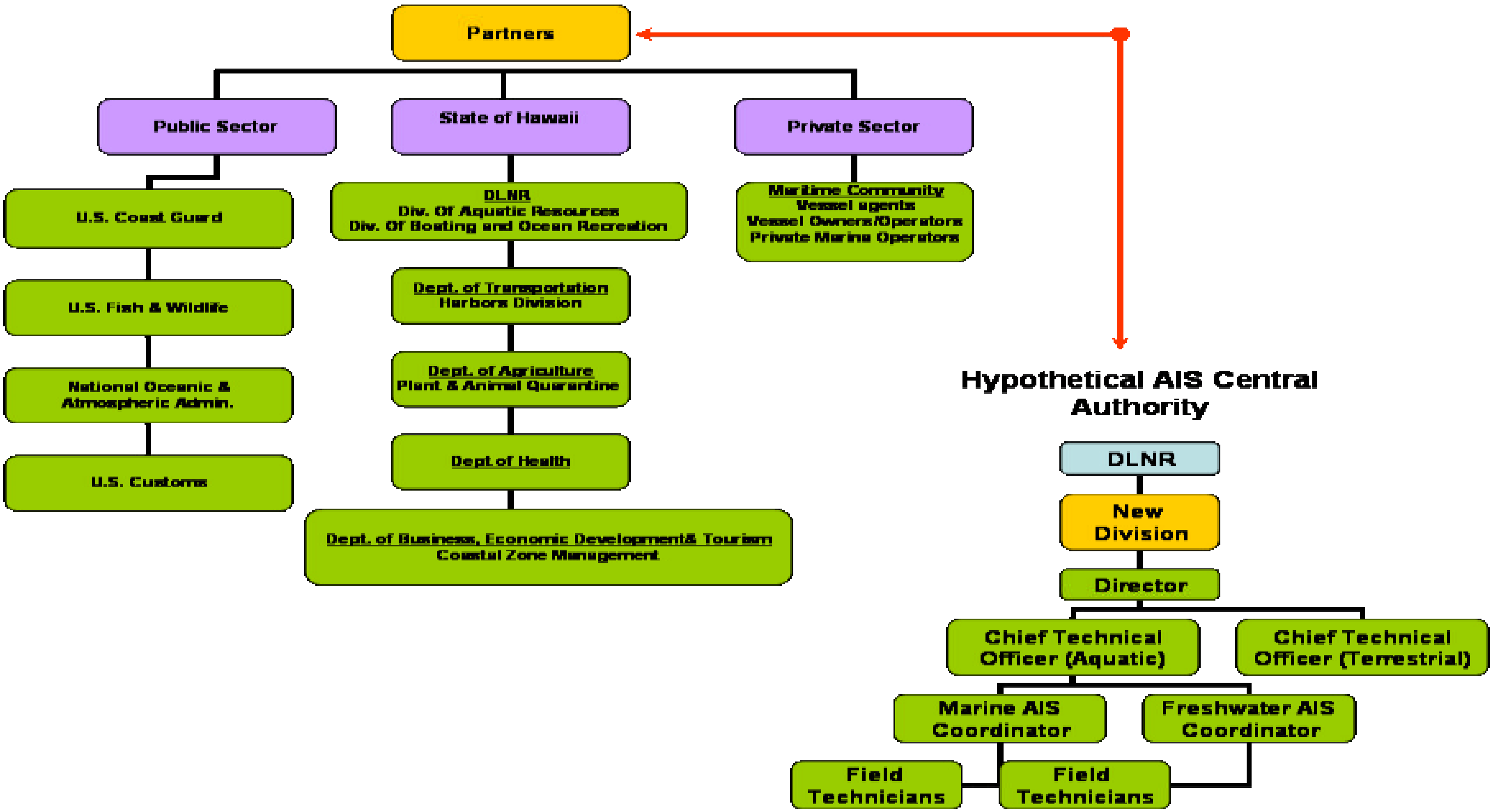
	Vessel #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
CRUSTACEA																																				
Suborder Gammaridea																																				
	Gammaropsis haliewa		X																																	
	Elasmopus pocillimanus		X																																	
	Elasmopus piikoi																		X																	
	Elasmopus diplonyx																					X														
	Maera pacifica										X								X																	
	Jassa lilipuna												X																							
	Jassa falcata																																		X	
	Photis hawaiiensis													X								X														
	Photis aina																		X																	
	Photis kapapa																		X																	
	Ericthonius brasiliensis																		X																X	
	Unknown Amphilochidae																																			X
Order Isopoda																																				
Family Sphaeromatidae																																				
	Unknown Species		X								X																						X		X	
Order Tanaidacea																																				
	Anatanais insularis										X	X	X			X	X				X											X	X			
	Mesanthuria sp.																		X																	
Infraorder Brachyura																																				
	Dynomene hispida																																			X
	Unknown Xanthidae (Juvenile)																		X		X					X										
PYCNOGONIDA																																				
	Anoplodactylus sp.																				X															
ECHINODERMATA																																				
Class Ophiuroidea																																				
	Ophiactis savignyi											X									X	X														
	Ophiactis modesta																									X										
BRYOZOA																																				
Class Gymnolaemata																																				
Family Bugulidae																																				
	Bugula neritina															X					X															
	Bugula robusta											X																								
	Holoporella pilaefera										X					X	X																			
Family Chorizoporidae																																				
	Rhamphostomella argentea										X																									

	Vessel #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
BRYOZOA																																				
Family Scrupocellariidae																																				
	Scrupocellaria cf. *sinuosa*										X																									
Family Hippopodinidae																																				
	Hippopodina feegeensis										X					X					X															
Family Schizoporellidae																																				
	Schizoporella errata										X											X		X		X					X	X	X			
Family Watersiporidae																																				
	Watersipora edmondsoni											X									X															
Family Cellaporidae																																				
	Celleporina sp.										X																									
Class Stenolaemata																																				
Family Crisiidae																																				
	Crisina radians																					X											X			
	Unknown species	X													X				X			X	X	X							X	X	X		X	
UROCHORDATA																																				
Order Ascidiacea																																				
Family Didemnidae																																				
	Diplosoma listerianum		X																							X										
	Didemnum sp.																					X				X										
Family Ascidiidae																																				
	Phallusia nigra		X												X																					
	Ascidia species "A"																						X													X
FamilyStyelidae																																				
	Botrylloides simodensis																					X										X	X			
	Symplegma brakenhielmi		X																			X	X								X					
	Polyandrocarpa sagamiensis																					X				X										
	Eusynstyela hartmeyeri																																X			
	Polycarpa aurita										X			X							X	X		X												
	Styela plicata																								X											
	Styela clava																								X											
Family Pyuridae																																				
	Microcosmus exasperatus												X								X	X	X	X							X	X	X			X
	Herdmania momus		X								X											X	X	X		X					X	X	X			

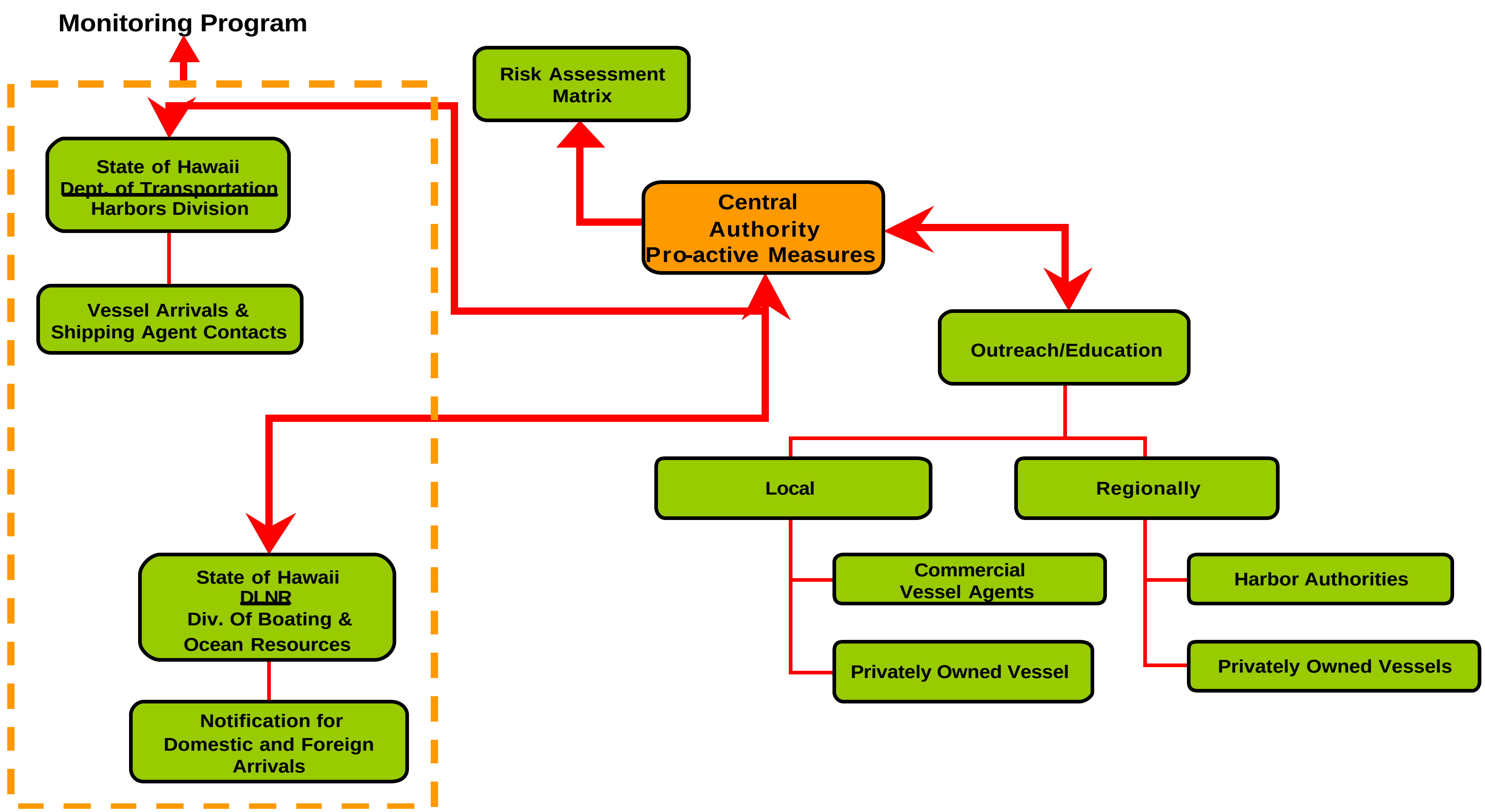
Appendix D. Full Size Images of Diagrams from Section III and Field Photos



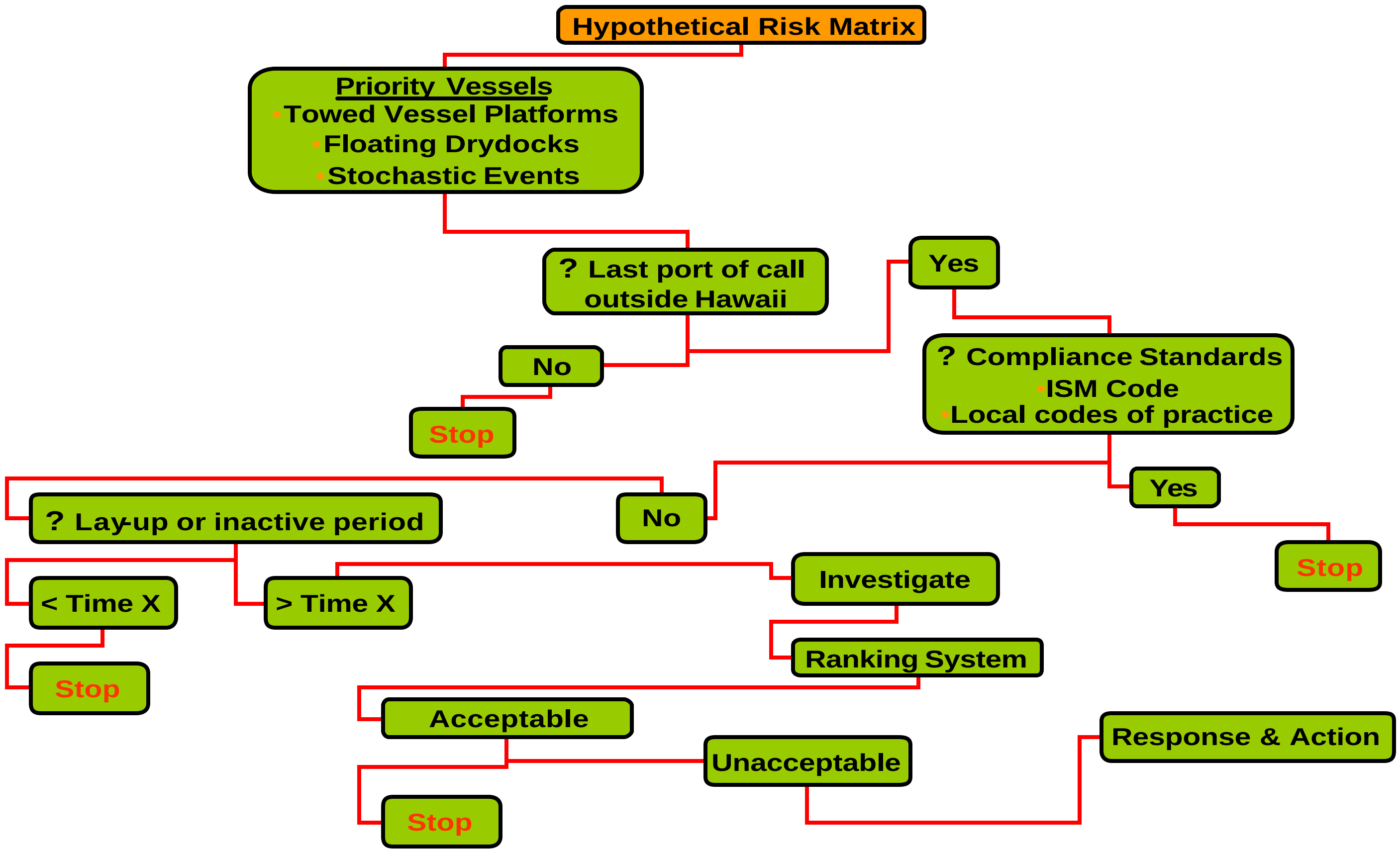
Framework for the management of marine AIS transported by hull fouling



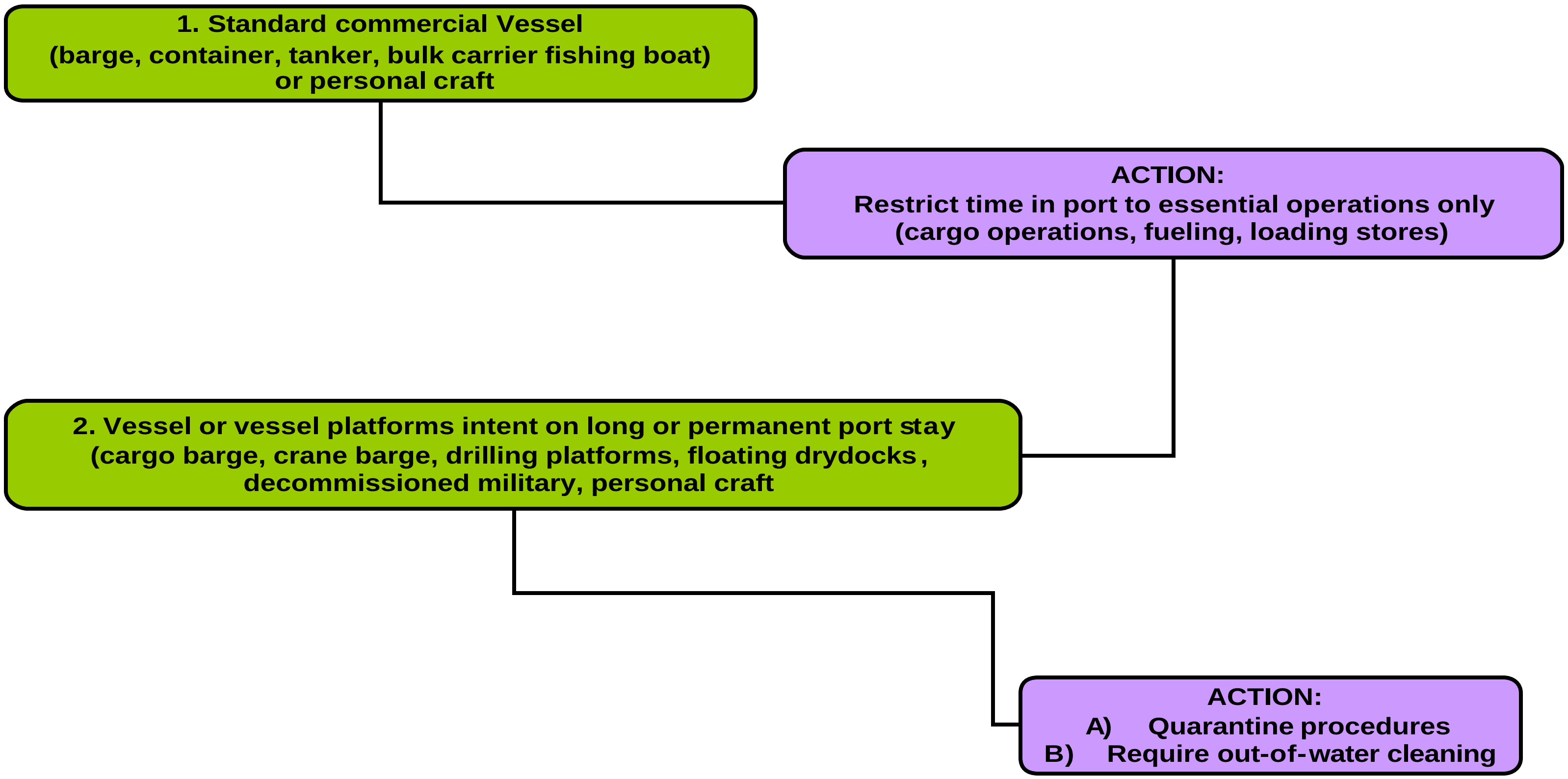
Hypothetical AIS central authority for invasive species activities



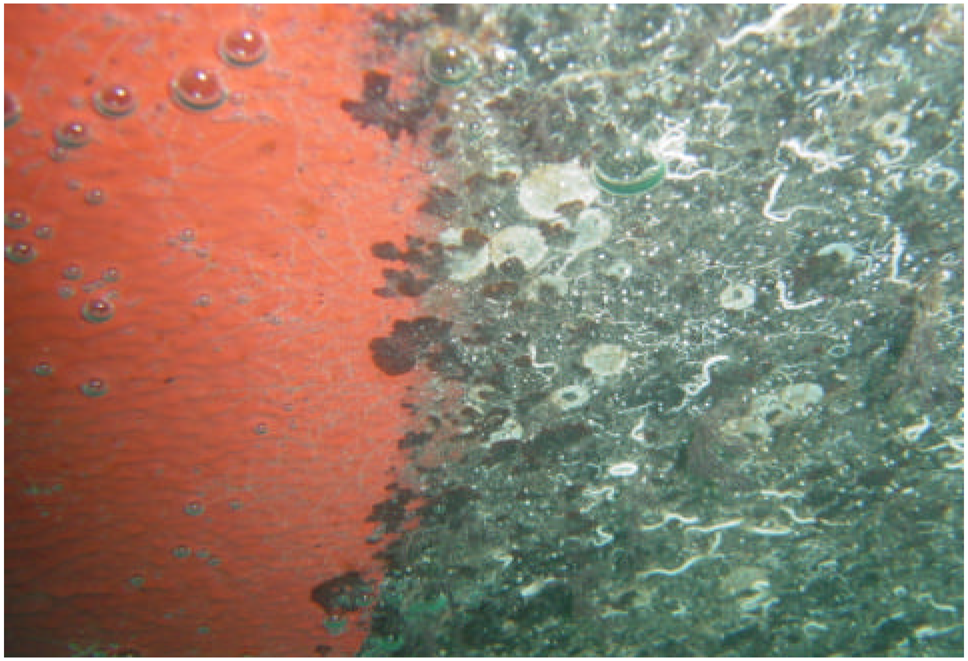
Pro-active measures for management of marine AIS transported by hull fouling



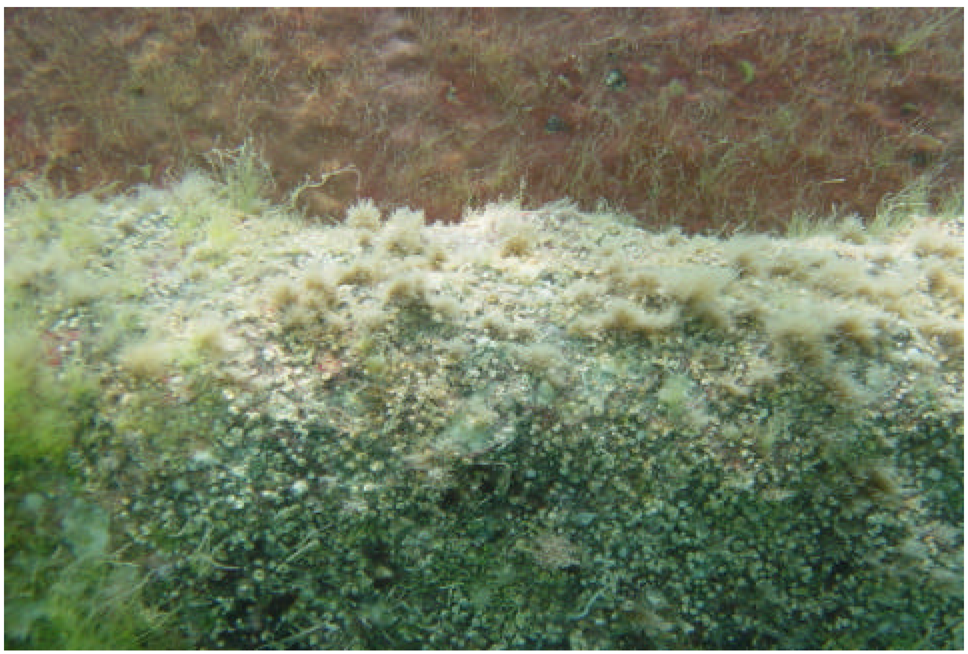
Hypothetical Risk Matrix



Vessel scenarios and actions for response to high risk event

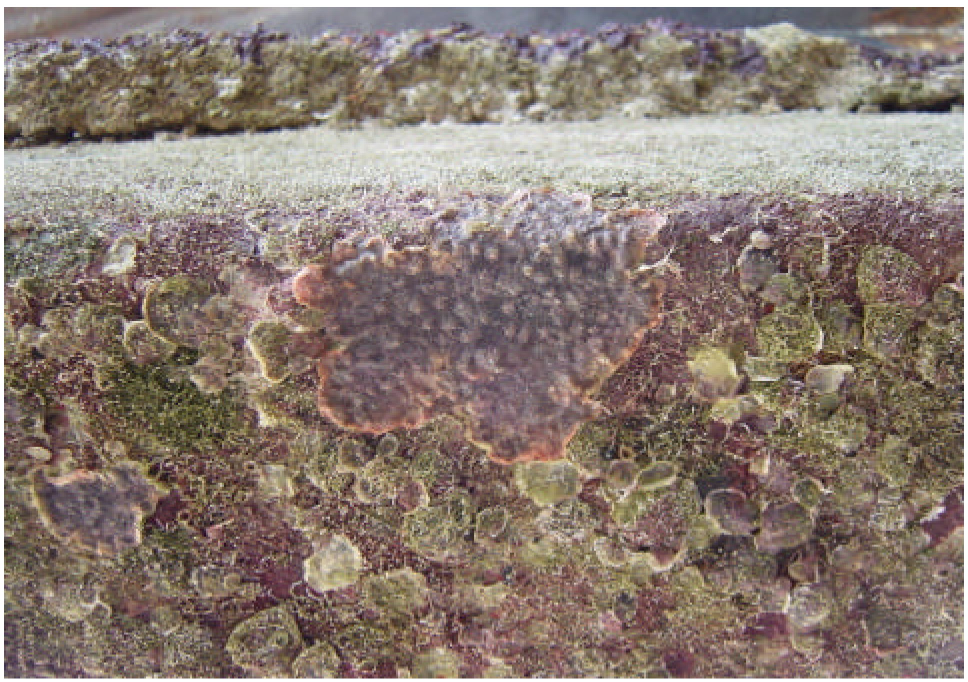


Fouled dry dock support strip compared to vessel hull with fresh antifouling coating. Photo by L.S. Godwin



Fouled zinc block. Photo by L.S. Godwin

The marine invasive barnacle *Chthamalus proteus* **on the hull of an inter-island barge in Honolulu Harbor. Photo L.S. Godwin**



The marine invasive bryozoan *Schizoporella* **on the hull of a vessel in Honolulu Harbor. Photo L.S. Godwin**