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**NON-SHIPPING PATHWAYS
FOR MARINE INVASIVE SPECIES IN MAINE**

**Report prepared by Shannon Weigle
for the Casco Bay National Estuary Program
January 9, 2007**

MARINE INVASIONS AND NON-SHIPPING PATHWAYS

The vast majority of marine biological invasions have resulted from unintentional introductions. Many of these introductions have been attributed to ballast water transport and hull transfers from commercial ships. Non-shipping pathways for marine invasive species include commercial enterprises, such as the aquaculture, seafood, bait, and pet industries; research and educational organizations, such as colleges, universities, and public aquariums; and private or government environmental activities, such as coastal wetlands restoration and fishery stock enhancement. Among commercial enterprises, the aquaculture and seafood industries have played a substantial role in marine biological invasions, particularly with regard to the transport of shellfish. For example, salt marsh cordgrass (*Spartina alterniflora*), used as packing material for Atlantic oysters (*Crassostrea virginica*), was introduced to Oregon by 1939. It has since spread along the Oregon coast. Although the Chinese mitten crab (*Eriocheir sinensis*) was banned for importation and aquaculture in the U.S. in the late 1980's, the crab was discovered in San Francisco Bay in 1994. The crab's high market value and resistance to the ban by California aquaculturists suggest that the crab may have been intentionally introduced. In 2002, Debbie Rudnick, a mitten crab specialist, spoke at the Massachusetts Bays Program's conference on marine invasive species, and said, "Based on what is known about transport vectors, distribution and environmental tolerances of the mitten crab, it is possible that this species could be introduced to and established in estuaries of the Northeastern US." In 2004, the mitten crab was spotted in several locations along the St. Lawrence River in Canada and in Maryland in 2006.

Bait and pet industries have also been associated with aquatic invasions. For example, both the green crab (*Carcinus maenas*) and the green alga *Codium fragile* may have been transported to the west coast of the United States in seaweed used with shipments of bait worms. *Caulerpa taxifolia*, a common seaweed in the pet trade, was recently discovered along the California coast. With Internet access, the ease with which exotic marine species can be obtained is startling. On a typical aquaria related website, over fifty types of marine life were available for shipment to anywhere in the United States.

Researchers and educational organizations have been implicated in several marine invasions. In 1972, the tunicate *Botrylloides diegensis* was accidentally released by a researcher at the Marine Biological Laboratory into the waters of Woods Hole, Massachusetts. Since then, this ascidian has spread along much of the coast of New England. Over the years, other exotic marine organisms have been found near Woods Hole. Finally, privately or publicly funded coastal wetland restoration projects may pose another important pathway for marine invasions. Historically, landscapers have selected plants for ornamental reasons and restorers have chosen plants for functional purposes. Until recently, little attention has been paid to the geographic origin of the plants. Due to the recent increase in coastal restoration projects, some nurseries now sell marine plants specifically for restoration purposes and advertise shipment to anywhere in the United States.

Although we know that non-shipping pathways have played a role in the transfer of marine exotic species, prior to this study, we did not know the relative importance of currently active pathways for a given region. In particular, there had been little comparative information on the variety and volume of species being moved, the current handling practices for each pathway, and the stakeholders understanding of the threat of non-indigenous species. This information is essential if we are to prevent unwanted species from being introduced into our local marine environment.

COMPREHENSIVE REGIONAL STUDY OF NON-SHIPPING PATHWAYS

For a marine invasion to succeed, certain basic criteria must be met. At the outset, the exotic species or its gametes must reach the new environment. Upon arrival, the species must then be able to tolerate prevailing biotic and abiotic conditions (e.g. temperatures, salinities) (Smith *et al.*, 1999). The risk of a successful introduction increases if a pathway: 1) provides repeated opportunities for the introduction of exotic species or their gametes into the local marine environment, 2) transports exotic species that are capable of surviving in local waters, and 3) includes sufficient numbers of the exotic species to sustain a population. Theoretically, a marine invasion could be prevented if we interrupt the pathway at one or more of these points.

In our study, we began by examining seven non-shipping pathways in Massachusetts for the presence of high-risk features that may lead to a marine invasion. We later expanded this study to include the other coastal states of New England. This report describes our findings for Maine. To collect the data, we compiled a database of companies and organizations in Maine for each pathway and then designed and administered a survey that inquired about a) the pathway-specific opportunities for introduction (e.g. proximity of water body, shipping and handling methods); b) the type, quantity, and frequency of exotic marine species being imported; c) the type, quantity, and frequency of exotic and local marine species being exported; and d) the respondents' familiarity and interest in marine bioinvasions. The data from the surveys were used to compare risky characteristics within and between the pathways. Based on our findings, I provide recommendations to each pathway for reducing the risk of unwanted introductions. This study was funded by the National Sea Grant Program. Students from MIT Sea Grant assisted in the data collection for the Maine study group.

Additional information about the results of the Massachusetts study, the methods used for all of the study groups, and references can be found in the following two publications:

Weigle, S. M. W. 2002. Prevention of marine bioinvasions: the live marine species trade and potential risks for exotic species introductions in Massachusetts. M.S. thesis. Northeastern University, Boston, Massachusetts.

Weigle, SM, Smith, LD, Carlton, JT, and Pederson, J. Assessing the risk of introducing exotic species via the live marine species trade. *Conservation Biology* 19 (1): 213-223, (2005).

METHODS

PATHWAY IDENTIFICATION

Local trade directories and publications were used to identify the potential non-shipping pathways in Maine that handle live or fresh (i.e., dead but not frozen or processed) marine species. Potential pathways for Maine included commercial enterprises (seafood, pet, and bait industries), marine research and educational organizations (henceforth referred to as research), aquaculturists, public aquariums, and coastal restoration projects. Public aquariums and coastal restoration projects were not surveyed in Maine. Maine was unique as compared to the other New England coastal states in that the state has numerous seaweed harvesters. Since special surveys were not developed for the seaweed industry in Massachusetts, we distributed aquaculture surveys to the Maine seaweed companies.

DATABASE COMPILATION

In the spring of 2001, a database of relevant organizations and companies for each of the potential pathways in Maine was assembled into an Excel spreadsheet. The company name, address, and telephone number were recorded. The database served three purposes: 1) to approximate the number of entities and geographic distribution for each pathway, 2) to approximate the number of exchange points in each pathway, and 3) to generate a list of potential survey candidates. With the exception of marine researchers, individuals (i.e., aquatic pet owners, seafood customers, recreational fishermen) were not included in this study. Primary resources used to compile the company lists included the 1999 – 2000 Bell Atlantic Yellow Pages, the Maine Seafood Directory (Maine Department of Marine Resources), and an online list of aquaculturists on the State of Maine website. The list of marine biological researchers was compiled by searching the websites of biology departments at local universities and colleges.

SURVEY DESIGN

To compare the risk of exotic marine species introductions between the pathways, a survey was developed and administered to a subset of entities within each pathway. Survey methodology followed the recommendations of Salant and Dillman (1994). The survey consisted of approximately 30 questions divided into four sections. The first section included questions about the facility and the company (e.g., proximity of company to nearest body of water, annual income from non-local species). The second and third sections consisted of questions and charts designed to collect information on the variety and volume of live marine species being imported and exported, respectively, and the associated en route handling practices. Throughout the survey, "local" referred to the coastal states of New England (Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut) and their associated water bodies ranging from the Gulf of Maine to the northern portion of Long Island Sound. The term "non-local" was used to describe regions outside of the coastal states of New England. Finally, the fourth section asked about the respondent's familiarity with and interest in the topic of marine bioinvasions.

TELEPHONE SCREENING

I screened the database to maximize candidate responses and eliminate non-responses. During the telephone screening process, companies and organizations were contacted by telephone or email to determine which ones imported live exotic marine plants or animals to Maine and which ones exported live marine plants or animals outside of New England. I asked each company or organization the following three questions: (1) Do you work with live marine plants or animals? (2) Do you import any of these plants or animals

from areas outside of New England? (3) Do you export any live plants or animals to areas outside of New England? If the company or organization answered “yes” to question 1 and either question 2 or 3, they were considered to be a survey candidate. If a telephone call resulted in a “no longer in service” message, the organization was assumed to be no longer operational. Unanswered phone calls or busy signals were assumed to mean that the organization was still in business. The data collected during the telephone screening was also used to estimate the potential population sizes of importers and exporters for each pathway.

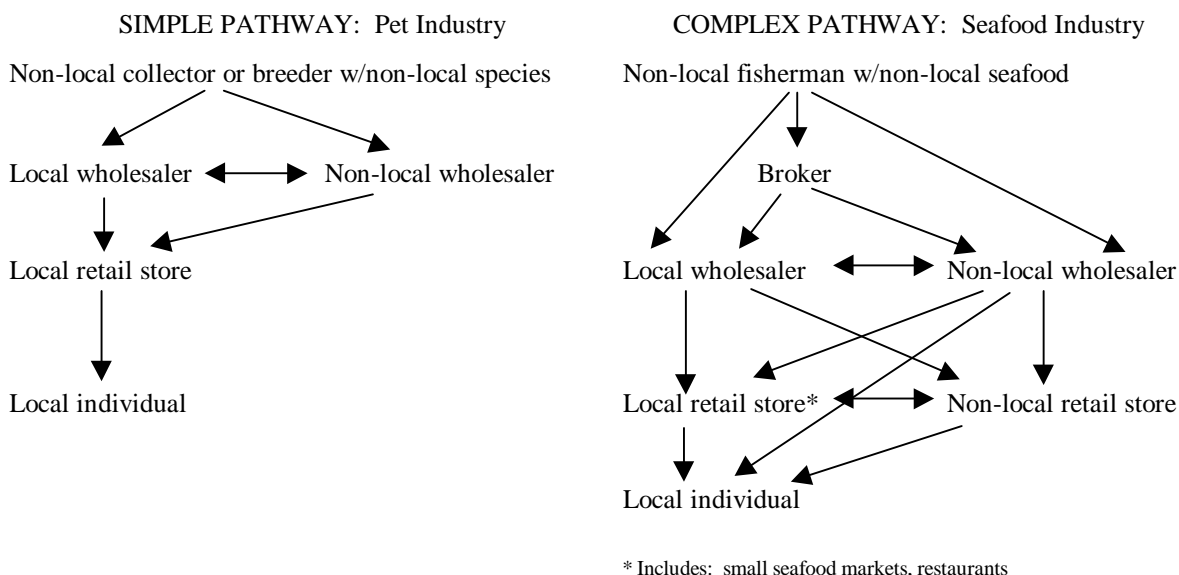
MAIN SURVEY DISTRIBUTION

After the screening process was complete, the list for the survey distribution was compiled that included all survey candidates that answered “yes” to question 2 or 3 in the telephone screening process. To increase the sample size, I also included an additional number of companies and organizations that were unreachable during the screening process (e.g. aquaculture operations). Prior to the survey distribution, a preview letter was mailed to those on the list. This letter briefly described the project and notified them that the survey would arrive in one week.

RESULTS

DATABASE COMPILATION

Pathways that handled live marine organisms in Maine varied greatly in the number of entities and level of complexity. Prior to screening, over 360 entities were identified for the seafood pathway while other pathways ranged from 21 to 116 entities. Pathways differed in their level of complexity. For example, the seafood pathway contained as many as five possible exchange points between source and end point with companies playing multiple roles in the exchanging of product. In contrast, the pet pathway had only 2-3 exchange points and each company had a clearly defined role in the exchange.



TELEPHONE SCREENING

The telephone screening showed that there was a significant difference among the pathways in both the percentage and total number of companies that import and export live or fresh marine species. For example, approximately 92% of the pet shops import marine species while only 6% of the bait shops import species. The telephone screening data was also used to estimate the number of potential importers and exporters for each pathway.

SURVEY RESULTS: WITHIN PATHWAYS

Approximately 35% of the 216 surveys distributed to Maine companies and organizations in 2001 were completed and returned. Survey responses for the seafood, aquaculture, bait, pet, and research pathways are summarized in the attached tables. Throughout the text of this section, the survey data are provided as "number of respondents answering a given category/number of total respondents answering the question." The terms "import" and "export" refer to product that is delivered from or shipped to regions outside of New England, including both domestic and foreign destinations.

I. THE SEAFOOD PATHWAY

We contacted sixty-one seafood companies through the telephone screening. A portion of these companies were no longer in business or sold only frozen or processed product. Of those remaining, many of these companies sold live or fresh species from (15/42) or to (28/42) non-local regions. Based on the telephone screening, we estimated that there are 131 importers and 244 exporters of live or fresh marine species in the seafood industry. Most seafood company personnel were receptive to the pre-survey calls. Only a few people said they were "too busy" to answer any questions or they just "didn't want to do the survey."

Seafood companies were located throughout the study region however; most companies were located within coastal towns, and the highest concentration of companies was found in Portland. Ninety-eight surveys were distributed to the seafood pathway. Twenty-nine surveys were completed and returned, which included sixteen companies that import product (16/29) and twenty companies that export product (20/29).

A. IMPORTS

I. COMPANY DETAILS AND ONSITE HANDLING PRACTICES

Most of the respondents that imported non-local species were located within 500 feet (13/16) of a saltwater body. Of those that contained their product in water tanks (12/15), half discharged the water through a municipal drainage line. The remaining respondents discharged the water into the local water body untreated and unfiltered (6/15) or after treatment (4/15). Most of the companies that created solid fish processing waste disposed of the waste at the landfill (6/9). One company sold the waste to fisherman to use as bait, another sold it for fertilizer, and another disposed of the solid waste in the local water body.

Most of the survey respondents used their own equipment to collect non-local species (9/16). Presumably, they used their fishing boats to travel to waters in non-local regions. Others bought them from local (5/16) or non-local wholesalers (6/16). A small portion of the respondents used the Internet to order non-local seafood (2/16). If the non-local product arrived via ground transportation, it was generally delivered by the supplier's trucks (11/13). Of those respondents that wash down their delivery trucks, most use fresh water (11/13), a few use saltwater (3/13), and only a small portion use a detergent (1/13). The non-local product was usually packaged with ice packs (6/14) or ice (8/14). Seaweed was sometimes used (3/14). The seaweed was usually sent out with the trash. Most of the respondents also disposed of the unsold non-local product with the trash (8/12).

II. TAXONOMIC VARIETY & VOLUME

Many of the respondents completed at least a portion of the charts on species variety and volume (11/16) but none of the respondents used scientific names. Live products reported by the survey respondents included Jonah crabs, lobsters, and mussels from Canada and soft shell crabs from the mid-Atlantic region. Fresh products included salmon and

halibut from the Pacific coast, tuna from the mid-Atlantic and south Pacific Ocean, crabmeat from Canada, and shrimp from the Gulf of Mexico. Seventy-nine percent of the seafood respondents observed non-target organisms accompanying the non-local products (11/14). These included crustaceans (2/11), mollusks (3/11), worms (3/11), seaweed (5/11), and barnacles (8/11).

Presently, there is no source for data on the domestic trade of seafood. This lack of trade data has been frustrating for researchers, especially fishery scientists. A NOAA scientist remarked, "There is really no source that I'm aware of which tracks movement of live marine animals in and out of New England." A representative from the New England Fisheries Development Association agreed saying, "[Live fish] is difficult to track because a lot of it is moving through Asian distribution channels which are pretty closed regarding information. Also live fish is sometimes transported at night and off the interstate in small trucks."

The seafood pathway imported an enormous volume of live and fresh species as compared to the other pathways. However, most of these imports came from the cold waters of Eastern Canada and consisted of species that are indigenous to the Maine coast.

B. EXPORTS

More than half of the survey respondents export live or fresh marine species to regions outside of New England (20/29). Before shipment to domestic and foreign non-local regions, less than half of the respondents washed the live products (7/20) or fresh products (7/18) and none of the companies used a chemical dip on the product (0/19). The product was usually packaged with ice packs (17/20), seaweed (14/20), or ice (12/20). Most of the companies, or 79% , shipped the product via a parcel service (e.g., UPS, Fed-Ex) (15/19) and more than half of the respondents used the Internet to sell live or fresh product (10/19). Species variety and volume was collected in the survey but was not analyzed for this report. If needed, this information can be provided.

C. INVASIVE AWARENESS AND INTEREST

The level of interest in marine invasions varied greatly between seafood companies. Survey respondents were most familiar with the following terms used in marine invasion biology: non-indigenous species (17/19), exotic species (14/19), and non-native species (14/19). Most of the companies were familiar with the topic of marine invasions (14/16) and 82% were interested in learning more about the issue (13/16). Since the seafood industry is already heavily regulated, many of the seafood companies were hesitant to participate in the survey for fear of additional regulations. One company from the Massachusetts survey group wrote, "Please be advised that the fishing industry is already inundated with paperwork required to local and federal agencies and doesn't look fondly on additional requests for such inquiries."

Several companies had already witnessed the impact of marine invasive species, and some were extremely interested in the study. One Maine respondent said, "Glad to see you are studying this. The green crab and other species not native to Maine have had serious consequences." However, another respondent (from Massachusetts) seemed to think there was little need for concern saying, "The seafood industry deals mainly in dead fish, so there would be little potential for escapees." Most of the respondents were interested in receiving a copy of the survey results (11/19).

II. THE AQUACULTURE PATHWAY

Based on our experience with the Massachusetts survey group in which most of the aquaculturists were unreachable during the telephone screening process, we decided to not conduct a telephone screen with the Maine group. Surveys were mailed to a randomly selected group of twenty-three aquaculturists. Nine were completed and returned. One of the companies reported that they imported non-local species (1/9) and five exported product (5/9).

A. IMPORTS

The one survey respondent reported that their company grows tropical corals and inverts for the aquarium industry. They are located less than 500 feet from the Kennebec River and discharge their tank water into cedar beds. They do not dispose of any fish processing waste. They buy their non-local product from a supplier outside of New England and distribute their product to retailers and wholesalers within New England.

B. EXPORTS

More than half of the survey respondents ship their product to regions outside of New England (5/9). All of the respondents washed their live product (5/5) and most washed their fresh product (4/5) before shipment. None of the respondents used a chemical dip or other treatment to maintain freshness. Most of the companies used their own trucks to deliver the product (4/5). Ice packs were the primary packing materials used (4/5). The respondents worked with local species, including Atlantic salmon and American oyster (*Crassostrea virginica*). Two of the respondents observed non-target organisms with the outgoing product including crustaceans, seaweed, and barnacles.

C. INVASIVE AWARENESS AND INTEREST

Most of the respondents were familiar with the terms used in invasion biology, especially non-indigenous species (5/5) and exotic species (5/5). Most of the respondents were familiar with the issue (5/6) yet they were not interested in learning more. The non-familiar respondent however was interested in learning more about invasive species. The respondent who worked with tropical corals was confident that their company's product was not a risk to the local environment remarking, "None of the animals that we deal with could ever survive the New England coastal waters, mostly due to water temps, nor could they adapt to freshwater. There is absolutely no environmental risk from this kind of aquaculture process. There are no by-products, only saltwater discarded as water changes are performed on the tanks." Two of the companies were interested in receiving a copy of the survey results.

III. THE BAIT PATHWAY

Saltwater bait shops were located throughout the coastal towns of the study region. I reached thirty-six of the estimated 116 bait shops during the telephone screening process. Only ten of these companies sold live or fresh species (10/36). Two companies said that they carried non-local live or fresh bait (2/36) and five companies reported that they ship live or fresh bait to regions outside of New England (5/36). Based on the telephone screening data, we estimated that there are 6 importers and 16 exporters of live or fresh marine species in the bait industry. Forty-one surveys were sent out to a randomly selected group of bait shops. Seventeen were completed and returned. Of this group, two reported selling non-local product (2/17), and four reported distributing product to non-local regions (4/17).

A. IMPORTS

COMPANY DETAILS AND ONSITE HANDLING PRACTICES

The two bait shops that sold non-local species were located within 1 mile (2/2) of a body of saltwater. One company, located along the New Meadows River, discharges their tank water untreated and unfiltered while the other does not contain their product in salt water tanks. The bait shops did not process the product so they did not create fish processing waste. One purchased their product through a non-local wholesaler. Both reported that they obtained some of their product through a “directed fishery.” Neither ordered bait over the Internet. Bait was delivered via the supplier’s truck or a truck rented by the shop owner. Ice was sometimes used as packing material.

TAXONOMIC VARIETY

No live species were reported. The fresh species included menhaden, flounder fillets, and herring from the mid-Atlantic region, and redfish racks and ocean perch from Canada. One respondent observed host organisms with the product, including crustaceans and mollusks.

B. EXPORTS

Approximately 24% of the survey respondents ship their product to regions outside of New England (4/17). Half of the respondents washed their live product (2/4) and most washed their fresh product (3/4) before shipment. Two of the companies used their own trucks to deliver the product (2/4), the others used a truck provided by the airline (1/4) or a truck provided by the buyer (1/4). Ice (3/4), ice packs (2/4), and seaweed (2/4) were the primary packing materials used. None of the respondents reported using the Internet to sell their product.

The variety of species included fresh herring to Canada, and live bloodworms and sandworms to a variety of non-local regions including Europe, the Pacific coast, and the southern Atlantic coast. The company that exports live bloodworms and sandworms estimated that they ship out over three million worms annually. The same company uses both seaweed and sea water as packing material and observed a variety of host organisms with the product.

C. INVASIVE INTEREST AND AWARENESS

Only one of the respondents answered the question on invasive species terms. He was familiar with all of the terms used. Three of the four respondents answered the question on invasive species familiarity. Two were familiar with the issue and two companies expressed an interest in learning more about the topic. The company that sells bloodworms and sandworms expressed a great concern that the two species are being over harvested. This

company was not familiar with the topic of marine invasions but was interested in learning more. Another company also expressed concern that there have been few studies done on bloodworms and sandworms. A marine researcher also commented in his survey, “Bait dealers I know of ship bloodworms worldwide from downeast Maine in *Ascophyllum*. You might want to contact them.”

IV. THE PET PATHWAY

We estimated that there were 21 pet stores in Maine and we reached 13 through the telephone screening process. Most of these stores sold saltwater species (12/13). All of these stores sold species from outside of New England (12/12) yet only two stores sold species to areas outside of New England. Based on the telephone screening, we estimated that there are 19 importers and 3 exporters of live or fresh marine species in the pet industry. Surveys were sent out to twenty pet stores. Of the six that were completed and returned, six of the companies sold species from non-local regions (6/6) and none of the companies sold species to regions outside of New England (0/6).

A. IMPORTS

I. COMPANY DETAILS AND ONSITE HANDLING PRACTICES

Two of the pet stores were located within 1 mile (2/6) of a saltwater body. All contained their product in water tanks (6/6) and they generally discharged the water through a municipal drainage line (3/6). The remaining stores discharged the water through a private septic system (1/6) or onto cedar beds (1/6). None of the pet stores discharged the water untreated and unfiltered into a local water body (0/6). The pet stores did not create fish processing waste and they did not wash down the delivery trucks.

Half of the pet stores obtained their non-local marine species from local wholesalers (3/6). Some of them bought from wholesalers in Massachusetts but most of them bought from New England's largest aquatic pet distributor, which is located in Connecticut. Though there are numerous commercial Internet sites for the marine hobbyist, only one of the respondents ordered non-local marine species over the Internet (1/5). The product was usually delivered by the supplier's truck (4/5). The non-local species were usually packaged with saltwater (3/5). There were no reports of seaweed being used. The companies generally disposed of the unsold non-local species by dumping them in the trash (3/5), taking them home (1/5), or donating them to a local university (1/5).

II. TAXONOMIC VARIETY AND SPECIES VOLUME

Of the surveys returned, half of the respondents completed some portion of the charts on species variety and volume (3/6). As compared to the other pathways, the pet pathway imported the greatest variety of species, including fish, echinoderms, cnidarians (mostly coral), crustaceans, and alga. The greatest volume of any type of taxa was fish. "Live rock" was also very popular but none of the respondents knew the variety and volume of species contained within the live rock. According to one aquarium website (<http://www.aquarium-live-rock-saltwater-reef-tank-supplies.com/index.htm>), "Live rock is simply old reef substrate that has become the home to multiple small plants and animals. Pieces vary in size and shape from baseball size to dinner plate size in typical tanks." The survey respondents reported that the average volume of rock sold was 75 lbs. The respondents generally used common names however a few used scientific names.

Some shops sold a greater variety of species than other shops but they all sold a comparable volume of certain species. Most of the species came from the warm waters of the Caribbean and the Indo-Pacific. For this reason, some of the respondents felt that the study was futile. One survey respondent from Maine said, "We sell many, many marine animals, very few saltwater caulerpa-type plants – too many to list. Here are my two cents worth on possible New England bioinvasions... migratory birds defecating over bodies of water and shipping traffic (i.e. barnacle encrusted hulls, etc.). With these two examples and my 30 years in the fish business, I can't fathom how a customer could take a \$60.00 coral or animal and dump it off the wharf in Bar Harbor! Sorry to be so cynical but I come from a state that

has the most strict laws when it comes to pet shops.” Seventy-five percent of the respondents observed non-target organisms (3/4) with the imported species, including crustaceans, mollusks, worms, seaweed, and barnacles.

B. EXPORTERS

None of the survey respondents reported that they export live or fresh marine species to regions outside of New England.

C. INVASIVE AWARENESS AND INTEREST

Sixty-seven percent of the respondents were familiar with marine invasions (4/6) and most were interested in learning more about the topic (5/6). They were familiar with most of the terms, especially exotic species (4/4), non-indigenous species (3/4), introduced species (3/4), and non-native species (3/4). Through my onsite visits in Massachusetts, I found that an awareness of marine environmental issues was prevalent in the pet pathway. Many storeowners were proud of the fact that they did not purchase species from regions that were over-fished or mismanaged. Though many were apprehensive about additional regulations, they were still interested in and supportive of the study because of its environmental motive.

Some of the Massachusetts stores belonged to the American Marine Dealers Association (AMDA), a non-profit organization, which promotes sustainable trade of living marine organisms for the aquarium trade. A representative from AMDA contacted me after numerous pet storeowners called him concerned about the study. After our discussion, the AMDA representative was interested in learning more about marine invasive species and participating in the Sea Grant workshops.

Some of the Massachusetts pet storeowners had already experienced marine invasive species in the tank environment. As a result, they had suggestions for potential aquatic nuisance species and ways to deal with them. For example, one of the pet shop owners said, “When a fish contracts a microorganism in the store, I dip it in the freshwater to kill off the parasite before I put it in the tank with the other fish.”

V. THE RESEARCH PATHWAY

The sixty-four marine scientists in Maine were located throughout the study region however; most researchers were based at the University of Maine in Orono (40/65). Of the 37 researchers that we reached through telephone calls and emails, 25 worked with live or fresh marine species and 15 used non-local marine species either with their research or in the classroom (15/37). Four marine researchers ship live or fresh marine species to other facilities around the country to be used either as research or teaching specimens (4/37). Based on the telephone and email screening, we estimated that there are 26 importers and 7 exporters of live or fresh marine species among the marine research community. Surveys were sent to thirty researchers. Thirteen were completed and returned.

A. IMPORTS

I. FACILITY DETAILS AND ONSITE HANDLING PRACTICES

We received eight surveys from researchers who work with live or fresh marine species from regions outside of New England (8/13). Only two of the respondents were less than 500 feet from a body of saltwater. The other six were more than five miles from a body of saltwater. Of those that contained their product in water tanks (6/8), most of them discharged the water through a municipal drainage line (5/8). One discharged the water treated and filtered into the local water body (1/8). Researchers generally did not process their product and thus did not create solid processing waste.

Eighty-eight percent (6/8) of the marine researchers working with non-local species obtained their organisms from non-local suppliers. Marine researchers rarely ordered non-local species over the Internet (1/8). The product was usually delivered by a non-federal parcel service such as UPS or Fed-Ex (7/8). The non-local product was packaged with ice packs (3/8) or seawater (4/8). Seaweed was sometimes used (2/8). Most researchers discarded the packing material with the trash.

II. TAXONOMIC VARIETY AND VOLUME

Most of the respondents that worked with non-local species completed at least a portion of the charts on species variety and volume (6/8) and almost all of the respondents used scientific names. Of those that imported species, most purchased organisms from Gulf Specimens in Florida or Carolina Biological Supply in North Carolina.

Species reported by the respondents included four different species of urchins, the spiny lobster, two different species of diatoms, cumaceans, rockweed, and fiddler crabs. Most of the researchers observed host organisms with the non-local species (5/7), including crustaceans, mollusks, worms, seaweed, and barnacles.

The research pathway imported a relatively small volume of marine species. Within the research pathway, the volume of imports from non-local domestic regions was greater than those from foreign regions. The average number of specimens imported each year was 50-100.

B. EXPORTS

We received three surveys from researchers who transport or supply live or fresh marine species to facilities outside of New England. The researchers exported a very small volume of marine species as compared to the seafood, aquaculture, and bait industries. It was assumed that they would not wash the organisms prior to shipment and they were not asked this question. They mainly used ice packs (3/3) and seawater (2/3) as packing materials for

shipping. One respondent used seaweed (1/3). Exports described included polychaete worms to Tampa, FL and flatworms to Austria and California. Another researcher did not list the species that he supplies but said that he sends them out to be used as teaching specimens.

C. INVASIVE AWARENESS AND INTEREST

Survey respondents were familiar with all of the terms used in marine invasion biology especially exotic species (10/10), introduced species (10/10), non-indigenous species (9/10) and non-native species (9/10). All of the marine researchers were familiar with the topic of marine invasions (10/10) and eighty percent were interested in learning more (8/10). Seventy-five percent of the researchers had a personal protocol for handling live or fresh marine species (6/8) yet only 25% of the researchers said that their institution had a comparable protocol (2/8). One researcher remarked, “Concerning protocols, don’t have one and don’t need one. Thanks!” Another agreed saying, “And we don’t need one – thanks!” Overall, we received very few comments from the marine researchers.

V. OTHER PATHWAYS

We did not compile a list of Maine public aquariums or companies involved in wetland restorations. We sent out five surveys to companies within the seaweed industry. Two of the surveys were mailed back to us; however, both were left blank and one of the surveys included the following comments, “I am unable to fill out this survey. Due to the sensitive nature of our business and highly competitive marketplace, I cannot disclose any information at this time. Also. I have privacy concerns regarding data.” Since Massachusetts does not have a seaweed industry, we did not have a survey that was tailored to this pathway. Instead, we sent surveys that had been designed for the aquaculture industry. It is possible that the seaweed company respondents did not find the questions pertinent to their industry and this may be the reason why we did not receive any completed surveys from this pathway.

SURVEY RESULTS: COMPARISONS AMONG PATHWAYS

In this section, I compared the high-risk features between the five pathways to determine if any single pathway was a greater risk than the others of introducing exotic marine species into the local marine environment. I also compared the export trade characteristics that might facilitate a bioinvasion in a marine environment elsewhere.

A. IMPORTS

The telephone screening data showed that pathways differed significantly in both the proportion and total number of entities that import non-local species. This is important because even though only 36% of the seafood industry imports live or fresh marine species as compared to 92% of the pet industry, the total number of seafood importers in Maine may be as many as 131 companies as compared to only 19 pet importers.

I. FACILITY DETAILS AND ONSITE HANDLING PRACTICES

Within each of the pathways that imported non-local species, I compared the trade characteristics that might facilitate the release of non-local species into the local marine environment. For example, an exotic species' ability to reach the local marine environment would most likely depend on the proximity of a pathway's facilities to the nearest body of saltwater. The pathways differed significantly in the proportion of facilities that were within 500 feet of the nearest body of saltwater. Proportionately, more seafood, aquaculture, and bait companies were located within 500 feet of the nearest body of saltwater than were pet or research facilities. We estimated that the seafood pathway has approximately ten times the number of facilities within 500 feet of the nearest body of saltwater as compared to the other pathways.

The bait pathway was the only pathway that intentionally released non-local species directly into the marine environment. In the case of the bait pathway, however, most bait is dead upon release; hence, they are generally not considered to be a high-risk for a marine invasion. However, live non-target organisms, gametes, or packing material may be attached to the bait and thus released into the marine environment. Survey responses showed that at least some parties in the seafood and bait pathways discharged untreated tank water, potentially containing non-local species, directly into the waterway. The seafood pathway also disposed of fish processing waste into the local water body.

II. TAXONOMIC VARIETY

Pathways differed significantly in the variety of species that they imported. The pet pathway imported the greatest variety of species as compared to the other pathways. However, most of the species imported by the pet pathway were from tropical regions and thus had a low chance of survival in Maine's cold marine environment. Many of the species that were imported by the seafood and bait pathways are indigenous to Maine. Unless they carried parasites, diseases, or invasive host organisms, their release would cause little impact. Each of the pathways had a similarly high percentage (50-79%) of survey respondents that observed non-target species attached to the imported non-local species. The seafood and research pathways also received imported species packaged in fresh seaweed and the seafood, research, and pet pathways received non-local species packaged in seawater.

III. SPECIES VOLUME

Pathways differed significantly in the total volume of species that they imported. The seafood pathway imported the greatest volume of species however, many of the fish (chordate) species were no longer alive upon arrival and most of the shellfish species were

indigenous to Maine. Therefore, non-target organisms associated with the imported fresh and live taxa are of greater concern than the target organisms in the seafood pathway.

B. EXPORTS

In this section, I compared the pathways to see if any single pathway was of a particularly greater risk than the others of exporting live or fresh saltwater species to a region outside of New England. High-risk traits that may lead to a marine invasion elsewhere are not considered in this section because this is primarily dependent on the organizations within the recipient regions.

The telephone screening process showed that the seafood, bait, and research pathways regularly export fresh or live marine species to domestic and foreign destinations. The pet pathway rarely exports marine species. Though the aquaculture pathway was unreachable during the telephone screening process, the survey responses indicated that the pathway also exports product to regions outside of New England.

The seafood pathway exported an exponentially greater number of species than the other pathways. Aquaculture companies primarily sold their product to seafood companies and distributors; therefore, their products followed similar routes as the seafood pathway. The seafood pathway distributed product throughout the United States and to multiple foreign destinations. The bait pathway exports a large volume of bloodworms and sandworms to both domestic and foreign regions. The survey data showed that only the seafood pathway used the Internet to sell their product. It is important to keep in mind, however, that this survey was conducted in 2001 and many more companies may now be using the Internet to advertise their product. I conducted a recent Internet search and found that at least one bait company in Maine has a website for exporting bloodworms.

C. INVASIVE AWARENESS AND INTEREST

The respondents' level of awareness and interest in marine invasions may also affect the pathway's risk of causing a marine invasion. Presumably, a pathway with an overall low level of awareness and interest would be at a greater risk of facilitating a marine invasion than a pathway with an overall high level of awareness and interest. In general, most of the pathways had a high level of familiarity with the topic of marine invasions, ranging from 66-67% in the bait and pet pathways to 83-100% in the seafood, aquaculture, and research pathways.

Most of the names for marine invasives were understood across the pathways. Certain pathways were more familiar with certain names. Overall, "non-indigenous species," "exotic species," and "non-native species" were selected as the most commonly understood names. Respondents were least familiar with the term "alien species."

Pathways ranged in the total income they received from saltwater species with the seafood pathway having the largest gross sales. Individual companies also ranged in their dependency on local versus non-local saltwater species as a source of income. While the bait and seafood pathways worked with both local and non-local species, the pet pathway was entirely dependent upon non-local species for their source of income. The level of each pathway's dependency on non-local species may influence their willingness to comply with control measures, especially those that are voluntary.

DISCUSSION

Historically, there have been few regulations that control the release of exotic marine species. The Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA) regulates the international trade of perishable commodities yet it focuses primarily on controlling the spread of viruses and terrestrial pests. APHIS also regulates the international and interstate trade of genetically engineered microorganisms but only for biotechnology operations. The Fish and Wildlife Service (FWS) of the U.S. Department of the Interior regulates the international trade of wildlife yet they only prohibit the importation of a limited number of “injurious fish and wildlife.” In 1993, this included two families of fish, 13 genera of mammals and shellfish, and 6 species of mammals, birds, and reptiles. These regulations are not industry specific. Amendments to the Lacey Act in 1981 prohibited the interstate movement of “state-listed” injurious fish and wildlife, in addition to the FWS list.

Some regulatory activities may have inadvertently impeded the spread of marine invasive species. An example of this is the National Pollutant Discharge Elimination System (NPDES) Program of the Environmental Protection Agency (EPA) (www.epa.gov/npdes/). If an organization plans to discharge water into a local water body, they must apply for a NPDES permit. NPDES was developed to decrease the flow of toxic and infectious pollutants into waterways, including substances that might impact the nutrient level or temperature of the waterway. If an organization discharges a limited amount of water that does not contain these pollutants, they can discharge the water into the waterway. So, though the NPDES permit probably reduces the number of point sources that may introduce non-local marine species into the waterway, it certainly does not cover all of them. The EPA recognizes pollutants that may cause biological pollution; however, they have also stated that it is unclear whether aquatic nuisance species meet the definition of “pollutant” under the NPDES program. The number of loopholes and the limited amount of regulation is disconcerting when we consider that the volume of perishable imports into the United States is increasing each year. If we do not regulate the trade of live marine species to manage intentional introductions and to limit unintentional ones, increased trade activity will undoubtedly result in a greater number of invasions.

Because pathways showed great variability in the number and type of high-risk traits, regulators need to adopt a pathway-specific approach to risk management in order to enact effective control measures for marine invasive species. Presumably, regulatory measures that provide the least amount of encumbrance will be best received by industries. It would be helpful for managers to modify current regulatory mechanisms, such as the National Pollution Discharge Elimination System (NPDES), and include stakeholders in the decision-making process.

In recent years, there has been an increase in the amount of pathway specific educational efforts directed towards industries that import non-local marine organisms. Most of these efforts in the northeast have been led by the Northeast Aquatic Nuisance Species Panel (NEANS Panel). The NEANS Panel was established in 2001 as the fourth regional panel of the National Aquatic Nuisance Species Task Force, a federal intergovernmental organization. The NEANS Panel includes members from numerous state and federal agencies located throughout New England, New York, and parts of northeastern Canada. Educational efforts have included:

2003 ANS-HACCP Workshop for Seafood and Aquaculture Industries

HACCP (Hazard Analysis and Critical Control Point) is a voluntary program that was developed by the USFDA for the seafood industry to decrease the spread of food-borne illnesses. In 2001, the USFWS developed ANS-HACCP, based on HACCP, to control the

spread of aquatic invasive species through their hatchery, fish-farming, and bait operations. In 2003, the Massachusetts Bays Program teamed up with the local USFWS branch to further expand this program to include control measures that would impede the spread of marine invasive species through the saltwater aquaculture industry. Several saltwater aquaculturists from New England, including representatives from Maine, attended the 2003 workshop in Hadley, MA. Reviews of the program suggested that additional workshops geared specifically towards the saltwater aquaculture industry would be well received by Maine aquaculturists, especially if workshops were offered at a location that was closer to their operations.

2003 New England Aquarium “Checklist” for Clean Water Discharge

The Massachusetts Bays Program worked with representatives from the New England Aquarium to develop a checklist for controlling the release of non-local species into Boston Harbor through their tank discharge. The Massachusetts Office of Coastal Zone Management has also been involved in modifying water discharge protocols at research facilities to further decrease the risk of introducing non-native species into the local marine environment.

2004 “Protect Your Pet, Preserve the Environment” – Invasive Species Educational Materials Developed for the Aquatic Pet Owner Community

This flyer was created by the Massachusetts Bays Program in cooperation with the Pet Industry Joint Advisory Council (PIJAC) and FishMart (New England’s largest aquatic pet distributor). The flyer was funded by the EPA and developed for aquatic pet owners. Copies of the flyer were distributed to pet stores throughout Massachusetts and are available through the Massachusetts Bays Program. This flyer was developed as a follow-up outreach effort to a study conducted by Smith College showing that the level of awareness of invasive species was relatively low among aquatic pet owners.

2006 “Into the Pan, Not into the Wild” - Invasive Species Educational Materials Developed for Non-English Speaking Communities

This flyer was created by the MIT Sea Grant Program and the Massachusetts Bays Program and was funded by the National Sea Grant Program. Copies of the flyer are available through the MIT Sea Grant Program.

It is important to keep in mind that even though a pathway may not currently exhibit a particular high-risk trait, markets and handling practices can change and alter a pathway’s overall risk. For example, the data collected from this survey in 2001 showed that the bait industry did not use the Internet to advertise their live product however, a recent Internet search turned up at least one company that has since developed a website to market their product, advertising shipment to both domestic and foreign non-local destinations. If the seafood, bait, and aquaculture industries attempt to bring a new non-local species to market, regulators may wish to monitor these species closely in the event they present any unusual risks. Preemptive strategies are a more effective management strategy for controlling marine invasive species.

Other Possible Pathways

This study investigated the major likely pathways for exotic marine species introductions. Small, cryptic, or ephemeral pathways undoubtedly exist, but these were not assessed in this study. For example, certain populations, such as restaurants, individual consumers, and non-English speaking markets, were excluded from the survey pool. This is worth noting because past marine invasions have been attributed to individuals and non-

English speaking groups. For example, the mitten crab *Eriocheir sinensis* is thought to have been introduced to San Francisco Bay by the local Asian community. So, while we continue to assess the cumulative impact of major non-shipping and shipping pathways, we should also be cognizant of less visible pathways.

RECOMMENDATIONS

In following section, I share my thoughts for future *management tasks* and *research*. In general, based on the results of this study, I feel that managers should implement control measures for release points identified from the survey, collect additional data on the variety and volume of species being imported into Maine, and prepare and disseminate educational materials based on the results from the interest and awareness results.

Seafood companies

While the following recommendations should apply to all seafood companies in coastal Maine, special attention should be paid to towns that have high concentrations of seafood companies, such as Portland, Harpswell, and Stonington.

Suggestions for managers:

- Closely monitor new non-local species being considered for the trade.
- Revise NPDES and other relevant discharge regulations to include water discharge from all seafood importers.
- Encourage seafood companies to become familiar with and use scientific names.
- Support efforts to have the US FDA revise regulations on acceptable common names for seafood.
- Develop best possible management practices for disposal of unused seafood that limit the potential for non-native species to be released into the marine environment.
- Encourage seafood harvesters to wash live and fresh product before distribution to rid product of host organisms.
- Encourage seafood companies to include warning labels about invasive species with exports of live or fresh product.

Suggestions for future studies:

- Are the host organisms associated with the product or the packing material able to reach the local water body after the delivery trucks are washed? *Sample water bodies and wet surfaces near delivery site for live or fresh species.*
- What are the new live species being considered for the international market? *Visit trade shows and monitor seafood industry websites to collect information on new exotic species being considered for the trade.*
- What are the handling practices for non-local species at seafood restaurants? *Survey local restaurants.*
- What are the handling practices for non-local species by individuals (e.g. at seaside clambakes, at homes)? *Survey seafood consumers.*
- What risk do non-English speaking seafood companies pose to introducing non-local species into the local marine environment? *Survey or find alternative method to investigate non-English speaking seafood companies.*
- What is the freezing tolerance of host organisms associated with frozen seafood? *Conduct studies on freezing tolerance of host organisms.*

Aquaculture facilities

Suggestions for managers:

- Encourage aquaculture facilities to wash live and fresh product before distribution to rid product of host organisms.
- Encourage aquaculture facilities to include warning label about invasive species with exports of live or fresh product.

Bait shops

Suggestions for managers:

- Revise NPDES and other relevant discharge regulations to include all water discharge from bait importers.
- Encourage bait shops to use or become familiar with scientific names of their product.
- Consider best possible management practice for the disposal of unused bait.
- Prohibit use of seaweed as packing material.
- Encourage bait shops to include warning labels about invasive species with exports of live or fresh product, especially with bloodworm and sandworm industry.
- Encourage bait shops to wash live and fresh product before distribution to rid product of host organisms.

Suggestions for future studies:

- What are the live and fresh species being sold in bait vending machines and where do they come from? *Survey vending machine supplier.*
- What are the handling practices for non-local species by recreational and commercial fisherman? *Contact sport fishing clubs and survey recreational and commercial fisherman.*
- What types of host organisms are associated with the product or the packing material? *Investigate and identify host organisms.*
- Certain types of dinoflagellates that are responsible for toxic algal blooms are associated with menhaden (aka “pogies”). Are these dinoflagellates also found with the pogies that are used in Massachusetts? *Investigate and identify host organisms associated with menhaden used in Massachusetts.*
- What is the freezing tolerability of host organisms associated with frozen bait? *Conduct studies on freezing tolerability of host organisms.*

Pet stores

Suggestions for managers:

- Revise NPDES and other relevant discharge regulations to include all water discharge from aquatic pet importers.
- Consider zoning restrictions or regulations for pet shops that limit building near marine waterways.
- Distribute educational materials to pet shops about *Caulerpa taxifolia* and other aquatic invasive species.
- Distribute educational materials to individual aquatic pet owners. Create displays or educational flyers that can be distributed to customers at the checkout counter.
- Encourage pet shops to include warning labels about invasive species with exports of live or fresh product.

Suggestions for future studies:

- Are there invasive coldwater species available to the pet trade? *Investigate on-line sources to see if any coldwater species are available to the pet trade.*
- What risk do individual aquatic pet owners pose to introducing non-local species into the local marine environment? *Survey individual aquatic pet owners.*

Research organizations and species suppliers

Suggestions for managers:

- Revise NPDES and other relevant discharge regulations to include all water discharge from research organizations that import species.
- Work with institutions to develop protocols for the handling and disposing of non-indigenous species for research.
- Encourage research organizations to keep live species for export in sterile marine

environment to reduce number of host organisms.

- Encourage research organizations to include warning label about invasive species with exports of live or fresh species.

Suggestions for future studies:

- What is the risk that primary and secondary schools in Maine pose to introducing marine invasive species? *Survey primary and secondary schools.*
- Are non-local species or host organisms being released into the local water body via the research institutions' outfall pipes? *Sample water bodies near research stations' outfall pipe for non-indigenous species.*

Public aquariums

Suggestions for managers:

- Revise NPDES and other relevant discharge regulations to include all water discharge from aquariums that import species.

Coastal restoration projects

Suggestions for managers:

- Prohibit the use of non-local species and soil in wetland restoration projects.
- Send educational materials to wetland consulting firms on the importance of using local species.

General recommendations for management strategies and research on marine invasions

- Examine the management approach taken with terrestrial invasive species. Some of the same tactics may apply to controlling aquatic and marine invasive species.
- Conduct similar surveys in other coastal regions. If I were to repeat this study, I would omit questions about en route risks. I would also omit questions about species volume from the survey charts. I believe that the survey would be easier to complete if these components were not included and thus would yield a higher return rate and more complete responses to the surveys.
- Continue investigation on risk of invasion by entities within 500 feet of local marine water body. As mentioned earlier, a marine invasion can occur from a single introduction by one company. Each company or organization that is within 500 feet of a waterway should be investigated.
- Investigate holding facilities for live, fresh, or frozen marine species at airports. How close are these facilities to a water body? What are the handling practices for these facilities and airline cargo services?
- Expand non-local species list. There are various resources (e.g. U.S. Customs service, Fish and Wildlife Service) that maintain lists of species that are being imported into Maine. Once the list is compiled, determine invasive potential of these organisms. Use this data to advocate for a "white list" of import species.

Additional suggestions for marine invasive studies and programs

- Marine Invasive Species Monitoring Program
Each coastal region should have a monitoring program for invasive species in conjunction with their current volunteer marine water quality monitoring program. Educational materials and workshops should be provided to these groups and the town's conservation commission.
- Marine Invasive Species Educational Programs
Teachers should incorporate the topic of invasive species into their environmental or ecology lesson plans. Graduate students should contact their state's environmental offices to learn about research needs related to marine invasive species.