BIOLOGICAL INVASIONS OF COLD-WATER COASTAL ECOSYSTEMS: BALLAST-MEDIATED INTRODUCTIONS IN PORT VALDEZ / PRINCE WILLIAM SOUND, ALASKA

FINAL PROJECT REPORT
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EXECUTIVE SUMMARY

PROJECT OVERVIEW

This study assesses the risk of biological invasion by nonindigenous species (NIS) associated with oil tanker traffic and ballast water management for Port Valdez / Prince William Sound (PWS), Alaska. This study included 8 major components:

- Review of risk factors for NIS invasions and ship-mediated transfer of species relevant to PWS, a high latitude, cold-water marine ecosystem.
- Analysis of ballast water delivery patterns and plankton communities associated with ballast water on tankers that arrived to PWS.
- Experimental analysis of initial survivorship of ballast water organisms in temperature-salinity combinations typical of receiving waters of Port Valdez.
- Experimental measurements of the effect of ballast water exchange and voyage duration on plankton communities arriving on tankers to PWS.
- Characterization of organisms fouling hulls and in sea chests of crude oil tankers.
- Characterization of organisms in sediments of tanker ballast tanks.
- Determination of NIS established within Alaska, as detected by field surveys and reviews of existing collections and literature conducted by experienced naturalists and taxonomic experts.
- Analysis of the biodiversity of PWS.

This study advances our understanding of invasion processes in many significant ways.

- Our study provides the most comprehensive analysis worldwide of the abundance and taxonomic composition of plankton communities in the segregated ballast water of tankers as well as domestic ballast transfer by any vessel type.
- We have undertaken an ambitious set of experimental and quantitative measures to (a) compare directly, for the first time, the relative efficiency of exchange methods (Empty–Refill and Flow-Through) for any vessel type or taxon, and (b) the effect of voyage duration on plankton survivorship in the ballast water of oil tankers.
- We provide the first synthesis of NIS known in Alaska, resulting from an extensive literature review and field-based surveys.
- The large scope of this study provides an unusually comprehensive analysis of the risks, mechanisms, and patterns of invasion in PWS.

The project represents a cooperative and successful partnership of industry, citizen, agency, and scientific groups. This strong cooperative program addresses critical gaps in our understanding of invasion risks, as well as facilitates information exchange and participation among a broad spectrum of industry, citizen, agency, and scientific groups.

- From a science perspective, this program results in a comprehensive analysis of invasion processes and risks for PWS, representing the first such study in the world for a high-latitude / cold-water marine ecosystem.

- From an industry and management perspective, this program assesses the effectiveness and trade-offs involved for various management strategies that are now required in Prince William Sound, and are being promoted on a national and international scale.
- From a public perspective, this program disseminates findings and serves as a key source of information, especially through groups like the Smithsonian Environmental Research Center, the Regional Citizens' Advisory Council of Prince William Sound, U.S. Fish & Wildlife Service, and NOAA Sea Grant.

RESULTS

Background

Biological invasions of marine ecosystems in Alaska are a major environmental concern.

- Biological invasions of coastal bays and estuaries are common throughout the world and are having significant ecological and economic impacts.
- High-latitude / cold-water regions are also subject to biological invasions by many species with potential ecological and economic consequences similar to those reported for more temperate latitudes.
- Transport of coastal planktonic organisms in ballast water of commercial ships appears to be the major source of new invasions worldwide in recent years.
- Tankers arriving to Port Valdez release the third largest volume of ballast water of any U.S. port.

BW Delivery Patterns and Biological Characteristics

A large quantity of ballast water arrives to PWS in oil tankers.

- For the past decade, tanker arrivals to Port Valdez have averaged 713 ships per year.
- Tankers arriving to PWS in 1998 carried an estimated average of 65,775m^3 of total ballast water, including both segregated (non-oily) and nonsegregated (or oily) ballast water.
- Segregated ballast water comprised an average of 54.7% of the total ballast water arriving to PWS in tankers.
- Overall, an estimated 17,000,000 m^3 of segregated ballast water (an average of 32,715 m^3 per arrival) was discharged into PWS by oil tankers in 1998.

Most ballast water delivered to PWS by crude oil tankers originates from U.S. domestic ports.

- Tankers arriving directly from western U.S. ports accounted for 95.8% of the total tanker traffic, and 96% of the total segregated ballast water delivered by tankers, to PWS in 1998.
- Arrivals from Puget Sound, San Francisco, and Long Beach comprised approximately 82.7% of all tanker traffic, as well as 86% of all segregated ballast water delivered by tankers, to PWS in 1998.
- Most (69.6%) of the tankers arriving to Port Valdez from overseas came directly from Korea in 1998.
- Tankers arriving from domestic ports transfer ballast water directly from that port to PWS, whereas foreign arrivals have replaced coastal ballast water with open-ocean exchange prior to their arrival.

The voyage duration of tankers arriving to Port Valdez is relatively short compared to traffic arriving at other commercial ports, where invasions are common.

- Ballast water spent an average of 6.6 days in the ballast tanks of oil tankers before arrival to Port Valdez, ranging between 4.8 to 10.2 days.

A large quantity of planktonic organisms is released into PWS with segregated ballast water from oil tankers.

- An average of 12,637 total organisms per m^3 (excluding chain-forming diatoms) was measured in our ballast water samples from 169 tanker arrivals, including those from both domestic and foreign source ports.
- Overall, we estimate that roughly 264 billion organisms were delivered to PWS in the segregated ballast water of oil tankers during 1998.
- Importantly, these estimates include only the largest plankton and miss many small planktonic organisms (e.g., bacteria, viruses, and other microorganisms), that would likely increase overall densities many fold.

The abundance of planktonic organisms was greater in segregated ballast water from domestic source ports compared to that from foreign source ports.

- Total density (across all taxonomic groups) of organisms was greatest on average in segregated ballast water from domestic arrivals compared to foreign arrivals.
- Average densities of most taxonomic groups were 10- to 100-fold greater in segregated ballast water from domestic versus foreign sources.
- The magnitude of density differences between domestic and foreign sources was much less for copepods and solitary diatoms.
- Dinoflagellates were a notable exception to the general pattern, as average density was greatest in ballast water of the foreign arrivals.

Significant variation existed in abundance of taxonomic groups in the segregated ballast water arriving from the major source ports.

- Total density of organisms was lowest on average in ballast water from foreign arrivals compared to arrivals from each of the three major domestic ports (Puget Sound, San Francisco, and Long Beach)
- Total density on average declined among the four major ports with increasing voyage duration.
- In contrast, the greatest average densities for individual taxonomic groups (e.g., protozoans, brachyuran crabs, and bryozoans) did not always correspond to the shortest voyage duration.

The abundance of plankton arriving in segregated ballast water from the major domestic ports varied both spatially and temporally.

- The greatest densities occurred for all taxonomic groups, individually and combined, during the spring and summer months.
- However, the timing of peak densities differed among taxonomic groups and among source ports.

- The magnitude of seasonal variation in plankton densities also differed among source ports, being greatest for Puget Sound and San Francisco Bay compared to Long Beach.
- Furthermore, significant annual variation also existed in the densities of plankton arriving to PWS from each of the major domestic source ports.

NIS are present in the segregated ballast water released by oil tankers in PWS.

- We identified 14 different nonindigenous species (13 crustaceans and 1 fish) arriving to Port Valdez in the ballast water of oil tankers.
- To date, all of these identified NIS have been in ballast water from San Francisco Bay or Long Beach.
- Importantly, these numbers are clearly underestimates, since only a subset of the plankton can be identified to species and only the largest fraction of planktonic organisms were included in our analyses.

Organisms discharged in tanker ballast water, including known NIS, have high potential of initial survival in the salinity-temperature conditions of Port Valdez and PWS.

- Seasonal cycles of salinities and temperatures in Port Valdez waters encompass the range of salinities and temperatures of arriving ballast waster, providing a good match between source ports and receiving waters.
- Laboratory experiments indicate that a wide range of ballast water species (including some NIS) can survive the salinity and temperature conditions of Port Valdez upon initial discharge from tankers.

Other Mechanisms of NIS Transport by Tankers

Tankers also transfer organisms that are not in ballast water and that may become established in PWS.

- Tanker hulls and sea chests sampled in dry dock sometimes carried a diverse array of fouling and nektonic organisms, including several NIS.
- Sediment taken into ballast tanks during ballasting in shallow ports sometimes carried diverse and abundant bottom-dwelling organisms, including reproductive adult individuals.

Ballast Water Exchange Experiments

Preliminary experimental results suggest that ballast water exchange is as effective for oil tankers as for other vessel types.

- Initial analyses suggest roughly 80-99% of the resident water is replaced per ballast water exchange event.
- The efficacy of exchange appears to differ between exchange method, with Empty–Refill Exchange replacing the greatest proportion of water.
- The efficacy of exchange also appears to differ among taxa.
- Importantly, all analyses for the exchange experiments are still underway, and final results / conclusions are therefore pending project completion (anticipated in June 2000).

Summary of NIS in Prince William Sound and Alaska

A diverse array of NIS have been introduced into PWS and Alaska.

- There are 24 species of NIS plants and animals in marine and estuarine ecosystems in Alaska, including 15 species recorded in PWS.
- These NIS are taxonomically diverse and occupy a wide range of ecological niches and habitats, although there appear to be more NIS associated with boat harbors and with aquaculture activities.
- Our focal taxonomic collections provided the first records of 7 NIS in Alaska, including some species that appear to be very recent introductions.
- Many of the Alaskan NIS have larval stages which could be transported in ballast water.
- None of the Alaskan NIS is clearly associated with ballast water of oil tankers as a primary mechanism of introduction, even though many NIS are frequently found in ballast water arriving to Port Valdez.
- Instead, the transfer of NIS may have resulted from any one of multiple transfer mechanisms, including ballast water, ship fouling communities, and aquaculture.
- Finally, it is important to note that many additional Alaskan marine species are cryptogenic (possibly introduced), as the historical baseline of biogeographic and taxonomic information is very limited for this biota. For example, we identified at least 29 cryptogenic species in Alaska (including 24 in PWS), exhibiting either wide global distributions often associated with spread by early shipping traffic or a variety of characteristics common to NIS.

Biodiversity of Prince William Sound

Taxonomy and biogeography of species in Alaskan marine ecosystems have received poor levels of study and understanding.

- We discovered 10 new, previously undescribed species, as well as recorded range extensions for 74 other species from a diverse array of taxonomic groups.
- It is now apparent that a large portion of many major groups remain undocumented, as well as cryptogenic in origin, due to limited surveys and historical analysis of the Alaskan biota.

We have now initiated a biodiversity data base for marine species in PWS.

- We have established a comprehensive data base for marine invertebrates in PWS.
- The scope of this data base will be expanded to include algae, fish, mammals and birds in the next year.

CONCLUSIONS

Multiple risk factors exist that favor the establishment of NIS in PWS.

- Approximately 550 tankers currently arrive per year to PWS and release an estimated 17,000,000 metric tons of segregated ballast water.
- Tankers repeatedly deliver ballast water from the same, limited source ports, providing repeated inoculations of the same species.

- The voyage duration of these tankers is usually short (3-7 days), favoring high survivorship of transported plankton and resulting in the dense inoculation of competent organisms into PWS.
- Environmental conditions of source ports match those in PWS for some portions of the year, and many organisms arriving in ballast water can tolerate conditions in receiving waters.
- Most (95.6%) of arriving tankers do not undergo ballast water exchange, a process which can limit the transfer rate of NIS.
- A large number (tens-to-hundreds) of NIS are known from the domestic ports that are the source of unexchanged ballast water arriving to PWS in oil tankers.
- NIS are present in this domestic ballast water arriving to PWS in oil tankers.

Ballast water exchange appears effective at reducing resident plankton on tankers, although a risk of invasion still exists.

- Ballast exchange experiments suggest that tankers arriving to Port Valdez from foreign ports have reduced resident coastal organisms by > 90% through the current exchange practices.
- Abundance of coastal organisms was 10-100 fold lower for oil tankers that were foreign arrivals (that underwent ballast water exchange) compared to domestic arrivals (that do not undergo exchange).
- Although roughly equivalent to efficacy of exchange estimated for other vessel types, both data sets suggest that tens to hundreds of thousands of organisms/ship still arrive with exchanged ballast water.

Alaskan waters, and those of PWS, are susceptible to invasion by NIS.

- It is now evident that a diverse array of taxa have become established in Alaska and PWS.
- These NIS occupy a broad range of marine and estuarine habitats.

The number of marine NIS in Alaska appears to be significantly lower than other marine ecosystems at lower latitude.

- Our surveys of PWS and Alaska were intensive and failed to detect many NIS known from the domestic source ports of oil tankers.
- However, the limited historical record and scope of past surveys limits direct comparisons with low latitude marine ecosystems, for which extensive surveys and knowledge have been developed over decades to centuries of biological research.

In general, the poor resolution of taxonomic and biogeographic data in Alaskan marine ecosystems is a substantial impediment for analysis of environmental impacts.

- To date, we have been able to provide only a minimum estimate of NIS, as many species remain undescribed or cryptogenic until further analysis.
- Assessment of other environmental impacts, such as oil spills, may also be limited without adequate baseline data on species composition and abundance.
- We recommend a program of standardized surveys across multiple sites in PWS and Alaska to both improve the existing knowledge of NIS and provide a regional baseline of data.

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This project was stimulated and encouraged by the Nonindigenous Species Working Group of RCAC, chaired by Robert Benda (Prince William Sound Community College) and Gary Sonnevil (USF&WS). We thank Joel Kopp of RCAC for his able oversight and friendly assistance at all stages of this project, and Marilyn Leland and Linda Hyce of RCAC for their support. We are grateful to Rex Brown and the managers and staff of the Alyeska Pipeline Service Company and the Valdez Marine Terminal for access and help in sampling. The Masters, Officers, and crew members of the tankers gave willingly of their time and help; and we especially thank those of the ships SR Baytown, SR Long Beach, and SR Benicia, ARCO Independence, and ARCO Spirit for their extensive help on ballast water exchange experiments. Thanks also to W.P. (Pete) Rupp of SeaRiver Maritime and Victor Goldberg of ARCO Marine for their support of the exchange experiments. We especially thank the following agents in Valdez for their logistical assistance, advice and suggestions, and support: Kurt Hallier and Wayne Brandenburger of ARCO Marine; Bill Deppe, Phil Eichenberger, and John Poulos of SeaRiver Maritime, and Tom Colby of BP. The full cooperation of the oil companies operating these ships is gratefully acknowledged.

Melissa Frey and George Smith of SERC provided key technical assistance for sampling ships, processing samples, conducting experiments, analysis, and many other crucial components at SERC's laboratories in Valdez and in Maryland. Exchange experiments were assisted on board tankers by additional technicians of the SERC Invasions Biology Program: Linda McCann, Kim Philips, Safra Altman, Lynn Takata, Cathleen Coss, Kate Murphy, Dani Lipski, Laura Rodriguez and Brian Steves. Sorting of samples was assisted by Melissa Frey, George Smith, Sara Chaves, Kim Philips, Dani Lipski and Safra Altman. Data management and analysis were assisted by: Safra Altman, Melissa Frey, Midge Kramer, Kim Philips, George Smith, and Brian Steves.

For assistance on the NIS cruises in Prince William Sound, special appreciation goes to: Todd Miller, for his assistance on the trip; Capt. Richard Vodicka who skippered the F/V Kristina in 1998 and helped in many ways large and small throughout the survey; Milos Falta, owner of the F/V Kristina and skipper during the 1999 surveys; Joel Kopp, RCAC, for loan of his zodiac, searching for a charter, and other logistical and support assistance; and the community of Tatitlek for housing the survey team, especially village leader Gary Kompkoff and boat operator/guide Steve Totemoff for logistical assistance in the survey of Valdez Arm and Tatitlek areas. Peter Jordan and Bryna Dunaway, high school students in Oregon, assisted in curating the dried plant collection. Mike Stekoll of the University of Alaska provided microscopes for the study. Lavern Weber, Director of the Hatfield Marine Science Center provided office and laboratory space for G.I. Hansen. These people all helped make the cruises a success.

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In addition to participation in the project by taxonomic experts (see cover page), species identifications were assisted by Klaus Ruetzler for sponges; Frank Ferrari, Olga Kalata and Chad Walter for copepods; Judy Winston for bryozoans; Lea Ann Henry for hydroids. Charles Lambert assisted with field collections of ascidians during the 1999 field survey.

The cooperative support by all of these individuals and organizations made this project possible.

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Chapter 1. Introduction

Anson H. Hines, Smithsonian Environmental Research Center
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1A. Project Goals

The overall goal of this project was to assess the risk of biological invasion by nonindigenous species (NIS) introduced into Port Valdez / Prince William Sound, Alaska. Currently, ballast water is the major vector for introductions of NIS in coastal ecosystems, where ballast-mediated biological invasions are causing severe ecological and economic impacts. While the significance of ballast-mediated invasions has focused on temperate zone ports, little consideration has been given to NIS invasions at high latitudes, despite the volume of shipping and critical importance of certain cold-water ports to the world economy and especially US energy interests. Port Valdez is a high latitude-cold water port receiving the third largest annual volume of ballast water in the USA. Moreover, our recent review of NIS invasions at high latitude (Ruiz & Hines 1997) indicates that such cold water ecosystems have been invaded by a diverse array of marine and estuarine species. The specific objectives of the project were:

- To analyze the delivery patterns, biological characteristics, and management practices of ballast water and other ships arriving to Port Valdez from coast-wise versus foreign voyages.
- To assess viability of selected organisms arriving in tanker ballast water to Port Valdez.
- To conduct experiments on the effectiveness of ballast water exchange procedures of tankers.
- To evaluate organisms occurring in entrained sediments at the bottom of ballast tanks of crude oil tankers.
- To evaluate fouling organisms on hulls and in sea chests of tankers as potential sources of NIS.
- To analyze and search for NIS currently invading or already established in coastal waters of south central Alaska, using literature searches, an array of field sampling methods (field collections, fouling plates, and plankton sampling), and examination of existing preserved samples from Prince William Sound.

The purpose of this report is to summarize the research conducted during 1997-1999 to assess the risk of biological invasions in Prince William Sound, especially with regard to oil tankers as a vector for transporting NIS into marine ecosystems. Progress during the project was reported in Ruiz & Hines, 1997 and Hines et al., 1998. Modified elements of the earlier reports are included in the present report, so as to provide a complete overview of the project within one document. Certain limited elements of research will be completed during 2000, including further analysis of existing collections at the University of Alaska Museum and Institute of Marine Sciences, and work-up of sample from ballast water exchange experiments conducted during summer 1999. These last elements will be reported separately upon completion.

1B. Structure & History of Project

This research project has built upon a Pilot Study conducted in 1997 (see Ruiz & Hines, 1997), and includes an expanded scope of work conducted during 1998-1999. The multi-faceted approach to the research required a team of diverse CoPrincipal Investigators and subcontracted taxonomic experts. Drs. Anson Hines and Gregory Ruiz (SERC) have served as over-all project leaders, providing over-all administrative and scientific oversight for the team. In addition, Drs. Ruiz and Hines (SERC) had primary responsibilities for: analysis of ballast water delivery patterns; biological characteristics of ballast water; experimental analysis of initial survival of ballast water organisms; ballast water exchange experiments; analysis of ballast tank sediments and tanker hull fouling; fouling community analysis, and management of most of the focal taxonomic studies; as well many aspects of field surveys of Prince William Sound. To sample and analyze ballast water of tankers arriving to Port Valez, two Biological Technicians (Melissa Frey and George Smith, of SERC) alternately rotated at about four month intervals between SERC's temporary laboratory established in Valdez, Alaska and the SERC Biological Invasions Laboratory in Edgewater, Maryland. Ballast water exchange experiments were conducted with participation by several technicians and students from the SERC Biological Invasions Laboratory (see Acknowledgments). Co-PIs Nora Foster (UAF) and Dr. Howard Feder (UAF) had primary responsibility for analysis of existing samples in museum, reference and voucher collections in the UA Museum and UAF Institute of Marine Science. Nora Foster also participated actively in rapid community assessment surveys of Prince William Sound, and focal taxonomic analysis of molluscs. Dr. Howard Feder provided oversight to subcontracted focal taxonomic analysis of polychaetes. CoPI Dr. John Chapman (OSU) had primary responsibility to conduct rapid community assessment surveys of invertebrates of Prince William Sound, with focal taxonomic analysis of pericaridean crustaceans. CoPI Dr. Gayle Hansen (OSU) had primary responsibility for focal taxonomic field surveys of marine plants (especially macro-algae) of Prince William Sound. Dr. James Carlton (Mystic Seaport, Williams College) had primary responsibility for surveys of fouling communities of Prince William Sound. In addition, an array of systematic experts was subcontracted to analyze several focal taxonomic groups (see Chapter 9 below). Authorship of the chapters and subsections of this report indicate primary responsibilities for each major element.

Throughout the 1997 Pilot Study and the 1998-1999 expanded phase, the project received guidance and comment from the Alaska NIS Working Group, which was organized by the RCAC of Prince William Sound and composed of academic scientists, resource managers from state and federal agencies, representatives of the oil and shipping industries, and concerned citizens of Alaska (see also Acknowledgments).

Initial funding for the Pilot Study was provided by PWS RCAC, US Fish & Wildlife Service, and the US Coast Guard (Ruiz & Hines, 1997). Expanded research for the present project was extended with a proposal submitted in 1997 to the National Sea Grant Program, with co-funding from RCAC, USF&WS, Alyeska Pipeline Service Company, and in-kind support from the oil shipping companies (especially ARCO Marine, BP and SeaRiver Maritime). Funds awarded from the National Sea Grant Program were distributed to the Oregon Sea Grant Program for John Chapman at Hatfield Marine Science Center and to Alaska Sea Grant Program for Nora Foster and Howard Feder at University of Alaska Fairbanks and UA Museum. However, funding from Alaska Sea Grant was delayed for one year, so that funding was actually available beginning in 1999 and will carry through 2000. In 1998 SERC obtained supplemental funding from the American Petroleum Institute, supported by ARCO Marine and SeaRiver Maritime, to conduct ballast water exchange experiments on tankers. SERC also received further funding from USF&WS for these ballast water exchange experiments during 1999 through a proposal submitted to the National Sea Grant Program. The work plan for the ballast water exchange experiments specifies that sample processing and analysis continue into 2000.

SERC's technical staff worked in close coordination with the shipping agents, masters, officers and crews of the oil tankers, and with Alyeska staff of the Valdez Marine Terminal. All of these industry participants provided in-kind contributions and worked actively and cooperatively to assist project operations to sample ballast water and to conduct ballast water exchange experiments (see also Acknowledgments).

Significantly more work than originally proposed was accomplished in nearly all components of the project. Moreover, we have been successful in gaining additional resources to support expanded elements of the project, including contributions in kind, and added external funds for ballast water exchange experiments. Most importantly, a hallmark of the project was the enthusiastic support of the project by the full array of private citizens, scientific institutions, governmental agencies, and industry, which served as cooperative partners.

1C. Background

1C1. Invasive Species & Ballast Water

Aquatic nuisance species have invaded many, perhaps most, freshwater and marine ports around the world. Ballast water from commercial shipping is increasingly recognized as the most significant vector currently for those invasions occurring (Carlton and Geller, 1993). Ballast water consists of water pumped into dedicated tanks or cargo holds/tanks for trim and stability during oceanic voyages, especially when the vessel is empty or only partially full of cargo. Ballast water is usually taken from coastal water containing a rich diversity of planktonic organisms. Ballast water is often discharged into a receiving port prior to loading cargo, inoculating the ecosystem with exotic species. If any of the plankton are viable and become established, these non-indigenous species (NIS) can cause major ecological and economic disruption in the coastal ecosystem, with numerous examples in San Francisco Bay (Cohen and Carlton, 1995), the Great Lakes (Mills et al., 1993), Chesapeake Bay (Ruiz et al.,1999), Hawaii (Coles et al. 1999), and elsewhere (Ruiz et al., 1997). In San Francisco Bay, the rate of invasion has increased to about one new NIS invasion every 16 weeks, probably as a result of increased ballast water discharge (Cohen and Carlton, 1995). Whether the invasion is Eurasian zebra mussels in the Great Lakes, Asian clams in San Francisco Bay, or North American ctenophores in the Black Sea, impacts of ballast introductions have been devastating and irreversible. Despite the profound impact of ballast-mediated invasions, the biological characteristics of ballast water and the factors that regulate invasion success are little studied and poorly understood. In the USA, biological characteristics of ballast water have only been studied in two port systems: Coos Bay (Carlton and Geller, 1993) and Chesapeake Bay (Smith et al., 1996; 1999; Ruiz et al., unpubl. data); and in other countries the biology of ballast water has similarly received little quantitative analysis (Carlton, 1989; however see Williams et al., 1988; Hallegraeff and Bolsch, 1992).

1C2. NIS in High Latitude/Cold Water Ecosystems

Although there has been no significant analysis of NIS in polar marine ecosystems, there have been a limited number of NIS surveys in high temperate latitudes between 40^{o} - 60^{o} and a study of the Baltic Sea, which includes a major bay that extends substantially above 60^{o}. These studies include three regions in the northern hemisphere (Baltic Sea, Wadden Sea, and United Kingdom)(Reise et al., 1999, Lepapakoski 1984) and one region in the southern hemisphere (Tasmania/New Zealand)(Hayward 1997, R. Thresher, 1999 pers. comm.). Together, these studies clearly demonstrate that invasions are not limited to lower latitudes. The number of known NIS at these locations ranges between 32 and 80 species. For each region, the species include a broad range of taxonomic groups, and some of the invasions have generated serious concerns about their ecological and economic impacts. As with most invasions, the actual impacts remain unmeasured (e.g., Ruiz et al., 1999). Nonetheless, based upon reported abundances and known ecology, species such as the green crab *Carcinus maenas* (on the North American east and west coasts, Tasmania), the seastar *Asterias amurensis* (in Tasmania), and the laminarian kelp *Undaria sp.* appear likely to cause significant and irreversible changes. Furthermore, the cumulative effects of the entire NIS assemblage may cause many changes in ecosystem function that are not easily identified with any single invasion event (Cohen and Carlton, 1995).

The numbers of NIS at high latitudes may be lower than those for temperate regions, although it is not clear whether low numbers of documented NIS reflect lack of invasion in high latitude ecosystems or lack of research focused on the invasion biology of these areas. At the outset of this study, the number of NIS documented in Alaskan waters appeared to be lower than other high latitude/cold water ecosystems with more extensive analysis, despite the extensive environmental studies associated with the Exxon Valdez oil spill in Prince William Sound and other ecological research throughout the region (Ruiz & Hines, 1997).

We advanced two hypotheses why NIS have not been as evident at high latitude as at mid-latitudes:

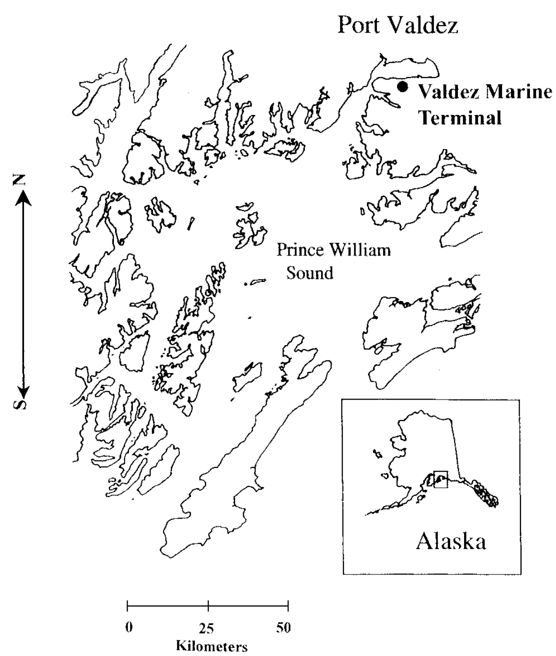
(1) NIS are truly rare at high latitude. High latitude communities may be resistant to invasion (e.g., severe seasonal stress requires specialized evolutionary adaptations not possessed by non-native species). Transport patterns may not have been conducive to inoculation. Shipping/ballast water is major source of rapidly escalating invasions in temperate latitudes, but perhaps neither the relatively recent (20 yrs) surge in tanker traffic to Alaska with very large ballast capacity, nor the current shift in tanker traffic to foreign ports has had time to produce invasions. Note, however, that NIS invasions mediated by ballast water have been common over the past 20 years in some cold temperate ports such as San Francisco Bay (Cohen and Carlton, 1995).

(2) NIS are actually common at high latitude, but have not yet received concentrated study by experts of invasion biology. For example, Carlton (1979) identified some 160 NIS in San Francisco Bay and Pacific northwest coast, but as of 1995 the number of NIS documented in San Francisco Bay was 212 species (Cohen & Carlton, 1995) and is now nearly 250 species (J.T. Carlton, personal communication). Three years ago, the number of NIS in Chesapeake Bay was considered to be only about 25 species; yet pursuant to our on-going literature search of the historical records, we have documented >140 NIS, and the list is still growing with continuing research. Despite extensive biological/ecological assessments of coastal ecosystems associated with oil spills in Alaska, NIS probably remain inadequately studied. The existing and on-going surveys from oil spill work and other studies in Prince William Sound are probably not adequate because those surveys were designed for purposes other than detecting introduced species. Also, they mainly focused on rocky shores rather than on soft-bottom and fouling communities that are most invaded in other regions (e.g., Cohen & Carlton, 1995). Most introduced species have been discovered by taxonomic experts systematically examining specimens previously identified by non-specialists or conducting field surveys of their own.

1C3. Risk Factors for Prince William Sound

Prince William Sound is a relatively pristine, cold water ecosystem at high latitude. Approximately 20% of US domestic oil production is shipped from Port Valdez at the head of the Sound (Fig. 1.1). Tankers arriving to Port Valdez come primarily from domestic source ports of the west coast of North America and Hawaii; but in the past three years tankers also have been traveling from foreign ports, especially in eastern Asia and rarely other locations (Fig. 1.2). Tankers arriving to Prince William Sound discharge two types of ballast water: (1) Segregated ballast water from tanks dedicated solely to ballast water and (2) non-segregated ballast water from tanks which are used to carry petroleum products. Approximately 20 million metric tons of segregated ballast water are discharged annually by tankers into the port and sound, a quantity of domestic ballast water that greatly exceeds the volumes of foreign ballast water released in other U.S. West Coast ports and is the third largest volume for all U.S. ports (behind port systems of New Orleans and Chesapeake Bay). All non-segregated, oily water (about 50% of total) discharged by tankers in Port Valdez must pass through the Ballast Water Treatment Facility located on shore at the Valdez Marine Terminal. Effects of the treatment plant on NIS were unknown prior to our Pilot Study (Ruiz & Hines, 1997). The Pilot Study showed that non-segregated ballast water contained few live planktonic organisms upon leaving tankers and entering the treatment plant, and that there is little risk of NIS in the discharge of water from the treatment plant (Hines et. al., in press). Accordingly, all of our analyses in subsequent research presented in this report focus on segregated ballast water.

Figure 1.1.Map of Prince William Sound, Alaska, showing location of Valdez Marine Terminal.



Segregated ballast water from tankers is discharged directly into the Sound/Port without treatment. This volume is many orders of magnitude greater than the ballast water released by other types of ships traveling to Prince William Sound. Release of ballast water into Prince William Sound increased markedly with the opening of the trans-Alaska Pipeline in 1977. Tankers have made more than 15,000 voyages through Prince William Sound to Port Valdez since the startup of the terminal in 1977. From 1987-1994, tanker arrivals to Valdez averaged

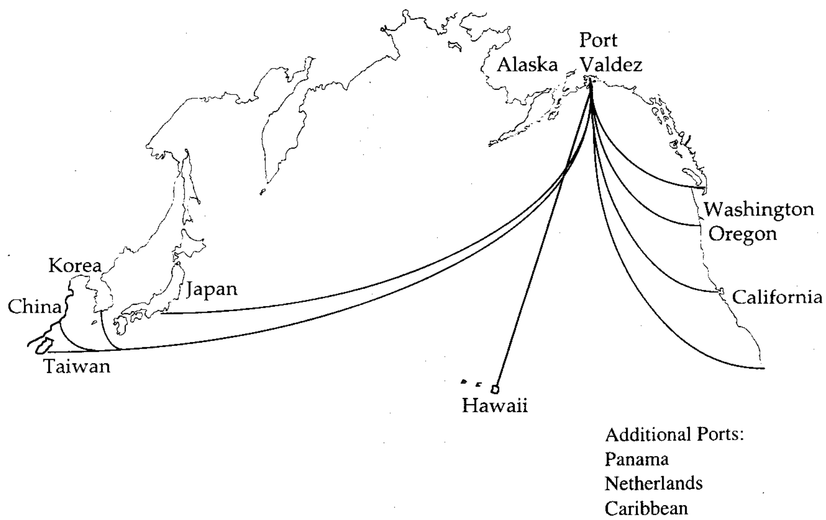
799 per year but have declined to less than 600 per year currently. Since 1996, oil shipping patterns authorized by the US Congress have changed to allow sale of crude oil on foreign as well as domestic markets. Tankers from foreign ports are required to conduct mid-ocean exchange of their coastal ballast water, which is expected to reduce numbers of organisms transported from foreign coastal ecosystems to Alaskan waters. However, the effectiveness of mid-ocean exchange is poorly measured. Moreover, the greatest volume of ballast water coming to Alaska derives from domestic ports of the west coast of North America, which themselves are highly invaded by NIS. Tankers on these domestic, relatively short coast-wise voyages are not required to exchange ballast water.

To determine whether the known NIS in Alaska provide an accurate indicator of the probability for biological invasions, we considered 6 factors which contribute elements of risk for invasions of Prince William Sound:

1. Huge volume of ballast water. The greatest quantities of ballast water are transported by bulk cargo carriers and tankers (Carlton et al., 1995; Smith et al., 1996). Chesapeake Bay receives 10-fold more ballast water than other ports on the east and west coasts of the U.S. because of the high volume of bulkers arriving to the ports of Baltimore and Norfolk. The tanker traffic to Port Valdez releases the third largest volume of ballast water into a US port. Other things being equal, larger ballast volumes mean larger inoculations of NIS.
2. Short voyage time. Our analysis of biological characteristics of ballast water arriving to Chesapeake Bay shows a marked inverse relationship between densities of organisms and length of voyage, such that ballast water after voyages of 14-24 days had more than 10-fold fewer organisms than voyages of 5-13 days (Smith et al., 1996; 1999). However, these effects may be confounded by differences in the source of ballast, which co-varies with the length of voyage (Smith et al., 1996; 1999). Voyages of tankers delivering ballast water to Prince William Sound average only 3-6 days, quite short compared to most trans-oceanic voyages that average 12-22 days. Short voyages mean that many larvae and other organisms are likely to be in good health when they are discharged (see Chapt 2 and 3 below).
3. Pattern of repeated delivery from same donor locations. Although Chesapeake Bay receives about 10-fold more ballast water than does San Francisco Bay, San Francisco Bay appears to be invaded by many more ballast-mediated NIS. This greater risk could be due to San Francisco Bay receiving repeated ballast inoculations delivered from relatively fewer ports than does Chesapeake Bay. Similarly, Prince William Sound could be at increased risk not only by the large volume of ballast water, but also by the repeated inoculation of ballast from a small set of west coast ports (Fig. 1.2, Chapt 2 below).
4. The match of environmental conditions of source and receiving ports. Environmental conditions in Alaska are often perceived as being harsh and inhospitable to most potential invaders from temperate latitudes where moderate conditions prevail. Obviously, temperature, light and other conditions during winter are indeed more extreme than those in temperate regions of North America and Asia. However, temperature-salinity conditions in Prince William Sound during spring and summer often approximate conditions in source ports of northwest North America, especially during productive periods of cold water up-welling. In fact, many of the native marine/estuarine species in Alaska have geographic ranges which extend to British Columbia, Washington, Oregon, and Northern California. Temperature-salinity conditions in segregated ballast water of tankers arriving from several west coast source ports is shown to be similar to the waters of Port Valdez (see Chapt 4 below). In the fjords of Prince William Sound, such as Port Valdez, heavy loads of

suspended sediment during summer snow/glacial melt also may be a major stress on marine organisms in surface waters.

Figure 1.2. Major tanker routes to Port Valdez, Alaska.



5. Lack of mid-ocean exchange of ballast water delivered to Prince William Sound. Mid-ocean exchange of ballast water reduces concentrations of larvae and plankton by 50-90% (Smith et al., 1996). Exchange presumably limits the risk of invasion, as mid-ocean species are generally thought to be incapable of invading near-shore habitats. Delivery of ballast from coastal ports of the U.S. West Coast without oceanic exchange before release into Prince William Sound poses an elevated risk. Further experimental assessment of this role of mid-ocean exchange in reducing plankton abundance and diversity in ballast water is presented below in “Ballast Water Exchange Experiments”. While ballast water exchange is required for tankers from foreign ports, the National Invasive Species Act of 1996 considers tankers from U.S. west coast ports to be domestic, coast-wise traffic that does not require exchange.
6. High frequency of known NIS - especially those transported by ballast water - in source regions of ballast coming to Prince William Sound. Some workers consider that there may be "hotspots" of invasion or donation of NIS. If such hotspots exist, certainly San Francisco Bay and other ports of the U.S. west coast qualify as having among the highest prevalences of documented ballast-mediated invasions. These, in turn, form the sources donating much of the ballast water delivered to Prince William Sound. The 310+ known NIS of the west coast of North America vary considerably in abundance among 6 latitudinally separate regions (southern California, San Francisco Bay, northern California, Coos Bay Oregon, northwest region from the Columbia River estuary to British Columbia, and Alaska) (Ruiz & Hines, 1997). The number of known NIS varies from about 80+ species in southern California to about 40+ species in the northwest region of Washington and British Columbia, with the largest number of nearly 250 species occurring in San Francisco Bay. At each location along the west coast, NIS are common in a diverse array of taxonomic groups, with arthropods, mollusks, and annelids comprising major fractions of NIS at most locations. In several locations (San Francisco Bay, Northern California, Oregon), vascular plants and chordates also comprise major portions of the NIS. Much of the variation in number of NIS

probably reflects the level of study and state of knowledge for each location, especially since the highest numbers occur at two locations (San Francisco Bay and Coos Bay) where J.T. Carlton has focused his past research. Many NIS occur in several locations along the west coast, indicating that invasions by the same species have occurred widely across latitudinally separate sites. The similarity of NIS at less studied sites may be expressed as a percent overlap with NIS in well-studied San Francisco Bay. The overlap of NIS at west coast source ports with those in San Francisco Bay is high, ranging from about 60-75%. For the limited sample known for Alaska, the overlap of NIS with San Francisco Bay is substantially lower at about 25%. However, it is not clear whether this lower overlap reflects reduced compatibility with the Alaskan region or the small sample size, or both.

7. History of other vectors for NIS in Prince William Sound. Although ballast water from tankers is currently a major vector for introductions of NIS in Prince William Sound, several other vectors have been, and continue to be, active in Alaska for long periods of time and in the present. These transport mechanisms include:
   - Ballast water from other types of ships, especially bulk carriers of such products as wood (logs, wood chips), ore, and coal, which come from foreign or domestic ports to Alaska in ballast to load. These may provide inoculations in ports nearby Prince William Sound (e.g., Homer, Seward), that may be spread by coast-wise traffic.
   - Fouling of ship hulls, which was especially important historically in wooden ships and before anti-fouling paints. However, fouling continues to be common, and may be especially important in coast-wise transport to and within Alaskan waters. This vector may include all types of private, recreational and commercial vessels.
   - Intentional and accidental release from aquaculture activities. Both species that are cultured and species that may be coincident with the aquaculture (including disease organisms) may be released. Oyster culture, salmon culture, and cultured herring roe on kelp are especially common and potential sources of NIS in Prince William Sound. Mussel culture may be initiated in the area.
   - Fishery release has occurred commonly in the past through efforts of state and federal agencies to improve stocks.
   - Aquarium and pet trades have resulted in NIS invasions at many places around the world.
   - Large-scale changes in current patterns may transport NIS into Alaskan waters. During 1998 the very strong El Niño along the eastern Pacific may have brought warm-water species much further north than their typical distribution. These shifts may also allow species transported by human activities to become established.

In many ecosystems, NIS invade over time as a series of vectors shift in importance, and this accumulation of NIS can result in major changes in the diversity and function of coastal ecosystems (Cohen & Carlton 1995).

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Chapter 2. Ballast Water Delivery Patterns

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2A. Purpose

The primary goal of this portion of the study was to characterize the traffic patterns and volumes of ballast water discharged into Port Valdez and Prince William Sound (PWS) by oil tankers. Since ballast water is a major mechanism for the transfer of NIS, we wished to describe the delivery patterns of the ballast water to the region by season, source region, voyage duration. Analysis of the biota associated with the tankers' ballast water is discussed in the next chapter.

2B. Methods

We obtained data on ship arrivals and ballast water histories in two ways. First, we obtained information about the long-term (10-year) pattern of arrivals to Port Valdez from Alyeska and RCAC. Second, to characterize current patterns, we collected detailed data from vessels arriving to Port Valdez over the one-year period of 1998. Our goal in this latter approach was to collect comprehensive information on the origin (i.e., last port of call), date of arrival, and ballast water histories for as many arriving vessels as possible. Most of these data were collected by SERC staff, during interviews aboard vessels (see below). Additional data were sent to us by the ships' personnel and shipping agents.

Beginning December 1997, we implemented a sampling scheme to estimate the amount of segregated ballast water delivered to Prince William Sound and Port Valdez by source port and season. For tankers arriving to Port Valdez from each of the three primary domestic source port systems (Los Angeles, San Francisco Bay, Puget Sound), we boarded approximately 3 tankers per month (i.e., 10 per quarter x 3 source ports = 30 per quarter). In addition, we attempted to board most tankers arriving to Port Valdez from foreign ports.

Upon boarding, we conducted an interview of the ships' personnel to collect information on the quantity, age, source region, and management of all ballast water. Following the interview, we proceeded to sample the segregated ballast water to characterize temperature, salinity, and resident biota (see Chapter 3).

We excluded non-segregated ballast water from most of our current analyses. Although this can account for roughly 50% of the total ballast water aboard tankers arriving to Prince William Sound (see below), previous analyses indicated that very few viable organisms were present in this ballast water, which often includes some residual oil. Furthermore, the nonsegregated ballast water is pumped to an on-shore treatment facility at the Alyeska terminal. For review of previous results, as well as description of the treatment process, see Ruiz and Hines 1997.

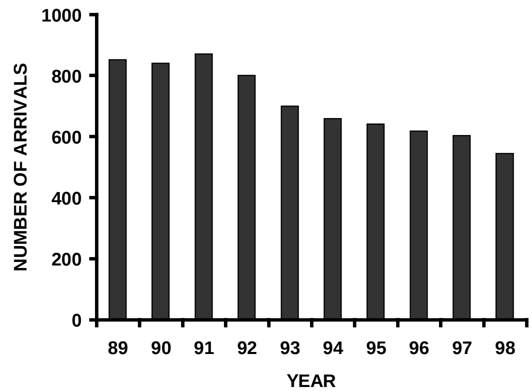
Since vessels with double bottoms are difficult to sample for biota, we focused our sampling effort primarily on vessels without double bottoms. Thus, to characterize the entire fleet (i.e., all arrivals), we obtained additional data on ballast water histories of nearly all oil tankers arriving to Port Valdez in 1998. Ships' personnel and shipping agents generously provided these data.

2C. Results

2C1. Number and Source of Tanker Arrivals to PWS

Over the past decade (1989-98), tanker arrivals to Port Valdez have averaged 713 (se=37.2) ships per year**,** ranging from 870 to 549 (Fig. 2.1). There has been a noticeable decline in arrivals since 1991, with each year having fewer arrivals than the previous one.

Figure 2.1. Annual number of oil tankers arriving to Port Valdez, 1989-1998. Data as provided by Alyeska.



Using 1998 to examine spatial and temporal patterns, tanker arrivals to Port Valdez were both distributed evenly among seasons and dominated by arrivals from U.S. domestic ports (Fig. 2.2). An average of 137.3 (s.e.=2.98) vessels arrived each quarter, and 95.8% (s.e. = 0.82 %) of all arrivals came directly from a U.S. port. Of all tanker arrivals, 82.7% came from one of three domestic ports (Fig. 2.3): Puget Sound, Washington (43.0%); San Francisco Bay, California (28.8.%); and Long Beach, California (10.9%). The residual came from Oregon, Hawaii, Alaska, or foreign ports. Among arrivals from foreign ports, most (69.6%) came directly from Korea (Fig. 2.4).

Figure 2.2. Number of oil tankers arriving to Port Valdez from foreign and domestic source ports by season in 1998. Seasons include: Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December). Data based upon boarding interviews and reports from ships' personnel (see text).

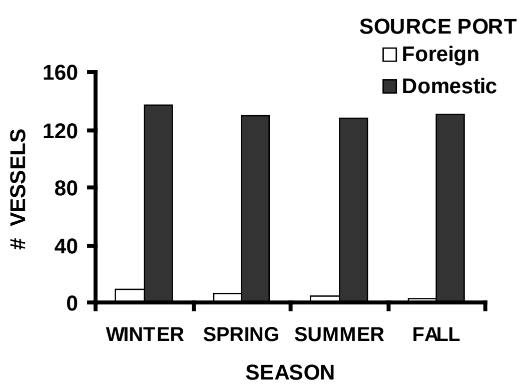


Figure 2.3 Number of oil tankers arriving to Port Valdez from each domestic source port by season in 1998. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Columbia River, Oregon (OR); Cook Inlet, Alaska (AK); and Barbers Point, Hawaii (HI). Seasons include: Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December). Data based upon boarding interviews and reports from ships' personnel (see text).

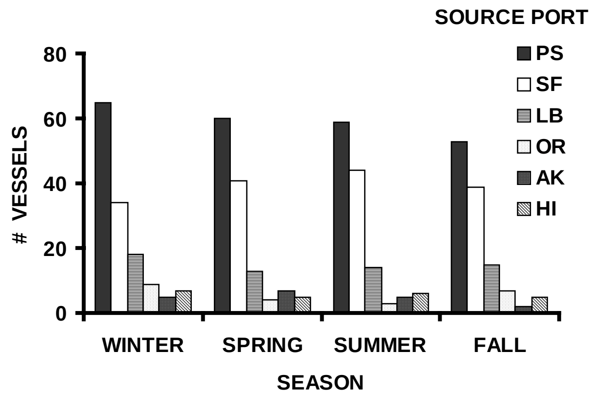
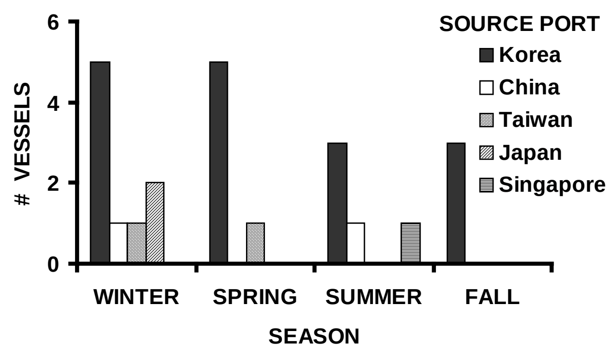


Figure 2.4. Number of oil tankers arriving to Port Valdez from each foreign source port by season in 1998. Seasons Include: Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December). Data based upon boarding interviews and reports from ships' personnel (see text).



2C2. Volume of Ballast Water delivered to PWS

During 1998, oil tankers arriving to PWS carried an estimated average of 65,775m^3 (s.e.=1,252; n=472) of total ballast water, the combination of segregated and nonsegregated ballast water. Segregated ballast water comprised an average of 54.7% (s.e.=2.1%; n=472) of the total among tankers.

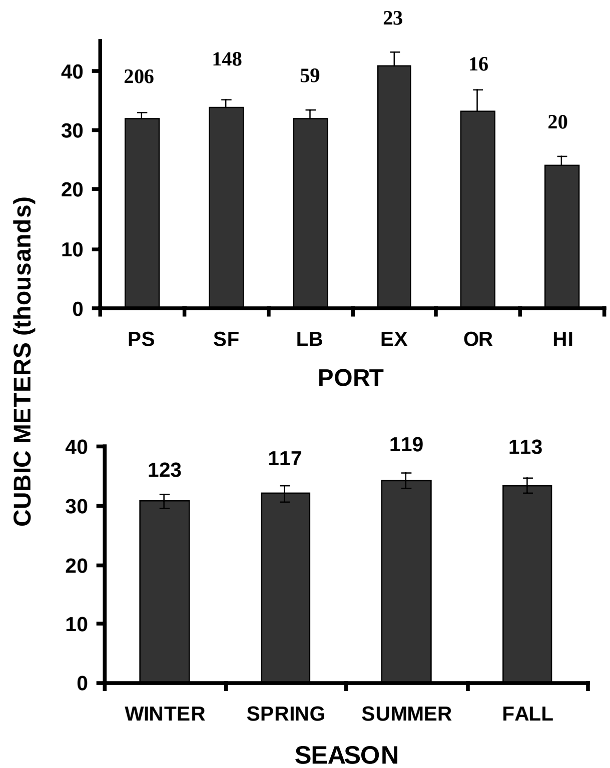
Across all vessels, tankers discharged an average of 32,715 m^3 (s.e.= 645; n=472) of segregated ballast water upon arrival to PWS (Table 2.1). Although there were no seasonal differences in the average amount of ballast water per tanker, there was a significant difference by source port (Fig. 2.5; 2-way ANOVA, $F_{(3\text{ (seasons)}, 5\text{ (port source)}, 517\text{ obs})}$ =3.52, P = 0.004). Specifically, the mean volume was significantly greater for arrivals from foreign ports compared to arrivals from all other ports, and the mean volume was significantly lower for tankers from Hawaii relative to all other sources.

Table 2.1. Estimated volume of ballast water delivered by oil tankers to Port Valdez and PWS in 1998. Shown by source port and season are: (1) the estimated mean volume of ballast water arriving per tanker, including the standard error and sample size (n=number of vessels for which we have volume estimates), (2) the total number of tanker arrivals which is shown as N, (3) the total estimated volume of ballast water (calculated as mean volume X total arrivals). The bottom row (Overall) estimates the total ballast water volume and number of arrivals for all ships combined. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI). Seasons include: Winter (January-March), Spring (April-May), Summer (July-September), and Fall (October-December). Source of data on volumes and arrivals as described in text.

		BW vol. (m^3)			
Port/Source	**Season**	**Mean(se)**	**n**	**N**	**Total**
	Winter	28163(1734)	56	64	1,802,432
	Spring	31421(2095)	51	60	1,885,260
PS	Summer	34448(1901)	53	59	2,032,432
	Fall	33894(2199)	46	53	1,796,382
	Grand total		206	236	7,516,506
	Winter	31841(2798)	31	34	1,082,594
	Spring	32809(2984)	40	41	1,345,169
SF	Summer	35765(2361)	40	44	1,573,660
	Fall	34371(2372)	37	39	1,340,469
	Grand total		148	158	5,341,892
	Winter	32526(3237)	18	18	585,468
	Spring	30399(2902)	12	13	395,187
LB	Summer	36045(3633)	14	14	504,630
	Fall	28850(1346)	15	15	390,180
	Grand total		59	60	1,875,465
	Winter	42153(4093)	9	9	379,377
	Spring	44294(3775)	6	6	265,764
EX	Summer	29856(3689)	5	5	149,280
	Fall	47056(5199)	3	3	141,168
	Grand total		23	23	935,589
	Winter	29182(6929)	4	9	262,638
	Spring	28250(2169)	4	4	113,000
OR	Summer	32429(1631)	2	3	97,287
	Fall	39138(5740)	6	7	273,966
	Grand total		16	23	746,891
	Winter	27142(2279)	6	7	189,994
	Spring	22229(1651)	4	5	111,145
HI	Summer	23766(4197)	6	6	142,596
	Fall	21729(1544)	4	5	108,370
	Grand Total		20	23	552,105
Overall		32,715	472	523	16,968,448

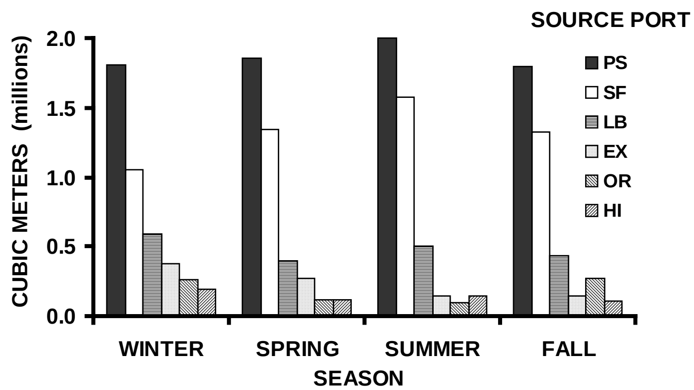
Note: Not included in the table are arrivals from Nikiski, AK (19) which provided no data, and other arrivals (7) for which port data are unavailable.

Figure 2.5. Mean volume of segregated ballast water per tanker arriving to Port Valdez and PWS by source port and season, 1998. The mean volumes are estimated for: (A) Each source port across all seasons; (B) Each season across all source ports. Standard error and sample size is shown above each bar; see Table 2.1 for further information. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI). Seasons include: Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December). Data based upon boarding interviews and reports from ships' personnel (see text).



We estimated the total amount of segregated ballast water discharged into Prince William Sound during 1998 was approximately 17,000,000 m^3 (no. arrivals x average ballast water volume) for source port by season (see Table 2.1). The relative contribution of different source ports to the total varied greatly, reflecting variation in the number of arrivals (Fig. 2.6; Table 2.1). As a result, Puget Sound contributed approximately 44% of the total, followed by San Francisco 31% and Long Beach 11%.

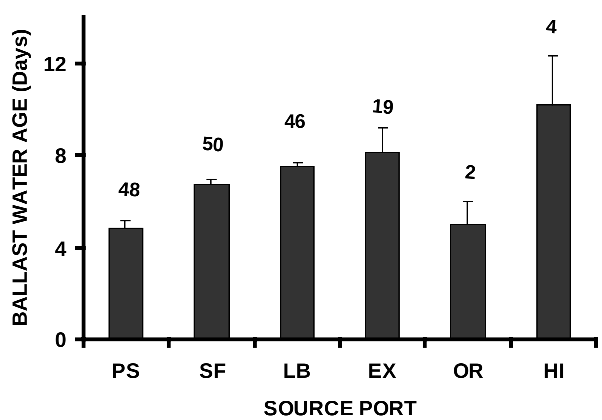
Figure 2.6. Cumulative volume of ballast water arriving to Port Valdez and PWS by source port and season, 1998. The cumulative volumes are estimated for season by source port (see Table 2.1 for further detail). Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI). Seasons include: Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December). Data based upon boarding interviews and reports from ships' personnel (see text).



2C3. Age and Management of Ballast Water delivered to PWS

The average age of ballast water arriving in tankers varied among source ports, ranging between 4.8 to 10.2 days (Fig. 2.7). The mean age among all arrivals was 6.6 days (s.e.= 0.2). For domestic source ports, the age of water was correlated with distance from Port Valdez to the source port, as ballast water came directly from the last port of call (the exception was for experiments conducted at our request, as described in Chapter 4). In contrast, all foreign arrivals exchanged their ballast water at sea, so the age of water was less than the voyage duration. Thus, for foreign arrivals, the actual source was considered open ocean exchange (EX) instead of the last port of call.

Figure 2.7. Mean age (voyage duration) for ballast water arriving to Port Valdez by source port. The mean age is estimated for each source port based upon all boarding data (December 1997-July 1999). Standard error and sample size is shown above each bar. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI).



2D. Discussion

Over the past decade, Prince William Sound and Port Valdez together have received approximately 23.3 million m^3 (= 713 arrivals/yr x 32,610 m^3/arrival) of segregated ballast water each year from oil tankers arriving to the Alyeska terminal. Although most of this water is released in Port Valdez, ships will sometimes begin discharging upon entering Prince William Sound en route for the Port. Thus, organisms released with this ballast water may experience a broader range of conditions outside of Port Valdez than we had originally considered.

The total volume of ballast water delivered to Prince William Sound by tankers greatly exceeds the estimated quantity of ballast water arriving to other western U.S. ports (Carlton et al. 1995). However, it is important to recognize that existing estimates for the other ports have included only the ballast water from foreign sources. In contrast, our estimates for Prince William Sound included both foreign and domestic sources, but were dominated by the latter. The amount of domestic ballast water released in other U.S. ports is only now being estimated. Nonetheless, even when we can include data on domestic sources for all ports, it appears likely that the total volume of ballast water released to PWS will still exceed that for the other western ports, due to the absence of extensive domestic tanker and bulker traffic (i.e., those vessels that discharge the greatest quantities of ballast water) at the other ports. Instead, the domestic traffic for other western U.S. ports is dominated by container ships, which release relatively small amounts of ballast water (Carlton et al. 1995; National Ballast Water Information Clearinghouse, unpubl. data).

The total amount of ballast water arriving to Prince William Sound in tankers is also relatively large on a global scale. Within the U.S., PWS is third only to Chesapeake Bay and New Orleans in estimated ballast water discharge for 1991 (Carlton et al. 1995, Smith et al. 1999). In a similar estimate of ballast water discharged to 46 Australian ports in 1991, only that for the port of Dampier exceeded the volume for PWS (Kerr 1994). As above, estimates for the both the U.S. and Australian ports were restricted to arrivals from foreign ports. Although these totals would clearly increase when including domestic arrivals, the overall patterns provide a useful context, suggesting PWS is on the extreme end of the spectrum for amount of ballast water discharge.

It is also important to recognize the present level of tanker activity, and the magnitude of ballast water delivery, as a recent development in Port Valdez. The terminal began transporting oil via tankers in 1977. Based upon the arrivals rate and discharge volumes observed in this decade, we estimate over 700 million m^3 of segregated ballast water have been delivered over the past 3 decades of operation. This large cumulative volume underscores the potential importance of ballast water as a vector for the transfer of species. Unlike many other commercial ports, however, the volume of ballast water prior to oil exportation was virtually absent, as very few other vessels currently deliver ballast water to the Port (Ruiz et al., unpubl. data).

Furthermore, the foreign export of oil from Port Valdez has only occurred since 1996, following authorization by U.S. Congress. Prior to this time, all oil export was only to domestic U.S. ports, which were therefore the source of ballast water delivery to PWS and Port Valdez. Although tankers now export oil to foreign ports from PWS, the delivery of ballast water from foreign traffic remains a small fraction (<5%) of the total annual volume. In addition, tankers arriving from foreign ports are required to undergo ballast water exchange, further reducing the actual amount of ballast water and organisms coming from coastal habitats surrounding foreign ports (see Chapters 3 and 4 for further discussion of biota).

2E. References

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Chapter 3. Biological Characteristics of Ballast Water in Oil Tankers

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3A. Purpose

The overall goal of this research component was to characterize the biota associated with segregated ballast water of tankers arriving to Port Valdez. For this analysis, we designed a sampling program to measure temporal (seasonal, annual) and spatial (source port) variation in the biota associated with the ballast water.

We focused primarily on the mid-large (>80 micron) zooplankton resident in the water column of ballast tanks, and present the results of this analysis here. We have included some information on the phytoplankton concentrations present in our samples, but the sampling methods (below) were not designed to characterize these organisms and many of the other taxa (e.g., bacteria, viruses, and other microorganisms) that are small in size. This choice does not imply that small organisms are not significant from an invasion standpoint, as the potential effects of toxic dinoflagellate blooms are very evident (see Introduction). Instead, we simply did not have the resources to include all taxonomic groups in our analyses.

We chose to focus on the mid-large zooplankton for multiple reasons. First, the taxonomic resolution is relatively good compared to many of the other (smaller) organisms. Second, most known NIS that are established at the source ports of oil tankers, such as San Francisco Bay, occur (for some portion of their life history) in this zooplankton community. Third, we could readily gain access to the plankton community (as opposed to the bottom sediments). Finally, the sample analysis for larger zooplankton is not as technically difficult or time consuming as that necessary for the smaller organisms, allowing us to analyze samples from a large number of ships for statistical comparisons.

The analysis of zooplankton presented here is one of the most comprehensive and quantitative studies of ballast water in the world. Additional data on the biota associated with ballast water also appear in other chapters. Our analysis of ballast water exchange (Chapter 5) includes survivorship of plankton during 8 separate voyages, effects of exchange on zooplankton, and some information on bacteria and ciliate protozoans. Biota associated with the bottom sediments of ballast tanks, as well as the hulls and seachests, are also examined (Chapters 6 and 7, respectively).

3B. Methods

3B1. Source and Number of Sampled Ships

For a 13-month period (December 1997 – December 1998, hereafter 1998), we conducted an intensive sampling program of ballast water on tankers that was stratified by source port and season. Most tankers and ballast water arriving to Port Valdez came from three U.S. domestic port systems: Puget Sound, San Francisco Bay, and Long Beach (see Chapter 2). To characterize biota for these ports by seasons, we sampled a minimum of 3 tanker arrivals per month from each of the three domestic source port systems (i.e., 10 per quarter x 3 source ports = 30 per quarter). Although relatively few (23) tankers arrived from foreign ports in Port Valdez during this year, we sampled as many as possible (n=19) to compare the biota arriving from foreign versus domestic sources. We also sampled a limited number of arrivals from the other two domestic ports: Oregon and Hawaii (which comprised < 10% all arrivals; see Chapter 2).

In June of three consecutive years (1997, 1998, 1999), we collected samples from approximately 10 tankers arriving to Port Valdez from the domestic ports of Puget Sound, San Francisco Bay, and Long Beach. Samples from 1997 were collected as part of a Pilot Study that we conducted for RCAC (Ruiz and Hines 1997), and the samples for 1998-1999 were collected in the present study. Together, these samples were used to characterize annual variation in the ballast water biota arriving to Alaska.

3B2. Sample Collection and Analysis

We boarded and sampled tankers immediately upon their arrival to Port Valdez. As described above, we sampled approximately 2-3 vessels per week over the 13-month period. Although we attempted to collect ballast water from every tanker boarded, vessels with double bottoms could not be sampled easily without disruption of ship operations and modification of our standard sampling protocol. In the present analysis, we therefore have included primarily (but not exclusively) vessels without double bottoms.

We applied our established methods for qualitative and quantitative analysis of biota transported in ballast water, which evolved from methods developed by J.T. Carlton (e.g., Carlton and Geller, 1993; LaVoie et al.1999; Smith et al., 1999). Our protocol consisted of collecting the following information and samples:

- Ship and ballast management information: Last port of call, number of tanks by type, capacity of tanks, amount of segregated and non-segregated ballast water on board, source(s) of ballast water, age of ballast water, date of arrival, ballast management practices;
- Physical variables of ballast water: Water temperature and salinity were measured (surface and 10m depth) for each tank sampled (as below), collecting ballast water with a Niskin bottle through the Butterworth hatches; oxygen (O_2) concentration was not measured because previous extensive analysis of ballast water tanks in other cargo ships indicated that O_2 concentrations rarely varied and were not appreciably lower than saturation (Smith et al., 1996).
- Biological samples of ballast water: Plankton samples were collected by towing a standard plankton net (80 micron mesh, 30 cm diameter) vertically through the entire height of the water column in each ballast tank; access to ballast tanks was obtained through the Butterworth hatches. A single tank was sampled for each ship, when ballast water was present and accessible, and two plankton tows were collected for each tank; the height of each plankton tow was measured to the nearest 10 cm.
- Additional observations and opportunistic samples: Upon initiating sampling of ballast tanks, we routinely examined the surface waters to look for large, mobile biota (e.g., fish) and organisms attached to the sides of tanks; we often took opportunities to collect any such

organisms observed, as well as bottom sediments, since these are usually missed in our plankton tows.

- Physical variables of port water: Shipside water temperature and salinity were measured (surface and 10m depth) usually within an hour of sampling ballast water of most vessels; the samples were collected from the berth platform (within 50m of the ship), using a Niskin bottle.

Most plankton samples were returned to the laboratory at Valdez and examined initially within an hour of collection to assess condition of organisms present. More specifically, we examined each plankton sample with our dissecting microscopes (10-40x), to provide a qualitative assessment of plankton viability. Each sample was washed carefully into a finger bowl for examination, and the presence of each morphologically distinct taxonomic group was noted. For each taxon identified, the percent of individuals alive was estimated by evaluating their morphological integrity, movement, and activity; although status of some organisms (e.g., diatoms or eggs) was difficult to discern with confidence during a brief screening. After initial microscopic examination, the plankton samples were preserved in 5% buffered formalin for later identification and enumeration of organisms (as below).

We used two different methods to characterize the plankton samples, as follows:

- Coarse Analysis. All samples were characterized by Coarse Analysis, consisting of a direct count of individuals according to general taxonomic groups, usually phyla (e.g., molluscs, crustaceans, echinoderms). The minimum of number of distinctly different taxa were also estimated in Coarse Analysis of each sample.
- Fine Analysis. For a subset of samples (roughly 1/3 of the ships from domestic ports), Fine Analysis was used to enumerate all morphologically distinct taxa at the lowest taxonomic level possible. For many groups that included larval invertebrates (e.g., bivalves, gastropods), identification could not progress beyond gross taxonomic groups; further identification can only be accomplished with intensive culture of larvae to adult stages, upon which taxonomy is based, or the use of molecular probes. For other groups that include adult stages (e.g., copepods), we sought species-level identifications.

The two methods were selected to provide different types of information. The Coarse Analysis allowed us to test for patterns in the biota across all ships, increasing the statistical power of the analysis. Since many species were not present on each ship, such an approach was not feasible with finer taxonomic resolution. In contrast, the Fine Analysis allowed us to quantify the densities of particular taxa, usually crustacean groups with adult forms (see results), and test for the presence of nonindigenous species known from the source ports. These data also allow us to characterize the frequency and density of particular nonindigenous species in the ballast water.

For both analyses, samples were concentrated on an 80 micron sieve and washed into a finger bowl for identification and enumeration. Each whole sample was examined using a stereo microscope, and all morphologically distinct taxa were identified to the desired taxonomic level (as above). For abundant taxa (> 100 individuals/sample), samples were split using a Folsom plankton splitter to achieve counts between 10-100 individuals per subsample (usually splits of 1/8 to 1/32). For organisms in split samples, two subsamples were counted.

Taxonomic identification of plankton followed a standard protocol. For those groups of organisms that can be identified using the life stages present in ballast water samples (as discussed above), we made an initial identification based upon our current knowledge and literature that was immediately available to us at SERC. For many copepods, we were able to discern genera without much difficulty. Enumeration proceeded based upon the lowest discernible taxonomic units, and representative specimens were vouchered (in Fine Analysis) for taxonomic verification and, wherever possible, species-level identification. These voucher specimens were sent to taxonomists at the Smithsonian Institution's National Museum of Natural History and elsewhere for verification and identification.

3B3 Data Analysis

Throughout our analyses, we use "ship" as the level of replication within a class variable (e.g., source port, season, year), because multiple samples from the same ship are not independent of each other. Although our replicate plankton samples per ship provide some important information on variation within ships, these are not statistically independent (since the ballast water originates from the same source and time) and mainly provide greater confidence in estimating plankton communities per ship. Thus, we estimated density per ship as the mean of replicate tows.

We derive most of the results reported from the Coarse Analysis. All enumeration is also completed for the Fine Analysis, but identification of only a portion of the voucher specimens has been finished to date. Although we cannot yet discuss the frequency and density of individual taxa (as described above), we confirm the presence of numerous nonindigenous species in the Fine Analysis, and these are reported here. We will include full results of the Fine Analysis, when completed, in a future publication and provide a copy to RCAC.

Virtually all organisms collected in the ballast water samples were alive and appeared to be in good condition. Indeed, many of the organisms collected from these samples performed well in laboratory culture and experiments, as described in Chapter 4. Thus, we considered all organisms counted in fixed samples to be alive at the time of sampling.

In most of the analyses, we have excluded the chain-forming diatoms. Although we enumerated these organisms to the full extent possible, quantitative counts are particularly problematic and unreliable, because the chains break apart during sample collection and processing. We have therefore included information on their prevalence and the counts made but excluded these data from most estimates of organism densities.

Finally, the presentation of water temperature and salinity, for both the ballast water of oil tankers and Port Valdez, are presented in Chapter 4.

3C Results

Source and Number of Sampled Ships

During this study, we sampled the ballast water of 169 tankers arriving to Port Valdez (Table 3.1). Our samples included 8-15 arrivals per quarter for each of the three major domestic ports (Puget Sound, San Francisco Bay, and Long Beach) and 3-7 arrivals per quarter from foreign ports (primarily Korea; see Chapter 2).

Table 3.1. Prevalence and densities of taxa in the ballast water arriving to Port Valdez for each source port. Shown for each taxon and source port are the prevalence, density among all ships, and density for ships only when taxon was present. Standard errors are shown in parentheses with each density measure. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI). The data include all sample dates. Sample sizes for each source port as follows: PS (n=48), SF (n=50), LB (n=46), EX (n=19), OR (n=2), HI (n=4).

				(%)		(density/m³)
Phylum	**Taxa**	**source**	**n**	**Prevalence**	**mean(se) all ships**	**mean(se) when present**
DINOFLAGELLATA						
		PS	48	88	775(223)	902(245)
		SF	50	54	66(21)	114(34)
		LB	46	65	71(30)	107(45)
		EX	19	84	729(658)	886(780)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	100	3.0(1.0)	3.0(1.0)
DIATOMACEA						
		PS	48	100	13866(3270)	13866(3270)
		SF	50	100	11683(4384)	11683(4384)
		LB	46	100	1170(241)	1170(241)
		EX	19	100	5346(2184)	5346(2184)
		OR	2	100	9409(6120)	9409(6120)
		HI	4	100	277(107)	277(107)
PROTOZOA						
		PS	48	83	316(122)	361(139)
		SF	50	90	5506(3638)	6120(4037)
		LB	46	93	210(57)	220(59)
		EX	19	74	82(58)	110(78)
		OR	2	100	31(13)	31(13)
		HI	4	100	4.0(1.3)	4.0(1.3)
CNIDARIA						
		PS	48	63	19.5(11.9)	55(32)
		SF	50	22	1.8(0.7)	8.3(2.3)
		LB	46	87	45(18)	53(21)
		EX	19	5	0.3(0.3)	5.7(0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
CTENOPHORA						
		PS	48	17	0.2(0.1)	1.2(0.3)
		SF	50	4	0.01(0.008)	0.5(0.0)
		LB	46	37	1.6(0.6)	4.0(1.5)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)

Table 3.1 continued

Phylum	Taxa	source	n	Prevalence (%)	mean(se) all ships	mean(se) when present
PLATYHELMINTHES						
		PS	48	27	3.4(1.4)	13(4.3)
		SF	50	28	10.5(4.6)	37(14)
		LB	46	80	11(2.2)	13(2.4)
		EX	19	16	0.1(0.07)	0.9(0.1)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
NEMATODA						
		PS	48	6	0.2(0.1)	2.5(0.9)
		SF	50	8	0.5(0.3)	6.5(2.4)
		LB	46	4	0.1(0.07)	2.5(0.5)
		EX	19	5	0.1(0.1)	1.4(0.0)
		OR	2	100	4.4(3.0)	4.4(3.0)
		HI	4	0	0(0.0)	0(0.0)
ROTIFERA						
		PS	48	2	0.3(0.3)	12.5(0)
		SF	50	2	0.7(0.7)	33(4.5)
		LB	46	2	0.6(0.6)	27(0.0)
		EX	19	5	0.3(0.3)	5.6(0.0)
		OR	2	50	0.2(0.2)	0.4(0.0)
		HI	4	0	0(0.0)	0(0.0)
SIPUNCULA						
		PS	48	0	0(0.0)	0(0.0)
		SF	50	4	0.8(0.7)	19.8(11)
		LB	46	4	0.7(0.6)	15(4.1)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
NEMERTEA						
		PS	48	8	1.0(0.6)	12.4(5.3)
		SF	50	8	41(27)	516(275)
		LB	46	15	23(12)	150(66)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
ANNELIDA		PS	48	90	370(136)	404(148)
		SF	50	80	199(55)	251(68)
		LB	46	100	33(6.5)	33(6.5)
		EX	19	2	2.1(1.3)	6.3(3.6
		OR	2	0	0(0.0)	0(0.0)
		HI	4	25	0.31(0.31)	1.2(0.0)
MOLLUSCA						
	Bivalvia	PS	48	90	371(100)	396(106)
		SF	50	82	319(79)	389(93)
		LB	46	98	240(72)	246(74)
		EX	19	53	8.0(3.5)	15.2(5.5)
		OR	2	50	0.5(0.5)	1.0(0.0)
		HI	4	75	1.3(0.7)	2.0(0.5)

Table 3.1 continued

Phylum	Taxa	source	n	Prevalence (%)	mean(se) all ships	mean(se) when present
	Gastropoda	PS	48	71	139(39)	191(44)
		SF	50	54	34(18)	58(38)
		LB	46	91	35(7.6)	37(6.8)
		EX	19	37	26.6(17.6)	72(38)
		OR	2	50	0.2(0.2)	0.4(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Other Mollusca	PS	48	8	8.0(7.7)	105(83)
		SF	50	6	0.6(0.5)	10(7.6)
		LB	46	2	0.2(0.2)	9.0(0.0)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
ARTHROPODA/CRUSTACEA						
	Amphipoda	PS	48	29	1.9(1.3)	6.1(3.8)
		SF	50	30	0.61(0.16)	1.9(0.3)
		LB	46	48	0.7(0.2)	1.4(0.3)
		EX	19	19	0.07(0.05)	0.7(0.2)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Anomura	PS	48	29	0.91(0.64)	3.7(2.2)
		SF	50	24	0.2(0.08)	0.9(0.3)
		LB	46	63	3.8(1.4)	5.9(2.1)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Brachyura	PS	48	44	3.5(1.3)	9.2(2.8)
		SF	50	14	0.13(0.07)	1.1(0.5)
		LB	46	76	23.6(13.9)	30.2(18.6)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Caridea	PS	48	15	0.2(0.10)	1.3(1.2)
		SF	50	2	0.02(0.01)	0.2(0.0)
		LB	46	22	1.2(0.60)	3.8(1.5)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)

Table 3.1 continued

Phylum	Taxa	source	n	Prevalence (%)	mean(se) all ships	mean(se) when present
	Cirripedia	PS	48	85	832(559)	951(637)
		SF	50	66	96(34)	108(47)
		LB	46	63	18(5.4)	37(7.2)
		EX	19	16	0.8(0.5)	6.9(1.7)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	50	3.1(1.9)	4.8(4.3)
	Cladocera	PS	48	15	2.7(1.2)	21.7(5.1)
		SF	50	16	1.9(0.8)	11.7(3.7)
		LB	46	7	0.04(0.02)	0.6(0.1)
		EX	19	5	0.3(0.3)	5.7(0.0)
		OR	2	100	3.5(1.9)	3.5(1.9)
		HI	4	0	0(0.0)	0(0.0)
	Copepoda	PS	48	100	2395(664)	2395(664)
		SF	50	100	9416(2060)	9416(2060)
		LB	46	100	5116(685)	5116(685)
		EX	19	100	2345(645)	2345(645)
		OR	2	100	43(6.0)	43(6.0)
		HI	4	100	8.2(4.4)	8.2(4.4)
	Cumacea	PS	48	10	0.05(0.03)	0.6(0.2)
		SF	50	30	0.70(0.2)	2.1(0.5)
		LB	46	22	0.13(0.05)	0.6(0.2)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Decapoda (misc.)	PS	48	4	0.05(0.04)	1.3(0.7)
		SF	50	8	0.02(0.02)	0.5(0.2)
		LB	46	4	0.05(0.02)	2.5(0.0)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Isopoda	PS	48	25	0.70(0.40)	2.1(1.3)
		SF	50	18	0.34(0.26)	2.1(1.5)
		LB	46	9	0.06(0.03)	0.7(0.1)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Mysidacea	PS	48	2	0.007(0.007)	0.3(0)
		SF	50	54	2.48(0.6)	4.6(0.9)
		LB	46	78	3.52(0.8)	4.4(0.9)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	25	0.15(0.15)	0.6(0.1)

Table 3.1 continued

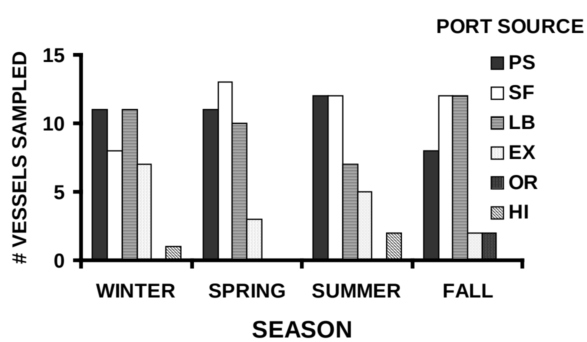
Phylum	Taxa	source	n	Prevalence (%)	mean(se) all ships	mean(se) when present
	Ostracoda	PS	48	25	0.35(0.16)	1.5(0.6)
		SF	50	8	0.40(0.20)	3.9(2.0)
		LB	46	17	0.28(0.14)	1.6(0.7)
		EX	19	16	0.93(0.54)	5.9(1.4)
		OR	2	50	0.6(0.6)	1.2(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Tanaidacea	PS	48	2	0.006(0.006)	0.3(0)
		SF	50	0	0(0.0)	0(0.0)
		LB	46	2	0.006(0.006)	0.3(0)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
BRYOZOA						
		PS	48	35	16.1(5.4)	40.7(11.5)
		SF	50	40	59(33)	147(80)
		LB	46	22	1.5(0.5)	6.7(1.7)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
PHORONIDA						
		PS	48	2	0.01(0.01)	0.5(0.0)
		SF	50	2	0.01(0.01)	0.7(0.0)
		LB	46	15	0.5(0.4)	4.2(2.7)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
CHAETOGNATHA						
		PS	48	33	0.7(0.4)	2.3(1.1)
		SF	50	12	0.5(0.3)	4.1(2.5)
		LB	46	72	5.8(2.2)	7.9(3.0)
		EX	19	21	0.2(0.1)	1.5(0.3)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
ECHINODERMATA						
		PS	48	33	32(15)	94(43)
		SF	50	12	6.3(4.8)	53(37)
		LB	46	26	5.8(3.5)	22(12)
		EX	19	5	0.3(0.3)	6.0(0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
CHORDATA						
	Cephalochordata	PS	48	0	0(0.0)	0(0.0)
		SF	50	0	0(0.0)	0(0.0)
		LB	46	9	0.1(0.01)	2.8(2.5)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)

Table 3.1 continued

Phylum	Taxa	source	n	Prevalence (%)	mean(se) all ships	mean(se) when present
	Fish	PS	48	10	0.05(0.02)	0.3(0.1
		SF	50	6	0.02(0.01)	0.5(0.1
		LB	46	7	0.04(0.02)	0.5(0.1)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Other Chordata	PS	48	21	4.9(2.2)	23.8(8.4)
	(incl. larvacea)	SF	50	8	5.2(3.5)	85(41)
		LB	46	63	59.1(30.6)	107(55)
		EX	19	5	0.06(0.06)	1.2(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
OTHER						
	Eggs	PS	48	73	87(39)	113(50)
		SF	50	66	39(16)	56(22)
		LB	46	61	141(41)	232(148)
		EX	19	21	6.3(4.1)	15(9.2)
		OR	2	100	12(11)	12(11)
		HI	4	20	7.3(2.4)	7.3(2.4)
	Trochophore					
		PS	48	33	20(8.2)	65(23)
		SF	50	16	16(10)	115(65)
		LB	46	30	11(4.6)	36(13)
		EX	19	0	0(0.0)	0(0.0)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)
	Unidentified larvae	PS	48	0	0(0.0)	0(0.0)
		SF	50	4	95(93)	2376(1388)
		LB	46	9	0.02(0.02)	0.4(0)
		EX	19	11	27(26)	253(178)
		OR	2	0	0(0.0)	0(0.0)
		HI	4	0	0(0.0)	0(0.0)

For June of 1997-1999, we sampled the ballast water of 31 tankers arriving to Port Valdez from the domestic ports of Puget Sound (n=14), San Francisco Bay (n=9), and Long Beach (n=9). The data for 1998 and 1999 are included in the total 169 vessels sampled during this study, and the data for 1997 are derived from our previous work (as above).

Figure 3.1. Number of oil tankers sampled upon arrival to Port Valdez. Shown are the number of ships from which ballast water samples were collected by source port (i.e., last port of call) and season. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI). Seasons include: Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December). Data were collected primarily from December 1997 – December 1998, and some additional data were collected in May-June 1999.

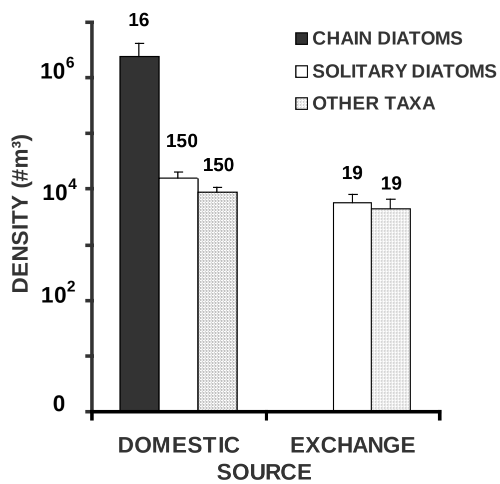


3C2. Abundance of Organisms in Ballast Water

(a) Total Density by Source

We measured an average of 12,637 (s.e. = 5,533) total organisms per m^3 in the ballast water for all 169 vessels from domestic and foreign source ports. This estimate excludes the chain-forming diatoms, which were detected in the samples from 16 domestic tankers. Although the chain-forming diatoms are difficult to quantify (as above), we estimated average densities in excess of one million organisms/m^3, approximately 100 fold higher than the densities of solitary diatoms and all other taxa measured for either domestic or foreign tankers (Fig. 3.2). We have excluded the chain-forming diatoms from the subsequent analyses and discussion of total density or abundance (i.e., abundance of all organisms) below.

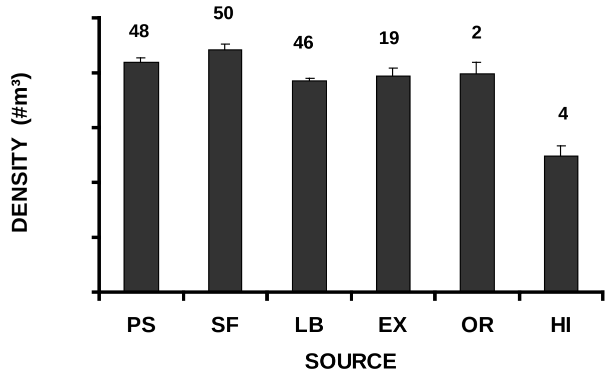
Figure 3.2. Densities of organisms in ballast water arriving to Port Valdez from foreign and domestic source ports. The estimated mean densities (#/m^3 and standard errors) are shown separately for chain-forming diatoms, solitary diatoms, and all other taxa in ballast water of ships arriving from each domestic ports and foreign ports. Chain-forming diatoms were only detected on domestic ships (n=16), whereas the other groups were present on all domestic (n=150) and foreign (n=19) arrivals that were sampled. The data include all sample dates. Since arrivals from foreign ports all underwent ballast water exchange in open ocean, the source is indicated as exchange.



The average total density was significantly greater in ballast water from domestic sources compared to that for foreign sources (Fig. 3.2; 1-way ANOVA, $F_{(1,168)} = 3.63$, $P = 0.048$). The chain-forming diatoms were only evident in the ballast water of domestic arrivals, increasing the magnitude of density differences between foreign and domestic traffic.

The total abundance of organisms in ballast water differed among domestic sources. Of the three major domestic ports, arrivals from Puget Sound and San Francisco Bay had significantly greater densities than those from Long Beach and foreign sources, whereas the latter two were not different (Fig. 3.3; ANOVA, $F_{(2,143)} = 3.71$, $P = 0.027$). We excluded both Oregon and Hawaii from this comparison, due to the limited sample size and absence of data for some seasons. Although average density from Oregon arrivals was similar to that for Long Beach and foreign arrivals, density for Hawaii arrivals was over 10-fold lower than all others.

Figure 3.3. Densities of organisms in ballast water arriving to Port Valdez for each source port. The estimated mean densities (#/m³ and standard errors) are shown for all organisms by source port. The data include all sample dates (sample size indicated above bars) but exclude chain-forming diatoms. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI).



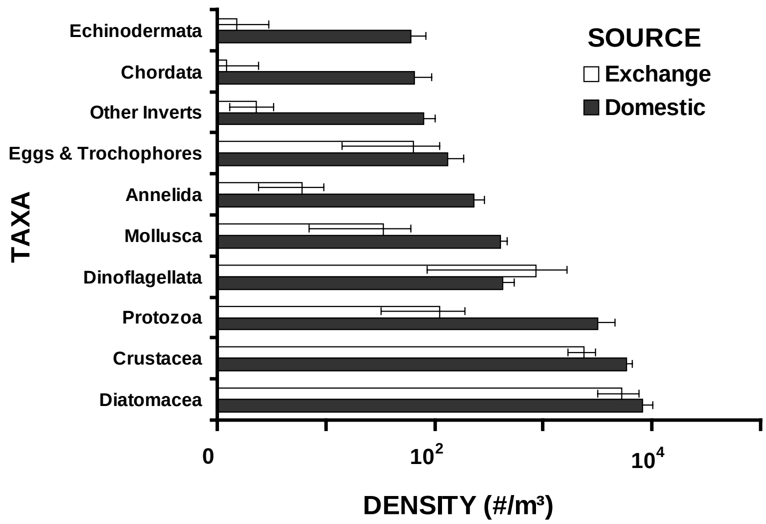
The average total densities among domestic source ports corresponded to voyage duration, with densities decreasing with voyage duration (see Fig. 2.7 of Chapt 2). Arrivals from Puget Sound and San Francisco Bay had the shortest voyage duration (average of 4.3 and 6.0 days, respectively) and highest densities. Tankers arriving from Hawaii had the longest voyage duration (average of 10.2 days) and lowest densities, whereas arrivals from Oregon and Long Beach were intermediate to the other domestic ports in both respects.

(b) Density by Taxonomic Group and Source

All ballast water samples contained living organisms, but the prevalence and density varied among taxonomic groups (Table 3.1). Copepods and diatoms were detected in ballast water from 100% of the ships sampled, and protozoans (primarily tintinnids) were found in nearly all samples. These three groups also exhibited the highest densities, dominating the plankton community in ballast water (see below).

As with the total density measures, most taxonomic groups also occurred at greater average densities in ballast water from domestic sources, when pooled, compared to that from foreign sources (Table 3.1 and Fig 3.4). For most groups, this difference was 10- to 100-fold. The magnitude of density differences between domestic and foreign sources were much less for crustaceans, primarily due to the presence of copepods (see Table 3.1) and solitary diatoms. Dinoflagellates were a notable exception to the general pattern, as average density was greatest in ballast water of the foreign arrivals.

Figure 3.4. Densities of major taxonomic groups in ballast water arriving to Port Valdez from foreign and domestic source ports. The estimated mean densities (#/m³ and standard errors) are shown separately for 10 different major groups of organisms in ballast water of ships arriving from each domestic ports (n=150) and foreign ports (n=19). Eight groups are distinct phyla that were most abundant in the ballast water, and two are composed of multiple phyla, including eggs and trochophores (which were abundant but could not be classified by phylum) and all other invertebrates. The data include all sample dates. Since arrivals from foreign ports all underwent ballast water exchange in open ocean, the source is indicated as exchange.



On a finer scale, significant variation existed in the abundance of taxonomic groups among specific source port systems (Fig. 3.5 and Table 3.1). More specifically, differences were present when comparing mean densities for each taxonomic group among Puget Sound, San Francisco Bay, Long Beach, and foreign arrivals (ANOVA, see Fig. 3.5 for statistically significant differences). Among these four ports, the densities of most taxa were relatively low for foreign arrivals, with the exception of diatoms and dinoflagellates. This pattern resulted from both the prevalence and densities of taxa among vessels. For example, the prevalence of most taxa was low in the ballast water of foreign arrivals, although the densities may not been particularly low for the few ships where a taxon was detected (Table 3.1). Across all arrivals, mean densities of the various taxa were generally lowest for both Oregon and Hawaii, although the limited sample size precludes any formal analysis.

In contrast to total organism density, the greatest average densities for taxonomic groups did not always correspond to the shortest voyage duration (Fig. 3.5 and Table 3.1). For example, the highest average densities of protozoans, crustaceans, and bryozoans were measured for San Francisco Bay arrivals, and the brachyuran crabs were most abundant in samples from Long Beach.

(c) Seasonal Variation in Density

Significant differences among months were present in the total densities of organisms present in domestic ballast water (Fig. 3.6; ANOVA, $F_{(11,168)} = 1.98$, $P = 0.033$). This resulted primarily from a relative increase during the spring and summer months.

Figure 3.5. Densites of major taxonomic groups in ballast water arriving to Port Valdez for each source port. The estimated mean densities (#/m³ and standard errors) are shown separately for 10 different major groups of organisms in ballast water of ships by source port. Eight groups are distinct phyla that were most abundant in the ballast water, and two are composed of multiple phyla, including eggs and trochophores (which were abundant but could not be classified by phylum) and all other invertebrates. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI). The data include all sample dates. Sample sizes for each source port as shown in Figure 3.3. Indicated by * are those taxa where mean density among ports, excluding HI and OR, is significantly different by ANOVA with confidence ≥95%.

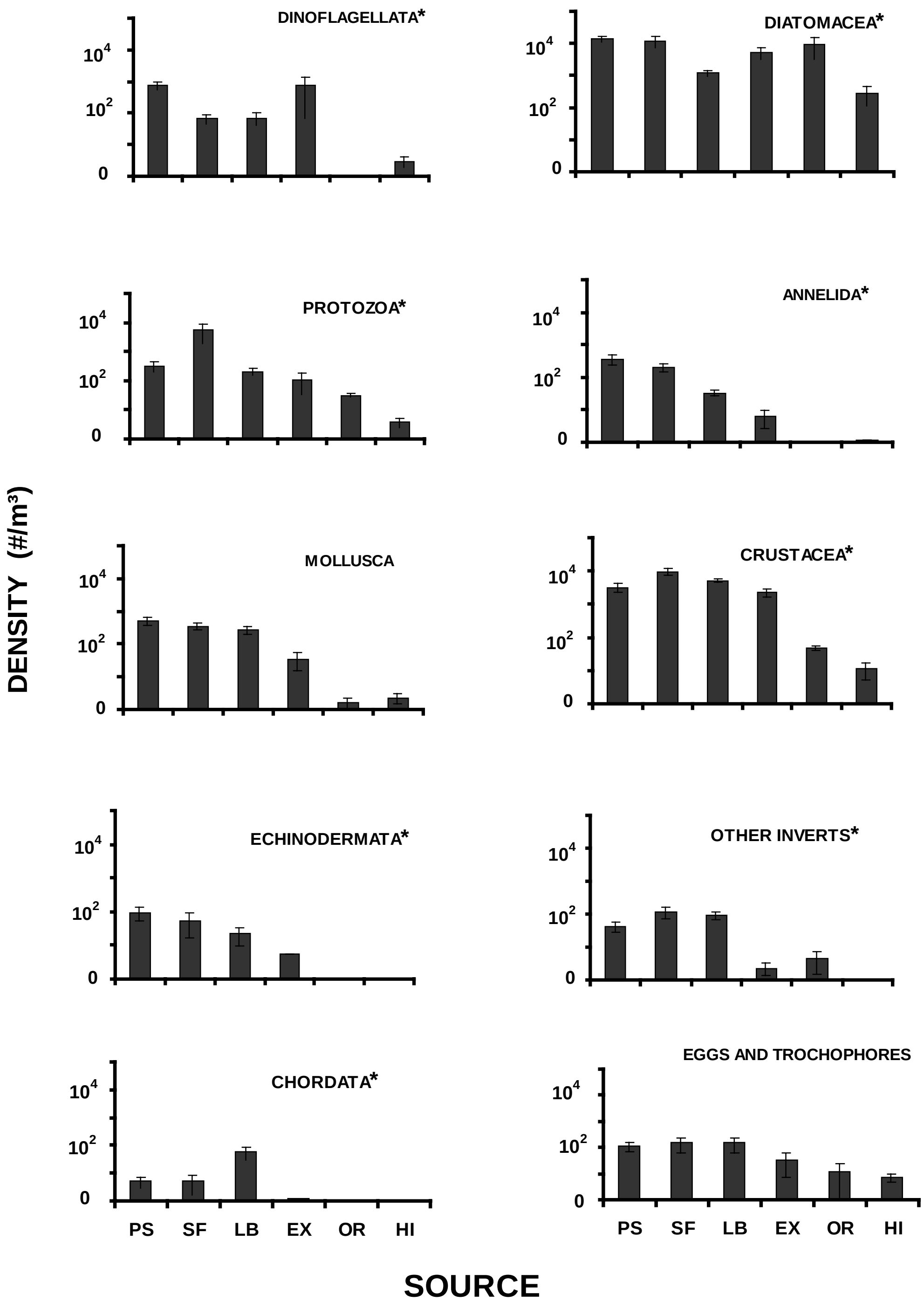
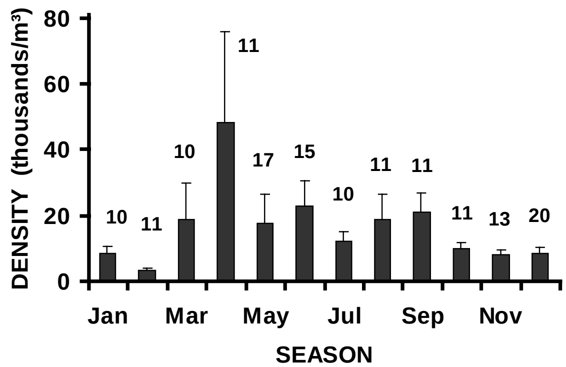
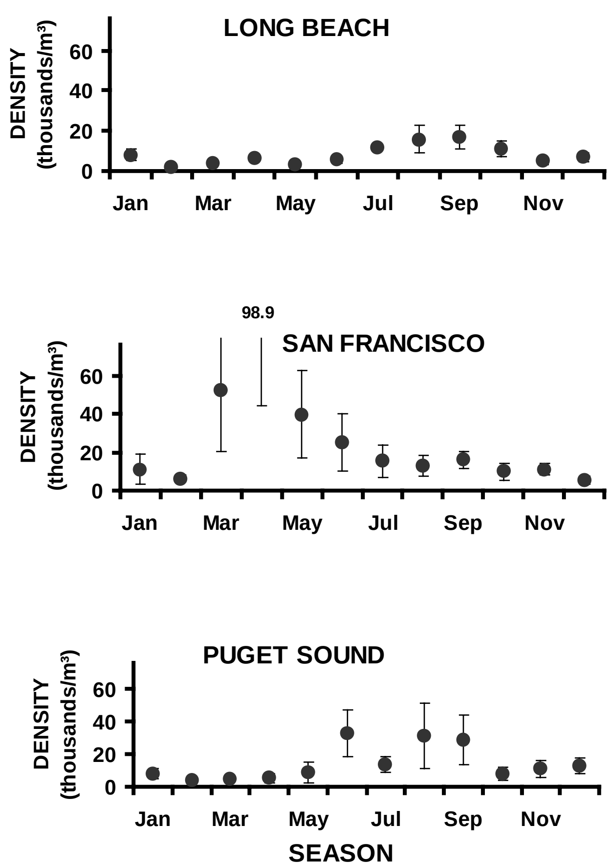


Figure 3.6. Monthly densities of organisms in ballast water arriving to Port Valdez from domestic source ports. The estimated mean densities (#/m³ and standard errors) are shown for all organisms, except chain-forming diatoms, by month. The data for all domestic source ports are included in each month (sample size shown above bars).



The seasonal pattern in total density varied among arrivals from the 3 major domestic ports (Fig. 3.7). Arrivals from San Francisco Bay exhibited a strong spring peak in total plankton density, whereas the peak appeared later in arrivals from Puget Sound. In contrast, the density of organisms arriving from Long Beach was relatively stable throughout the year.

Figure 3.7. Monthly densities of organisms in ballast water arriving to Port Valdez by domestic source ports. For each of the three major domestic source ports, the estimated mean densities (#/m³ and standard errors) are shown for all organisms, except chain-forming diatoms, by month. Sample size for each source port as follows, from left to right: Long Beach – 3,4,4,4,5,4,2,2,3,4,6,5; San Francisco –2,3,3,5,6,5,2,4,4,4,5,7; Puget Sound – 5,3,3,2,5,6,5,4,4,3,2,6.



For the individual taxonomic groups, densities varied both by source port and month (Fig. 3.8). In general, peak densities occurred between spring and summer months for all taxonomic groups, but the timing of these peaks differed among groups. Summed across the three major domestic ports (Puget Sound, San Francisco Bay, and Long Beach; Fig. 3.8a):

- Dinoflagellates, echinoderm larvae, chordates, and the combined eggs and trochophores exhibited peak mean densities in late summer;
- Protozoans and diatoms exhibited a spring to early summer peak in mean density.
- Molluscs and crustaceans for these combined ports were relatively high from spring through summer, exhibiting a bimodal distribution with spring and later summer peaks;
- Annelids exhibited peaks in density during the summer months of June and August;
- All other invertebrates, when combined, had relatively high densities from early spring through fall compared to the remainder of the year.

The relative contributions of the three port systems to the overall temporal patterns varied significantly (Fig 3.8b-d). The general seasonal patterns (i.e., spring-summer peaks) in density were similar among ports, but clear differences existed in the magnitude and month of peak densities among ports. As noted previously for total density across the entire year (Fig. 3.5), the magnitude of peaks for the taxonomic groups did not correspond consistently to voyage duration.

(d) Annual Variation in Density

There were significant differences among years in the total density of plankton arriving from the three major ports for June 1997-1999 (Fig. 3.9). A 2-way ANOVA revealed differences among years ($F_{(2,32)} = 3.28$, $P = 0.055$) but not ports ($P>0.05$), and the interaction was not significant ($P>0.05$).

The magnitude of variation among years was more pronounced for the individual taxonomic groups in each of these ports (Fig. 3.10). Over half of the taxonomic groups exhibited significant differences among years, when analyzed individually for each port source (1-way ANOVA, see Fig 3.10 for statistically significant differences). As discussed above, some groups (e.g., echinoderm larvae and chordates) could not be compared statistically, due to low prevalence among ships.

Interestingly, the changes among years were not consistent among port sources. For example, dinoflagellates increased in successive years for Puget Sound and Long Beach arrivals, but was greatest in 1998 and virtually absent in the other two years for San Francisco arrivals. While peak years in protozoan and crustacean densities were similar among the port sources, the peak years for all other taxa were highly divergent among the port sources.

Figure 3.8. Monthly densities of major taxonomic groups in ballast water arriving to Port Valdez from domestic source ports. The estimated monthly mean densities (#/m³ and standard errors) are shown separately for 10 different major groups of organisms in ballast water of ships arriving from domestic ports. Eight groups are distinct phyla that were most abundant in the ballast water, and two are composed of multiple phyla, including eggs and trochophores (which were abundant but could not be classified by phylum) and all other invertebrates. For each taxonomic group, the monthly mean densities are shown for: (a) Puget Sound; (b) San Francisco; (c) Long Beach; and (d) the three major ports combined. Sample size for each port as indicated in Figure 3.7.

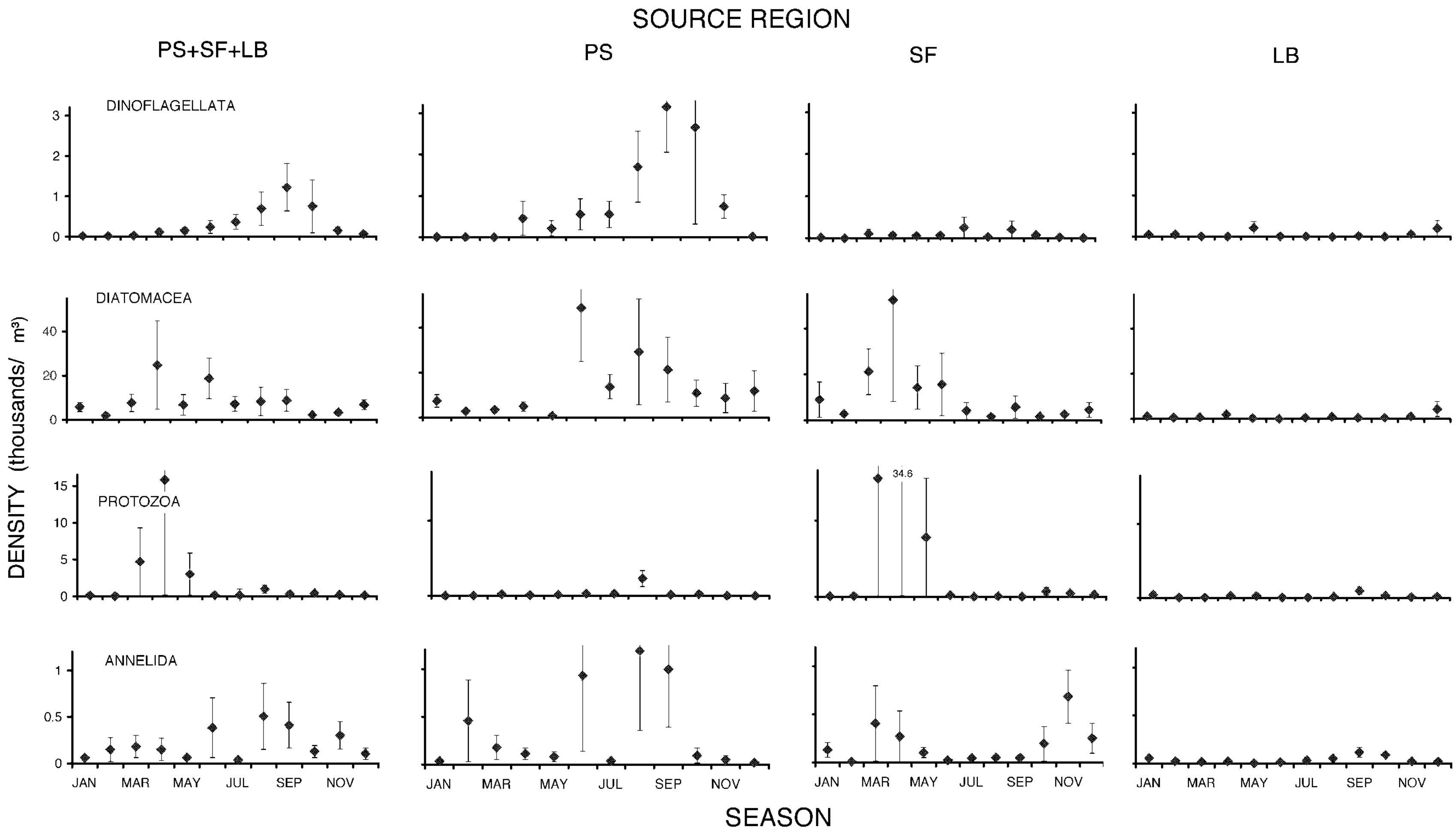


Figure 3.8 continued.

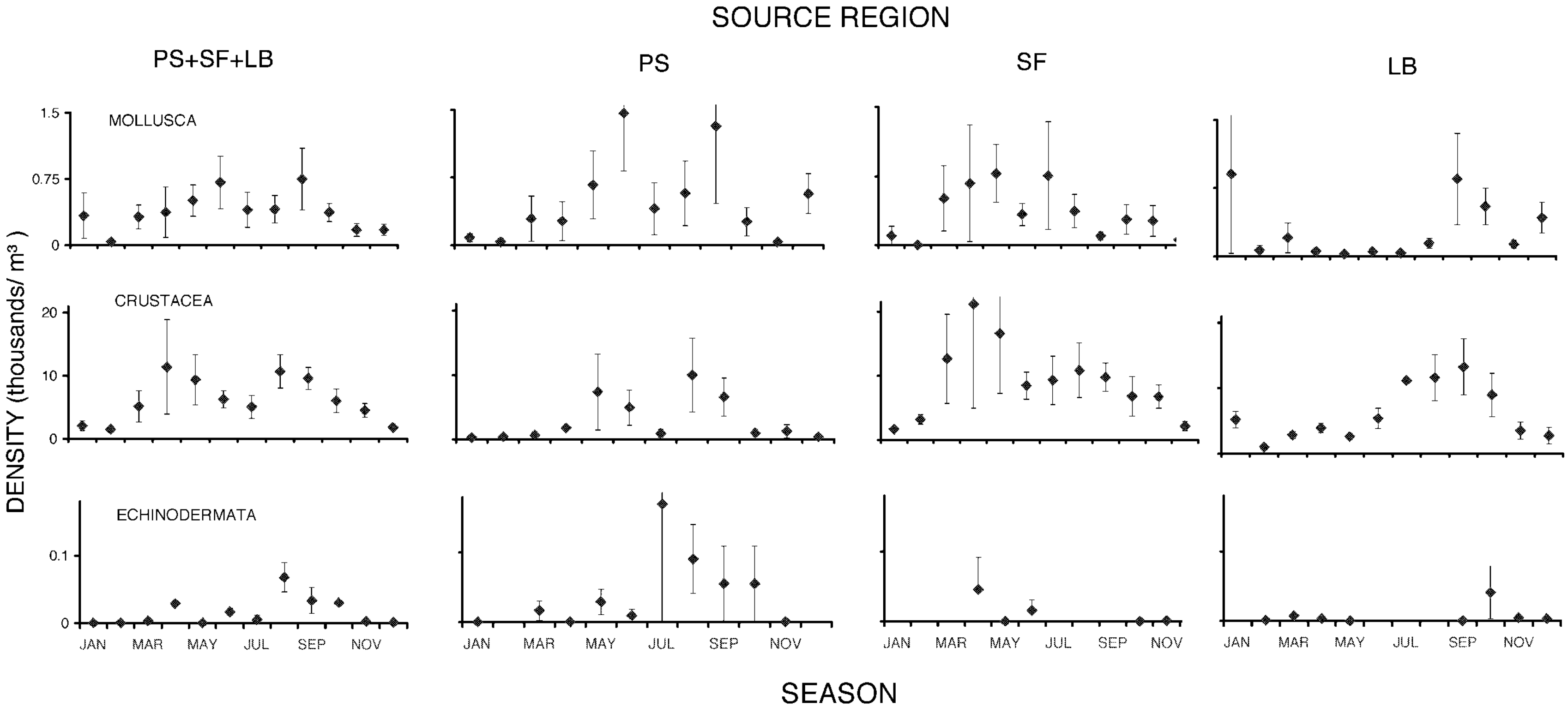


Figure 3.8 continued.

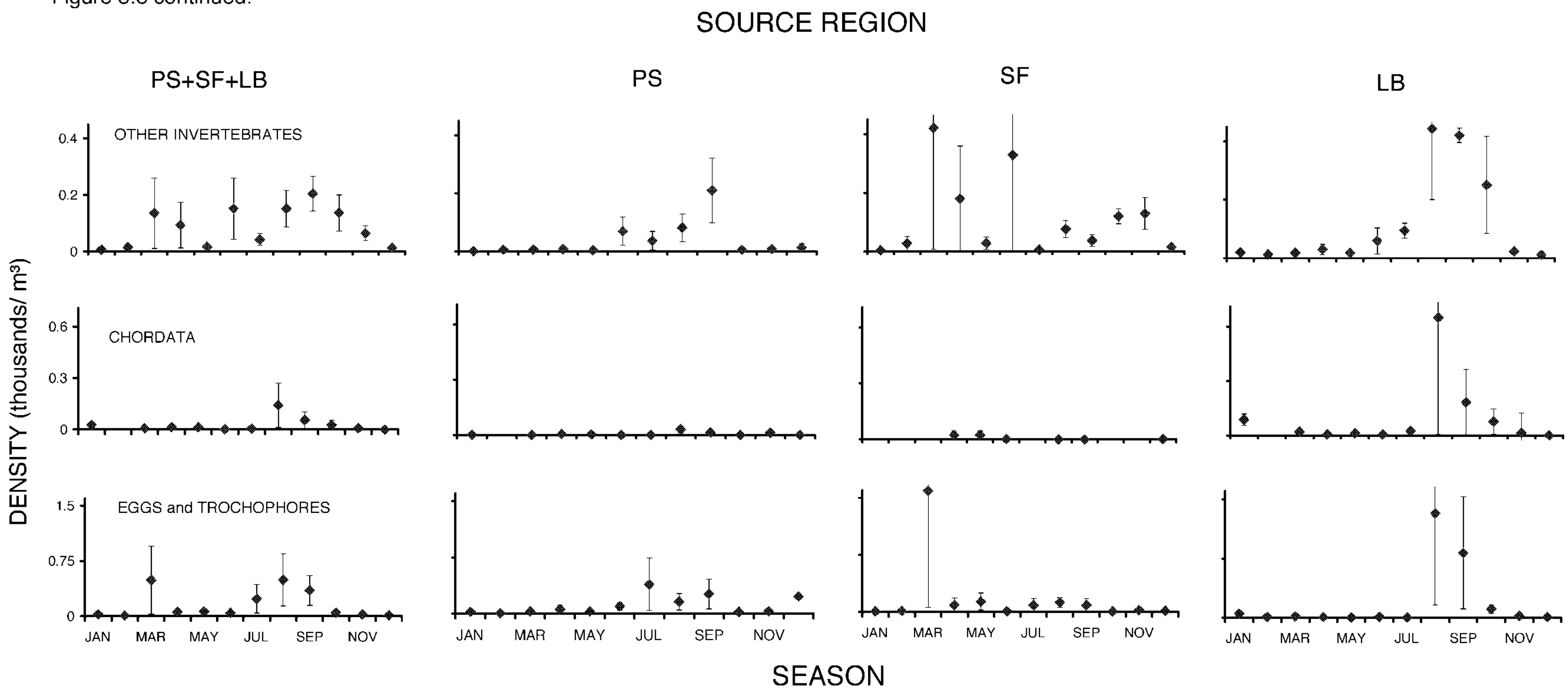


Figure 3.9. Densities of organisms in the ballast water arriving to Port Valdez from domestic ports in June of three consecutive years, 1997-1999. The estimated mean densities (#/m³ and standard errors) are shown for all organisms, excluding chain-forming diatoms, by source port in each year (sample size indicated above bars). Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB). Densities are also shown by year for all three source ports combined (Overall).

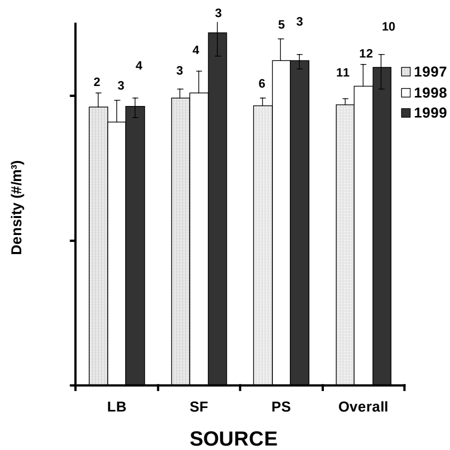
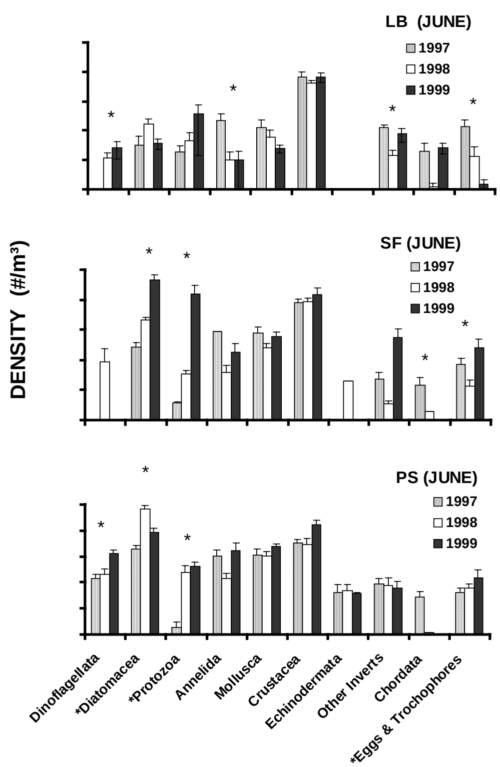


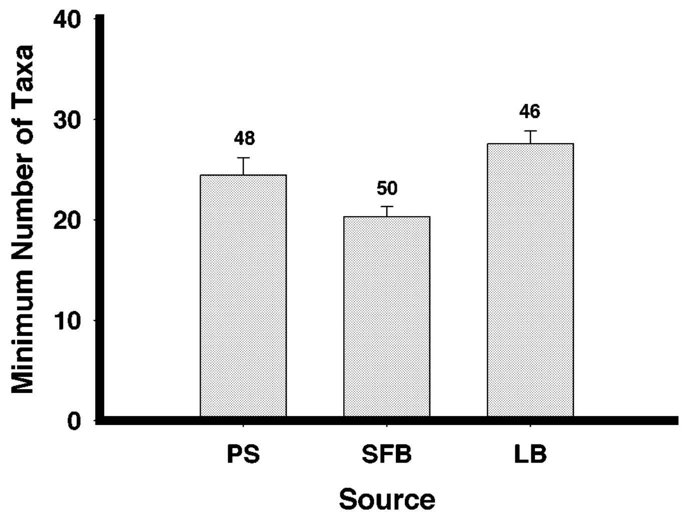
Figure 3.10. Densities of major taxonomic groups in the ballast water arriving to Port Valdez from domestic source ports in June of three consecutive years, 1997-1999. The estimated mean densities (#/m³ and standard errors) are shown for 10 different major groups of organisms in ballast water of ships arriving by year from three different source ports. Eight groups are distinct phyla that were most abundant in the ballast water, and two are composed of multiple phyla, including eggs and trochophores (which were abundant but could not be classified by phylum) and all other invertebrates. Sample size for each source port and year as indicated in Figure 3.9. Indicated by * are instances where ANOVA showed significant differences in density among years (above bars) and among ports (below taxa labels) with confidence ≥95%.



3C3. Diversity of Organisms in Ballast Water

In a preliminary analysis of our Fine Analysis data (see Methods), there was a significant difference in the minimum number of taxa, and/or species richness, detected among arrivals from the three main domestic ports (Fig. 3.11). The average species richness was greatest for Long Beach arrivals and lowest for San Francisco Bay arrivals, and it does not correspond to voyage duration.

Figure 3.11. Minimum number of taxa detected in the ballast water arriving to Port Valdez by domestic source ports. Shown are the mean number (including standard errors and sample size, above bars) of distinctly different taxa observed in plankton samples of ships from each source port. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB). All sample dates included.



The season of peak species richness differed among port sources (Fig. 3.12). Arrivals from Puget Sound and San Francisco Bay exhibited peaks in mean species richness in the spring and summer, whereas those from Long Beach had their highest species richness in the fall and spring. Subsequent analyses indicated differences among source ports for each season, as well as differences among seasons for each source port (1-way ANOVA, Fig. 3.12 indicates statistically significant differences).

To date, we have identified 14 different nonindigenous species arriving to Port Valdez in the ballast water of oil tankers (Table 3.2). One is a fish species and all the other species are crustaceans (copepods and amphipods, which have successfully invaded the respective source ports of arriving tankers. To date, all of these identified NIS have been in ballast water from San Francisco and Long Beach.

We expect the cumulative list will increase, as final identifications are still underway for the Fine Analysis data. Upon completion, we will report the frequency and density of these NIS in ballast water arriving from the respective source ports.

Figure 3.12. Minimum number of taxa detected in the ballast water arriving to Port Valdez among domestic source ports and seasons. Shown are the mean number (including standard error above bars) of distinctly different taxa observed in plankton samples of ships from each source port and season. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB). Seasons include: Winter, (December – February); Spring (March – May); Summer (June – August); and Fall (September – November). Indicated by * are significant differences (ANOVA with confidence ≥95%) in diversity among seasons within port (see legend) and among ports within season (see x-axis labels).

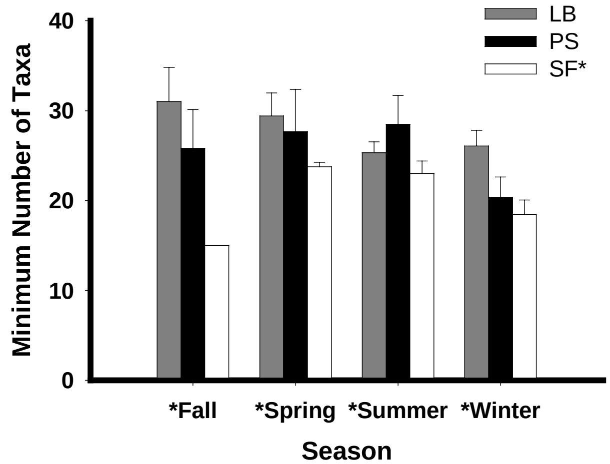


Table 3.2. Nonindigenous species identified in ballast water arriving to Port Valdez. The source of ballast water is indicated in which each species was detected; when two sources are indicated, the species was found in ballast water from each source port. Source ports are: San Francisco Bay, CA (SF); Long Beach, CA (LB).

Broad Taxa	Species	Ballast Source
Amphipoda	*Ampelisca abdita*	SF and LB
	Monocorophium acherusicum	SF
	Sinocorophium heteroceratum	LB
	Gammarus daiberi	SF and LB
	Grandidierella japonica	SF
Copepoda	*Limnoithona tetraspina*	SF
	Oithona davisae	LB
	Acartiella sinensis	SF
	Pseudodiaptimus marinus	SF
	Pseudodiaptimus forbesi	SF
	Sinocalanus doerrii	SF
	Tortanus dextrilobatus	SF
Mysidacea	*Acanthomysis bowmani*	SF
Chordata	*Acanthogobius flavimanus*	SF

3D. Discussion

Our analysis indicates that significantly greater numbers of organisms are discharged into Port Valdez and PWS in oil tankers arriving from domestic ports compared to those from foreign ports. This results from the number of arrivals and the density of organisms in their ballast water, as both are greatest for the domestic arrivals. Accounting for number of arrivals and density (by source port and season), Table 3.3 estimates the total supply of plankton that we sampled to be roughly 264 billion organisms in 1998. Of this, approximately 3% arrived from foreign traffic.

The differences observed in total density, as well as taxon-specific density, among arrivals from different source ports may result from a combination of multiple factors, including (a) differences in initial densities, (b) differences in survivorship, and (c) effects of ballast water exchange (conducted for foreign but not domestic arrivals).

Table 3.3. Estimated number of large, planktonic organisms delivered in tankers' ballast water to PWS and Port Valdez in 1998. Shown by source port and season are (1) the estimated total ballast water volumes, (2) mean densities of planktonic organisms, including standard errors and sample size, and (3) total number of planktonic organisms arriving in the ballast water of oil tankers. Total Volumes are derived from Table 2.1. Mean densities were estimated from analysis of plankton samples, which were collected by 80micron net, and exclude chain-forming diatoms (see text for description). Where no samples were available for a season (e.g., Hawaii and Oregon), the grand mean across all samples of that source port was used. The bottom row (Overall) estimates the total ballast water volumes and total organisms delivered as a sum. Source ports include: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB); Foreign port with open-ocean exchange (EX); Columbia River, Oregon (OR); and Barbers Point, Hawaii (HI). Seasons include: Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-November).

			Density organisms (#/m³)				
			Phyto.+Zoopl.	Zoopl.		Phyto.+Zoopl. Delivered	Zoopl. Delivered
Port/Source	Season	Total BW (m³)	Mean(se)	Mean(se)	n	Billions	Billions
	Winter	1,802,432	5963(1432)	879(343)	11	10.75	1.58
	Spring	1,885,260	17602(9543)	3427(1423)	11	33.18	6.46
PS	Summer	2,032,432	24116(8198)	8539(3062)	12	49.01	17.35
	Fall	1,796,382	8546(2636)	1269(384)	8	15.35	2.28
	Grand total	7,516,506			42	108.30	27.68
	Winter	1,082,594	24686(13263)	13435(9497)	8	26.72	14.54
	Spring	1,345,169	48504(23134)	29876(14848)	13	65.25	40.19
SF	Summer	1,573,660	14572(2914)	10696(1959)	10	22.93	16.83
	Fall	1,340,469	8840(1961)	7162(1488)	12	11.85	9.60
	Grand total	5,341,892			43	126.75	81.17
	Winter	585,468	4298(1094)	3426(954)	11	2.52	2.01
	Spring	395,187	4848(667)	3734(490)	10	1.92	1.48
LB	Summer	504,630	15951(3274)	15145(3175)	6	8.05	7.64
	Fall	390,180	6574(1613)	5508(1639)	12	2.57	2.15
	Grand total	1,875,465			39	15.05	13.27
	Winter	379,377	8791(3127)	1852(423)	7	3.34	0.70
	Spring	265,764	3466(2144)	1634(775)	3	0.92	0.43
EX	Summer	149,280	18447(14784)	3393(3141)	5	2.75	0.51
	Fall	141,168	3571(1398)	3179(1100)	2	0.50	0.45
	Grand total	935,589			17	7.51	2.09
	Winter	262,638	-	-	0	2.49	0.02
	Spring	113,000	-	-	0	1.07	0.01
OR	Summer	97,287	-	-	0	0.92	0.01
	Fall	273,966	9474(6138)	65(13)	2	2.60	0.02
	Grand total	746,891				7.08	0.05
	Winter	189,994	772	17	1	0.15	0.00
	Spring	111,145	-	-	0	0.05	0.00
HI	Summer	142,596	102(72)	14(2)	2	0.01	0.00
	Fall	108,370	-	-	0	0.05	0.00
	Grand Total	552,105			3	0.26	0.01
Overall		16,968,448			145	264.94	124.26

Among the domestic arrivals, many of the observed differences in prevalence and density probably result from initial differences at the locations where ballast tanks are filled. For example, this may explain the especially strong differences observed in densities of some organisms, such as dinoflagellates and protozoans (Fig. 3.8), among source ports. Although we have very limited data on the initial densities within ballast tanks at the start of the tankers' voyages (see Chapter 5), the published literature indicates that significant variation in the density and diversity of plankton communities among these and other source ports should be expected. In this context, it is perhaps important to recognize some conspicuous differences that existed among the domestic source ports. Certainly there are many differences in the habitat characteristics (e.g., composition, extent, quality, proximity to ports, etc), which may influence what is initially entrained in the tankers' ballast tanks. However, there are also two physical/chemical characteristics that are widely recognized to influence the composition and dynamics of biotic communities: temperature and salinity. Temperature clearly differed among domestic port systems, increasing from north to south. Among the major domestic ports, salinity was extremely low for San Francisco Bay compared to Puget Sound and Long Beach in 1998, in which rainfall was relatively high (due to El Nino Southern Oscillation) and had a disproportionately large effect on salinity in San Francisco Bay.

Despite any initial differences in plankton communities, it is evident that survivorship during transit can contribute strongly to the observed differences in biota arriving from various source ports. A variety of studies have now shown a significant decline in the density of planktonic organisms in ballast tanks during voyages, and the magnitude of decline is time-dependent, increasing significantly with voyage duration (Wonham et al. 1996, LaVoie et al 1999, Smith et al. 1999; however see below for possible exceptions). We have obtained similar results aboard oil tankers arriving to Port Valdez (Chapter 5). For most taxa, the decline has been attributed to mortality. However, for a few groups included in our analysis, such as diatoms and dinoflagellates, it is possible for the organisms to develop dormant stages that can accumulate on the bottom of ballast tanks.

Ballast water exchange undoubtedly had a significant effect on the plankton community associated with foreign arrivals, contributing to the major differences in biota between foreign and domestic arrivals. Exchange can significantly reduce the concentration of many organisms within ballast tanks, and it can also entrain additional organisms from the oceanic site of exchange (Ruiz et al. 1997, 1999; see also Chapter 5). In our study, the combination of ballast water exchange and voyage duration (which was relatively high for foreign ports) would both operate reduce initial densities of coastal plankton and contribute to the lower abundance of many taxonomic groups in ballast water of foreign arrivals compared to that from domestic arrivals. In contrast, the domestic arrivals did not undergo ballast water exchange and arrived to Port Valdez with the initial coastal water, following a relatively short voyage.

We hypothesize that the combined effects of ballast water exchange and voyage duration, instead of initial densities, were responsible for observed differences in abundance of coastal organisms between domestic and foreign arrivals. More specifically, we suggest that these forces reduced the densities of predominantly coastal organisms such as cnidarians, flatworms, annelids, molluscs, chordates, echinoderms, bryozoans, barnacles, and many other crustacean groups (see Chapter 5 for further discussion).

The effects of ballast water exchange for some taxonomic groups, and its contribution to observed differences in their abundance between foreign and domestic arrivals, is not so well resolved. Unlike the low abundance of coastal organisms, foreign arrivals had relatively high densities of dinoflagellates, copepods, and solitary diatoms in their ballast water. Most of these organisms were probably oceanic in origin and were entrained during the exchange process. This is certainly the case for the copepods, for which the species were recognized as oceanic and the generation time is in excess of the voyage duration. However, there is some suggestion that an increase of phytoplankton can result from ballast water exchange, as generation times are relatively short and the organisms may respond rapidly to changes in water quality following exchange (Gollasch et al.1998, LaVoie et al. 1999). The extent to which populations of these taxa, either of coastal or oceanic origin, may have increased following exchange is uncertain.

The temporal variation observed in plankton densities was largely expected. In general, the seasonal peaks in density corresponded to seasonal production and density variation measured for plankton in north temperate estuaries. The magnitude of variation observed among years also is evident in field studies, including especially an El Niño event such as that for 1998. The heavy rainfall in that year was associated with especially high densities of protozoans, solitary diatoms, and copepods in the arrivals from San Francisco Bay.

Although we have identified 14 nonindigenous species in the ballast water arriving to Port Valdez, and have provided some comparative data on species richness, these results must be viewed with caution. Clearly these numbers are minimum estimates. Although both estimates will increase upon completion of the voucher identification (see results), the measures can only be applied to a subset of the taxa and will always represent a minimum value. More specifically, most of the larval invertebrates (e.g., molluscs, barnacles) include many different species, which cannot be readily distinguished as larvae. All bivalve larvae are therefore treated as one species in our analysis, masking the diversity that most certainly exists. Thus, this approach is useful primarily in describing minimum diversity of native and exotic species arriving in ballast water, and does not necessarily reflect actual diversity patterns in space or time.

It is also important to recognize that our conclusions about patterns of abundance and diversity are focused on the large (>80 micron) segment of the plankton community within ballast tanks. We have provided some additional qualitative information about the macrofauna found on the bottom of tankers' ballast tanks (Chapt 6, this report). Thus, our data do not address density or diversity of microorganisms and taxa missed by an 80 micron mesh. The dynamics of these groups are very much in debate, as few good data exist to discern the potential for population changes (either declines or increases), due especially to mortality, dormancy and cyst formation, or ballast water exchange.

Beyond the variation in plankton delivery by time and source port, our data underscore that both the concentration and cumulative amount of plankton arriving in tankers' ballast water to Port Valdez and PWS is relatively high compared to that estimated for other ports (e.g., Carlton and Geller 1993, Smith et al. 1999). This results from both the volume of water delivered (Chapter 2) and the concentration of plankton, as both values are relatively high. We hypothesize that the abundant plankton results from the short voyage duration for domestic traffic, accounting for approximately 97% of the total tanker arrivals at present. In contrast, although Chesapeake Bay receives more total ballast water per year than PWS, most of the ballast water comes from Europe, arriving in 10-14 days with an average concentration of 200 organisms / m^3 (Smith et. al. 1999; Ruiz et al., unpubl. data). Furthermore, it appears that ballast water arriving to the Chesapeake from domestic ports also has a lower density than that arriving to PWS from domestic ports.

Finally, from an invasion perspective, there are three unusual features of our analysis that deserve explicit mention:

- This is the most comprehensive analysis of domestic, coastwise ballast transfer. Most organisms that arrive in ballast water to PWS come from domestic source ports, which are themselves highly invaded. Thus, our study examines the opportunity for sequential invasions, which can "leapfrog" up the coast following initial colonization of North America.
- The delivery of ballast water by tankers to Port Valdez is a relatively recent development, beginning in 1977. Although many features may influence the risk of invasion, it is often considered to increase with the frequency, density, and duration of inoculation. Our results indicate that the risk associated with the first two of these is relatively high. However, the operation of this transfer mechanism has only existed for three decades. Even at the current rates of organism delivery (see above), invasion success may be influenced strongly by duration. In contrast, many other ports have been receiving ballast water and ballast materials for a century or more.
- Delivery of ballast water from foreign sources by tankers is even a more recent development, beginning in 1996. Although this accounted for only 3% of the total volume of ballast water delivered in 1998, all of the ballast water delivered by foreign arrivals had undergone exchange. Some coastal organisms remained in the exchanged tanks (see Chapter 5); however, the total supply of organisms from foreign ports is both relatively small and extremely recent compared to other port systems.

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Chapter 4. Predicting Initial Survival of Ballast Water Organisms

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4A. Purpose

When ballast water is discharged into the receiving waters, the associated plankton encounters new conditions without time to acclimate. Survival may depend on short-term tolerances to accute variation in salinity-temperature combinations. If temperature-salinity conditions of ballast water closely match those of the receiving waters, then initial survival is predicted to be higher than when the conditions do not match closely. To determine if NIS arriving in ballast water can survive the initial exposure to temperature-salinity conditions in Prince William Sound, we tested the match of conditions between ballast water and ship-side water, and the short-term survival of ballast organisms in representative combinations.

4B. Temperature & Salinity: Match of Source and Receiving Ports

4B1. Methods

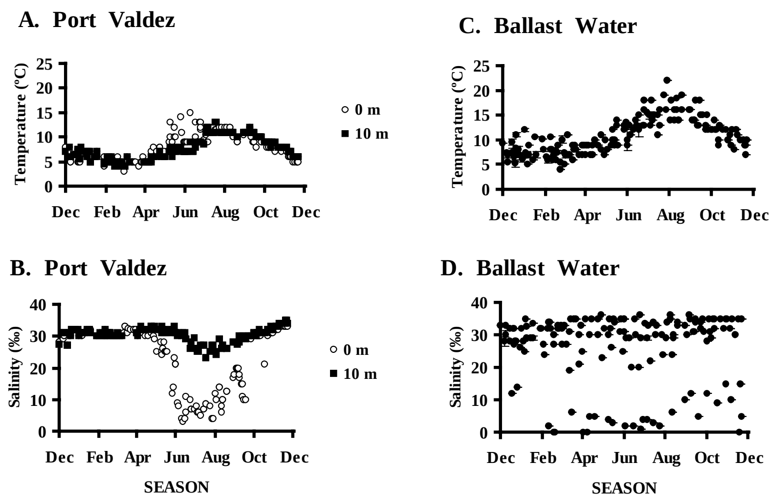
Samples of ballast water were collected from segregated ballast tanks and from ambient waters adjacent to each ship sampled for ballast water plankton. A small niskin bottle lowered through hatch covers into the ballast tanks and lowered off the end of the ship's berth to collect samples from the water surface and 10 m depth, which was determined to be below a potential thermocline or pycnocline. Salinity was determined to the nearest ppt with a refractometer and temperature to the nearest 0.5 ^{o}C with a hand-held thermometer.

4B2. Results

Temperature and salinity of the receiving waters of Port Valdez exhibit a distinct seasonal pattern (Fig. 4.1a, b). Water temperatures of Port Valdez at 10 m depth cycle seasonally from a low of 4 ^{o}C in February to a high of 13^{o}C in July. Surface water temperatures are more variable and 1-5 ^{o}C warmer than deep water in the spring. Salinity during December to April was about 31 ppt and the water column was well mixed. Water in Port Valdez was sharply stratified by depth as snow melted from late April to September, with salinities of surface waters dropping to 4-15 ppt while salinities at 10m depth declined only to about 25 ppt.

Water in the segregated ballast tanks rarely exhibited much depth stratification. Temperatures of segregated ballast water varied seasonally with a winter mean low of about 7.5 ^{o}C (+-3^{o}C) and a summer high of about 16^{o}C (+-3^{o}C) (Fig. 4.1c). Salinities of ballast water did not exhibit a seasonal pattern, but salinities fell into two distinct ranges, depending on the source port of the tanker (Fig. 4.1d). Most tankers delivered high salinity ballast water (ca. 30 ppt, range 20-36 ppt). In contrast, about 20% of the tankers throughout the year released ballast water of low salinity (ca. 4 ppt, range 0-14 ppt, mainly from Benicia in San Francisco Bay, especially during the heavy El Niño rains in 1998).

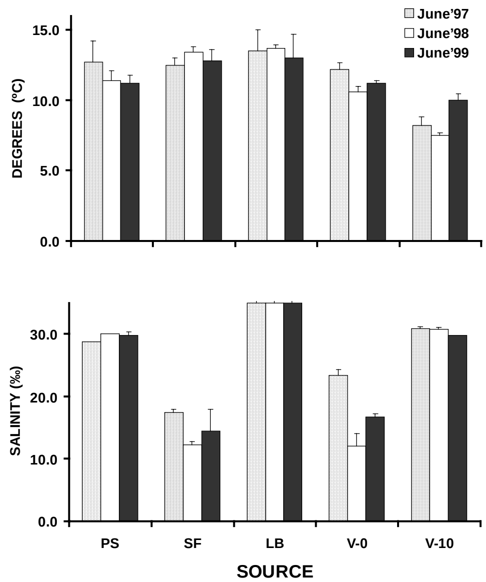
Figure 4.1 Seasonal Cycles of Temperatures and Salinities of Receiving and Ballast Water. Shown above are temperatures (A) and salinities of Port Valdez, Alaska at 0m and 10m depth. Shown below are average temperatures (C) and salinities (D) of ballast water discharged into Port Valdez by tankers. Averages are for two tank depths (0m and 10m depth) combined.



Annual variation in temperature and salinity among source ports and receiving waters of Port Valdez was compared in June of 1997, 1998, and 1999 (Fig. 4.2). Temperature of ballast water from Long Beach (13-14^oC) and San Francisco(13-14^oC) was about a degree warmer than from Puget Sound (11-12^oC), but temperature of ballast water from Puget Sound was similar to the surface water of Port Valdez (11-12^oC), which was 1-3^oC warmer than water at 10 m depth (7-9^oC). However, there were no significant differences in temperatures among years. Salinity of ballast water from Long Beach (33ppt) was highest of the source ports, while that from San Francisco (10-14 ppt) was the lowest, and Puget Sound was intermediate (29-30 ppt). Surface salinity at the surface of Port Valdez (10-21ppt) was similar to ballast water from San Francisco Bay, while salinity at 10 m depth in Port Valdez (29-30 ppt) was similar to ballast water from Puget Sound. Salinity of ballast water from Long Beach and Puget Sound, as well as deep water at Port Valdez, did not differ among years. However, salinity of ballast water from San Francisco Bay and at the surface in Port Valdez was lowest in 1998, highest in 1997 and intermediate in 1999.

Thus, there was often a good correspondence of physical characteristics between ballast water and receiving water, depending on the source port, time of year and water depth in Port Valdez. Temperatures of ballast water were a bit higher than of receiving waters, but the differences were not great, and there was considerable overlap between ballast and receiving water throughout the year. Higher salinities of ballast water from most source ports were similar to deeper water of Port Valdez throughout the year and similar to surface water during winter and early spring. During summer the vertical stratification in Port Valdez resulted in ballast water from both high and low salinities having good correspondence in major areas of the receiving waters. Based on these physical characteristics of ballast and receiving water, temperatures of Port Valdez would not appear to prevent survival of organisms from most source ports. Nonindigenous species from nearly fresh water, estuarine and full-strength sea water may also find corresponding salinities in Port Valdez.

Figure 4.2 Annual Variation in Temperature and Salinity of Ballast and Receiving Water. Shown are temperatures (top) and salinities (bottom) of ballast water arriving to Port Valdez in tankers from west-coast source ports (PS = Puget Sound, WA; SF = San Francisco, CA; LB = Long Beach, CA), and of recieving waters of Port Valdez at surface (V-0) and 10m depth (V-10). Bars indicate means and S.E. for June 1997, 1998, 1999.

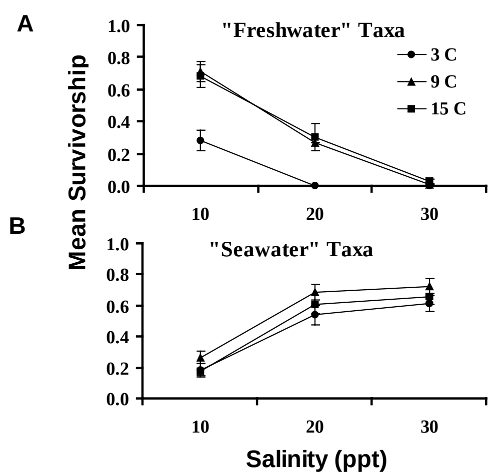


4C. Temperature-Salinity Tolerance Experiments of Ballast Water Plankton

4C1. Methods

We conducted experiments at the SERC laboratory in Valdez to test for temperature x salinity tolerance of selected planktonic organisms arriving in segregated ballast water. Based on the two salinity categories of segregated ballast water released into Port Valdez (see above, Fig. 4.1a, b), we grouped the experimental organisms into "freshwater taxa" and "seawater taxa" (Fig. 4.3).

Figure 4.3. Survivorship of Ballast Water Organisms in Salinity x Temperture Experiments. Survivorship of ballast water organisms at 96 hour exposure to 9 combinations of salinity and temperature in laboratory experiments. Three salinities (10, 20, 30 ppt) and three temperatures (3, 9, 15ºC) were tested to represent the range of seasonal variation in Port Valdez. (A) Trials with organisms from ballast water with fresh water sources (n = 9). (B) Trials with organisms from ballast water with seawater sources (n = 15).



Nine combinations of three temperatures (3, 9, and 15 ^{o}C) and three salinities (10, 20, and 30 ppt) were selected to represent the seasonal range of conditions for Port Valdez. Organisms used in the experiments are collected from the common species of plankton arriving in tanker ballast water. For each experiment, 10 individuals were placed in each of 3 replicate culture dishes at each of the 9 treatment combinations. Thus, there were 27 trials in each experiment (9 treatments x 3 replicates). The test organisms were sorted in the lab and transferred directly to culture dishes maintained in incubators for 96 hrs, simulating release of ballast water into conditions of the Sound. Phytoplankton or brine shrimp nauplii were supplied as food to the cultures during the test period.

Experiments (n = 24) were completed with organisms from the following taxonomic categories:

Tintinnid protistan	1 experiment
Nemertean worm larvae	2 experiments
Spionid polychaete worm larvae	3 experiments
Gastropod veliger larvae	1 experiment
Copepods	
calanoid	4 experiments
harpacticoid	1 experiment
cyclopoid (*Oithona* spp.)	6 experiments
Barnacle nauplii	3 experiments
Crab zoea	1 experiment
Mysid shrimp	2 experiments

Nine of these were "freshwater taxa" and 15 were "seawater taxa". We intentionally selected copepods especially *Oithona* spp., for many of our experiments, because we recognized these as NIS arriving in apparently good condition from San Francisco Bay.

4C2. **Results**

Short-term survivorship of these ballast water organisms was high (>50%) for fresh water taxa at 10 ppt, and for seawater taxa at 20-30 ppt. These short-term experiments also showed that the ballast organisms had distinct, but quite broad tolerances that clearly overlap conditions of temperature and salinities in Port Valdez. For example, although there was considerable variation in survivorship among individual experiments, mean survivorship of calanoid copepods varied from about 20-80% for each test salinity, but survivorship of calanoids in most experiments increased with salinity (Fig. 4.3). *Oithona* spp. (which include known NIS copepods) were able to tolerate salinity-temperature conditions they would encounter in the receiving waters of Port Valdez.

The freshwater and seawater taxa differed substantially in their patterns of temperature x salinity tolerance (Fig. 4.3). The survivorship of seawater taxa at any of the 3 test temperatures generally increased with increasing salinity, and there were not great differences in survivorship among temperatures. However, survivorship of freshwater taxa at all temperatures generally declined sharply with increasing salinity, and survivorship at 3^{o}C was markedly lower than at 9 or 15^{o}C.

4D. Conclusions

Planktonic species arriving to Port Valdez in ballast water have high potential of surviving the salinity-temperature conditions that they encounter during initial discharge from the ship. Although some taxa will not tolerate some salinity layers in the seasonally stratified conditions in the Port, the overlap of ballast water with Port conditions at some strata is high. Plankton in the ballast water, including known NIS such as *Oithona* spp., should be able to tolerate these conditions. Conditions other than initial salinity-temperature combinations probably determine whether or not these organisms survive to become established within Prince William Sound.

Chapter 5. Ballast Water Exchange Experiments on Tankers

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5A. Purpose

The primary objective of this research component is to measure the efficacy of ballast water exchange in removing various types of taxa from ballast tanks of oil tankers. There are very few quantitative studies that have measured the effects of exchange, and these are restricted to just a few vessel types and measure the effect on a small subset of entrained taxa. It is likely, however, that the efficacy of exchange varies by vessel type, tank design, and organism type. To date, there have been no measures of ballast water exchange for oil tankers.

Ballast water exchange is the most widely used national and international management strategy to limit new invasions associated with ships' ballast water (Hallegraeff 1998, Zhang & Dickman 1999, Dickman and Zhang 1999,. Moreover, exchange is currently the only treatment method available for commercial ships to reduce the quantities of non-indigenous coastal plankton in ballast water (National Research Council 1996). This practice is recommended by the International Maritime Organization (IMO) to reduce the risk of invasion by shipping. Furthermore, the U.S. Congress passed the National Invasive Species Act of 1996 (NISA) to encourage ballast water exchange. Specifically, NISA requests that vessels arriving from outside of the Exclusive Economic Zone (EEZ) voluntarily conduct open-ocean exchange of ballast tanks to be discharged in U.S. ports

Commercial ships practice two basic types of ballast water exchange to replace coastal with oceanic water. Flow-Through (FT) Exchange is conducted by pumping oceanic sea water continuously through a ballast tank to flush out the ballast water originating from a coastal source port. Empty-Refill (ER) Exchange is performed by emptying a ballast tank of its coastal water and refilling it with oceanic water.

Each exchange method may vary in efficacy due to the amount and circulation of water being removed, independent of any tank- or vessel-specific effects on efficacy. For example, FT Exchange initially has the effect of dilution but not complete replacement of ballast water. Alternatively, organisms may differ in their distribution or response to water turbulence. Some taxa may swim against currents or always reside near the bottom of tanks, which could greatly influence the effect of ballast water exchange on removal.

To maximize the degree of exchange, multiple exchanges are often recommended. The current IMO standard recommendation is 300% exchange for Flow-Through, while 100-200%

exchange is common for Empty-Refill. These recommended standards provide a theoretical level of at least 90% replacement of coastal water by oceanic water, but this is largely untested among the broad range of vessel types and tank configurations. Specifically, there are almost no experimental analyses which quantify the efficacy of alternative exchange methods and multiple tank exchanges, even though (a) this is the present national and international management strategy being implemented and (b) the cost of such exchanges is substantial in ship fuel and operations time.

We initiated a rigorous quantitative comparison of ballast water exchange methods on oil tankers arriving to PWS. Across two years, we conducted replicated exchange experiments, allowing us to measure the effects of both exchange methods on reduction of entrained organisms and standard physical and biological tracers.

We hypothesize that (1) Empty-Refill exchange will have the highest efficiency, (2) relatively little reduction in density occurs after the first exchange event, and (3) a significant difference exists among taxa on the effect of ballast water exchange. Our experiments were designed to directly test these hypotheses and provide needed quantitative data on this management practice.

This work was initiated in two phases, extending the duration of the analyses and allowing us to increase the replication (and therefore strengthen the statistical power and value of this analysis). The first phase was initiated in summer of 1998. Through the cooperation and financial support from the American Petroleum Institute, SeaRiver and ARCO, we conducted the ballast water exchange experiments on four separate voyages of tankers to Alaska in June/July of that year. The second phase was initiated in spring of 1999, when we received additional funding from U.S. Fish and Wildlife Service to conduct similar experiments (with increased measurements) on another four voyages in summer. In addition to analysis of these experiments, we agreed (with additional funding from phase two) to provide a review of existing data on the efficacy of ballast water exchange, allowing us to examine our results from oil tankers to those reported for other vessel types.

All of the experiments have been completed, but we have not yet completed the full analysis of all samples. We report here on the experiments conducted, including the status of sample analysis and initial results. We will provide a comprehensive report of the results across both phases upon completion of our analyses. We anticipate that these results will be available by June 2000.

5B. Methods

Although the overall goal of this research was to measure the efficacy of ER and FT methods of ballast water exchange in removing coastal plankton from ballast water, our experimental design allowed us to address three specific objectives:

- <u>Compare the efficacy of ER and FT exchange methods in removing a range of different materials (biotic and abiotic)</u>;
- <u>Measure the effect of repeated exchanges: comparing 100, 200, and 300% exchange of the tanks</u>.

- Measure the survivorship of organisms in ballast water over the course of routine voyages. Since the density of organisms can change during a voyage (see Chapter 3 for discussion), it was important to control for such changes in experimental tanks that were independent of the exchange treatment. For this purpose, we included identical measures for an unexchanged control tank on every vessel. Although key to the experimental analysis, this also provided an opportunity to address this third objective.

All experiments were conducted aboard oil tankers during regular operations, en route to Port Valdez. Each tanker served as an experimental platform. Each ship was boarded by a pair of SERC staff at a domestic source port (San Francisco, Puget Sound, or Long Beach), where ballast water used to fill the segregated ballast tanks just in advance of departure for Port Valdez. The tanks underwent various treatments and were sampled repeatedly during the voyage (below).

Experimental Design

The experiment consisted of a replicated, factorial, and paired design. On each ship, we sought to use 3 different ballast tanks that were each subjected to a different treatment: No exchange (=Control), ER Exchange, and FT Exchange. Each Treatment tank was sampled as many as 5 time points, coinciding with: initial ballast loading, 100% exchange, 200% exchange, 300% exchange, and final at arrival to PWS.

Ballast water was loaded in accordance with standard operating procedures at dockside. All exchanges occurred in open, oceanic conditions well outside the influence of coastal waters (>75 miles offshore). Exchanges of tanks were managed by ships' crews in coordination with the desired sampling schedule. For FT Exchange, sea water was pumped into the ballast tanks, causing ballast water to overflow through the top of the tanks and onto the deck. After a volume of water equal to the volume of the tank was pumped, the exchange was interrupted and samples were collected. For ER Exchange, ballast tanks were drained initially by gravity and then by pumping before refilling with sea water. The process required approximately 12 hours for each multiple of exchange.

The specific details of implementation and sampling are described below in various sections.

Biotic and Abiotic Tracers.

In addition to quantifying the effect of ballast water exchange on entrained plankton communities in the ballast tanks, we used four different types of tracers for parallel measures of efficacy. One of these (salinity of the resident water) simply involved collecting and measuring attributes of the resident water. The other three involved materials that we added directly to the ballast tanks, including: Rhodamine dye to trace the fate of the initial water; 1 um Fluorescent Microspheres that simulate passive particles such as cysts; and newly hatched *Artemia* (brine shrimp) nauplii, native to San Francisco Bay, as a living particle.

Each tracer can provide information about different components of the ballast tank environment during exchange (as indicated above). Moreover, we were interested in developing some standardized measures for comparisons across ships. Since the resident community within each ship's ballast tanks may differ considerably (see Chapter 3), the tracers could provide a common currency for comparing exchange performance among many ships in a way that is simply not possible for the entrained plankton communities.

Tracers were added to ballast tanks in a standardized way, following approval for use in these experiments by the U.S. Environmental Protection Agency. The quantity of tracer was chosen to produce desired concentrations for the specific volumes of each tank, such that anticipated dilution during exchanges would allow us to detect at least a 100-fold reduction in measurable concentrations of each tracer.

Tracers were added to at least two locations in each tank during early stages of ballast tank filling (i.e., before the tank was 25-50% full), so as to increase the opportunity for mixing throughout each tank. Rhodamie and microspheres were added directly to all tanks. In contrast, *Artemia* were initially cultured (i.e., the cysts were added to salt water and hatched in buckets in advance of boarding the ship), and the resulting organisms were used to inoculate ballast tanks.

Sample Collection.

Replicate samples were collected at 2 –3 different locations (i.e., tank access points) from each tank, for up to 5 different sampling periods (as above). Sampling procedures for the plankton community followed our established protocol for characterization of ballast water (see Chapter 3 for description); *Artemia* abundance was measured as a component of the plankton (see below). Replicate whole water samples were collected from two depths (0m and 10m), using a Niskin bottle. Whole water samples were used to measure salinity, temperature, and concentrations of dye and microspheres.

For each sampling location and period, we collected 2 replicate samples for all measures. Thus, for each tank and sampling period, we obtained at least: 4 plankton samples (2 locations x 2 samples); 8 rhodamine samples (2 locations x 2 depths x 2 samples); 8 mircosphere samples (2 locations x 2 depths x 2 samples). Temperature and salinity measures were made immediately upon all replication Niskin samples (at least 8 per tank and sampling period, as above).

Although we followed the same general sampling protocol for all voyages (in both years), we collected additional whole water samples during the 1999 experiments to measure changes in the abundance of total bacteria and ciliate protozoans. For both measures, we collected at least 8 samples per tank and sampling period (2 locations x 2 depths x 2 samples). Samples were collected from all experiments in 1999 to measure total bacteria. However, we only included samples from one vessel for the protozoans, due to the time-intensive nature of analysis for this group.

Sample processing.

Water temperature and salinity were measured immediately, using a hand-held thermometer and refractometer, respectively. Plankton/*Artemia* samples were examined aboard ship initially to assess general condition (live/dead, active, lethargic) soon after collection, using dissecting microscopes; these samples were then preserved in 5% buffered formalin. The preserved plankton samples were sorted and enumerated in the laboratory as described in Chapter 3 for Fine

Analysis. Thus, densities were estimated for each taxon, and voucher samples were sent to experts to verify the taxonomic identity.

The tracers in whole water samples are being quantified in the laboratory at SERC (dye concentration with a fluorometer, micro-spheres with direct counts under a fluorescent compound microscope). Total bacteria are also being estimated by direct count with a compound microscope, using standard techniques. The protozoan have been sent to a colleague (Dr. Richard Pierce, expert in ciliate protozoa) for direct counts by taxon.

5C. Results

The experiments were conducted on 8 different voyages, which were divided evenly between the two years (Table 5.1). All experiments were conducted from June to mid July, to control for seasonal variation and to occur during a period of high plankton abundance (see Chapter 3). Six of the 8 ships included all three treatments: ER exchange, FT exchange, and control. These were SeaRiver ships, departing from the ports of San Francisco Bay and Puget Sound. However, the large ARCO tankers were not able to perform ER exchange; experiments aboard these remaining 2 ships included only FT exchange and control tanks.

Table 5.1. Overview and status of ballast water exchange experiments conducted aboard oil tankers arriving to Port Valdez, 1998-1999. For each of 8 replicate experiments: (A) The upper table indicates the vessel, start date, source port, exchange methods, and number collected samples (physical/chemical and biological); (B) The lower table indicates the status of the respective samples. Physical/chemical tracers include salinity, rhodamine, and flourescent microspheres (shown in lower table). Biological tracers include resident zooplankton and brine shrimp (Artemia) in both years, as well as total bacteria in1999 only. . Source ports: Puget Sound, WA (PS); San Francisco Bay, CA (SF); Long Beach, CA (LB). Exchange types: Empty-Refill (ER) and Flow-Through (FT). See text for experimental design.

A.

Ship	Date	Port Source	Exchange type(s)	# of samples Physical tracers	# of samples Biol. Tracers
S/R Baytown	27-Jun-98	SF	ER+FT	120	60
S/R Benicia	01-Jul-98	SF	ER+FT	120	60
S/R Long Beach	08-Jul-98	SF	ER+FT	120	60
ARCO Independence	18-Jul-98	LB	FT	80	40
S/R Baytown	11-Jun-99	PS	ER+FT	60	144
ARCO Spirit	12-Jun-99	LB	FT	64	164
S/R Baytown	08-Jul-99	PS	ER+FT	60	144
S/R Long Beach	19-Jul-99	SF	ER+FT	120	252

B.

				status of proccessing (ip=in progress)		
Ship	Date	Salinity	Rhodamine	Microspheres	Zooplankton/Artemia	Bacteria
S/R Baytown	27-Jun-98	done	done	ip	done	-
S/R Benicia	01-Jul-98	done	done	done	done	-
S/R Long Beach	08-Jul-98	done	done	done	done	-
ARCO Independence	18-Jul-98	done	done	done	done	-
S/R Baytown	11-Jun-99	ip	done	done	done	ip
ARCO Spirit	12-Jun-99	ip	done	done	done	ip
S/R Baytown	08-Jul-99	ip	done	done	ip	ip
S/R Long Beach	19-Jul-99	ip	done	done	ip	ip

We distributed our experiments among the three source ports to maximize the range of conditions (e.g., taxonomic groups, voyage duration, vessel types, and salinity), allowing us to test for general patterns among oil tankers. For example, diversity (and salinity) was generally greatest for ships from Long Beach and Puget Sound, and voyage duration differed among source ports (see Chapters 2 and 3). However, the traffic from each source port presented some unique constraints to the overall design:

(1) Ships from Long Beach could not perform ER Exchange;
(2) Ships from San Francisco contained low salinity waters, especially during the 1998 El Nino year, creating a possible physiological stress for organisms when exposed to exchange (not present at the other ports);
(3) Ships from Puget Sound were not able to complete as many exchanges during the short voyage duration, limiting the total exchange volume to 100% or 200% (instead of the 300% possible for the longer voyages from other source ports).

For all experiments on all 8 vessels, we have measured the effect of at least one full (100%) exchange for the exchange methods and tracers indicated in Table 5.1. In addition, for the majority of vessels we have also measured the effect of multiple exchange events.

Table 5.1 also indicates the number of samples taken for each voyage and the status of these samples. The analysis for physical tracers is actually twice the number shown, as the same sample is used for analysis of rhodamine and microspheres.

Although the samples are now at various stages of analysis (Table 5.1), our initial analyses suggest a significant difference between ER and FT exchange in the reduction of rhodamine dye. For example, Figure 5.1 shows the average change in concentration of rhodamine for the respective treatments across multiple exchange events in 1998. The concentration of dye was reduced by 80 and 99% (for FT and ER exchange, respectively) compared to the initial concentrations. Interestingly, the concentration of dye in the control tank increased between the first and second measures, and this change is attributed to inadequate mixing at time T_o for some ships (as evidenced by vertical stratification that was present in our raw data). Similar patterns exist for the rhodamine data collected in 1999.

Despite the rhodamine results, demonstrating relatively high levels of exchange, it is premature to draw conclusions about the efficacy of exchange to remove organisms. We are now analyzing the samples to measure removal rates for both biological and physical tracers (i.e., microspheres), and we expect to complete these analyses by June 2000. At present, it is evident that some taxa declined in abundance (following exchange) to the same extent as rhodamine dye. Figure 5.2 shows a decline in the abundance of *Limnoithona* sp. for both ER and FT exchange on one vessel. The density actually increased in the control tank, and this was due most likely to growth of copepodite stages instead of mixing. Changes in the abundance of other taxa appear to be much less striking, although analysis of the overall pattern (including variation among taxa) must await completion of all quantitative counts and taxonomic verification.

Figure 5.1. Effect of ballast water exchange on rhodamine dye concentrations. Data are from exchange experiments conducted in the ballast tanks of oil tankers arriving to Port Valdez. Shown for 1998 voyages (n=4 vessels) is the mean percent change in rhodamine dye concentration (compared to the initial time measure) at each of four successive time points for 3 different treatments: Control – ballast tanks that did not undergo exchange; ER Exchange – ballast tanks that underwent Empty-Refill Exchange; FT Exchange – ballast tanks that underwent Flow-Through Exchange. See text for experimental design.

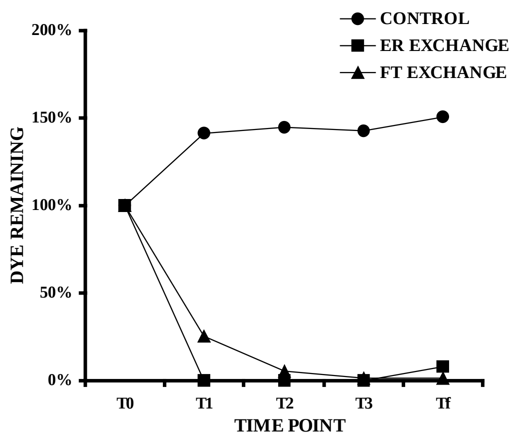
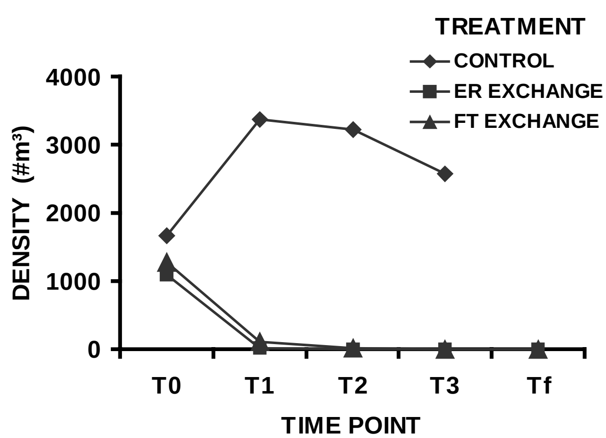


Figure 5.2. Effect of ballast water exchange on Limnoithona sp.density. Data are from exchange experiments conducted in the ballast tanks of an oil tanker arriving to Port Valdez. Shown for one voyage is the mean density of the copepod SPECIES at each of five successive time points for 3 different treatments: Control – ballast tanks that did not undergo exchange; ER Exchange – ballast tanks that underwent Empty-Refill Exchange; FT Exchange – ballast tanks that underwent Flow-Through Exchange. See text for experimental design.



Changes in the density of entrained biota within the control tanks of each vessel will measure survivorship over time (i.e., during transit). This will allow us to test our hypothesis (above) about the effect of voyage duration on survivorship, and whether differences among port sources are due to such time-dependent survivorship.

5D. Discussion

This is the first study to compare the relative efficiency of exchange methods (ER and FT exchange) for any vessel type or taxon.

Quantitative and experimental analyses of ballast water exchange have been very limited to date, and these can be classified into 3 general types:

1. **Comparison of ballast water in ships that have or have not exchanged ballast water.** These data indicate that, compared to ships that have not conducted mid-ocean ballast water exchange, ships with exchanged ballast water have reduced abundance of plankton. However, with this approach, it is not possible to (a) compare directly methods of exchange (FT vs. ER) , (b) control for initial plankton densities or the percentage of water exchanged (as below). Thus, the data are highly variable and interpretation is limited (e.g., Smith et al. 1996).

2. **Comparison of ballast water in tanks of the same ship that have not exchanged ballast water, with measurements made only after exchange is complete and upon arrival to port.** These data suggest a reduction of roughly 90% occurred, but interpretation is also limited with this design (Ruiz and Hines 1997; see below). Initial variation among tanks can be considerable, depending upon the timing (e.g., day vs. night) and sequence of ballasting, which creates potentially large differences among tanks independent of exchange treatment. Furthermore, it is not possible to compare efficiency between methods of exchange, or for multiples of exchange, because ships usually only perform one method and volume of exchange.

3. **Comparison of ballast water in tanks of the same ship before and after exchange of ballast water, with measurements made on board ship at various stages of the exchange process.** These data provide a clear measure of efficiency within a single tank, and we have conducted this analysis on approximately 5 military vessels and 1 commercial bulk carrier (Ruiz et al. 1999, Wohnam et al. 1996). However, the sample size is small (and taxa included in ships to date are limited), and comparison between exchange methods or multiples of exchange (on the same ship) has not been included or possible to date.

The 1997 Pilot Study provided initial data comparing the end result of FT Exchange (300% and 100%) on plankton abundance. These data suggested that approximately 70- 90% of coastal plankton was removed by FT exchange, compared to control tanks from the same source. Interestingly, it was not clear that an increased level of exchange (100 vs. 300 %) produced a parallel reduction in key taxonomic groups.

In both the Pilot Study and the current study (Chapter 3), it was evident that abundance of coastal organisms was 10-100 fold lower in tankers from foreign ports (that underwent ballast water exchange) compared to domestic arrivals (that do not undergo exchange). Although this difference may result from the exchange, it is confounded by differences in the initial concentrations (i.e., source ports) and voyage duration that can also have a strong influence.

The results of this study – the most comprehensive and rigorous to date - will significantly advance our understanding of the strengths and limitations of ballast water exchange, providing multiple quantitative measures for the two exchange methods, both for oil tankers specifically but for commercial ships more generally.

Importantly, when completed, our study will also provide a set of standards for evaluating ballast water management in two ways. First, we have developed and tested a standard set of assays to measure exchange efficiency across vessel types, vessel tanks, and under various conditions. This will be useful in comparing efficiency among studies. Second, the results obtained by this and future studies will provide a benchmark against which to assess the efficacy of emerging technologies.

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Chapter 6. Organisms in Sediments of Tanker Ballast Tanks

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6A. Purpose

At certain times and source ports, appreciable quantities of bottom sediment are taken up by tankers during ballasting. The entrained sediment potentially includes bottom dwelling organisms, which may be discharged and introduced into a receiving port (Smith et al. 1996). Few studies of such entrained sediment exist, but our samples of bulk carriers in Chesapeake Bay revealed that the bottoms of ballast tanks often hold a wide variety of large crabs, fish, shrimp, as well as many small organisms. To determine whether tankers arriving to Prince William Sound transported organisms associated with sediment in the bottoms of segregated ballast water tanks, we sampled a subset of ships traveling between Port Valdez and west coast ports, and between west coast ports and Asian ports.

6B. Methods

During 1998-99 we supplied 13 ships with "sediment sampling kits", which we developed in cooperation with the shipping agents. The ships' mates collected core samples and evident organisms in the sediment during routine cleaning operations, which usually occurred on voyages from Valdez to west coast ports, when ballast tanks were empty and open for maintenance, and in Asian ports, when ships were in dry-dock. The samples were preserved in 10% formaldehyde sea water, labeled and returned to Valdez. Samples were then sent to the SERC lab in Maryland for processing and identification. Subsamples of whole sediment were sent to Mary McGann in USGS, Menlo Park for identification of foramenifera. Remaining sediment was washed through a 0.5 mm mesh sieve and identified under a dissecting microscope.

6C. Results

Sediment samples of the 13 tankers contained a diverse array of taxa, including fish, polychaete worms, mollusks, adult crabs and other crustaceans, cnidarians, and other invertebrates (Fig. 6.1,Tables 6.1, 6.2). The ships averaged 2.8 taxa per ship, ranging from 0-6 taxa, with annelid worms occurring in about 90% of the ships. The number of individuals per sample varied widely from 1-147 individuals, with a mean of 47 individuals. Small crustaceans (particularly cumaceans) were the most abundant taxa, however polychaete worms were the most prevalent. The sediments also contained several species of Foraminfera, including *Trochammina hadai*, an NIS that has invaded many west coast ports and is very common in San Francisco Bay (McGann, pers. comm.), and which is reported from Prince William Sound in samples collected from deep sediments following the ExxonValdez oil spill. Organisms were abundant in sediments taken up in both San Francisco Bay (Benicia) and in Long Beach, where the ship intakes are near the port bottom. Ships sampled in dry dock in Asia tended to have few organisms, perhaps as a result of longer voyage time across the Pacific. However, the diversity of higher taxonomic groups present in sediments of ballast tanks did not show any obvious pattern by source port.

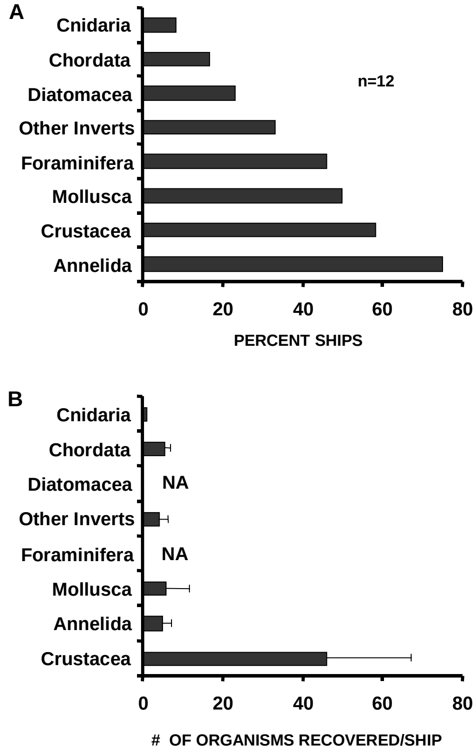
Table 6.1. Taxa Recovered From Ballast Tank Sediments of 12 Tankers.

Foraminifera	Annelida	Mollusca	Crustacea	Chordata	Other inverts.
Ammonia hadai	Capitellidae	Mytilidae	Alpheidae	Engraulidae	Bryozoa
Bulimina sp.	*Nereis* sp.	Nudibranchia	Amphipoda	Sciaenidae	Sipuncula
Elphidium sp.	Oligochaeta		*Balanus balanoides*		Turbellaria
Globigerina sp.	Spionidae		*Calanus*		
Haglophragmoides sp.	Syllidae		Canuellidae		
Jadammina macrescens			Caridea		
Lagena sp.			Cirripedia		
Rosalina globularis			Crangonidae		
Trochammina hadai			Cumacea		
Trochammina inflata			Grapsidae		
Trochammina pacifica			Harpacticoida		
			Hyperiidae		
			Majidae		
			Ostracoda		
			Tanaidacea		

Table 6.2. Presence/Absence of Taxa in Ballast Tank Sediment Samples Presented by Source Region(s).

Source(s)	Diatomacea	Foraminifera	Annelida	Mollusca	Crustacea	Chordata	Other Inverts	n
Korea	P	P	P	A	A	A	A	1
LB & Korea	P	P	P	P	P	P	P	2
PS	A	A	A	P	P	A	P	1
PS & SF	P	P	P	P	P	P	P	1
SF	A	P	P	P	P	P	P	6
SF&China	A	A	P	A	P	A	A	1

Figure 6.1. Prevalence (A) and numbers (B) of organisms recovered from sediments of tanker ballast tanks. Bars indicate means for 12 tankers.



6D. Conclusions

Sediment that accumulated in the bottom of ballast tanks often contained organisms from a diverse array of taxa. Many of these were adults in full reproductive condition. At least one NIS (the foraminiferan *Trochammina hadai*) found in these samples appears to be established in Prince William Sound, although the current status of this invasion is not known (McGann, pers. comm. 1999).

In future work, it would be valuable to sample sediment in ballast tanks that have undergone mid-ocean exchange. It is not clear if bottom-dwelling organisms will be affected by exchange in the same ways as planktonic organisms in the water column.

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Chapter 7. Organisms Fouling Hulls and Sea Chests of Tankers

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7A. Purpose

Historically, fouling organisms on ships have been a major source of introduced species (Carlton 1979a, 1979b, 1987, 1989). Modern anti-fouling paints and high ship speeds greatly reduce the amount of fouling today. However, fouling is often common in sea chests and at certain points on the bottom. We sampled tankers during routine maintenance in dry dock, selected to estimate the potential range of fouling and diversity of fouling organisms.

7B. Methods

We sampled the fouling communities of two ships in dry dock: the S/R Baytown (in San Francisco Bay), which had not been cleaned in dry dock for approximately 2 years; and the S/R Benicia (in Portland), which had been cleaned in dry dock within about 6 months. The S/R Baytown had remained within San Francisco Bay for several months without making an ocean voyage prior to haul out, providing time for further accumulation of fouling organisms. Representative patches of fouling communities were scraped from the bottoms of the ships within 6 hours of haul out and before any cleaning had commenced. The sea chests and strainers of the ambient water intakes were also sampled. All samples were preserved in 10% formaldehyde and returned to the laboratory for sorting and identification using a dissecting microscope.

7C. Results

The two ships exhibited divergent extremes in the quantity and diversity of organisms (Table 7.1). The ship that had not been in dry dock for approximately 2 years exhibited extensive fouling communities, with abundant mussels and associated worms, crustaceans, and sediments. At least one NIS for the west coast (the mussel *Musculista senhousia*) was identified specifically on this ship. In contrast, the ship that had been hauled recently had a relatively sparse number of organisms, with most of the hull completely clean of fouling communities, and only organisms present in the sea chest. However, even this ship had organisms that are NIS for the west coast (e.g., the striped bass *Morone saxatilis*) in its water intake strainers.

7D. Conclusions

We hypothesize that these two vessels represent the extremes in fouling communities, corresponding to the length of time since the last entry into dry dock for bottom cleaning. However, there are two other features that may contribute to these overall patterns. First, the S/R Baytown had been resident in San Francisco Bay for over 6 months, and may have developed an unusually rich fouling community. Second, the other vessel entered relatively fresh water of the Columbia River that may have had an adverse effect on the resident community of fouling organisms. To distinguish the effect of dry dock schedule on fouling community structure (from these other confounding variables), it would be valuable to sample more ships which differ in time since last haul out, but preferably sampled at the same dry dock to control for potential effects of different salinity. Nevertheless, both ships carried NIS, which indicates that this is an active mechanism of transport and introduction.

Table 7.1. Organisms from hulls and sea chests of two oil tankers in dry dock (*=NIS).

S/R Baytown	S/R Benicia
Algae	**Cnidaria**
Ulva sp.	*Garveia franciscana* *
Diatomacea	**Mollusca, Bivalvia**
Protozoa	*Mytlilus sp.*
Folliculina sp.	**Crustacea, Cirripedia**
Cnidaria	*Balanus sp.*
Cordylophora caspia *	**Crustacea, Amphipoda**
Garveia franciscana *	*Corophium sp.*
Nematoda	**Pisces**
Unidentified sp.	*Morone saxatlis* *
Nemertea	*Sardinopsis sagax*
Unidentified sp.	
Polychaeta	
Neries sp.	
Ophelidae, unidentified sp.	
Polydora sp.	
Mollusca, Bivalvia	
Musculista senhousia *	
Mytilus sp.	
Crustacea/Copepoda	
Cyclopoida, unidentified sp.	
Harpacticoida, unidentified sp.	
Crustacea/Amphipoda	
Corophium sp.	
Gammaridae, unidentified sp.	
Crustacea/Isopoda	
Unidentified sp.	
Crustacea/Brachyura	
Unidentified sp.	
Bryozoa	
Bowerbankia	
Membrenipora	
Victorella sp.	

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Table 7.1. Organisms from hulls and sea chests of two oil tankers in dry dock (* = NIS).

S/R Baytown	S/R Benicia
Diatomacea	**Cnidaria**
Protozoa	*Garveia franciscana* *****
Folliculina sp.	**Crustacea, Cirripedia**
Cnidaria	*Balanus* sp.
Garveia franciscana *****	**Crustacea, Amphipoda**
Cordylophora caspia *****	*Corophium* sp.
Hydroid – unident sp.	**Mollusca, Bivalvia**
Bryozoa	*Mytilus* sp.
Bowerbankia sp.	**Pisces**
Canopeum sp.	*Morone saxatilis* *****
Victorella sp.	*Sardinopsis sagax*
Nemertea	
Unidentified sp.	
Nematoda	
Unidentified spp.	
Polychaeta	
Ophellidae, unidentified sp.	
Polydora sp.	
Nereis sp	
Crustacea/Copepoda	
Harpacticoida, unidentified sp.	
Cyclopoida, unidentified sp.	
Crustacea/Amphipoda	
Gammaridae, unidentified sp.	
Corophium sp.	
Crustacea/Isopoda	
Unidentified sp.	
Crustacea/Brachyura	
Unidentified sp.	
Mollusca, Bivalvia	
Musculista senhousia *****	
Mytilus sp.	
Algae	
Ulva sp.	

Chapter 8. Summary of NIS in Prince William Sound and Alaska

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8A. Purpose

To summarize our knowledge of marine NIS in Prince William Sound specifically and Alaska generally, we extracted information obtained from the literature, our field surveys, focal taxonomic research by systematists, and analysis of existing specimens in museum and reference collections (see detailed reports in Chapt 9). Because prior ecological and systematic work in Alaska has not focused on NIS, we also wish to establish a baseline for the status of NIS in Alaskan waters, against which future introductions may be measured. We partitioned the species records into 5 categories:

(1) Definite & probable NIS, along with particularly suspicious cryptogenic species;
(2) Cryptogenic species;
(3) New, undescribed species discovered by this study.
(4) Species with range extensions into south central Alaska discovered by this study; and
(5) Species that were reported/suspected as NIS, but which we dismissed upon further analysis.

The sudden appearance of apparently new or undescribed species in an ecosystem is often a good indicator of a biological invasion. Similarly, analysis of species' range extensions is an important tool in detecting NIS, which may be introduced from distant biogeographic provinces or from adjoining provinces. However, where the native biota is as poorly studied as in Alaska, it may be difficult to distinguish NIS from native species that are new to science, or from new records of species within their normal range. Discovery of undescribed species and range extensions needs to be evaluated in the context of other indicators of biological invasions, such as association with sites of human activities and particular transport mechanisms. Thus, designating species as native or NIS requires a series of graded criteria (see Methods below), but the origin of many species may remain unknown, i.e., "cryptogenic". These cryptogenic species may be further categorized into species that have particular, suspicious attributes in some criteria, or species that have not received adequate research to evaluate their origin. In other cases, species initially may be designated or suspected as NIS, but further consideration by experts may refute the initial concern.

8B. Methods

The graded criteria (derived from J.T. Carlton, e.g., Carlton 1979a, Chapman & Carlton 1991) used to determine whether each species in our database is introduced, native, or cryptogenic are described below. "Cryptogenic species" cannot be identified clearly as native or introduced, and thus have unknown origin (Carlton 1996). In Alaska, the marine biota in many groups have received little systematic and biogeographic analysis, and a large portion of species in these groups may be cryptogenic in origin due to lack of study without particular suspicions of invasive characteristics. Further discussion of criteria for identifying species as introductions are given in Chapman (1988), Chapman and Carlton (1991) and Eno (1996). Often a single criterion is not sufficient to designate a species as being introduced, but combinations of several factors increase the probability of an accurate reconstruction of introductions and invasions. In several cases, we have indicated cryptogenic species that have some suspicious characteristics of NIS.

- Paleontological - NIS are absent from fossil record even though they are present in other locations; native species are found locally as recent fossils; cryptogentic species are not in the local fossil record, but they are not reliably fossilized generally.
- Archeological - NIS are absent from shell middens and other archeological deposits; native species are in local deposits; cryptogenic species would not be expected to be found in archeological deposits.
- Historical - NIS are not recorded by direct observation at early periods, especially by trained naturalists, but suddenly appear where trained observers did not find them previously; native species are recorded in the earliest observations of trained observers; cryptogenic species are species that were not studied by early trained observers.
- Biogeographic - NIS exhibit grossly disjunct patterns of distribution (we took care to evaluate artifacts of the distribution of biologists/taxonomists); native species have continuous geographic ranges which include Alaska/Prince William Sound or other high latitudes; cryptogenic species have poorly known distributions or "cosmopolitan" distributions.
- Ecological - NIS have habitats in close association with other NIS (co-evolved species; specialized predator-prey, commensal or host-parasite relations); native species are closely associated with other native species; cryptogenic species are more generalized, lacking close, specialized association with other species.
- Dispersal Mechanisms - NIS presence cannot be plausibly explained by natural dispersal mechanisms and have documented human-mediated mechanisms which could effect their distributions; native species have natural dispersal mechanisms and lack known human-mediated mechanisms of introduction; cryptogenic species have both natural and human-mediated mechanisms of dispersal that could account for their distribution.
- Evolutionary/Genetic - NIS have isozyme or DNA frequencies which match distant proposed source populations and are significantly different from adjacent natural populations; native species have population genetics which blend with adjacent natural populations; cryptogenic species have not been studied with molecular techniques.

We also researched all published and anecdotal reports of NIS or range extensions of species that we were able to find in the scientific and informed popular literature for the region. We use these reports interactively with our field and museum work, both to direct our field surveys and re-examination of existing collections, and to determine the history of suspicious species that we collected in the field.

8C. Results

A diverse array of 24 species of plants and animals has been introduced into Alaskan waters, with 15 of these species being recorded in Prince William Sound (Table 8.1; see also Species Notes below). Of these definite/probableNIS, we collected 12 species in our Focal Taxonomic Analyses (Chapt 9), including 5 species of algae (*Ceramium sinicola*, *Croodactylon ramosum*, *Fucus cottoni*, *Macrocystis integrifolia*, *Codium fragile tomentosoides*), 1 species of sponge (*Cliona thosina*), 1 hydroid at Homer (*Garveia franciscana*),1 polychaete worm (*Heteromastus filiformis*), 2 molluscs (*Mya arenaria, Crassostrea gigas*), 1 bryozoan (*Schizoporella unicornis*), and 1 tunicate (*Botrylloides violaceus*). Our findings include 7 “first

TABLE 8.1 Definite/Probable NIS for Alaska — * Found by this project

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	Population Status	Ecological Impacts?	References
Rhodophyta								
* *Ceramium sinicola*	a red alga	NE Pacific (CA)	Prince William Sound	1998	Probable	Established	Fouling	Hansen 1998
* *Chroodactylon ramosum*	a red alga	NW Pacific	Prince William Sound	1998	Probable	Established	Fouling	Hansen 1998
Phaeophyta								
* *Fucus cottoni (=muscoides)*	a rockweed	NE Atlantic	Prince William Sound; Kenai Peninsula		Probable	Established	Unknown	Hansen 1998; South and Tittley 1986
* *Macrocystis integrifolia*	a kelp	NE Pacific (SE AK)	Prince William Sound	1979	Definite	Not reproducing	NIS vector	Hansen 1998
* *Microspongium globosum*	a brown alga	NW Pacific	Prince William Sound	1998	Probable	Established	Fouling	Hansen 1998
Sargassum muticum	Japanese brown alga	NW Pacific	SE Alaska	<1986	Definite	Established	Fouling	Scagel et al. 1986; USGS 1998
Chlorophyta								
* *Codium fragile (ssp. tomentosoides?)*	Dead Man's Fingers	(NW Pacific?)	Prince William Sound	1998	Probable	Established	Fouling	Hansen 1998
Angiospermophyta								
Cotula coronopifolia	Brassbuttons	S. Africa	SE Alaska (FW)	<1948	Definite	Established	Competitor?	Hulten 1968; USGS 1998
Sacodina-Foraminifera								
Trochammina hadai	a foraminiferan	NW Pacific	Prince William Sound	1989?	Definite	Established	Benthic processes	Cohen and Carlton 1995; McGann and Sloan 1996; McGann 1998 pers. comm
Porifera								
* *Cliona thosina*	a boring sponge	Unknown	Prince William Sound	1998	Probable	Established	Oyster shell damage	Ruetzler 1998 pers. comm.
Cnidaria-Hydrozoa								
* *Garveia franciscana*	Rope Grass Hydroid	Unknown	Homer	1999	Definite	Established	Fouling	Henry 1999 pers. comm.
Annelida- Polychaeta								
* *Heteromastus filiformis*	a capitellid polychaete	N Atlantic?	Prince William Sound	1998	Probable	Established	Competitor?	Jewett 1998; Cohen & Carlton 1995, Feder & Jewett 1973
Lumbrineris heteropoda	a lumbrinereid polychaete	NW Pacific (Japan-Sakhalin)	Resurrection, Glacier Bays	1979	Probable	Unknown?	Unknown?	Feder et al. 1979; Foster 1999 pers. comm., UA
Mollusca- Bivalvia								
* *Crassostrea gigas*	Pacific Oyster	NW Pacific	SE Alaska; Prince William Sound	1980s?	Definite	Not reproducing	NIS vector	Quayle 1969; Hines, 1998 pers. obs
* *Mya arenaria*	Softshell Clam	NW Atlantic; Bering Sea	SE Alaska; Prince William Sound	1800s?	Definite	Established	Competitor?	Baxter 1971; Feder & Paul 1973; Carlton 1979;
Crustacea-Amphipoda								
* *Jassa sp. / Jassa marmorata?*	a tube-dwelling amphipod	NW Atlantic	Prince William Sound	1999	Probable	Unknown?	Unknown	Chapman 1999 pers. comm.
Bryozoa								
Cryptosula pallasiana	a bryozoan	N Atlantic	SE Alaska (Sitka?)	1944-1946	Definite	Unknown?	Fouling	U.S. Navy 1951; Carlton 1999 pers. comm.; Dick & Ross 1988; Powell 1970
* *Schizoporella unicornis*	a bryozoan	NW Pacific	Kodiak, Prince William Sound	1944-1949	Definite	Established	Fouling	U.S. Navy 1951; Carlton, pers. comm.; Winston 1999 pers. comm.; Powell 1970; Dick & Ross 1988
Echinodermata-Ophiuroida								
Ophiothrix koreana	a brittlestar	NW Pacific	SE Alaska (Juneau)	1998	Definite	Unknown	Unknown	Kyte 1998 pers. comm.

TABLE 8.1 continued

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	Population Status	Ecological Impacts?	References
Chordata- Ascidiacea								
***** *Botrylloides violaceus* **(=*Botrylus aurantius*)**	a tunicate	NW Pacific	Prince William Sound	1999	Definite	Established	Fouling	G.Lambert 1999pers.comm.
Chordata-Osteichthyes								
Alosa sapidissima	American Shad	NW Atlantic	N to Cook Inlet; Kodiak I.	1896	Definite	Migrant	Predator on salmonid fry?	Chapman 1942; McPhail and Lindsey 1986; USGS 1999
Dallia pectoralis (FW)	Alaska Blackfish	Arctic Slope (FW)	Anchorage area (FW)	1950s	Definite	Established	Predator on salmonid fry?	Morrow 1980; USGS 1999
Esox lucius (FW)	Northern Pike	Northern N. America (FW)	Anchorage area (FW)	1970s	Definite	Established	Predator on salmonid fry?	Morrow 1980; USGS 1999
Salmo salar	Atlantic Salmon	N Atlantic (Anadromous)	SE Alaska-Prince William Sound	1990	Definite	Unknown	Predator/ competitor of salmonids	Wing et al. 1992; Freeman 1998 pers. comm.; USGS 1999
Salvelinus fontinalis (FW)	Brook Trout	Eastern N. America (FW)	SE Alaska	1920	Definite	Established	Predator on salmonid fry?	Morrow 1980; Alaska Department of Fish and Game 1994; USGS 1999

records" for NIS in the region. Our Rapid Community Assessment (Chapt 9) found 1 NIS species (the soft-shelled clam *Mya arenaria*) to be widely distributed in intertidal sediments throughout Prince William Sound and the Kenai Peninsula. Two species (the oyster *Crassostrea gigas*, and the kelp *Macrocystis integrifolia*) are not established as self-sustaining, reproducing populations within the Sound; but these aquaculture introductions are being sustained by on-going inputs that serve as a potentially important mechanism of transport for many other associated species. Further notes on each of these NIS are provided below.

The literature reports 11 other NIS species, including 1 algal species (*Sargassum muticum*), 1 marsh plant (*Cotula coronopifolia*), 1 foraminiferan (*Trochammina hadai*), an amphipod crustacean (*Jassa marmorata*), 1 bryozoan (*Cryptosula pallasiana*), 1 brittle star (*Ophiothrix koreana*), and 5 species of fish (*Alosa sapidissima*, *Dallia pectoralis*, *Esox lucius*, *Salmo salar*, *Salvelinus fontinalis*). Several of these fish species were intentionally introduced in fresh water to augment fisheries, and we have included them here because they potentially have important impacts on native salmonid species in the region. Further notes on each of these NIS are provided below.

In addition, we consider two cryptogenic species to be particularly suspicious as NIS, because of their new appearance at harbor areas (i.e., Homer, Cordova)(Table 8.2). These species include a sea star (*Asterias amurensis*) that is native to Alaska in the Bering Sea, but which has a history of invading other regions (probably via ballast water transport), and which appears to have suddenly extended its range to Homer in south central Alaska. Despite surveys of the area by good naturalists, this large animal has not been recorded at Homer/Katchemak Bay until now. We also discovered a new, undescribed species of ascidian (*Dispalia* sp. nov.) in the fouling communities of Homer and Cordova, but it was not present at other locations with rich fouling communities but lacking intense boat/ship traffic. Further notes on each of these suspicious species are provided below.

A large portion of Alaskan marine species is cryptogenic in origin due to inadequate biogeographic and taxonomic study. However, many cryptogenic species also either exhibit wide distributions that may reflect global spread by early shipping traffic (Carlton 1996) or have other suspcicious traits of NIS (Table 8.3). During this project we collected at least 24 such species in Prince William Sound, and identified at least 5 others found elsewhere in Alaska.

During our study we discovered several apparently new/undescribed species (Table 8.4) and documented range extensions for many other species. (Table 8.5), which also highlights the need for more analysis of Alaskan marine biodiversity. We found specimens of 10 apparently new/undescribed species in Prince William Sound, including 1 brown alga, 6 polychaete worms, 2 molluscs, and 1 tunicate (Table 8.4). Formal species description of the tunicate species (*Distaplia* sp. nov.) is proceeding. We documented range extensions or first records for Prince William Sound or Cook Inlet (although some are known in the Bering Sea and further north) for 74 species (4 algae, 11 hydrozoan cnidarians, 2 ctenophores, 24 polychaete worms, 20 molluscs, 7 crustaceans, 2 bryozoans, 1 echinoderm, 2 tunicates, and 1 fish) (Table 8.5).

TABLE 8.2 Highly Suspicious Cryptogenic Species — * **Found by this project**

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	Population Status	Ecological Impacts?	References
Echinodermata - Asteroidea								
* *Asterias amurensis*	Asian Sea Star	NW Pacific; Bering Sea	Homer Spit	1999	Suspicious Range extension	Established	Predator on molluscs & other inverts	Baranova 1976; Ward and Andrew 1995; Foster et al. 1999 (Chapt 9, this report)
Chordata - Ascidiacea								
* *Distaplia* sp. nov.	a tunicate	unknown	Homer, Prince William Sound (Cordova)	1998	Suspicious New	Established	Fouling	G.Lambert 1999 pers. comm.

TABLE 8.3 Examples of Cryptogenic Species

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	Population Status	Ecological Impacts?	References
Rhodophyta								
Porphyra miniata	a red alga	?	Prince William Sound	1998	Cryptogenic	Established	Unknown	Hansen 1998
Phaeophyta								
Demaraeaea attenuata	a brown alga	NW Pacific?	Prince William Sound	1998	Cryptogenic	Established	Unknown	Hansen 1998
Punctaria latifolia		NE Pacific?	Prince William Sound	1998	Range extension			Hansen 1998
Punctaria plantaginea	a brown alga	?	Prince William Sound	1998	Cryptogenic	Established	Unknown	Hansen 1998
Heterokontophyta-Xanthophycaeae								
Vaucheria longicaulis	a golden-brown alga	NE Pacific?	Prince William Sound	1998	Range extension, overlooked			Hansen 1998
Chlorophyta								
Blidingia marginata	a green alga	NE Pacific?	Prince William Sound	1998	Cryptogenic	Established	Unknown	Hansen 1998
Caposiphon fulvescens	a green alga	NE Pacific?	Prince William Sound	1998	Cryptogenic	Established	Unknown	Hansen 1998
Halochlorococcum moorei	a green alga	NE Pacific?	Prince William Sound	1998	Cryptogenic	Established	Unknown	Hansen 1998
Kornmannia leptoderma non *zostericola*	a green alga	NE Pacific?	Prince William Sound	1998	Cryptogenic	Established	Unknown	Hansen 1998
Angiospermophyta								
Atriplex patula (=A. p. var. *littoralis)*	Orach; Spearscale	Eurasia?	SE Alaska	1883	Cryptogenic	Established	Unknown	Meehan 1884; Hulten 1968
Atriplex prostrata (=A. patula var. *hastata)*	Halberd-Leaved Orach	Eurasia?	SE Alaska	?	Cryptogenic	Established	Unknown	Hulten 1968
Cnidaria								
Protohydra sp.	a worm-like hydroid	Cosmopolitan? (CA-BC)	Prince William Sound		Cryptogenic	Established	Unknown	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Annelida- Polychaeta								
Barantolla (americana species complex?)	a capitellid polychaete	Circumboreal?	Prince William Sound	1988	Cryptogenic	Established	Unknown	Kozloff 1987; Kudenov 1998, pers. comm.
Amphitrite (cirrata species complex?)	a terebellid polychaete	Circumboreal	Prince William Sound	1998	Cryptogenic	Established	Unknown	Kozloff 1987; Kudenov 1998, pers. comm.
Capitella (capitata? species complex?*)*	a capitellid polychaete	Cosmopolitan	Prince William Sound	1980	Cryptogenic	Established	Unknown	Jewett 1998; Cohen and Carlton 1995; Kudenov 1998, pers. comm.
Decamastus sp.	a capitellid polychaete	Cosmopolitan? (WA-BC)	Prince William Sound	1998	Cryptogenic	Established	Unknown	Jewett 1998; Kozloff 1987; Cohen and Carlton 1995
Eteone (longa species complex?*)*	a phyllodocid polychaete	Circumboreal	Prince William Sound	1980	Cryptogenic	Established	Unknown	Pettibone 1963; Kozloff 1987; Kudenov 1998, pers. comm.
Eumida (sanguinea species complex?*)*	a phyllodocid polychaete	Circumboreal	Prince William Sound	1998	Cryptogenic	Established	Unknown	Kozloff 1987; Kudenov 1998, pers. comm.
Harmathoe (imbricata species complex?)	a polynoid polychaete	Circumboreal	Prince William Sound	1980	Cryptogenic	Established	Unknown	Kozloff 1987; Cohen and Carlton 1995; Kudenov 1998, pers. comm.
Mediomastus sp.	a capitellid polychaete	Cosmopolitan	Prince William Sound	1988	Cryptogenic	Established	Unknown	[Jewett 1998]; Cohen and Carlton 1995
Pholoe (minuta species complex?)	a sigalionid polychaete	Circumboreal	Prince William Sound	1979	Cryptogenic	Established	Unknown	Jewett 1998; Cohen and Carlton 1995; Kudenov 1998, pers. comm.
Polydora quadrilobata	a spionid polychaete	NE Pacific (British Columbia)	Prince William Sound	?	Cryptogenic	Established	Unknown?	Kozloff 1987; Foster 1999 pers. comm.; UAF collections

TABLE 8.3 continued

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	Population Status	Ecological Impacts?	References
Crustacea- Copepoda								
Leimia vaga	a harpactacoid copepod	NW Atlantic?	Prince William Sound	1999	Cryptogenic	Established	Unknown	Cordell 1999 pers. comm.
Mollusca- Bivalvia								
Macoma balthica	Baltic Clam	Northern oceans?, NW Atlantic cryptic	Alaska Pacific coast	before 1924	Cryptogenic	Established	Likely	Carlton 1979; Meehan et al. 1989; Cohen & Carlton 1995
Bryozoa								
Alcyonidium "polynoum" or "mytili"	a bryozoan	Unknown (Pacific, NW Atlantic?)	Kachemak Bay	?	Cryptogenic	Established	Unknown	Carlton 1979; Cohen & Carlton 1995; Winston 1999 pers. comm.
Callopora lineata	a bryozoan	Unknown	Prince William Sound	?	Cryptogenic?	Established	Unknown	Foster 1999 pers. comm.; Winston 1999 pers. comm.
Celleporella hyalina	a bryozoan	Unknown	Resurrection Bay	?	Cryptogenic?	Established	Unknown	Foster 1999 pers. comm.; Winston 1999 pers. comm.
Cellepora craticula	a bryozoan	Unknown	Prince William Sound	?	Cryptogenic?	Established	Unknown	Foster 1999 pers. comm.; Winston 1999 pers. comm.
Cribilina corbicula	a bryozoan	Unknown	Prince William Sound	?	Cryptogenic?	Established	Unknown	Foster 1999 pers. comm.; Winston 1999 pers. comm.
Parasmittina trispinosa	a bryozoan	Unknown	Prince William Sound	?	Cryptogenic?	Established	Unknown	Foster 1999 pers. comm.; Winston 1999 pers. comm.

TABLE 8.4 New or Undescribed Species

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	References
Phaeophyta						
Coilodesme n. sp.	a brown alga	NE Pacific	Prince William Sound	1998	New species	Hansen 1998
Annelida- Polychaeta						
Eumida sp.	a phyllodocid polychaete	Unknown	Prince William Sound	1998	undescribed species?	Kudenoff 1998 pers. comm.
Exogone sp.	a syllid polychaete	Unknown	Prince William Sound	1998	undescribed species?	Kudenoff 1998 pers. comm.
Glycera sp.	a glycerid polychaete	Unknown	Prince William Sound	1998	undescribed species?	Kudenoff 1998 pers. comm.
Nephtys sp.	a nephtyid polychaete	Unknown	Prince William Sound	1998	undescribed species?	Kudenoff 1998 pers. comm.
Polygordius sp.	an archiannelid polychaete	Unknown	Prince William Sound	1998	undescribed species?	Foster 1999 pers. comm.; UAF collections
Scolopos sp.	an orbiniid polychaete	Unknown	Prince William Sound	1998	undescribed species?	Kudenoff 1998 pers. comm.
Mollusca - Gastropoda						
**Adalaria* sp 1.	a nudibranch, Adalaria sp. 1 of Behrens (1991)	Unknown	Prince William Sound	1999	undescribed species?	Goddard 1999 pers. comm.
Adalaria sp. 2	a nudibranch	Unknown	Prince William Sound	1999	Unidentified species	Goddard 1999 pers. comm.
Chordata - Asciiacea						
**Diastaplia* n. sp.	a tunicate	Unknown	Homer, Prince William Sound (Cordova)	1998	New species	G. Lambert 1999 pers. comm.

* This species has been known from West coast of US for several years, but is not yet described (Goddard, 1999 pers. comm.)

TABLE 8.5 Species Range Extensions or First Records for Cook Inlet / Prince Wiliam Sound (sc AK)

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	References
Rhodophyta						
Polysiphonia senticulosa	a red alga	NE Pacific	Prince William Sound	1998	Range extension	Hansen 1998
Phaeophyta						
Ectocarpus acutus	a brown alga	NE Pacific	Prince William Sound	1998	Range extension	Hansen 1998
Ectocarpus dimorphus	a brown alga	NE Pacific	Prince William Sound	1998	Range extension	Hansen 1998
Chlorophyta						
Codium fragile spp. fragile	a green alga	NE Pacific	Prince William Sound	1998	Range extension	Hansen 1998
Cnidaria-Hydrozoa						
Aequorea aequorea	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Aequorea victoria	a hydromedusa	NE Pacific (SE AK)	Prince William Sound	1999	First Record sc AK	Mills, Chapt 9C2, this report
Clytia gregaria (=Phialidium gregarium)	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Eperetmus typus	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Euphysa sp.	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Gonionemus vertens	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Halitholus sp.	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Melicertum octocostatum	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Proboscidactyla flavicirrata	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Sarsia spp.	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Tiaropsis multicirrata	a hydromedusa	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1998	First Record sc AK	Mills, Chapt 9C2, this report
Ctenophora:						
Bolinopsis infundibulum	a ctenophore	NE Pacific (SE AK)	Prince William Sound, Bering Sea north	1999	First Record sc AK	Mills, Chapt 9C2, this report
Pleurobrachia bachei (?)	a ctenophore	NE Pacific (SE AK)	Prince William Sound, Dutch Harbor	1999	Range extension N	Mills, Chapt 9C2, this report
Annelida- Polychaeta						
Chaetozone senticosa	a cirratulid polychaete	NE Pacifc	Prince William Sound	1980	Range extension N	Kudenov 1998, pers. comm.
Cirratulus cirratulus	a cirratulid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Dodecaria sp.	a spionid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Drilonereis falcata minor	a lumbrinereid polychaete	NE Pacific (BC Canada)	Prince William Sound	1980	Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Drilonereis minor (?)	a lumbrinereid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Flabelligera mastigophora	a lumbrinereid polychaete	NW Pacific (Chukchi Sea)	Prince William Sound	1980	Range extension S	Foster 1999 pers. comm.; UAF
Hesperonoe complanata	a polynoid polychaete	NE Pacific	Prince William Sound	1980	Range extension S	Kozloff 1987; Foster 1999 pers. comm.;
Lumbrineris limicola	a lumbrinereid polychaete	NE Pacific	Prince William Sound		Range extension	Kozloff 1987; Foster 1999 pers. comm.;
Lumbrineris luti	a lumbrinereid polychaete	NE Pacific (BC Canada)	Prince William Sound	1988	Range extension N	Kozloff 1987; Kudenov 1998 pers. comm.
Magelona berkleyi	a magelonid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Magelona hobsoni	a magelonid polychaete	NE Pacific (BC Canada)	Prince William Sound	1988	Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Magelona sacculata	a magelonid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Mesochaetopterus taylori	a chaetopterid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Microphthalmus sczelkowi	a hesionid polychaete	NE Pacific (CA)	Prince William Sound	1980	Range extension N	Foster 1999 pers. comm.; UAF
Mysta barbata	a hesionid polychaete	NW Pacific (Chukchi Sea)	Prince William Sound		Range extension S	Foster 1999 pers. comm.; UAF
Onuphis (=Nothria,	an onuphid polychaete	NE Pacific	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Oriopsis sp.	a sabellid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.;

TABLE 8.5 continued

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	References
Nemidia sp.	a polynoid polychaete	Bering Sea	Prince William Sound		Range extension S	Foster 1999 pers. comm.; UAF
Nemidia tamarae	a polynoid polychaete	Bering Sea	Prince William Sound		Range extension S	Foster 1999 pers. comm.; UAF
Phyllodoce medipalpa	a phyllodocid polychaete	NE Pacific	Prince William Sound		Range extension N	Kozloff 1987; Kudenoff 1998 pers. comm.
Rhynchospio gluteae	a spionid polychaete	Unknown	Prince William Sound		Range extension	Kudenov 1998 pers. comm.
Syllis (Typosyllis) harti	a syllid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Foster 1999 pers. comm.; UAF
Syllis (Typosyllis) harti	a syllid polychaete	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Foster 1999 pers. comm.; UAF
Tharyx secundus	a cirratulid polychaete	NE Pacific (BC Canada)	Prince William Sound	1980	Range extension N	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Mollusca- Gastropoda- Prosobranchia						
Barleeia acuta	Acute Barleysnail	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Turgeon et al. 1988; Foster 1999 pers. comm.; UAF collections
Mollusca- Gastropoda- Opisthobranchia						
Acanthodoris nanaimoensis	Wine-Plumed Spiny Doris	NE Pacific (BC Canada)	Prince William Sound	1999	Range extension N	Kozloff 1987; Turgeon et al. 1988; Foster 1999 pers. comm.; UAF collections; Goddard 1999 pers. comm.
Adalaria jannae	Janna's Adalaria	NE Pacific (BC Canada)	Prince William Sound	1999	Range extension N	Kozloff 1987; Goddard 1999 pers. comm
Adalaria sp.1 of Behrens (1991)	Armed Adalaria	NE Pacific (SE AK)	Prince William Sound	1999	Range extension N	Goddard 1999 pers. comm
Alderia modesta	Modest Alderia	NE Pacific (BC Canada)	Prince William Sound	1999	Range extension N	Kozloff 1987; Turgeon et al. 1988; Goddard 1999 pers. comm
Ancula pacifica	Pacific Ancula	NE Pacific (SE AK)	Prince William Sound	1999	Range extension N	Kozloff 1987; Turgeon et al. 1988; Goddard 1999 pers. comm
Cuthona albocrusta	White-Crust Cuthona	NE Pacific (BC Canada)	Prince William Sound	1999	Range extension N	Kozloff 1987; Turgeon et al. 1988; Goddard 1999 pers. comm
Cuthona pustulata		NE Pacific (BC Canada)	Homer	1999	Range extension N	Kozloff 1987; Turgeon et al. 1988; Goddard 1999 pers. comm
Eubranchus olivaceus	Green Balloon Aeolis	NE Pacific (BC Canada)	Prince William Sound and Cook Inlet		Range extension N	Kozloff 1987; Turgeon et al. 1988; Foster 1999 pers. comm.; UAF collections; Goddard 1999 pers. comm
Geitodoris heathi	Heath's Dorid	NE Pacific (SE AK)	Prince William Sound	1999	Range extension N	Goddard 1999 pers. comm
Janolus fuscus		NE Pacific (SE AK)	Cook Inlet	1999	Range extension N	Foster 1999 pers. comm.; Goddard 1999 pers. comm
	Albatross Aglaja	NE Pacific (SE AK)	Prince William Sound	1980	Range extension N	Kozloff 1987; Turgeon et al. 1988; Foster 1999 pers. comm.; UAF collections
Melanochlamys diomedeum		NE Pacific (SE AK)	Prince William Sound	1998	Range extension N	Kozloff 1987; Foster 1999 pers. comm.;
Melanochlamys ocelliger	Arctic Odostome	Bering Sea	Prince William Sound,Shumagin Is., Kodiak Is.		Range extension S	Berh 1894; Lee & Foster 1985; Foster 1999 pers. comm.; UAF collections
Odostomia arctica	Hansine Seaslug	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Turgeon et al. 1988; Goddard 1999 pers. comm
Olea hansineensis	Banded Polycera	NE Pacific (N to Hawkins Island, Prince William Sound)	Prince William Sound		Range extension W	Foster 1999 pers. comm.; Goddard, pers. comm., 1999
Palio zosterae	Arctic Barrel-Bubble	Bering Sea	Prince William Sound		Range extension S	Turgeon et al. 1988; Foster 1999 pers. comm.; UAF collections
Retusa obtusa						
Mollusca- Bivalvia	Glacial Mussel	Bering Sea	Prince William Sound		Range extension S	Foster 1999 pers. comm.; UAF collections
Musculus glacialis						
Crustacea- Copepoda	Unidentified copepod	NE Pacific (subtropical)	Prince William Sound		Range extension S	Ted Cooney 1998 pers. comm.
Unidentified Calanoid						
Crustacea- Leptostraca						
Nebalia sp.	a nebaliacean	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Crustacea- Isopoda						
Gnathia tridens	an isopod	NE Pacific (CA)	Prince William Sound		Range extension N	Foster 1999 pers. comm.; UAF collections

TABLE 8.5 continued

Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	References
Munna chromocephala	an isopod	NE Pacific (WA)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Munna ubiquita	an isopod	NE Pacific (WA)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Pleurogonium sp.	an isopod	NE Pacific (WA)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Synodidotea ritteri	an isopod	NE Pacific (CA)	Prince William Sound		Range extension N	Smith and Carlton 1975; Foster 1999 pers. comm.; UAF collections
Brachiopoda						
Terebratalia crossei	a brachiopod	NW, NE Pacific	Prince William Sound		Range extension N, NE	Foster 1999 pers. comm.; UAF collections
Bryozoa						
Cribilina annulata	a bryozoan	Bering Sea	Prince William Sound		Range extension S	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Filicrisia smithi	a bryozoan	Bering Sea	Prince William Sound		Range extension S	Foster 1999 pers. comm.; UAF collections
Echinodermata-Asteroida						
Asterias amurensis	Asian Sea Star	NW Pacific; Bering Sea	Homer Spit	1999	Range extension	REFS
Chordata- Ascidiacea						
Chelysoma columbianum	a tunicate	NE Pacific (BC Canada)	Prince William Sound		Range extension N	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Halocynthia hilgendorfi igaboja	a tunicate	NE Pacific (BC Canada)	Prince William Sound		Range extension	Kozloff 1987; Foster 1999 pers. comm.; UAF collections
Chordata- Osteichthyes						
Sphyraena argentea	Pacific Barracuda	NE Pacific (BC Canada)	Prince William Sound	1998	Range extension	Valdez Vanguard newspaper, 1998

We also considered several reports and specimens that were initially considered as possible NIS, but which we reject primarily as misidentifications of similar native species (Table 8.6).

TABLE 8.6 Species/Specimens Misidentified as NIS

Putative Species	Common Name	Probable Region of Origin	AK Regions	Date 1st Record	Invasion Status	References
Rhodophyta						
Porphyra redidiva	a red alga	NE Pacific	Prince William Sound	1998	Misidentified earlier	Hansen 1998
Chlorophyta						
Monostroma fractum	a green alga	NE Pacific	Prince William Sound	1998	Misidentification, overlooked	Hansen 1998
Angiospermophyta						
Myriophyllum spicatum	Eurasian Watermilfoil	Eurasia	SE Alaska (FW)		Probable misidentification	USGS 1998
Cnidaria-Hydrozoa						
Halitholus sp.	a hydromedusa	NE Pacific	Prince William Sound	1998	Not identifiable to species	Mills, Chap9C2,this rep
Leuckartiara sp.	a hydromedusa	NE Pacific	Prince William Sound	1998	Not identifiable to species	Mills, Chap9C2,this rep
Annelida- Polychaeta						
Anaspio boreas	a spionid polychaete	Gulf of Alaska	Prince William Sound		Uncertain identification	Foster 1999 pers. comm.; UAF collections
Polydora cf. *P. brachycephalata*	a spionid polychaete	NE Pacific (Oregon)	Prince William Sound	?	Misidentification?	Kozloff 1987; Foster 1999 pers. comm.; UAF collections

There are few over-arching ecological traits that characterize marine NIS in Alaska. NIS were variable in their local distributions in the region, with distributions of most species apparently limited to particular sites, but with many sites having some NIS. Although NIS were frequently associated with harbor areas and aquaculture sites, some species (e.g., *Mya arenaria*) occurred widely wherever the appropriate habitat was present. NIS occurred in a wide range of habitats from coastal marshes (*Cotula coronopifolia*) and the high intertidal zone (*Fucus cottonii*) to deep subtidal waters (*Trochammina hadai*), and from variable and low salinity areas (*Mya arenaria*, *Heteromastus filiformis*) to stenohaline high salinities (*Botryloides violaceus*). NIS included species inhabiting hard and soft substrates. NIS also include species from a wide range of motility, from migratory fish to sessile plants and invertebrates; and they included a full range of trophic modes from autotrophs (algae) to suspension feeders to predators. While many of the NIS have life cycles with a dispersal stage (especially echinoderms and bivalves with long-lived planktonic larvae), others had little motility (e.g., sessile tunicates with short-lived planktonic larval stages). Thus, although NIS were most common in habitats most impacted by human activities, there were few sites or habitats within the region and few ecological niches that were immune from invasion.

Although oil tankers transport great quantities of abundant and diverse plankton (including known NIS) into Prince William Sound, we have not identified any established NIS that is clearly attributable to introduction via tanker ballast water. However, analysis of probable transport mechanisms for species introductions is difficult in most regions where multiple transfer agents have been active. In south central Alaska, NIS were commonly found at harbor areas (e.g., Homer), where ballast water and hull fouling associated with cargo ships and the full range of fishing and other vessels are potential vectors. Bulk carriers like wood chip and log ships arriving in ballast to Homer, as well as tankers arriving to Port Valdez, are sources of the largest volumes of ballast water (Smith et al., 1999). Fishing and recreational vessels often have extensive fouling communities which may be transported coastwise within the region. NIS were also found at sites of associated with aquaculture (e.g., Tatitlek) and with fishery introductions (e.g., Atlantic salmon). Oyster (*Crassostrea gigas*) culture imports spat from Washington and Oregon hatcheries as “clean” seed for grow-up in the field. However, associated parasitic, commensal and fouling organisms frequently could be transported unintentionally with the spat (Carlton, 1992). Similarly, transfer of kelp (*Macrocystis integrifolia*), however “clean” in appearance, from Oregon and Washington (in the past) and southeast Alaska (in the present) could also serve as a vector for many fouling species, epiphytes, or organisms hiding in holdfasts. Several species of fish have been introduced intentionally into Alaskan freshwaters, where they may impact salmonids at key stages of their migratory life cycle. Also, escapes of Atlantic salmon from pen culture have resulted in established populations of *Salmo salar* in British Columbia, as well as in increasingly frequent instances of this NIS fish being caught in Prince William Sound and throughout south central to southeast Alaska.

The number of marine NIS in Alaska appears to be significantly lower than other marine ecosystems along the west coast of North America, where numbers of NIS range from about 50 species in Puget Sound (Cohen et al., 1998) to 250 species in San Francisco Bay (Cohen & Carlton, 1995; Carlton, pers. comm.).

Species Notes:

RHODOPHYTA

Ceramium sinicola- This red alga was found as an epiphyte of *Codium fragile* (*tomentosoides*?) near Green Island. It has not been found previously north of southern California, and is strongly suspected of being an introduction (Hansen 1998).

Chroodactylon ramosum- This microscopic, primitive, red alga was found growing on oyster floats at Tatilek. This species is previously known from Japan, Australia, and southern California (and the Great Lakes, where it was introduced, Mills et al. 1993) but has not been found in the well-studied waters of British Columbia and Washington. It may have been introduced with oysters (Hansen 1998).

PHAEOPHYTA

Fucus cottoni (=muscoides)- This brown seaweed is known from European coasts from northern Spain to Scandinavia (South and Tittley 1986). In the northeast Pacific, it was first found by G. I. Hansen on Vancouver Island in 1981, and subsequently found to be abundant in high marsh and mudflat areas along Prince William Sound (Hansen, 1998; Chapt 9 Hansen). Its status as a separate species has been questioned by Fletcher (1987), who considers this species to be an ecotype of *F. vesiculosus* adapted to marsh and mudflat habitats. Specimens from Prince William Sound have been sent to Esther Serrao, Portugal, who is studying the phylogenetic relationships of *Fucus* using molecular techniques. The widespread distribution of this plant in British Columbia and Alaska, suggests that it is not a recent introduction (Hansen 1998; Chapt. 9 Hansen).

Macrocystis integrifolia- This giant kelp is found from California to southeast Alaska. Since 1979, this kelp had been transported by plane from southeast Alaska to Prince William Sound to be used as substrate for the Herring-Roe-on-Kelp fishery. Blades of kelp are placed in impoundment nets with gravid herring, which deposit their eggs on the kelp. The egg-laden blades are then harvested and shipped to Japan, as a delicacy. Blades and holdfasts of kelp are commonly found in Prince William Sound, but attached plants have not been found, indicating that this kelp has not become established. While “clean” kelp blades are selected for the fishery, the practice represents a potential vector for transport of microscopic developing stages of algae and invertebrates into Prince William Sound (Jay Johnson, Alaska Fish and Game, pers. comm. to G. I. Hansen ; Hansen 1998). Our examination of several large plants including blades, stipes and holdfasts at Knight Island in the Sound during June 1998 showed that a variety of gastropods, ophiuroids, amphipods and bryozoans were present. It was not clear whether these associated organisms colonized the plants or were present at the time of release into the Sound.

Microspongium globosum- This tiny brown alga is known previously from the North Atlantic and Japan, but it has not been found in the waters of British Columbia and Washington. It grows epiphytically on the cryptogenic brown alga *Demaraeaea attenuata*, attached to oyster floats at Tatilek (Hansen 1998).

Sargassum muticum- This Japanese seaweed was first observed on the U.S. west coast in 1947, in Coos Bay, Oregon. By 1986, it was well established from southern California to southeast Alaska. It was probably transported across the Pacific on the shells of Pacific Oysters from Japan, and then transported along the coast by currents, shipping, and oyster transplants (Scagel 1956; Scagel et al. 1986; Cohen and Carlton 1995; US Fish & Wildlife Service, Nonindigenous Aquatic Species Database 1999).

CHLOROPHYTA

Codium fragile (ssp. tomentosoides?), Dead Man’s Fingers- The green algal species *Codium fragile* occurs on the West Coast as a species complex consisting of several unnamed subspecies, presumably native (Cynthia Trowbridge, pers. comm. to G. I. Hansen), as well as the introduced *C. f. tomentosoides.* The latter is native to the Northwest Pacific, and now widely introduced in temperate waters (Farnham 1980; Carlton and Scanlon 1985; Trowbridge 1995). On the West Coast, this seaweed has previously been known only from San Francisco Bay, where it was first collected in 1977, and probably was introduced on ship fouling (Cohen and Carlton 1995). A form of *Codium* nearly identical to *C. f. tomentosoides* was found in 1998, at Green Island, in Prince William Sound, together with a more typically native *Codium*. According to experts on the genus consulted by Hansen, both forms lie within the morphological range of the native populations, but molecular studies will be needed to determine their identity and relationships. In any event, the occurrence of *Codium* in Prince William Sound represents a range extension from southeastern Alaskan waters, and a possible introduction.

ANGIOSPERMOPHYTA

Cotula coronopifolia, Brass Buttons- This attractive flowering plant of the aster family is native to South Africa. It was first reported on the Pacific Coast in 1878, along San Francisco Bay and now occurs in coastal marshes from southern California to southeast Alaska (Hultén 1968; Cohen and Carlton 1995). Brass Buttons was probably transported in the dry ballast of ships to San Francisco Bay and other Pacific ports, as well as to scattered sites on the Atlantic coast of North America and Europe (Hultén 1968). Seeds of this plant (Cohen and Carlton 1995) are a favorite food of waterfowl, which may be how this species reached Alaska.

Additional flowering plants, identified by Hultén (1968) as "introduced weeds" of "waste places" and roadsides, probably occur at the edges of seashores and salt-to-fresh tidal marshes on the Pacific coast of Alaska, based on their habits and distribution elsewhere in North America. The following species are likely to occur in tidal marsh and shore habitats, especially disturbed ones: *Agrostis gigantea* (Redtop); *Polypogon monspeliensis* (Beard Grass); *Puccinellia distans* (Alkali Grass); *Rumex crispus* (Curly Dock); *Rumex obtusifolius* (Round-Leaved Dock)); *Rumex maritimus* (Golden Dock*); Polygonum prolificum* (Prolific Knotweed); *Spergularia rubra* (Sand Spurrey); *Plantago major* (English Plantain) (e.g. Fernald 1950; Gleason and Cronquist 1991; Cohen and Carlton 1995). *Polygonum prolificum* is native to eastern North America; the other species are of Eurasian origin (Hultén 1968). Many of these species were present on the coast of southeast Alaska by 1883 (Meehan 1884), and may have been introduced in ship's ballast.

PROTOZOA- FORAMINIFERA

Trochammina hadai- This foraminiferan is native to Japan, and was first found in North America in San Francisco Bay in 1990-1993 (Cohen and Carlton 1995; McGann and Sloan 1996). It was subsequently found in many Pacific Coast estuaries, from San Diego Bay to Puget Sound (Cohen et al. 1998; McGann 1998 pers. comm.). In San Francisco Bay it forms very dense populations and it processes large amounts of carbon in the benthic communities throughout the estuary. *T. hadai* was also found in EVOS samples taken from deep (300 ft) water of Prince William Sound (McGann 1998 pers. comm.). This benthic protozoan inhabits the sediments (preferably muddy) of brackish-marine estuaries (Matsushita and Kitazato 1990, Kitazato and Matsuchita 1996). It probably has been introduced in ballast water, and was common in sediments in the ballast tanks of oil tankers travelling between west coast ports and Port Valdez (McGann and Sloan 1996; McGann 1998 pers. comm.). However, sediment samples collected from low intertidal to shallow subtidal zones throughout Prince William Sound during 1998-1999 did not contain *T. hadai*, so the extent of this population in the Sound remains unclear (Hines & McGann, pers. comm.).

PORIFERA

Cliona thosina- This boring sponge was originally described in 1888 using specimens on oyster shells from an unknown locality (possibly France or Mexico). *C thosina* was found boring in field cultured oysters (*Crassostrea gigas*) in Prince William Sound in 1998 (Hines, 1998; Ruetzler pers. comm. 1998). Its boring activities weaken oyster shells and can cause shell deformation, breakage and increase vulnerability to predators (such as crabs). The larval stages of C. thosina are short lived (1-2 days), limiting its ability to be transported in ballast water. Oysters cultured in the Sound arrive as "clean" spat derived from laboratory cultures in Oregon and Washington. However, oyster spat is not always as "clean" as the suppliers claim, and many associated species may be found in these types of aquaculture sources (Carlton, 1992). *Cliona* is common in oysters of the lower west coast, so it is possibly derived from these populations.

CNIDARIA- HYDROZOA

Garveia franciscana (Rope Grass Hydroid)- This hydroid has been found in many estuaries around the world, but its origin is uncertain. The Indo-Pacific and the Black--Caspian Sea basin have been suggested as possible native regions (Cohen and Carlton 1995; Calder 1997 pers. comm.) It was first described from San Francisco Bay in 1902, which was its only known location on the west coast of North America (Cohen and Carlton 1995), until we found it near

Homer in 1999 (Lee-Anne Henry pers. comm. 1999; Chapt 9 Fouling Communities). In other regions of the world, this hydroid has been an economically important fouling organism, adversely affecting ships, power plants and fishing gear (Simkina 1963; Andrews 1973; McLean 1972).

ANNELIDA- POLYCHAETA

Heteromastus (filiformis?)- This sediment-dwelling, free-burrowing polychaete, of the family Capitellidae, was first described from Europe, but it is now widely distributed in coastal waters around the world. On the west coast of North America, *H. filiformis* was first reported in 1936, from San Francisco Bay, and subsequently has been found north to British Columbia and Prince William Sound. Its introduction to the Pacific Coast could have occurred with Atlantic or Pacific oysters, or in the ballast water of ships (Carlton 1979; Cohen and Carlton 1995). *Heteromastus "filiformis"*, as with some other capitellid species, may constitute a complex of several morphologically similar species (Cohen and Carlton 1995). *H. filiformis* was collected commonly in Port Valdez in 1971-1972, 7 years after the 1964 earthquake that disrupted the benthic system, indicating that it was established well before initiation of tanker traffic to the Port (Feder et al. 1973).

Lumbrineris heteropoda- This infaunal and polychaete is known from the Sahkalin and Japan, and from two Alaskan specimens, one from Resurrection Bay, and another from Glacier Bay. The wide gap between the known range and the Alaska records is suggestive of an introduction (Nora Foster, 1999 pers. comm.).

MOLLUSCA- BIVALVIA

Crassostrea gigas (Pacific Oyster; Japanese Oyster)- The Pacific Oyster was first planted in North American waters in 1902, in Puget Sound. By 1939, it was cultivated in Ketchikan, Alaska, and it is now reared in Prince William Sound, Katchemak Bay and other locations. Alaskan waters are too cold for natural reproduction of *C. gigas*, so spat must be transferred from southern waters (Quayle 1969; Carlton 1979;R. Piorkowski 1999 pers. comm.).

Mya arenaria (Softshell Clam)- The Softshell Clam has a complex biogeographical history. This species evolved in the Pacific, in the Miocene Period, and subsequently invaded the Atlantic, but became extinct in the Eastern Pacific (Strasser 1999). Living populations of *Mya arenaria* remain in the Bering Sea, but on the Eastern Pacific Coast, shells of softshell clams are absent from subfossil deposits and shell middens, including those recently examined for *M. arenaria* (Foster, Chapt 9C7, this report). *Mya arenaria* was re-introduced to the Pacific Coast in San Francisco Bay in 1874, probably with plantings of Eastern Oysters (*Crassostrea virginica*). It was soon widely transplanted along the coast, reaching Alaska by the 1960s-1970s (Carlton 1979). The clam has been widely established for decades in Prince William Sound and Port Valdez (Feder et al. 1973, Feder and Paul 1973), and was heavily impacted by benthos upheaval in the 1964 earthquake (Baxter 1971).

CRUSTACEA-AMPHIPODA

Jassa sp.; *Jassa marmorata*- A tube-dwelling amphipod of the genus *Jassa* from Prince William Sound was found in University of Alaska collections (Nora Foster pers. comm.). Specimens are being examined by John Chapman, but are not yet identified to species. *Jassa marmorata*, native to the northwest Atlantic, has been widely introduced in the world's oceans, and has been collected from Alaska waters (Point Slocum, Conlan 1989; Cohen and Carlton 1995; Chapman 1998 pers. comm.). Amphipods of this genus build tubes on hard surfaces, including ship hulls, but also have been collected from ballast water (Cohen and Carlton 1995).

BRYOZOA

Cryptosula pallasiana- This bryozoan is apparently native to the Atlantic Ocean, but is now widely distributed in the Pacific. An early (1925) record of *C. pallasiana* from Homer, Alaska was a misidentified specimen of *C. okadai*, but in 1944-46 it was found in Sitka (U. S. Navy 1951; Carlton, pers. comm.), as well as San Francisco Bay, and Newport Harbor, California. It was probably transported in ship fouling (Cohen and Carlton 1995).

Schizoporella (unicornis?)- This northwest Pacific bryozoan was first collected in the Eastern Pacific in 1927, in Puget Sound (Carlton 1979; Cohen and Carlton 1995). Its first Alaska collection was made between 1944 and 1949, in Kodiak (U. S. Navy 1951; Powell 1970; Dick and Ross 1988; Carlton, pers. comm.). *Schizoporella unicornis* may have been introduced in ship fouling or with plantings of Pacific Oysters (Cohen and Carlton 1995). In 1999, it was found in Tatitlek. (This form, while definitely introduced to the Pacific coast, may actually be a complex of several species (Winston 1999 pers. comm.).

ECHINODERMATA- OPHIUROIDEA

Ophiothrix koreana- A single brittlestar from Southeast Alaska (Juneau) has been tentatively identified as *O. koreana (*Kyte 1998, pers. comm.). If this identification is correct, this collection would be the first record of this northwest Pacific ophiuroid from the eastern Pacific. Since only a single specimen has been collected, the existence of established populations is unknown. Most brittlestars have long-lived planktonic larvae, so ballast-water transport is likeliest, but transport with oysters or ship fouling can not be ruled out.

CHORDATA- ASCIDIACEA

Botrylloides violaceus (=*Botryllus aurantius*)- This colonial tunicate is native to the northwest Pacific (Japan), and may have been first found on the West Coast in 1973, in San Francisco Bay (Cohen and Carlton 1995). It is now widespread, from southern California to British Columbia (Cohen et al. 1998; Lambert and Lambert 1998). *Botrylloides violaceus* was abundant on fouling plates in Prince William Sound in 1999 (G. Lambert 1999 pers. comm.).

CHORDATA-OSTEICHTHYES

Alosa sapidissima (American Shad)- This anadromous fish, native to the Atlantic coast of North America, was introduced in 1871, to the Sacramento River. It rapidly spread along the Pacific coast, and was first collected in Alaska in the Stikine River in 1896. Shad spawn in freshwater rivers from San Francisco Bay, north to the Columbia River, but feeding adult and juvenile fish wander as far north as Cook Inlet and the Kamchatka Peninusla (Chapman 1942; Cohen and Carlton 1995). A specimen of this species from Port Moller, Alaska Peninsula resides in the University of Alaska Museum collections (Foster 2000, pers. comm.). American Shad have been captured by seines and gill nets in Southeast Alaska during strong El Niño years, e.g., 1969 and 1983 (J. Karinen, 2000 pers. comm.)

Dallia pectoralis (Alaska Blackfish)- This small freshwater fish is native to the North slope and Yukon-Kuskakwim Delta of Alaska and eastern Siberia, but it was introduced in 1950 to Hood and Spenard Lakes in Anchorage, in the Susitna River drainage, and has spread to other lakes in the vicinity (Morrow 1980). We are unaware of records of this fish in brackish or tidal waters, but we are including it here because of concerns of adverse impacts on Rainbow Trout (*Oncorhynchus mykiss*) and other salmonid populations in the Anchorage area (Morrow 1980).

Esox lucius (Northern Pike)- This large predatory, freshwater gamefish is native to most of the glaciated regions of North America and Eurasia (Scott and Crossman 1973). In Alaska, the native range includes the Bering Sea drainage, and North Slope, but not Pacific watersheds. Northern Pike were illegally introduced to the Susitna River valley in the 1970s (Morrow 1980). This species is known to enter brackish waters (Scott and Crossman 1973), though we are unaware of estuarine occurrences in Alaska. Pike have a reputation as predators of salmonids, so their introduction has long been discouraged on the West Coast (Lampman 1946; Dill and Cordone 1997).

Salmo salar (Atlantic Salmon)- Atlantic Salmon are native to both sides of the North Atlantic, and spawn in rivers of Europe and eastern North America. Many unsuccessful attempts were made to stock this species on the West Coast, beginning in the Sacramento River in 1874 (Dill and Cordone 1997), but the extensive use of *S. salar* in net-pen aquaculture has again raised the possibility of its establishment in Pacific waters. Rearing of Atlantic Salmon is illegal in Alaskan waters, but occurs in British Columbia and Washington (USGS, Nonindigenous Aquatic Species Database 1999). In Alaska, the Atlantic Salmon was first caught off Cape Cross, in southeastern waters, in 1990 (Wing et al. 1992). Since then, many *S. salar* have been caught in the state's marine waters, and in 1998, the first one was caught in Alaska freshwater (Freeman 1998 pers. comm.; USGS, Nonindigenous Aquatic Species Database 1999), and some have been caught in Prince William Sound with landings reported at Port Valdez and Cordova (Benda 1997 pers. comm., Freeman 1998 pers. comm.). Many escaped cultured fishes are in poor condition (USGS, Nonindigenous Aquatic Species Database 1999), but successful reproduction has been documented on Vancouver Island (Volpe 1999), and could well occur in Alaska waters.

Salvelinus fontinalis (Brook Trout)- This eastern North American fish was introduced into southeast Alaska in the 1920s, and continued to be stocked into the 1950s. In its native range, the Brook Trout has anadromous populations in coastal regions, from Massachusetts to Labrador (Morrow 1980). We have not found documentation of sea-running fish in Alaskan waters, but estuarine occurrences of this trout are possible. However, few populations occur in coastal lakes, and none are known from streams or rivers (Alaska Department of Fish and Game 1994) The Brook Trout may hybridize with the native Dolly Varden, but the impact of this crossing on native populations is unknown (Morrow 1980).

Suspicious Species

ECHINODERMATA- ASTEROIDEA
Asterias amurensis (Common Asian Sea Star)- This sea star is native to the Northwest Pacifc, including the coasts of Japan and Russia north to the Tatarskii Inlet and the southern Kuril Islands, and to the Bering Sea Coasts of Russia and Alaska (Baranova 1976; Ward and Andrew

1995, Jewett and Feder 1981). Its recent appearance at Homer in Cook Inlet could represent a natural range extension. However, this species has long-lived planktonic larvae and could also be carried in ship ballast water. *Asterias amurensis* has successfully invaded the coast of Tasmania, where it poses a threat to shellfisheries (Ward and Andrew, 1995). Shipping traffic into Homer by bulk carriers of logs and wood chips increased markedly recently as spruce trees killed by a beetle outbreak have been forested. These ships probably bring large quantities of ballast water to Homer from Asian ports within the established of range *A. amurensis*. The recent appearance of *A. amurensis* in the low intertidal zone at the tip of Homer Spit was noted as a sudden arrival by experienced naturalists (C. & C. Field, 1999 pers. comm.), who have been studying the area for several years. This large conspicuous sea star would not be overlooked easily and was not recorded previously in the many benthic trawl surveys of the Gulf Alaska (N. Foster, UA Museum 1999 pers. comm.). Specimens of *A. amurenis* are not represented in the University of Alaska Museum's collections for trawl surveys in either the Gulf of Alaska (Foster, 1999 pers. comm.) or Cook Inlet (Feder and Paul 1981, Feder et al. 1981). The survey of Cook Inlet also included scuba surveys. It would have been very unusual for such collections to miss a large conspicuous sea star (30 cm from ray tip to ray tip). We consider this species to be cryptogenic in Cook Inlet, with characteristics that are very suspicious of an NIS. Because it is a voracious predator, it could have a major impact on benthic communities.

ASCIDIACEA
Distaplia n. sp.- This tunicate is a new, undescribed species (G. Lambert, 2000, Chapt 9C10, this report), which is very abundant in fouling communities on floats and man-made substrates in marinas at Homer and Cordova. It was first collected in 1998 in Homer and was found in both Homer and Cordova in 1999. It was not found at other sites within Prince William Sound where other, native species of tunicates were common in fouling communities but lack similar shipping/boating traffic (e.g., Tatitlek, Chenega, Port Chalmers). These sites were sampled by the same expert taxonomists and systematists who found the species at Homer and Cordova. Also, sites with and without the new species were sampled at the same times with an equivalent sampling effort (fouling plates, Chapt 9D, this report). Its appearance is also suspicious, because it was not identified in 1901 when tunicates were collected in the region at nearby sites (Ritter 1903), but this ascidian taxonomist tended to "lump" species of *Distaplia* (G. Lambert, 1999 pers. comm.). This tunicate could be a formerly rare native species that has taken advantage of the newly created marina habitat (G. Lambert 1999 pers. comm.), or a recent introduction.

CRYPTOGENIC SPECIES
PHAEOPHYTA
Demaraeaea attenuata- This is a possible introduction from the Northwest Pacific, but G. Hansen treated this alga as cryptogenic, although she considered its epiphyte *Ceramium sinicola* to be a more likely introduction (Chapt 9C1, this report).

ANGIOSPERMOPHYTA
Atriplex patula & A. prostrata- These flowering plants commonly occur on marshes and beaches, but Hultén (1968) refers to them (lumped as *A. patula*) as an "introduced weed". Botanists are divided on their status in North America, and on the East Coast they can be traced back to the early 1700's. Here, we designate them "cryptogenic".

ANNELIDA-POLYCHAETA
Capitella capitata and other polychaete species complexes- Many cosmopolitan polychaete "species" are believed to represent groups of sibling species, with little morphological differentiation, but possibly with differing life histories and environmental adaptations. This has been shown for the pollution-tolerant worm *Captitella capitata* (Grassle and Grassle 1976), and is suspected for many others. Cryptic invasions by foreign sibling species could be common for species with planktonic larvae, especially in newly polluted harbors, where less-tolerant natives could be replaced by better adapted invaders. Such invasions could only be detected by genetic methods, or by very exacting morphological studies.

Polydora quadrilobata- This spionid polychaete has a wide distribution, including both sides of the North Atlantic, the Northwest Pacific, and the Northeast Pacific coast from California to Puget Sound (Blake 1971; Kozloff 1987). At least 7 species of spionids have been introduced to the Northeast Pacific (Cohen and Carlton 1995; Cohen et al. 1998). Foster (N. Foster, UA Museum, 1999 pers. comm.) considers *P. quadrilobata's* wide distribution to be suspicious, in view of the numerous introductions of this group: "The suspicious designation results from my perception that Spionidae do seem to make up a large proportion of the NIS listed by the Puget Sound expedition."

BRYOZOA
Alcyonidium (polyoum?) Native and introduced cryptic species are presumed to exist on the Pacific Coast. However, Alaska animals may be more likely to represent native forms, while San Francisco Bay bryozoans are more likely to be introduced (Cohen and Carlton 1995).

MOLLUSCA- BIVALVIA
Macoma balthica- Native and introduced cryptic species are presumed to exist on the Pacific Coast. However, Alaska animals may be more likely to represent the native forms (Meehan et al. 1989; Cohen and Carlton 1995).

CRUSTACEA-COPEPODA
Leimia vaga- This benthic harpacticoid copepod was first described from Nova Scotia, but has a limited distribution in the North Atlantic and is found in several Oregon and Washington estuaries (Chapt 9C5; Jeff Cordell 1999 pers. comm.). In 1999, our surveys found it in Prince William Sound (Chapt 9C5, this report). Its disjunct distribution is suggestive of transport between coasts, but the origin of this species is unknown.

8D. Conclusions

We have identified 24 species of plants and animals comprising the NIS of marine related ecosystems in Alaska, including 15 species recorded from Prince William Sound. In addition, 2 cryptogenic species have highly suspicious characteristics of NIS. These species represent a diverse array of taxa that occupy a wide range of ecological niches and habitats, although there appear to be more NIS associated with boat harbors and with aquaculture activities. Several of these NIS are first records for Alaska. We also recorded several new, previously undescribed species as well as numerous range extensions for species, which probably reflect the poor level of study and understanding of taxonomy and biogeography in Alaskan marine ecosystems. Many of the Alaskan NIS have larval stages which could be transported in ballast water; however, other vectors (including intentional and incidental release for fisheries and aquaculture) are obvious possibilities. None are clearly associated with ballast water of oil tankers as a primary mechanism, even though many NIS are frequently found in ballast water arriving to Port Valdez (see Chapt 3, this report). The number of marine NIS in Alaska appears to be significantly lower than other marine ecosystems along the west coast of North America, where numbers of known NIS range from about 50 to 250 species. The complexities and uncertainties of the native biota and the history of vectors in the south-central Alaskan region will inevitably result in an evolving analysis, typically revealing previously hidden importance and impacts of NIS.

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Chapter 9A. Overview of NIS Surveys

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9A1. Purpose

A central goal of this project was to determine whether NIS have been, or are becoming, established within Prince William Sound. Because of the diversity of potential vectors and changing patterns of transport mechanisms, our purpose was to provide as broad and comprehensive a search for NIS as possible with our resources. Since previous ecological and systematic work in Alaska has not focused on NIS, we also wished to provide a baseline for the status of NIS in Alaskan waters, against which future introductions could be measured. Recent and on-going work on NIS along the temperate west coast of North America indicates that many invasive species appear to be spreading northward from a peak of NIS diversity in San Francisco Bay, as well as other highly invaded source ports for ballast water arriving to Prince William Sound. Some of these NIS (e.g., *Carcinus maenas*) have moved rapidly from central California to Washington and British Columbia, and may be expected to reach Alaskan waters in coming years. We focused on Prince William Sound for our field surveys and analysis of existing samples; but because NIS often spread coast-wise, we also sampled ports on the adjacent Kenai Peninsula, and we considered scientific reports broadly from Alaskan waters.

9A2. Approach

To detect recent or well-established NIS in Port Valdez / Prince William Sound and adjoining areas of risk for invasion, we used several methods, including:

- <u>Rapid assessment field surveys</u> of estuarine and marine invertebrates and plants for Port Valdez, Prince William Sound, Seward and Homer. The objective was for experienced general ecologists to survey major habitats and communities, especially for large NIS plants and animals detectable in the field by experienced naturalists.
- <u>Focal taxonomic field collections</u> in Prince William Sound, Seward and Homer. The objective was for taxonomic experts to sample and analyze key taxonomic groups that have known NIS but which are difficult for generalists to identify, providing definitive identification and careful, authoritative assessments of the native, invasive and cryptogenic status. Whenever possible, we also wished the taxonomic experts to have the opportunity to sample the sites using their specialized methods and knowledge for collecting the focal taxon.
- <u>Fouling plate surveys</u> in Prince William Sound, Seward and Homer. The objective was to provide a replicated standard sampling method of assay for NIS in a community that is prone to invasions, but which has received little prior ecological analysis in Alaska.
- <u>Re-examination of museum and reference collections</u> for Prince William Sound. The objective was to re-examine extensive collections already available in the University of Alaska Museum and vouchers samples from Exxon Valdez Oil Spill (EVOS) and other ecological studies, developing a screening method of screening for potential NIS.

Our approach of utilizing this array of methods served to maximize spatial, temporal, taxonomic, and habitat coverage, while still focusing our limited resources upon elements known to be of highest risk of invasion. The field surveys provided broad coverage of Prince William Sound, as will as Anchorage, Homer and Seward as important ports in neighboring Cook Inlet and the Kenai Peninsula (Fig. 9.A.1).

Figure 9A.1. Map of Sampling Sites for NIS Surveys (1997-1999).

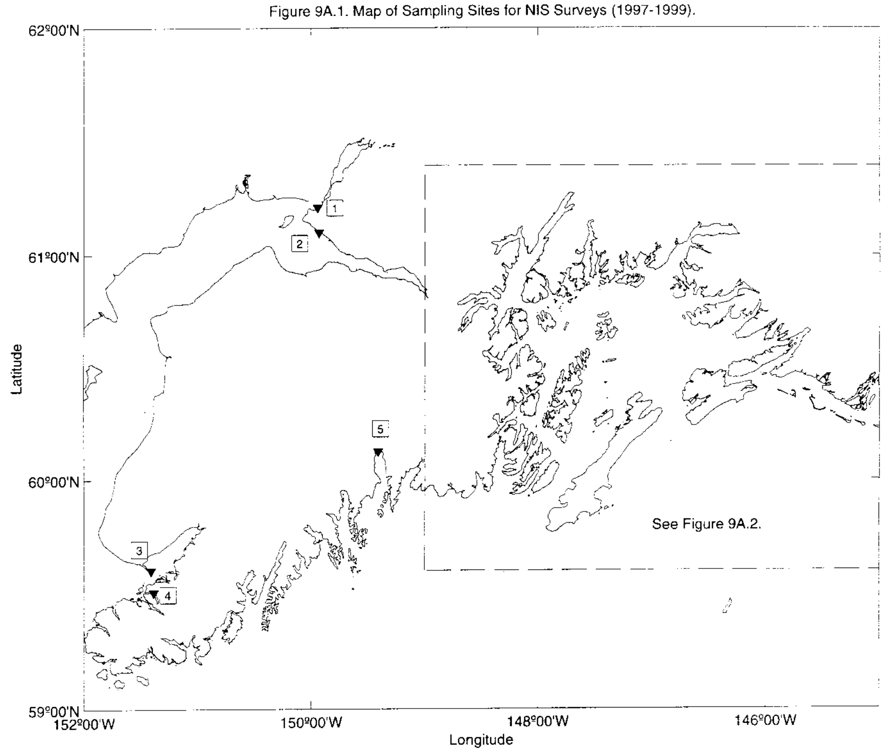
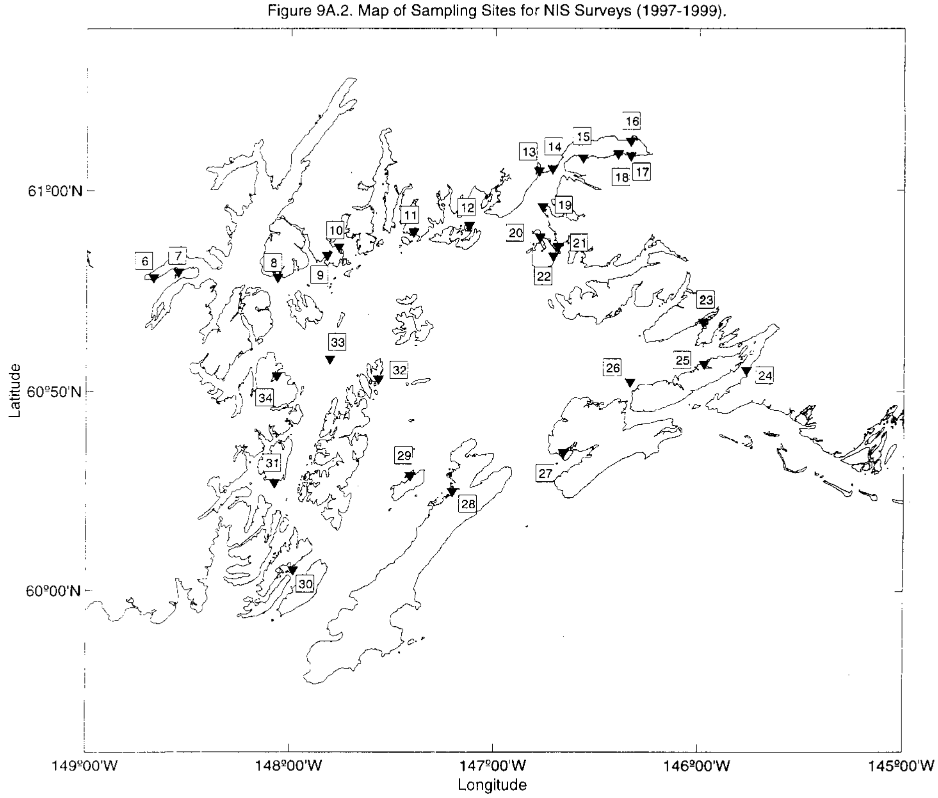


Figure 9A.2. Map of Sampling Sites for NIS Surveys (1997-1999).



In any ecosystem, the ability to detect established NIS varies in space and time, because most aspects of species distribution and abundance are probabilistic. Like any population, NIS populations are typically patchily distributed across the full range of habitats, and may undergo marked seasonal and annual fluctuations. In high latitude ecosystems like Prince William Sound, this variation is extremely pronounced, due to rapid changes in photoperiod and fluctuations in surface salinities resulting from warm season runoff. By using an array of sampling at several times throughout the growing season, we increased the probability of detecting NIS.

In addition to the stochastic aspect of detecting NIS, detection of NIS in Prince William Sound is difficult because the biota is not well described by taxonomists and biogeographers. Despite the extensive sampling in Prince William Sound for EVOS and other ecological programs, there are no comprehensive keys or field guides to the biota of the region (a notable exception is the guide to Alaskan molluscs; Foster 1991). In our Pilot Study (Ruiz & Hines 1997) of Port Valdez alone, we found a surprisingly high percentage of new species records, and our literature analysis showed that 20-50% of the species are cryptogenic in origin.

It was necessary to sample several habitats of Prince William Sound that have received little scientific study. For example, there are almost no publications on the fouling community of floats and pilings, yet NIS are very common in this habitat in west coast source ports, where some of these NIS have been very destructive. Soft-bottom habitats of Prince William Sound have received less study than rocky substrates.

Also, in much of the previous work associated with the Exxon Valdez Oil Spill, taxonomic identifications were not carried out to species but were reported at relatively high taxonomic levels (e.g., Family, Order). Without careful identification to species by expert taxonomists, NIS are often confused with similar native species. Therefore, we brought systematic experts for several focal taxonomic groups to Alaska for field collections or contracted them to identify selected subsets of samples.

9A3. Site selection and sampling design

In addition to a survey of Port Valdez and Sawmill Bay during our Pilot Study in June 1997, we conducted two broad expeditions to survey Prince William Sound for NIS during low tide series of 20-28 June 1998 and 8-16 August 1999. Fouling Plate Surveys were conducted during 7-17 September 1998 and in 8-16 August 1999.

The surveys in September 1998 and August 1999 included sampling stations at Homer and Cordova on the Kenai Peninsula adjacent to Prince William Sound. The survey sampling design focused on invertebrates and plants in a variety of habitats of shallow water, the intertidal zone, and accessible man-made surfaces (e.g., floats, pilings, buoys). We selected sampling sites that were judged to be most susceptible to invasion by NIS:

- areas most likely to be in the path of ballast water discharged from tankers (as estimated by circulation models and the path of the Exxon Valdez Oil Spill);
- ports and sites of sustained disturbance by human activities (especially Port Valdez, Cordova, and Whittier, as well as Homer and Seward);
- habitats associated with previously reported NIS and cryptogenic species;

- warmer water areas;
- marinas, floats, buoys, and pilings with accessible fouling communities; and
- sites of active aquaculture for the Japanese Oyster *Crassostrea gigas*.

Together, these habitats comprise a broad area of the shallow, nearshore margins and islands of Prince William Sound. The survey attempted to gain broad coverage of these habitats, including 46 sites in June 1998, 9 sites for fouling plates in September 1998, and 33 sites including a subset of 7sites for fouling plates in August 1999, which were spread throughout the major regions of the Sound and the port sites of the Kenai Peninsula (see map Fig. 9A.1, Table 9A.1). The survey sampled three major habitats: intertidal and shallow rocky substrates; intertidal and shallow soft sediments; and fouling communities on floats, buoys, pilings and oyster culture structures. The salinity of the array of sites ranged from fresh to fully marine areas of the Sound.

The rapid assessment survey methods were similar to those employed in NIS surveys of San Francisco Bay (Cohen & Carlton 1995) and Puget Sound (Cohen et al. 1998). The approach utilizes a team of experienced naturalists and general ecologists to sample as great a diversity of organisms at as broad an array of sites as possible within the region of concern. The team for the surveys consisted of:

- John Chapman (OSU), general NIS of northeast Pacific and peracaridan crustacea;
- Nora Foster (UAF), marine invertebrates of Alaska, especially mollusca;
- Anson Hines (SERC), barnacles and decapod crustaceans; and
- Todd Miller (Hatfield Marine Science Center), technical assistance and peracaridan crustaceans.

The survey teams utilized a variety of transportation modes to travel among sites throughout Prince William Sound, including vans, ferries, float planes, small boats, vessels of Stan Stephens Tours, and the Fishing Vessel Kristina. Following collecting, samples were processed in temporary laboratories provided by USF&WS Refuge in Homer, the Seward Marine Science Center, University of Alaska in Seward, Prince William Science Center in Cordova, the SERC Invasions Biology Laboratory in Valdez, the Prince William Sound Community College in Valdez, and several hotels. The F/V Kristina also served as laboratory platform for processing of samples while in transit among some of the sites. For each sampling site, the diversity and relative abundance of species were recorded. Field notes included GPS readings, sketches of the sites, salinity and temperature readings, and notes on common or abundant species identified in the field. Samples were collected by hand, by scraper to remove fouling organisms, and by trowel to collect soft sediment. Samples of sediment, algal-invertebrate turf, and scrapings of fouling communities were washed and sieved on 5mm, 1mm and 0.5 mm mesh. Each sample was "rough sorted" immediately after collection to aid in identification of large or delicate specimens and to preserve voucher specimens for subsequent work-up in the laboratory. Voucher samples were preserved in either 70% EtOH or 10% formalin (as appropriate to the type of organism). Voucher samples from the survey have been distributed to appropriate taxonomic experts for definitive identification in the laboratory using microscopes.

TABLE 9A.1. Collecting Sites for NIS Surveys (1997,1998,1999).

Map No.	Site	Station	98 Cruise Station No.	Latitude	Longitude	Rapid Community Assessments 1997 Pilot Study	Rapid Community Assessments 1998 Surveys	Rapid Community Assessments 1999 Survey	Fouling Plate Surveys 1998	Fouling Plate Surveys 1999
1	Anchorage	Port Anchorage		61º14'N	149º45'W		X			
		Westchester Lagoon		61º13'N	149º50'W		X			
2	Potter	Potter flats		61º05'N	149º40'W		X			
3	Katchemak Bay	Homer small boat harbor						X	X	X
		Homer spit						X	X	X
		Homer spit mudflat						X	X	X
4		Sadie Cove								X
5	Seward	Seward small boat harbor						X	X	X
		Lowell Point								X
6	Whittier	Whittier small boat harbor		60º46'37"N	148º41'24"W		X	X	X	
		Whittier ferry dock		60º46'25"N	148º40'55"W		X		X	
7	Shotgun Cove	Shotgun Cove		60º47'26"N	148º32'30"W		X			
8	Esther Island	Lake Bay buoy	28	60º47'37"N	148º05'01"W		X			
		Lake Bay oysters	30	60º48'00"N	148º05'24"W		X			
9	Squaw Bay	Squaw Bay oysters	36	60º50'00"N	147º49'20"W		X			
10	Eaglek Bay	Eaglek Bay oysters	37	60º51'00"N	147º45'36"W		X			
11	Fairmont Bay	Fairmont Bay oysters					X			X
12	Growler Island	Growler mudflat	38	60º54'15"N	147º07'48"W		X		X	
		Growler dock	39	60º54'13"N	147º07'48"W		X		X	
13	Valdez Arm, Sawmill Bay	Sawmill Bay shore	9	61º03'15"N	146º47'24"W	X	X			
		Sawmill Bay mudflat	10	61º03'23"N	146º47'24"W	X	X			
		Navigation buoy	40	61º03'16"N	146º41'39"W		X			
14	Valdez Arm	Potato Point								X
15	Port Valdez	Anderson Bay				X				
16	Valdez	Duck Flats low intertidal	44	61º07'28"N	146º18'00"W	X		X		
		Duck Flats high intertidal	45	61º08"24"N	146º19'30"W		X	X		
		Floating cargo dock	43	61º07'25"N	14618'36 "W				X	X
		SERVS dock		61º07'25"N	146º21'15"W	X			X	X
		Small boat harbor	46	61º07'25"N	146º21'15"W	X	X	X	X	X
		USCG dock		"	"				X	X
		Ferry dock		"	"					X
17	Port Valdez, Dayville flats	Dayville flats	4	61º04'54"N	146º19'00"W	X	X			
18	Valdez Marine Terminal	Alyeska small boat ramp	1	61º05'12N	146º23'30"W	X	X			
		Alyeska small boat harbor	2	61º05'10"N	146º22'28"W				X	X
		Alyeska entrance	3	61º05'10"N	146º21'55"W					
		Terminal floats	42	61º05'20"N	146º24'09"W				X	X

TABLE 9A.1. (continued) Collecting Sites for NIS Surveys (1997,1998,1999).

Map No.	Site	Station	98 Cruise Station No.	Latitude	Longitude	Rapid Community Assessments 1997 Pilot Study	Rapid Community Assessments 1998 Surveys	Rapid Community Assessments 1999 Survey	Fouling Plate Surveys 1998	Fouling Plate Surveys 1999
19	Valdez Arm, Rockey Point	Rockey Point	11	60º57'36"N	146º45'36"W		X			
20	Busby Island	South reef	5	60º52'55"N	146º46'29"W		X			
		Busby Island	6	60º52'54"N	146º46'24"W		X			
21	Tatitlek	Tatitlek Narrows oysters	8,12	60º52'06"N	146º43'30"W		X	X		X
		Village dock		60º52'06"N	146º43'30"W		X	X		X
		Ferry dock		60º52'06"N	146º43'28"W			X		X
22	Bligh Island	Cloudman Bay	7	60º50'11"N	146º43'15"W		X			
23	Sheep Bay	Upper Sheep Bay	13	60º52'12"N	146º43'48"W		X			
		Middle Sheep Bay	14	60º40'21"N	145º57'06"W		X			
24	Cordova	Small boat harbor	15,19	60º32'30"N	145º46'28"W		X	X		X
		Mudflat S of Small Boat Harbor	18	60º32'28"N	145º46'28"W		X	X		X
		Marine Science Center	17	60º32'48"N	145º46'27"W		X			X
		Fish Dock & Flats	16	60º32'27"N	145º46'26"W		X			
		Ferry dock		60º32'27"N	145º46'24"W					X
25	Hawkins Island	Windy Bay	20	60º33'54"N	145º58'38"W		X			
26	Orca Bay	Channel Buoy	21	60º32'22"N	146º55'55"W		X			
27	Hinchinbrook Island	Constantine Harbor						X		
28	Montague Island	Port Chalmers							X	X
29	Green Island	Green Island	22	60º18'19"N	145º58'38"W		X			
30	Evans Island	Sawmill Bay	23	60º03'31"N	147º59'47"W		X			
		Port San Juan	24	60º04'2"N	148º03'36"W		X			
31	Chenega Island	Chenega dock					X		X	
32	Eleanor Island	Northwest Bay middle arm	25	60º32'57"N	147º34'48"W		X			
33	Knight Island Passage	Knight Island Passage buoy	26	60º33'52"N	147º49'11W		X			
34	Main Bay	Main Bay	27	60º31'58"N	148º04'41"W		X			
		Main Bay fish hatchery	28	60º31'16"N	148º05'35"W		X			

The experts for the Focal Taxonomic Collections included:

- Gayle Hansen (Hatfield Marine Science Center, Oregon State University), phycologist with special expertise in Alaskan macroalgae;
- John Chapman (Hatfield Marine Science Center, Oregon State University), peracarid crustacea;
- Jeff Cordell (School of Fisheries, University of Washington), copepod crustaceans;
- Nora Foster (University of Alaska Museum), molluscs and other marine invertebrates of Alaska;
- Jeffery Goddard (University of California, Santa Barbara), opisthobranch molluscs
- Jerry Kudenov (University of Alaska, Anchorage), polychaete worms;
- Gretchen Lambert (Friday Harbor Laboratories, University of Washington), ascidians;
- Charles Lambert (Friday Harbor Laboratories, University of Washington), ascidians;
- Claudia Mills (Friday Harbor Laboratories, University of Washington), cnidarian medusae and ctenophora;
- Lise Schickel (University of California, Santa Barbara), decapod crustaceans and parasitic crustaceans;
- Anson Hines (SERC), barnacles and decapod crustaceans;
- Judith Winston (Virginia Natural History Musem), bryozoans; and
- Lea Ann Henry (University of Toronto), hydrozoan cnidarians.

At numerous locations in Port Valdez / Prince William Sound, sediment samples were collected for identifications of foraminiferans, particularly the Asian NIS *Trochammina hadai*, which is extensively introduced in San Francisco Bay and other west coast source ports. This NIS was reported from deep-water samples taken for the Exxon Valdez Oil Spill study. Samples were processed and sent to Mary McGann of US Geological Survey, Menlo Park, CA, for identification.

Other details of the methods are provided below within the individual chapters for each Focal Taxonomic Collection, the Fouling Community Analysis and the Re-examination of the Museum, Reference and Voucher Collections.

9A4. References

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Foster, N.R. 1991. Intertidal Bivalves: A Guide to the Common Marine Bivalves of Alaska. University of Alaska Press, Fairbanks. 152 pp.

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Chapter 9B. Rapid Community Assessment

John Chapman, Hatfield Marine Science Center, Oregon State University

Collections of some taxonomic groups from the 1998 survey were transferred to systematic experts for focal taxonomic analysis provided in other sections of this report- see sections below for Focal Taxonomic Collections.

Other data and analysis to be provided by John Chapman have not been forthcoming.

Chapter 9C1. Focal Taxonomic Collections: Marine Plants in Prince William Sound, Alaska

Gayle I. Hansen, Hatfield Marine Science Center, Oregon State University

Background

Several NIS marine plants with potential for invasion of Alaskan waters have been reported on the west coast of North America. For example, the pervasive algae *Sargassum muticum, Lomentaria hakodatensis*, and the Japanese eelgrass *Zostera japonica* are thought to have been introduced with the aquaculture of oysters by the importation of spat from Japan. At least 5 oyster farms occur in Prince William Sound, and all have imported spat. For the herring-roe-on-kelp (HROK) pound fishery, the giant kelp *Macrocystis integrifolia* is transported to Prince William Sound via plane from southeast Alaska (the northern limit of this species) to be used as a substrate for herring roe. Although the giant kelp cannot recruit in Prince William Sound, it seems likely that other species, accidentally co-transported with *Macrocystis*, could become established. Our Pilot Study (Ruiz and Hines 1997) also considered several NIS algal species reported from Alaskan waters, including a report of a cosmopolitan species *Codium fragile tomentasoides* from Green Island.

Methods

Sample Period. Marine benthic algae, seagrasses, and intertidal lichens were sampled as a part of the cruise aboard the F/V Kristina during 20-28 June 1998, described above for invertebrates.

Site Information. A subset of 19 of the 46 sites selected for invertebrate sampling were chosen for the plant study, including 13 intertidal sites (4 within Port Valdez and 9 in Prince William Sound) and 6 off-shore float sites. Site abbreviations (for tables and figures to follow), coordinates, temperature, and salinity are given in Table 9C1.1. Please note that the site numbers in Table 9C1.1 for plants do not correspond to the site numbers on the map (Fig. 9A2) or Table 9A1 for invertebrates. The substratum types, listed for each site, are only those sampled for algae and seagrasses. For analysis and discussion, the 19 plant sites have been grouped into 5 basic habitat types: harbors, mud bays, rocky headlands and reefs, rocky bays, and floats. These will be discussed in greater detail in the Results section below.

Surveying Techniques. At each site, intertidal areas accessible by foot within the time period provided were sampled. Since introduced species could potentially occur in any of the marine plant taxonomic groups, it was important to sample the entire range of species present from as broad an area as possible. Marine algal populations are well-known for being extremely patchy in distribution, caused primarily by narrow species requirements (and tolerances) for substratum, tidal height (exposure), salinity, nutrients, and sunlight. Since the species were patchily distributed, they were encountered and collected sporadically, not uniformly over time. For this study, abundance was noted only when unusually large patches of a particular species were encountered; it was not documented uniformly for entire sites.

Time Allotment. As shown in Table 9C1.s, sampling times at major sites varied from 10 minutes to 2 hours. At low diversity sites, such as Cloudman Bay, the time provided was sufficient for complete algal collection; at other sites, such as Green Island, the time was often

TABLE 9C1.1. General Site Information, 1998 Collections*

ABBR.	DATE	LOCATION	LAT	LON	SUBSTR.	T (ºC)	SAL (0/00)
Port Valdez (Val)							
al-sbr	Jun 20	Alyeska, small boat ramp, Port Valdez	61º 05' 12"N	146º 23' 30"W	br, co	9	0
al-pil	Jun 20	Alyeska, small boat harbor, Port Valdez	61º 05' 10"N	146º 22' 28"W	pi	9	0
sough	Jun 20	Slough, near Alyeska gate, Port Valdez	61º 04' 54"N	146º 19' 00"W	mu	11	0
duckflat	Jun 28	Duckflat, Port Valdez	61º 07' 28"N	146º 18' 00"W	mf	17-22	0-4
Other Harbors							
Cor	Jun 23	Cordova, Orca Inlet	60º 32' 28"N	145º 46' 28"W	dm, mf	10-16	5-28
Whit	Jun 26	Whittier, Passage Canal	60º 46' 25"N	148º 40' 55"W	dm, bo, gr, mu	4-10	8-14
Mud/Cobble Bays							
CB	Jun 21	Cloudman Bay, Bligh I.	60º 50' 11"N	146º 43' 15"W	mu, co	10	3
SMB	Jun 22	Sawmill Bay, Valdez Arm	61º 03' 15"N	146º 47' 24"W	mu, co	8	5
Gro	Jun 27	Growler I.	60º 54' 15"N	147º 07' 48"W	mu, co	22	11
Rk Headlands and Reefs							
RP	Jun 22	Rocky Point, Valdez Arm	60º 57' 36"N	146º 45' 36"W	br, co	11	15
Bus	Jun 21	Busby I., south reef	60º 52' 55"N	146º 46' 29"W	br, co	11	23
Green	Jun 24	Green I., northwest reef	60º 18' 19"N	147º 23' 47"W	bo, br	11	30
Rk Bays							
NW	Jun 25	Northwest Bay, middle arm, Eleanor Island	60º 32' 57"N	147º 34' 48"W	gr, co	12	10-27
Floats and Buoys							
TAT	Jun 22	Tatitlek Narrows, Bligh I.	60º 52' 12"N	146º 43' 48"W	oy	12	26
WBF	Jun 23	Windy Bay, Hawkins I.	60º 33' 54"N	145º 58' 38"W	oy	14	28
MBF	Jun 25	Main Bay	60º 31' 58"N	148º 04' 41"W	bb	14	19-20
EIF	Jun 25	Lake Bay, Esther I.	60º 48' 00"N	148º 05' 24"W	bb	12	16
SBF	Jun 26	Squaw Bay	60º 50' 00"N	147º 49' 20"W	oy	14	24
EBF	Jun 26	Eaglek Bay	60º 51' 00"N	147º 45' 36"W	oy	14	24

Abbreviations:

*= coordinates, temperature, and salinity provided by T. Miller
abbr.=abbreviations
bb=barrier buoy
bo=boulders
br=bedrock
co=cobble
dm=docks/marina
gr=gravel
lat=latitude
lon=longitude
mf=mudflat
mu=mud
oy=oysterfloats
pi=wood pilings
rk=rocky
sal=salinity
subst=substratum
t=temperature

seriously inadequate to sample fully the algal diversity present. Differences among sites in amount of time for collecting were not factored out or corrected after sampling was completed; however, the sites which were judged to be undercollected are designated with an "*" in Table 9C1.2.

TABLE 9C1.2. Collection Efficiency Records

Data Type	Major Collection Sites (without off-shore floats)													
	Val	al-sbr	al-pil	slough	duckflat	Cor	Whit	CB	SMB	Gro	RP	Bus	Green	NW
New Records	5	1	1	1	4	5	2	2	5	4	2	2	6	1
Total Species	47	35	7	7	24	41	56	10	45	63	61	59	71	69
Collection Time	165	40*	10	15	100	120	120	30	45*	105	70*	75*	65*	136

Correlation	R	R^2
Total Species:Time**	0.896	43%
New Records:Time**	0.498	7%

*** = undercollected sites**
**** = both without Val (Total Valdez) included**

Field Sampling & Processing. All algal sampling was done by hand or with a chisel. Collected specimens were then placed in plastic bags for transport back to the boat for processing. On board, the samples were sorted to species and then either pressed in a plant press or preserved in 5% formalin/seawater. Site notes and preliminary species lists were made in the field, and some final identifications were done on board. However, for most species final determinations were not made until returning to the Hatfield Marine Science Center in Newport, Oregon, where compound microscopy was available. The smaller marine algae that require microscopic examination while still alive for identification were necessarily excluded from this study. After identification, both liquid and dried specimens were curated, labeled, and deposited in the herbarium at OSU/HMSC for reference in future Alaskan marine algal studies.

Identifications. Since no marine flora (identification guide) of Prince William Sound exists, the algae collected during this study were identified using a wide variety of literature. For common species, the most important references utilized were Abbott and Hollenberg (1976), Gabrielson et al. (1993), Perestenko (1994), and Sears (1998). For more obscure species, much of the world taxonomic literature on temperate/arctic marine algae was employed. To confirm the identification of particularly difficult or important species, some specimens were sent out to colleagues for identification using molecular techniques. These taxa are designated with a "#" in the species charts. Due to the costs of these tests, these results will not be presented here, but instead will be presented at a later date as part of the papers prepared by these experts.

Distributions, Residency Status, and New Records. In determining if species were introduced, the local and global distributions had to be determined from the literature. Some of the references used for this process were: Scagel et al. (1993), Sears et al.(1998), Selivanova and Zhigadlova (1997), Lee (1980), Guiry (1998), Rueness (1977), Phillips and Menez (1988), Yoshida et al. (1995), Adams (1983, 1994), Womersley (1984, 1987, 1994, 1996), Lindstrom (1977), Hansen et al. (1981), and Hansen (1997). These distributions, summarized in the abbreviated form explained below, are shown under range (Ra) in the first column of the species site lists (Tables 9C1.3 – 9C1.5). The ranges provided the basis for determining the Residency Status (St) of the species. Residency status rankings include the following 5 categories:

- E (Endemic) = species known only from Alaska
- N (Native) = species native to the North Pacific, including species with ranges limited to the northeast Pacific (nep) and those that occur in all other areas around the northern Pacific rim (np).
- C (Cryptogenic) = species with extremely broad distributions that occur circumboreally (cb) and/or extend to the southern hemisphere (ws).
- I? (Introduced?) = species that appear to have been introduced to the area.
- F (Failed Introduction) = deliberately introduced species that have failed to colonize the area

TABLE 9C1.3. Marine and Estuarine Plants Collected in Port Valdez, Alaska

NIS ANALYSIS				TAXA	PORT VALDEZ					
					………….June 1998 Collections………..					Total
Ra	St	NR	So		Val	al-sbr	al-pil	slough	duckflat	Checklist
RHODOPHYTA, Rhodophyceae										
ws	C			*Ahnfeltia fastigiata*						O
nep	N			*Ahnfeltiopsis gigartinoides*						O
nep	N			*Antithamnionella pacifica*						O
ws	C			*Audouinella purpurea*						O
ws	C			*Bangia atropurpurea*	X		X			X
nep	N#			*Ceramium gardneri*						O
np	N			*Constantinea subulifera*						O
np	N			*Corallina frondescens*						O
np	N			*Corallina vancouveriensis*						O
np	N			*Cryptonemia borealis*						O
np	N			*Cryptonemia obovata*						O
nep	N			*Cryptosiphonia woodii*	X*	X*				O
cb	C			*Devaleraea ramentacea*	X				X	O
cb	C			*Dumontia contorta*						O
np	N			*Dumontia simplex*						O
nep	N			*Endocladia muricata*						O
ws	C			*Erythrotrichia carnea*						O
np	N			*Gloiopeltis furcata*	X*	X*				O
np,ar	N			*Halosaccion firmum*	X	X				O
np	N			*Halosaccion glandiforme*	X*	X*				O
ws	C			*Hildenbrandia rubra*						O
np	N			*Leachiella pacifica*						O
np	N			*Lithophyllum dispar*						O
nep	N			*Mastocarpus papillatus* complex	X*	X*				O
np	N			*Mastocarpus* cf. *pacificus* ?	X*	X*				X
nep	N			*Mazzaella heterocarpa*						O
np	N			*Mazzaella phyllocarpa*	X	X				X
nep	N			*Mazzaella splendens*						O
nep	N			*Microcladia borealis*						O
ws	C			*Nemalion helminthoides*						O
np	N			*Neorhodomela aculeata*	X	X				O
np	N			*Neorhodomela larix*	X	X				O
np	N			*Neorhodomela oregona*	X*	X*				O
nep	N			*Odonthalia floccosa*						O
np	N			*Odonthalia kamtschatica*						O
np	N			*Odonthalia setacea* (drift?)						O
nep	N			*Palmaria hecatensis*	X*	X*				O
cb	C			*Palmaria mollis/palmata*						O
np	N			*Phycodrys riggii*						O
ws	C			*Polysiphonia brodiaei*						O
nep	N			*Polysiphonia hendryi* v. *deliquescens*	X	X				O
nep	N			*Polysiphonia hendryi* v. *hendryi*						O
nep	N			*Polysiphonia hendryi* v. *luxurians*						O
nep	N			*Polysiphonia pacifica* v. *pacifica*						O
nep	N			*Porphyra cuneiformis*						O
nep	N			*Porphyra mumfordii*						O
np	N			*Porphyra perforata*						O
cb	C#	NR	NAT	*Porphyra purpureo-violacea ?*						O

Table 9C1.3. continued

nep	N	NR	Wa	*Porphyra rediviva*	X*				X*	X
np	N			*Pterosiphonia bipinnata*	X*	X*				O
np	N			*Ptilota filicina*						O
cb	C			*Ptilota serrata* (incl. *pectinata*)						O
cb	C			*Rhodomela lycopodioides*						O
cb	C			*Scagelia americana*						O
np	N			*Tokidadendron kurilensis*	X	X				O
nep	N			*Weeksia coccinea*	X*	X*				X
HETEROKONTOPHYTA, Phaeophyceae					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
cb	C			*Agarum clathratum (cribrosum)*						O
cb	C			*Chordaria flagelliformis*	Xun				X un	O
np	N			*Chordaria gracilis*						O
cb	C			*Coilodesme bulligera*						O
np	N			*Costaria costata*						O
cb	C			*Desmarestia aculeata*						O
cb	C			*Desmarestia viridis*						O
cb	C			*Dictyosiphon foeniculaceus*	X*	X*			X un	O
nep	N			*Ectocarpus parvus*						O
ws	C			*Ectocarpus siliculosus*						O
nep	N			*Elachista lubrica*	X*	X*				O
cb	I ?	NR	NAT	*Fucus cottonii*	X*			X*		X
cb	C			*Fucus gardneri/distichus/evanescens*	X*	X*		X* un	X*	O
cb	C			*Fucus spiralis*	X	X			X	X
np, a	N			*Laminaria "groenlandica"/bongardiana*	X*		X*			O
cb	C			*Laminaria saccharina*	X*		X*		X	O
np	N			*Laminaria yezoensis*	X*		X*			O
ws	C			*Leathesia difformis*						O
cb	C			*Melanosiphon intestinalis*	X	X				O
ws	C			*Petalonia fascia*						O
ws	C			*Pilayella littoralis/washingtonensis*	X*	X*		X	X*	O
ws	C			*Scytosiphon simplicissimus*	X*	X*			X un	O
np	N			*Soranthera ulvoidea*	X*	X*				O
ws	C			*Sphacelaria rigidula*						O
cb	C			*Spongonema tomentosum*						O
HETEROKONTOPHYTA, Xanthophyceae					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
ws	C	NR	BC	*Vaucheria longicaulis* (?) mats	X*				X*	X
CHLOROPHYTA, Chlorophyceae					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
cb	C			*Acrosiphonia arcta*	X*	X*			X*	O
nep	N			*Acrosiphonia coalita*						O
np	N			*Acrosiphonia saxatilis*						O
cb	C			*Blidingia chadefaudii*						O
ws	C	NR	BC	*Blidingia marginata*	X*		X*		X*	X
ws	C			*Blidingia minima*	X*	X*			X*	O
cb	C			*Blidingia subsalsa*	X*	X*	X*		X*	O
cb	C			*Chaetomorpha capillaris/cannabina*						O
nep	N	NR	Wa	*Chaetomorpha recurva*						O
ws	C			*Cladophora albida*						O
ws	C			*Cladophora sericea*						O
ws	C			*Enteromorpha clathrata*						O
ws	C			*Enteromorpha in compressa*						O
ws	C			*Enteromorpha intestinalis*	X*	X*			X*	O
ws	C			*Enteromorpha linza*						O
ws	C			*Enteromorpha prolifera/torta*	X*	X*		X*	X*	X

Table 9C1.3. continued

Ra	St	NR	So		Val	al-sbr	al-pil	slough	duckflat	Checklist
cb	C			*Gayralia oxyspermum*	X*				X*	X
cb	C	NR	BC	*Halochlorococcum moorei*	X*	X*			X*	X
cb	C			*Kornmannia zostericola* (epiphytic)						O
cb	C			*Monostroma grevillei/arcticum*						O
ws	C			*Rhizoclonium implexum*	X*	X*		X*	X*	O
ws	C			*Rhizoclonium riparium*	X*	X*		X*	X*	O
ws	C			*Rhizoclonium tortuosum*						O
ws	C			*Ulothrix implexa* (non *flacca*)	X*	X*	X*	X?	X*	O
np	C#			*Ulva fenestrata /expansa/lactuca*	X*	X*			X*	O
cb	C			*Ulvaria obscura*	X*	X*			X*	O
ws	C			*Urospora penicilliformis* ?	X*	X*				X
SEAGRASSES					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
cb	C			*Zostera marina*	X*				X*	O
LICHENS					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
cb	C			*Verrucaria maura*						O
cb	C			*Verrucaria mucosa*						O
Ra	**St**	**NR**	**So**		**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
TOTALS:				**Species**	**47**	**35**	**7**	**7**	**24**	**112**
				New Records	**5**	**1**	**1**	**1**	**4**	**7**

Abbreviations:

! = abundant or common
= currently being examined with molecular techniques
?= uncertainty of identification
al-sbr=Alyeska boat ramp and vicinity
al-pil=Alyeska small boat harbor pilings
BC=British Columbia
C=cryptogenic
cb=circumboreal
Checklist=total records for Port Valdez including literature and the present study
duckflat=Mudflat east of the town of Valdez
N=native to North Pacific
NAT=North Atlantic
nep= northeast Pacific
np= North Pacific
NR = new record to Alaska
nr = northward range extension within Alaska
O= records from the literature and pilot study
slough=Slough about 1 mile from Alyeska gate
So=Closest source to PWS
Stat=NIS Status (native, cryptogenic, introduced, etc)
un= living unattached
Val=Total records for Port Valdez for the present study
Wa=Washington
ws= widespread, occurring in North Pacific, North Atlantic, and Australia or New Zealand
X*= current record noted with specimen
X= current record noted in the field

TABLE 9C1.4. Marine and Estuarine Plants Collected at Shore* Sites in Prince William Sound**

NIS ANALYSIS				TAXA	HARBORS			MUD BAYS			HEADLANDS AND REEFS			RK BAYS
Ra	St	NR	So		Val	Cor	Whit	CB	SMB	Gro	RP	Bus	Green	NW
RHODOPHYTA, Rhodophyceae														
ws	C			*Ahnfeltia fastigiata*								X*		X*!
nep	N			*Antithamnionella pacifica*							X*		X*	X*
ws	C			*Antithamnionella spirographidis*		X?	X?							
ws	C			*Audouinella purpurea*		X*							X*	
ws	C			*Bangia atropurpurea*	X	X*	X*							X*
np	N			*Bossiella cretacea*								X*		X*
nep	N			*Bossiella plumosa*									X*	
nep	N			*Callithamnion acutum*										X*
nep	N			*Callithamnion pikeanum* v. *laxum*									X*	
nep	N			*Callithamnion pikeanum* v. *pikeanum*										X*
cb	C#			*Ceramium cimbricum*		X*?				X*?				
nep	I?#	NR	Cal	*Ceramium sinicola?* (on *Codium*)									X*	
nep	N#			*Ceramium gardneri*			X*							
nep	N#			*Ceramium pacificum/washingtonensis*					X*	X*	X*	X*	X*?	X*!
ws	C#			*Ceramium rubrum/kondoi*			X*?						X*	
np	N			*Constantinea subulifera*					X*	X	X*		X*!	X*!
np	N			*Corallina frondescens*							X*	X*	X*	X
np,ch	N			*Corallina officinalis* v. *chilensis*							X*	X*	X*!	
nep	N			*Cryptosiphonia woodii*	X*		X*		X*	X*	X*	X*	X*!	X*
nep	N			*Delesseria decipiens*			X?							
cb	C			*Devaleraea ramentacea*	X		X*			X*				
cb	C			*Dumontia contorta*					X*	X*	X*	X*	X	X*
np	N			*Dumontia simplex*		X								
nep	N			*Endocladia muricata*							X*		X*	
ws	C			*Erythrotrichia carnea*			X*		X*			X*		X*
np	N			*Gloiopeltis furcata*	X*	X	X*		X*		X*	X*	X*!	X*!
np,ar	N			*Halosaccion firmum*	X					X*	X?	X?	X?	
np	N			*Halosaccion glandiforme*	X*				X	X*	X	X*	X	X*
np	N			*Leachiella pacifica*			X*					X*	X*	X*
nep	N			*Mastocarpus papillatus* complex	X*					X*				
np	N			*Mastocarpus* cf. *pacificus*	X*	X				X*	X*		X	X*
np	N			*Mazzaella phyllocarpa*	X				X*	X*	X*!	X*	X*!	X!
nep	N			*Mazzaella splendens*			X							
nep	N			*Microcladia borealis*									X	
np	N			*Neorhodomela aculeata*	X		X		X*	X*	X*	X*!	X*!	X!
np	N			*Neorhodomela larix*	X					X*	X*		X*	
np	N			*Neorhodomela oregona*	X*		X*!	X	X*	X*	X	X*!	X*!	X*!
np	N			*Neoptilota asplenioides*						X*	X	X*	X!	X
nep	N			*Odonthalia floccosa*			X!		X		X*!	X*	X*!	X*!
np	N			*Odonthalia setacea* (drift?)			X*							
nep	N			*Opuntiella californica*									X*	
np	N			*Palmaria calophylloides/stenogona*			X		X	X			X**	X*!
nep	N			*Palmaria hecatensis*	X*		X*!			X*	X*			X
cb	C			*Palmaria mollis/palmata*		X*	X!			X*	X	X*	X*	X!
np	N			*Phycodrys riggii*					X	X*	X*			X*

Table 9C1.4. continued

nep	N			*Platythamnion pectinatum*			X?			X?				X*
np	N			*Pleonosporium* cf *vancouverianum*								X*		
nep	N			*Polysiphonia eastwoodae*								X*		
ws	C			*Polysiphonia brodiaei*									X?	
nep	N			*Polysiphonia hendryi* v. *deliquescens*	X				X					
nep	N			*Polysiphonia hendryi* v. *hendryi*								X*	X*	
nep	N			*Polysiphonia pacifica* v. *determinata?*						X*				
nep	N			*Polysiphonia pacifica* v. *pacifica*			X*				X*		X*	X*
np,nz	N	nr	SeA	*Polysiphonia senticulosa*		X*	X*				X*	X*	X*	X*
cb	C			*Polysiphonia stricta (urceolata)*								X*	X*	X*
nep	N			*Porphyra cuneiformis*		X*				X*				X?
cb	C	NR	Com	*Porphyra miniata*						X*				
nep	N			*Porphyra nereocystis*									X*	
nep	N	NR	Wa	*Porphyra rediviva*	X*									
np	N			*Porphyra torta/abbottae*										X*
np	N			*Pterosiphonia bipinnata*	X*	X*	X*			X*	X*	X*	X*	X*!
cb	C			*Ptilota serrata* (incl. *pectinata*)						X*	X*		X*	X*
np,ar	N			*Rhodymenia pertusa*					X		X*	X	X*	X!
cb	C			*Scagelia americana*		X*	X*			X*		X*	X*	X*
nep	N			*Smithora naiadum*								X*		
np	N			*Tokidadendron kurilensis*	X						X*		X*!	X*!
nep	N			*Weeksia coccinea*	X*								X?	X*
HETEROKONTOPHYTA, Phaeophyceae					**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
np	N#			*Alaria taeniata/angusta/crispa*							X*	X	X	
np	N#			*Alaria tenuifolia/pylaii//membranacea*		X*								
np	N#			*Alaria praelonga/marginata*		X					X*	X*	X*!	
cb	C			*Agarum clathratum (cribrosum)*							X	X*		X*
np	N			*Analipus japonicus*			X		X*		X*	X*	X*	X
cb	C			*Chorda filum*		X*			X*	X*		X		
cb	C			*Chordaria flagelliformis*	Xun		X*!		X*	X*	X*	X*	X*	X*
cb	C			*Coilodesme bulligera*						X*				
ak	E	NR		*Coilodesme* n. sp.									X*	
np,nz	N			*Colpomenia bullosa*						X*				
ws	C			*Colpomenia peregrina*							X*	X*	X*	X*
np	N			*Costaria costata*							X*		X*	
np	N			*Cymanthera triplicata*						X*				
np	N			*Cystoseira geminata*									X*	
cb	C	NR	Com	*Delamarea attenuata*					X*			X*		
cb	C			*Desmarestia aculeata*			X		X	X	X	X*	X	
cb	C			*Desmarestia viridis*					X		X	X*		
cb	C			*Dictyosiphon foeniculaceus*	X*	X*!	X*!	X*	X*	X*	X*	X*	X*	X
ws	C			*Ectocarpus siliculosus*						X?				
cb	C			*Elachista fucicola*		X*	X			X	X*			
nep	N			*Elachista lubrica*	X*					X*				X*
cb	C			*Eudesme virescens*					X*	X*	X*	X*		
cb	I ?	NR	NAT	*Fucus cottonii*	X*			X*	X*	X*				
cb	C			*Fucus gardneri/distichus/evanescens*	X*	X*!	X*!	X	X	X* un	X*	X	X*!	X*
cb	C			*Fucus spiralis*	X			X*	X?	X	X		X!	X!
np,ar	N			*Laminaria "groenlandica"/bongardiana*	X*	X*	X*			X*	X*	X*	X*	X*!
cb	C			*Laminaria saccharina*	X*	X	X*!			X*				X!
np	N			*Laminaria yezoensis*	X*								X*!	X*

Table 9C1.4. continued

ws	C			*Leathesia difformis*					X		X	X*	X!	X
nep	N			*Leathesia nana*					X*		X*	X*	X*	
nep	F			*Macrocystis integrifolia*										X* drift
cb	C			*Melanosiphon intestinalis*	X		X*!		X*	X*	X*	X*	X*	X*
ws	C			*Pilayella littoralis/washingtonensis*	X*	X*	X*	X*	X*	X*	X	X		X*
ws	C	nr	SeA	*Punctaria latifolia*					X*		X*			
ak	E			*Punctaria lobata*		X*								
cb	C	NR	Jap	*Punctaria plantaginea**		X	X*		X?	X?			X*	
cb	C			*Punctaria tenuissima*										X*
cb	C			*Ralfsia fungiformis*			X*							X*
np	N			*Saundersella simplex*					X*		X*			
ws	C			*Scytosiphon simplicissimus*	X*		X*		X*	X*	X	X*	X*	X*
np	N			*Soranthera ulvoidea*	X*		X*		X?	X*	X	X*	X*	X*
np	N			*Soranthera ulvoidea* f. *difformis*						X*				X*
cb	C			*Sphacelaria racemosa*						X*				X*
ws	C			*Sphacelaria rigidula*						X?		X*	X*	X*
HETEROKONTOPHYTA, Xanthophyceae					**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
ws	C	NR	BC	*Vaucheria longicaulis* (?)	X*	X*!								
CHLOROPHYTA, Chlorophyceae					**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
cb	C			*Acrosiphonia arcta*	X*	X*	X*!		X?	X*	X*	X*	X?	X*
np	N			*Acrosiphonia saxatilis*		X*	X*			X*				
ws	C	NR	BC	*Blidingia marginata*	X*									
ws	C			*Blidingia minima*	X*	X*	X*		X*	X	X*	X*		X*
cb	C			*Blidingia subsalsa*	X*	X*	X*							
cb	C	NR	BC	*Capsosiphon fulvescens*				X*						
ws	C			*Cladophora albida*		X*	X*		X*	X*	X		X*	X*
cb	C			*Cladophora hutchinsiae*		X*								
ws	C			*Cladophora sericea*		X	X*	X	X*	X*	X*	X*	X*	X*!
np	N			*Cladophora stimpsonii*			X*					X*		
nep	N	nr	SeA	*Codium fragile* subsp. *fragile*									X*	
ws	I?#	NR	Wa	*Codium fragile* subsp. *tomentosoides?*									X*	
ws	C			*Enteromorpha intestinalis*	X*	X*	X			X	X		X	X?
ws	C			*Enteromorpha linza*		X*!				X	X*	X*	X	
ws	C			*Enteromorpha prolifera/torta*	X*	X	X*	X*	X*	X				X*
cb	C			*Gayralia oxyspermum*	X*		X?				X?		X*	
cb	C	NR	BC	*Halochlorococcum moorei*	X*	X*								
cb	C			*Kornmannia zostericola* (epiphytic)			X*							
cb	C	NR	NAT	*Kornmannia leptoderma* (epilithic)		X*								
nep	N	NR	Wa	*Monostroma fractum*					X*	X*				
cb	C			*Monostroma grevillei/arcticum*			X?					X?	X*	X*
ws	C			*Percursaria percursa*		X*			X*					
ws	C			*Rhizoclonium implexum*	X*									
ws	C			*Rhizoclonium riparium*	X*									
ws	C			*Rhizoclonium tortuosum*		X*	X*			X*		X*	X	
ws	C			*Ulothrix implexa* (non *flacca*)	X*	X*	X							
ws	C#			*Ulva fenestrata /expansa/lactuca*	X*	X*	X		X*	X*	X*	X*		X*
cb	C			*Ulvaria obscura*	X*		X?			X*	X?			X*
np	N			*Ulvella setchellii*					X*					
ws	C			*Urospora penicilliformis*?	X*		X							

Table 9C1.4. Continued

SPERMATOPHYTA, Seagrasses					**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
cb	C			*Zostera marina*	X*	X*	X*	X	X*	X		X*		
nep	N			*Phyllospadix scouleri*							X	X*		
nep	N			*Phyllospadix serrulatus*								X		
LICHENS					**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
cb	C			*Verrucaria maura*			X				X			X
					47	41	56							
TOTALS:			**Species (total =146)**		**47**	**41**	**56**	**10**	**45**	**63**	**61**	**59**	**71**	**69**
			New Records (total =17)		**5**	**5**	**2**	**2**	**5**	**4**	**2**	**2**	**6**	**1**
GROUP TOTALS (with overlap excluded)**:**					**Harbors**			**Mud Bays**			**Headlands**			**Rk Bays**
				Species in Merged Groups	87			78			96			69
				New Records in Merged Groups	8			7			8			1

Abbreviations:

! = abundant or common
= currently being examined with molecular techniques
***=shore sites include both shore and marina sites
?= uncertainty of identification
ak=Alaska
ar=arctic
BC=British Columbia
C=cryptogenic
Cal=California
cb=circumboreal
Ch=Chile
Com=Commander Islands, Russia
Cor=Cordova
drift= dying unattached
E=endemic to Alaska
F=failed introduction
I?=possible introduction
Jap=Japan
N=native to North Pacific
NAT=North Atlantic
nep= northeast Pacific
np=North Pacific
NR = new record to Alaska
nr = northward range extension within Alaska
nz=New Zealand
O=Presence known from the Pilot Study and literature
Ra=Distribution Range
RK=rocky
SEA=Southeast Alaska
So=Closest source to PWS
St=range status (see N, C, E, and I)
un= living unattached
Wa=Washington
ws= widespread, occurring in North Pacific, North Atlantic, and Australia or New Zealand
X*=Presence known from the current study; specimens available
X=Presence known from the current study; no specimen taken

Site Abbreviations and Dates:

Bus=Busby Island south reef, 21 June
CB=Cloudman Bay, East Bleigh I, 21 June
Cor=Cordova, 23 June
Green=Green Island, northwest point, 24 June
Gro=Growler Island, near resort, 27 June
NW=Northwest Bay, Knight Island, 25 June
RP=Rocky Point headland, 22 June
SMB=Saw Mill Bay, 22 June
V-Ck=Port Valdez checklist (all records known)
Val=all Port Valdez collections, June 1998
Whit=Whittier, 26 June

TABLE 9C1.5. Marine Algae Collected from Off-Shore*** Floats in Prince William Sound, June 1998

NIS ANALYSIS				TAXA	Float	FLOATS						Only
Range	Stat	NR	So		Cklist	TAT	WBF	MBF	EIF	SBF	EBF	on floats
CYANOPHYTA, Cyanophyceae												
ws	C			*Calothrix crustacea*	X	X*						**
ws	C			*Rivularia atra*	X	X*						**
RHODOPHYTA, Rhodophyceae												
nep	N			*Antithamnionella pacifica*	X				X*			
cb	I?	NR	SD	*Chroodactylon ramosum*	X	X*						**
nep	N	nr	SeAk	*Polysiphonia senticulosa*	X	X*						
ws	C			*Polysiphonia urceolata*	X	X*						**
cb	C			*Scagelia americana*	X						X*	
HETEROKONTOPHYTA, Phaeophyceae												
nep	N			*Coilodesme californica*	X	X*						**
ak	E	NR		*Coilodesme* n. sp.	X	X*						
np	N			*Cystoseira geminata*	X	X*						
cb	C	NR	Com	*Delamarea attenuata*	X						X*	
nep	N	nr	BC	*Ectocarpus acutus*	X			X*				**
nep	N	nr	BC	*Ectocarpus dimorpha*	X						X*	**
nep	N			*Ectocarpus parvus*	X	X*						**, V-CK
				Ectocarpus sp. (*Acinetospora*?)							X*	
				Giffordia sp.		X*						
np	N			*Laminaria groenlandica*	X					X*		
ws	C			*Laminaria saccharina*	X	X*					X*	
np	N			*Laminaria yezoensis*	X	X*						
cb	C			*Melanosiphon intestinalis*	X	X*						
cb	I?	NR	Jap	*Microspongium globosum*	X						X*	**
ws	C			*Pilayella littoralis*	X			X*				
				Pilayella sp. (elongate intercalary structures)						X*		
cb	C	NR	Jap	*Punctaria plantaginea*	X		X*					
cb	C	nr	SeAk	*Punctaria latifolia* (*Desmotrichum*)	X	X*						
ws	C			*Scytosiphon simplicissima*	X			X*				
CHLOROPHYTA, Chlorophyceae												
ws	C			*Cladophora albida*	X			X*		X*		
ws	C			*Cladophora sericea*	X	X*				X*	X*	
ws	C			*Enteromorpha prolifera/torta*	X	X*						
ws	C			*Percursaria percursa*	X	X*						
				TOTALS:	27	**17**	**1**	**4**	**1**	**4**	**7**	**9**
				New Records	9	**4**	**1**	**1**	**0**	**0**	**3**	**4**

Abbreviations:

*=Specimen available
**=Only on floats in this study
***=Sites accessed by boat
BC=British Columbia
C=cryptogenic
cb=circumboreal
Com=Commander Islands,
Jap=Japan

LJ=LaJolla, California
N=native
nep=northeast Pacific
np=North Pacific
nr=new record from neighboring area
NR=new record from remote area
SeAk=Southeast Alaska
V-Ck=also known from the Valdez Checklist
ws=widespread

Float Sites and Dates (Coord. with JC)
EBF=Eaglek Bay floats, 26 June
EIF=Ester Island float, 25 June
MBF=Main Bay barrier buoy, 25 June
SBF=Squaw Bay float, 26 June
TAT=Oyster floats near Tatilek, 21 & 22 June
WBF=Windy Bay floats, 23 June
Float Cklist=species used in this study

Species were then categorized as to whether they were new distribution records (NR) to the area. These included species that had never before been reported from Prince William Sound (nr) or Alaska (NR). In each of these cases, the closest known records to the area were given as the source (So). Since the new records seemed to be the most likely category in which to find recognizable NIS, they are highlighted in gray throughout the charts and tables.

This preliminary quantification of marine plant species and NIS in Prince William Sound required a number of lengthy, detailed steps. After gathering, identifying, and curating all of the species, site lists had to be prepared and both local and global biogeographic information compiled. Then, with this information in hand, the residency status and new distribution records of each species were determined. Only after all of this was completed could NIS begin to be recognized. Since many of the steps in this process revealed important data that characterized not only NIS but the marine flora in general, this report presents the site lists in their entirety and then summarizes the results for comparative purposes in tables and graphs. Since the results are lengthy, they have been organized into the following 7 major parts that are presented below:

- The Species Lists by Site, including Port Valdez, Shore, and Floats.
- The Total Species Numbers and Composition of the Individual Sites.
- Total Species Numbers and Composition in each Habitat Type.
- Native, Cryptogenic, and Introduced Species and their Taxonomic Composition.
- Native, Cryptogenic, and Introduced Species in the Habitat Types.
- New Species Records and Probable Introductions.
- Comments on the Five Probable Introductions and One Important Failed Introduction.

Results

During our 9-day search for NIS in Port Valdez and Prince William Sound, 489 plant samples were processed (Table 9C1.6). These samples contained 155 different species dominated by the red (Rhodophyceae), brown (Phaeophyceae), and green (Chlorophyceae) algae, in that order. Among these species, 21 were found to be new records to the area, and, of these, at least 5 appear to be introduced. In addition, 70 species were found to be cryptogenic, some of which have suspicious characteristics of NIS.

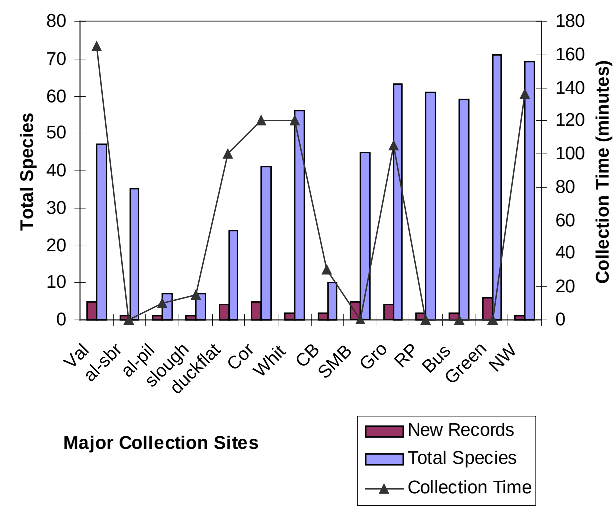
TABLE 9C1.6. Collection Data*

TAXONOMIC GROUP	SAMPLES			TOTAL SPECIES	NEW RECORDS
	Total	Herb.	Form.		
Rhodophyceae	199	135	64	69	5
Phaeophyceae	162	120	42	49	8
Chlorophyceae	117	99	18	30	7
Xanthophyceae	2	2	0	1	1
Seagrasses	7	4	3	3	0
Lichens	0	0	0	1	0
Cyanophyceae	2	1	1	2	0
Total, June 1998	489	361	128	155	21

Abbreviations:
* =Samples and species counts are only for the June 1998 trip.
Herb.=Pressed herbarium sheets
Form.=Bottles of preserved specimens

The total species and new species records/collecting site were correlated with collection time (Fig. 9C1.1). Longer collecting periods yielded more species at an R^2 value of 43%. New records, on the other hand, appear to be almost unaffected by collection time, showing an R^2 of only 7%.

FIG. 9C1.1. Collection Efficiency



The Site Species Lists. Species of marine and estuarine plants identified at all sites sampled during our June 1998 survey are listed in Tables 9C1.3, 9C1.4, and 9C1.5. The plants sampled were predominantly macrobenthic marine algae of the Rhodophyceae, Phaeophyceae, Chlorophyceae, Xanthophyceae, and Cyanophyceae along with several species of seagrasses and marine lichens. Species occurrence at the various sites is designated with an *X* in the lists. If samples were taken and curated for identification purposes, the species are listed with an *X**, indicating that vouchers are available in the OSU/HMSC herbarium for study. In addition, each species is categorized for several biogeographic features that are necessary for the NIS Analysis, explained in the Methods section above.

- <u>Species of Port Valdez.</u> Samples from 4 sampling sites in Port Valdez included 47 algal species and 5 new records (Table 9C1.3). The sites covering the largest areas (the Alyeska small boat ramp and the duckflat) contained the majority of the species. The highest species count occurred at the Alyeska boat ramp where the greatest amount of hard substratum was available for algal settlement. The highest number of new records occurred in the duckflat. A few of these species are good candidates for NIS status. However, their lack of earlier discovery may have an obvious explanation. Mudflats, like the duckflat, are not only notoriously poor habitats for most marine algae, but they can be dangerous in Alaska. Therefore, earlier phycologists avoided many of these areas. Knowing this to be true, it was possible to predict the occurrence of some new records (e.g., *Fucus cottonii* and *Vaucheria longicaulis*) in the mudflats and sloughs. Also shown in Table 9C1.3 is a Checklist of Algal Species for Port Valdez, which includes the species collected from the 1998 sampling, as well as those found previously during the 1997 Pilot Study (Ruiz & Hines, 1997) and the literature (Calvin and Lindstrom, 1980, and Weigers et al., 1997). In addition to our summer sampling, this list includes year-round collections taken by the earlier investigators. The total count for the entire Port Valdez area, including these earlier records, amounts to 112 species.

- Species of Shore Sites. Shore sites include all intertidal areas and marinas sampled during the June 1998 cruise, along with the combined records for Port Valdez (Table 9C1.4). These 10 sites covered a wide range of habitats, which were grouped into 4 major habitat types: Harbors, Mud Bays, Headlands and Reefs, and Rocky Bay (presented in more detail below). The overall species count for all of the shore areas was 146 species with 17 new records. The highest species diversity occurred at Green Island, Northwest Bay, and Growler Island, all of different habitat types; while the highest number of new records occurred at Green Island, Saw Mill Bay, Cordova, and Port Valdez, also a mixture of habitat types. Only two species (*Dictyosiphon foeniculaceus* and *Fucus gardneri*) were found at all shore sites sampled. Four others (*Cladophora sericea*, *Acrosiphonia arcta*, *Pilayella littoralis*, and *Neorhodomela oregona*) were found at all but one site (and were possibly overlooked there). Numerous species (31) were common to all of the habitat types, but there were also an extraordinary number of species that appeared to be limited to only 1 habitat type (17 were found only in harbors, 9 only in mud bays, 19 only on headlands and reefs, and 5 only in rocky bays). Two species restricted to harbors are new records to the area: *Porphyra rediviva*, a newly discovered free-floating marsh plant that could be easily transported by ships, and *Vaucheria longicaulis* , a species unique to high mudflats that is common to many southern west coast harbors. Although not a new record, another interesting harbor species is *Antithamnionella spirographidis*. This species is reported to be common to harbors in British Columbia and is thought to be introduced to that area (Lindstrom in DeWreede 1996). However, its circumboreal and Australian existence leads me to categorize it as cryptogenic in this paper.

- Species from Floats. Marine plants were sampled from five oyster floats and one barrier buoy (MBF) (Table 9C1.5). A total of 27 different algal species were identified from the floats. Of these, 9 were not collected at any of the other sites during our trip. Most of these unique species are small and could have been overlooked in other areas, but several are species that probably could only find suitable habitat on the floats. Over half the 27 species collected are well-known fouling organisms (e.g., *Cladophora sericea*, *Pilayella littoralis*, and *Polysiphonia urceolata*). Nine new species records, the highest habitat number in our survey, were also found on the floats. This may be related to the fact that most of the floats sampled are used in aquaculture, which could be a source of introductions. The highest counts for both species and new records occurred on the floats at Tatitlek Narrows (TAT) and Eaglek Bay (EBF) used in active oyster culture. Two of the new records found at these *sites (Chroodactylon ramosum* and *Microspongium globosum*) and possibly more are thought to be introduced. One species (*Polysiphonia senticulosa*) is considered to be a range extension from southeast Alaska, but it is already widespread in Prince William Sound. This species is presumably native in Washington to Southeast Alaska, and was recently reported to be introduced and pervasive in New Zealand (Nelson and Maggs, 1996).

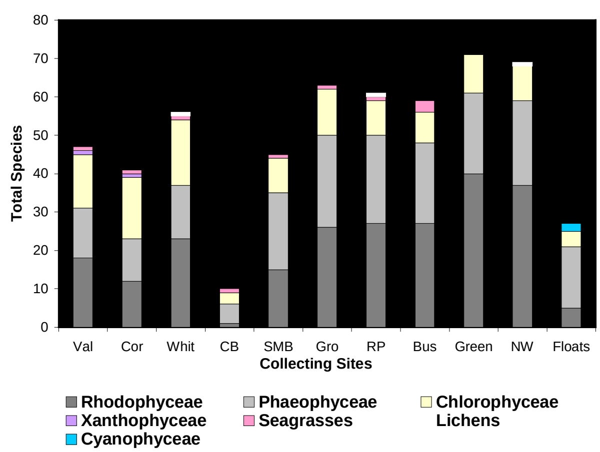
The Total Number of Species and Species Composition of the Individual Sites. The overall number of species was 155 for all sites, but the numbers of species per site ranged from only 10 to 71 species, indicating that there is considerable variation in species composition among habitats (Table 9C1.7, Fig. 9C1.1, 9C1.2). The 21 new records across all areas ranged from 1 to 9 at the individual sites and was highest on floats. The highest species count (71 species) occurred at Green Island, the most exposed and highly saline site. At this site, the proportion of red algal species was nearly 2 times that of the brown algae and 4 times that of the greens. The lowest species count (10 species) occurred at Cloudman Bay, a sheltered, estuarine mud bay. At this site there were almost no red algae, and the brown algae were more abundant than the greens.

Table 9C1.7. Total Species Numbers and Composition at Each Site, June 1998

Taxonomic Group	Val	Cor	Whit	CB	SMB	Gro	RP	Bus	Green	NW	Floats	Total*	V-Total**
Rhodophyceae	18	12	23	1	15	26	27	27	40	37	5	**69**	84
Phaeophyceae	13	11	14	5	20	24	23	21	21	22	16	**49**	52
Chlorophyceae	14	16	17	3	9	12	9	8	10	9	4	**30**	36
Xanthophyceae	1	1	0	0	0	0	0	0	0	0	0	**1**	1
Seagrasses	1	1	1	1	1	1	1	3	0	0	0	**3**	3
Lichens	0	0	1	0	0	0	1	0	0	1	0	**1**	2
Cyanophyceae	0	0	0	0	0	0	0	0	0	0	2	**2**	2
TOTALS	**47**	**41**	**56**	**10**	**45**	**63**	**61**	**59**	**71**	**69**	**27**	**155**	180
NEW RECORDS	**5**	**5**	**2**	**2**	**5**	**4**	**2**	**2**	**6**	**1**	**9**	**21**	23

Abbreviations: Sites as in Table 1; Val=the Port Valdez collections combined; Floats=the float collections combined; Total*=with overlap and earlier collections excluded; V-Total**=Total* with the Port Valdez Checklist species included.

Figure 9C1.2. Total Species Numbers and Composition at each Site, June 1998



Total Species Numbers and Composition in each Habitat Type. Since several sampling sites had mixed habitats, categorizing the sites into distinct habitat types had some weaknesses. However, it increased the number of species sampled for each category of habitat, providing more power to the data analysis (Table 9C1.8, Fig. 9C1.3a, b).

TABLE 9C1.8. Habitat Type and Species Composition

Taxonomic Group	Valdez	Harbors	Mud Bays	Rk Bays	Headlands	Floats	Total
Rhodophyceae	18	37	31	37	48	5	**69**
Phaeophyceae	13	22	31	22	30	16	**49**
Chlorophyceae	14	25	15	9	14	4	**30**
Xanthophyceae	1	1	0	0	0	0	**1**
Seagrasses	1	1	1	0	3	0	**3**
Lichens	0	1	0	1	1	0	**1**
Cyanophyceae	0	0	0	0	0	2	**2**
Total	**47**	**87**	**78**	**69**	**96**	**27**	**155**

Fig 3a. Habitat Type and Species Composition

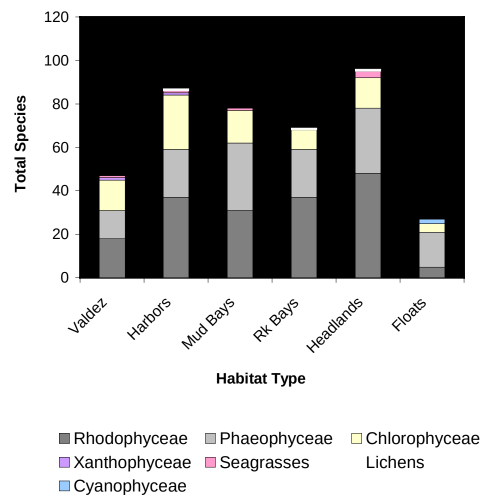
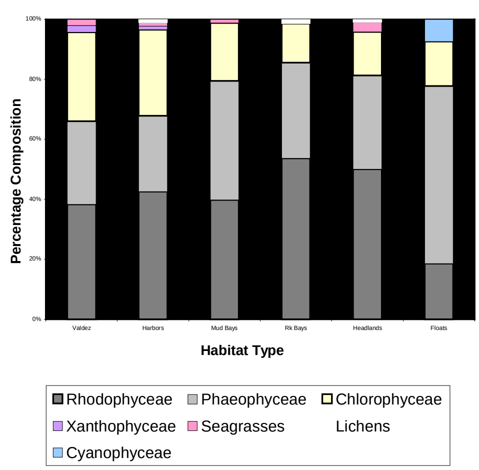


Fig. 3b. Habitat Type and Percentage Composition



The 5 habitat types with their features and included sites are:

- Harbors* (Val, Cor, and Whit). Sheltered areas with variable salinities (0-28 ppt) and variable substrates including mud, cobble, and wood (the pilings). Heavily influenced by boat traffic and other human activities. [* Note that Port Valdez (Val), also included in the Harbor group, is included separately in several of the tables to show the comparable diversity of this targeted site.]
- Mud Bays (CB, SMB, Gro). Sheltered bays with salinity ranges from 3-11 ppt with a substratum of primarily mud, although cobble and bedrock was often available.
- Rocky Bays (RB). One semi-sheltered bay with a salinity ranging from 10-27 ppt and a substratum varying from gravel to cobble to bedrock.
- Headlands and Reefs (RP, Bus, Green). Very exposed habitats with salinity ranges from 15-30 ppt and a substratum consisting almost totally of bedrock and cobble.
- Floats (TAT, WBF, MBF, EIF, SBF, EBF). Exposed to semi-sheltered off-shore habitats. Salinities ranged from 16-28 ppt and substrata included 5 plastic oyster floats and line and 1 cement buoy (MBF).

Headlands and reefs with high exposure and high salinity had the greatest species diversity. As would be expected for temperate zones, they are dominated in descending order by red, brown, and green algae. Surprisingly, the next largest diversity of species occurred in the harbors. Although the red algae also predominated there, harbors had a large number of green algae. In the mud bays and on off-shore floats, there was a tendency for increase in the percentage of brown algae. However, since total species number varies among habitat types, composition of algal groups may be partly an artifact of small number of species at the low diversity sites.

The numbers of new records among the various habitat types were fairly uniform except in rocky bays where the sample size (1 bay) was small (Table 9C1.9). The slight increase in numbers on floats may be significant, but overall, the data indicate that habitat type has little to do with the discovery of new species records.

TABLE 9C1.9. Habitat Type and New Species Records

TAXONOMIC	Valdez (mixed)		Harbors (mixed)		Mud Bays (mud/cob)		Headlands and Reefs		Rk Bays (gravel/cob)		Floats (pvc/ concrete)		Totals*		
GROUP	SP	NR	SP	NR	SP	NR	SP	NR	SP	NR	SP	NR	SP	NR	%
Rhodophyceae	18	1	37	2	31	1	48	2	37	1	5	2	**69**	**5**	**7**
Phaeophyceae	13	1	22	2	31	4	30	4	22	0	16	7	**49**	**8**	**16**
Chlorophyceae	14	2	25	3	15	2	14	2	9	0	4	0	**30**	**7**	**23**
Xanthophyceae	1	1	1	1	0	0	0	0	0	0	0	0	**1**	**1**	
Seagrasses	1	0	1	0	1	0	3	0	0	0	0	0	**3**	**0**	
Lichens	0	0	1	0	0	0	1	0	1	0	0	0	**1**	**0**	
Cyanophyceae	0	0	0	0	0	0	0	0	0	0	2	0	**2**	**0**	
Total	47	**5**	87	**8**	78	**7**	96	**8**	69	**1**	27	**9**	**155**	**21**	
% Habitat Total		**11**		**9**		**9**		**8**		**1**		**33**		**14**	
% NR Total (21)		**24**		**38**		**33**		**38**		**5**		**43**		**100**	

* = excludes overlapping records
cob= cobble

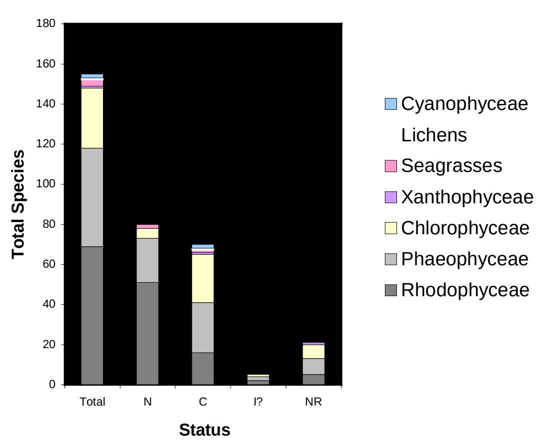
Native, Cryptogenic, and Introduced Species and their Taxonomic Composition. Of the 155 total algal species found, 52% are native, 45% are cryptogenic, and 3% (5 species) appear to be introduced (Table 9C1.10, Fig. 9C1.4). The taxonomic composition of these groups parallels the findings in the Pilot Study survey for Port Valdez. The native species contain a very large percentage of red algae, about 64% of the total. The brown algae make up 27% of the natives, and the greens only 6%. The composition of the cryptogenic forms is almost the reverse. The red algae are only about 23% of the total count, while the browns and the greens both average about 35%.

Table 9C1.10. Native, Cryptogenic, and Introduced Species and their Taxonomic Composition

Taxonomic Group	Total	Status**			NR
		N	C	I?	
Rhodophyceae	69	51	16	2	5
Phaeophyceae	49	22	25	2	8
Chlorophyceae	30	5	24	1	7
Xanthophyceae	1	0	1	0	1
Seagrasses	3	2	1	0	0
Lichens	1	0	1	0	0
Cyanophyceae	2	0	2	0	0
Totals	155	80	70	5	21
% of Total	100	52	45	3	14
NR	21	7	9	5	

** = For simplification, 2 endemics and 1 failed introduction are included with the natives.
N=native, C=cryptogenic, I?=potentially introduced, NR=new records

Fig. 9C1.4. Residency Status and Taxonomic Composition



Of the 21 new species records across all habitats, 5 were red algae, 8 brown, 7 green, and 1 was a Xanthophyte (Table 9C1.9), reflecting a fairly uniform distribution of new records across at least the 3 major taxonomic groups. However, the percentage of new species records by group increased dramatically from red to brown to green algae. It is possible that this increase relates, in part, to our overall level of taxonomic understanding in each of these 3 major classes. Since stable morphological features usable in taxonomy decrease as one moves from the red to the brown to the green algae, ease of accurate identification likewise decreases. Hence, it is likely that our knowledge of the Alaskan flora is correspondingly most complete for the reds, then the browns, and lastly the greens.

Native, Cryptogenic and Introduced Species by Habitat Types. In all habitat types except the floats, the native and cryptogenic species were fairly evenly distributed and ranged from 44 to 55% of the species (Table 9C1.11, Fig. 9C1.5a, b). However, there were some predictable reversals of dominance. In the harbors and mud bays and on the floats, the cryptogenic species were the most abundant, while on the headlands and reefs and in the rocky bays, the native species predominated. This reversal reflects the confounding effect of variation in groups among habitats (Figs. 9C1.3a, b). Since red algae predominated on the reefs and rocky bays (and green algae are relatively low in numbers), native species, consisting mostly of red algae, were also predominant there. On the other hand, in harbors and mud bays red algae were not as common (and green algae are more abundant); hence the numbers of native species were lower in those habitats. The reefs and rocky bays were under-collected in most cases, weakening the conclusions about algal species in these areas. On floats the cryptogenic forms consisted of 55% of the species while the native species consisted of only 37%. Since most of the floats sampled were from oyster farms, it is likely that they are periodically cleaned. Each cleaning of the floats would provide cleared primary substrata for ephemeral (opportunistic) species that are quick to colonize and reproduce. Since ephemeral species are most often cryptogenic, their higher percentage may be understandable.

Table 9C1.11. The Native, Cryptogenic, and Introduced Species Occurring in Each Major Habitat

Residency Status	Habitat Types					Totals
	Harbors	Mud Bays	Headlands	Rk Bays	Floats	
Native*	38	35	52	36	10	80
Cryptogenic	48	42	42	33	15	70
Introduced?	1	1	2	0	2	5
Totals	87	78	96	69	27	155
New Records	8	7	8	1	9	21

*2 endemics and 1 failed introduction (under rk bay browns) are included in natives.

Fig 9C1.5a. Species Residency Types Occurring in Each Major Habitat

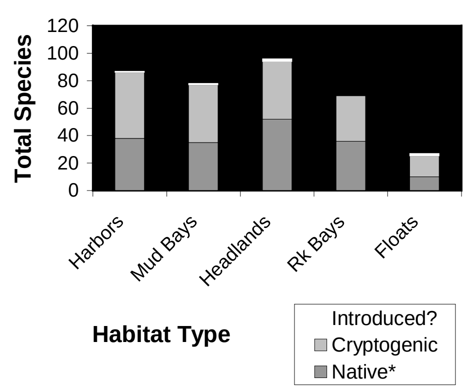
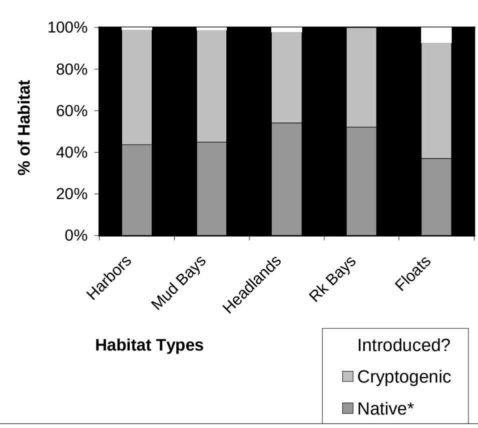


Fig 9C1.5b. Major Habitats and Residency Type Composition



New Species Records and Probable Introductions. The 21 new species records for the June 1998 trip are the most likely candidates to be NIS; however, several factors should be considered further before the status of the species can be determined definitively (Table 9C1.12). Since all of the new records appeared to have been overlooked for at least some period of time, the obvious questions related to why this oversight occurred are:

TABLE 9C1.12. New Records of Benthic Marine Algae to Prince William Sound
(species overlooked, misidentifications, range extensions, and possible introductions)

Justification	Stat	Taxon	Location	Type	Ra	So	C	Comments
		Rhodophyta, Rhodophyceae						
gi	I?	*Ceramium sinicola*?	Green	Exp	nep	Cal	3	epiphyte, MB in progress
gi, sol	I?	*Chroodactylon ramosum*	TAT	F	cb	S. Cal.	1	microscopic
rex	N	*Polysiphonia senticulosa*	RP, Cor, Whit, Bus, Green, NW, TAT	All ex M	np,nz	SeAk	1	easy to recognize invasive
mid	C	*Porphyra miniata*	Gro	M	cb	Com.	2	MB in progress
mid	N	*Porphyra redidiva*	Val (duckflat)	M	nep	Wa	1	recently described
		Heterokontophyta, Phaeophyceae						
mid	E	*Coilodesme* n. sp.	Green, TAT	Exp, F	ak		1	epiphyte, morph. needed
mid	C	*Delamaraea attenuata*	SMB, Bus, EBF	Exp, F	cb	Com	1	recently illustrated
rex	N	*Ectocarpus acutus*	MBF, EBF	F	nep	BC	1	
rex	N	*Ectocarpus dimorphus*	EBF	F	nep	BC	1	
gi	I?	*Fucus cottonii*	Val (slough), SMB, CB, Gro	M	cb	N. Atl	1	common in marshes MB in progress
gi, sol	I?	*Microspongium globosum*	EBF	F	cb	Jap, N. Atl	1	microscopic
rex	C	*Punctaria latifolia*	TAT, SMB, RP	Exp, F	cb	SeAk	1	
mid	C	*Punctaria plantaginea*	SMB, Cor, Whit, Green, Gro	All ex F	cb	N. Atl.	1	some think cold water form of latifolia
		Heterokontophyta, Xanthophyceae						
sol, rex	C	*Vaucheria longicaulis*?	Val, Cor	M, H	ws	BC	3	reproductive material needed to confirm sp.
		Chlorophyta, Chlorophyceae						
rex	C	*Blidingia marginata*	Val	M	ws	BC	1	
sol, rex	C	*Capsosiphon fulvescens*	CB	M	cb	BC	1	microscopic
rex	N	*Codium fragile** (NE Pacific form)	Green	Exp	nep	SeAk	1	epi=*C. sinicola*?
gi	I?	*Codium fragile* subsp. *tomentosoides*?	Green	Exp	ws	Wa.	2	MB needed for subsp.
sol, rex	C	*Halochlorococcum moorei*	Val, Cor	H	cb	BC	1	microscopic, endophytic
mid, sol	C	*Kornmannia leptoderma* non *zostericola* (epilithic) ?	Cor	H	cb	N. Atl.	2	Culture work needed
mid, sol	N	*Monostroma fractum*	Gro	M	nep	Wa.	2	Culture work needed

Abbreviations: (see earlier charts)

* = Recently also reported in O'Clair *et al.*, 1996, from my earlier EVOS collections
Category=preliminary decisions based on morphological and distributional features and the literature available
ex=except
Exp=exposed cobble
F=on floats
H=harbor, on cobble
gi=geographic isolation
I=likely introduction
ID=identification
M=mud
MB=molecular biological study
mid=earlier misidentification

morph.=morphological studies
rex=range extension
sol=species overlooked
Stat=residency status
Type=habitat type

C=Certainty of Idenfication
1=absolute certainty
2=Morphological identity but additional study (eg, MB or cultures) needed
3=Vegetative morphology similar, but reproductive or MB data needed for positive identification

- Are any of the species taxonomically problematic? Such problematic species often end up in new records lists; and, indeed, several of the new records are problematic species that require further study for positive identification. Investigations are currently in progress for 5 of these species.
- Could the species have been mistaken for other similar species in the past? Species that resemble one another can be confused easily. Often these mistakes are not revealed until a species is newly illustrated or described. In these cases, misidentifications and distributions could easily be corrected with herbarium searches. In the list, at least 6 species fall into this category, including at least 1 undescribed species.
- Has small size or habitat restriction influenced the species discovery? Microscopic species are frequently overlooked as are species from unusual habitats. On the list, 4 species are microscopic, and 1 occurs in the unlikely habitat of a high marsh.
- Is the species new to the area through range extension or through an actual introduction? For marine plants, historical (baseline and fossil) information, geographic isolation, and molecular data are appropriate for proving the latter.

The final justification for categorizing a species of marine plant as introduced (Table 9C1.12) was based on many of these factors, but remains tentative. All 5 species listed as introduced are geographically isolated. Nine other species are northward range extensions from southeast Alaska or British Columbia, and these species are tentatively identified as native. However, these range extensions could be caused by either natural dispersal, possibly caused by El Niño events of the past few years, or they could be introduced with aquaculture transports.

Of the 21 new records, at least 5 are at this time very strongly supported for NIS status based on their geographic isolation, and this is a very conservative estimate. To further confirm the status of these, molecular biological proof of identifications are currently in progress.

Comments on the 5 Probable Introductions and on 1 Important Failed Introduction. Additional description of each of the most probable introduced species and their habitats and distribution are provided below:

Chroodactylon ramosum. *Chroodactylon* is a microscopic primitive red alga that is typically bright bluegreen in color. Its uniseriate, dichotomously branched filaments are unmistakable under the microscope. Although common to the North Atlantic in both Europe and North America, in the Pacific it is only known from Japan, southern Australia, and southern California. Because this alga generally occurs in estuarine or freshwater habitats (Vis and Sheath 1993), its occurrence in the turf algae of the oyster floats at Tatitlek was a surprise, except that it could have been brought in with oysters. The lack of records for this species in the well-worked marine and estuarine environments of British Columbia and Washington indicates that it is truly an isolated population and in all likelihood introduced.

Codium fragile subsp. tomentosoides and the northeast Pacific complex*. The normal range of the native species complex of *Codium fragile* in the northeast Pacific is from Baja California to southeast Alaska. This complex appears to consist of several unnamed subspecies (C. Trowbridge, pers. comm.). Separate from this is an alien subspecies called *tomentosoides* that has been reported to occur in San Francisco Bay. This alien subspecies is differentiated from the native complex by having a different branching frequency and more rounded and mucronate utricle tips. At Green Island, two different subspecies of *Codium* appear to occur. The low intertidal form appears to be identical to the native complex. Its utricle tips are sharply pointed and it is fairly tightly branched. The second form occurs in the mid to upper intertidal and is more loosely branched with very short mucronate tips, nearly identical to subsp. *tomentosoides*. However, experts in the field (Silva and Max) have told me after considerable hesitancy, that neither are truly subsp. *tomentosoides*, and that both fall clearly within the native complex. This indicates that the Green Island *Codium* is probably a range extension or an introduction from southeast Alaska or from Washington, Oregon, or California. Perhaps studies on its epiphyte (discussed below) will enable us to detect its true source. (* Recently O'Clair et al., 1996, also noted that *Codium* occurs on Green Island. This record appears to be based on G.I. Hansen's earlier EVOS project collections, now located in Juneau.)

Ceramium sinicola. This *Ceramium* species was an epiphyte of *Codium fragile* at Green Island. The species, unlike *Ceramium codicola*, does not have bulbous rhizoids. It is completely corticated except for some slightly broken cortication near the tips like in the southern California species *Ceramium sinicola*. The morphology of the plants most closely matches the descriptions of Dawson (1950) and Setchell and Gardner (1924) for *C. sinicola*, and male, female, and tetrasporic specimens have all been observed. Its occurrence in Alaska is extremely unlikely unless it is a recent introduction. This past year I have been working with Mr. Tae Oh Cho, who is monographing the world species of *Ceramium* with both morphological and molecular techniques. He has agreed to look at this material for me and will also look at my Alaskan material of *Ceramium rubrum* which he feels may actually be *C. kondoi*, a Japanese/Korean species, and possibly another introduction to Alaska.

Fucus cottonii. This species is unrecorded for the North Pacific, and yet it occurred in nearly all of the high mudflat/marsh areas visited during the June 1998 cruise of Prince William Sound. The plant was first observed in unpublished notes by G.I. Hansen on Vancouver Island in 1981 and then at several Prince William Sound and Kenai sites during the EVOS studies. In some areas it dominated the supralittoral zone extending even into the terrestrial. At Cloudman Bay it occurred 100 meters away from the bay on stream banks intermixed with mosses and vascular plants. The plants in Alaska are mat-forming and either loose-lying on mud, entangled with other algae (such as *Fucus gardneri*), or intermixed with terrestrial plants. They range from 1-5 cm in height. The blades are dichotomously branched and often terete and only 1-3 mm in diameter. In some habitats, they become flattened, still without a visible midrib, and up to 5 mm in diameter. No receptacles were found during the June trip, but during the EVOS studies G.I. Hansen found a number of plants with relatively small (up to 2 cm long), elongate, somewhat pointed receptacles with conceptacles and oogonia bearing 8 eggs. In some areas, the extent of the mats of this small fucoid makes me question its form of reproduction. Since receptacles are so uncommon, propagation of the mats must be by fragmentation and vegetative growth, an advantageous feature for dispersal.

There is some question as to the use of *Fucus cottonii* (= *F. muscoides*) as a valid species. Fletcher (1987) considers the species as a high marsh ecad of *Fucus vesiculosis*, an Atlantic and Arctic species, but others have accepted *F. cottonii* as a distinct species (Guiry, 1998). To confirm the validity of the species and my designation of the Prince William Sound material, samples are being sent to Esther Serrao in Portugal, who is studying the phylogenetic relationships of the genus with molecular techniques.

Microspongium globosum. This tiny brown alga was found growing epiphytically on *Delamaraea attenuata* on the floats at Tatitlek. The thalli were abundant and bore plurilocular sporangia that clearly match the diagrams for this species in Fletcher (1987). Known only from the North Atlantic and Japan, the species makes a surprising appearance in Alaska. It also has not been reported from the well investigated areas to the south. Its occurrence on the oyster floats at Tatitlek as an epiphyte on another new record to Alaska indicates to me that this species, possibly along with its host, is another new introduction to the area. However, its vector could also have been oysters from Japan.

Macrocystis integrifolia. Since 1979 (Jay Johnson, Alaska Fish and Game, pers com.) *Macrocystis* has been imported (by plane) from southeast Alaska to Prince William Sound to be used as substrate for herring eggs in the lucrative Herring-Roe-On-Kelp (HROK) fishery. Normally only blades and fronds of the giant kelp are transported northward for the fishery. These are then placed in impoundment nets which house both the kelp and the fish. The egg-laden blades are then harvested and sold primarily to Japan as a gourmet food item. Theoretically, the blades that are brought up to the Sound are clean (the most desirable for HROK) and are all harvested for later sale. However, during our June trip and during many of Hansen's earlier trips to the area, blades and holdfasts of the kelp that had escaped were found adrift in Prince William Sound. Perhaps due to the climate, none of these plants appear to have propagated in the area since none have ever been found attached anywhere north of southeast Alaska. Hence, in the site list the species is listed as a failed introduction. However, even with the transport of "eye-clean" blades, it is likely that numerous small algal and animal species are co-transported accidentally from southeast Alaska to Prince William Sound every year with this kelp. This may account, as much as the current El Niño, for many of our new range extensions.

Discussion

During the search for marine plant NIS in Prince William Sound, it was important to characterize the flora at each of the sites so that the probable introduced species and their impacts on the community could be recognized. In addition, information on the taxonomic and residency status composition of these communities was absolutely essential to be able to determine vulnerable sites for future invasions. Although 155 species of plants collected during the 1998 cruise is probably only about half that of the actual flora of Prince William Sound, the data compiled reveal important trends in community composition. In addition, the final lists of new records and probable introductions give valuable insight into the difficulties of recognizing NIS.

Limitations of the data. Although 19 sites were visited during the June 1998 survey, the time allowed for sampling was inadequate at many of the beaches. This had a substantial impact on the overall data. Moreover, the lack of year-round collections for the area limits the results in ways that cannot even be predicted. In terms of numbers, this can be shown clearly by comparing the total count of 112 species shown for Port Valdez in the Checklist (which includes seasonal collections) with the count of 47 for the area obtained during this short trip.

Information derived from additional collections and herbarium specimens from our sites would help to overcome these difficulties and to improve the resolution of the data.

Although temperature and salinity influenced the total species counts for marine algal species, this could not be demonstrated clearly with the data on hand. Prince William Sound has regions heavily effected by rain, snow and ice melt, and marked changes in temperature and salinity occur throughout the year. During summers, salinity is the lowest as runoff produces a freshwater lens on the surface of many of the bays, including Port Valdez and Whittier. In these areas intertidal species are subjected to wide salinity fluctuations with the tidal cycle. Since these physical factors were measured only during the limited sampling periods, they do not reflect the range of conditions encountered over time by the intertidal species sampled.

Limited historical knowledge of the flora and new records. Only two floristic papers on the marine algae (and plants) of Prince William sound have ever been published (Calvin and Lindstrom, 1980; Wiegers et al., 1997). In addition, an overall identification guide to the marine algae does not exist for Prince William Sound or even for Alaska, and we are left with using an assortment of references from neighboring areas to identify species. This lack of both taxonomic information and baseline data for Prince William Sound is clearly evident in the discovery of 21 new records to the area amounting to 13.5% of the species collected during our short 9 day cruise. During our earlier Pilot Study, an additional 3 new records were found in Port Valdez alone. Though fairly evenly distributed among the 3 major taxonomic groups, there were a few more new records among brown and green algae than among the red, and the majority of the species appeared to be cryptogenic. In addition, new record species were slightly more abundant at certain sites. Green Island, the most diverse site in the study, bore 6 new records, while the float sites combined bore 9. Both of these areas (probably along with many others in Prince William Sound) appear to have been understudied in the past. Since, for this study, our probable NIS were derived from the new records, it is understandable that each of these 2 sites (or site types) also bore 2 of the 5 probable NIS designated in the study.

Taxonomic composition. In nearly all temperate outer-coastal habitats, the red algal species are the highest in numbers followed by the brown and then the green algae forming a R>B>G hierarchical pattern of dominance. Proceeding from open coasts into protected bays and estuaries, the ratio changes to reflect a reduction in the number of red algae. For instance, off the coast of Oregon, the R:B:G ratio is 61:22:17. In Prince William Sound, the overall ratio of R:B:G in the species surveyed was 47:33:20, a ratio probably indicating the influence of sheltered and less saline water. However, the overall composition pattern was still R>B>G (Table 9C1.13). The R>B>G dominance pattern in Prince William Sound occurred only at Rocky Headlands and Reefs and in Rocky Bays, all areas of moderate to high water movement (exposure) and relatively uniform salinity and temperature supporting established communities with numerous annuals and perennials. In Harbors, the proportion of green algae increased and the pattern became R>G>B, reflecting the tolerance of green algae for lower salinities found in this habitat. In addition, since many of the green and brown algae are ephemeral (opportunistic), they can survive the wide fluctuations in temperature and salinity. Moreover, since ephemeral forms are often fouling organisms, many are repeatedly brought in to seed these areas by boat traffic. In the mud bays and on the floats, the proportion of brown algae increased. In mud bays, the frequent shifts in mud level smothers many of the species, providing niches primarily for ephemerals and unattached forms. On the oyster floats, the early successional ephemeral forms are also encouraged due to the periodic cleaning of the habitat. The higher and generally more uniform salinity of both of these habitats appears to enable the ephemeral browns to outcompete the ephemeral greens.

Table 9C1.13. Summary of the Hierarchical Composition and Physical Features of each Habitat Type Observed during the June 1998 Survey

	Habitat Types				
Composition	**Harbors**	**Mud Bays**	**Rk Headlands and Reefs**	**Rk Bays**	**Floats**
Taxonomic*	R>G>B variable	B=R>G variable	R>B>G	R>B>G	B>R>G variable
Residency Status	C>N	C>N	N>C	N>C	C>N
Exposure	low	low	high	low	med-high
Salinity	variable	low-med	high	variable	high
Temperature	variable	variable	uniform	uniform	uniform
Substratum	variable	soft	hard	hard	hard

* = includes only the 3 major taxonomic groups sampled.

Resident type composition. Cryptogenic species predominated in the more disturbed and variable habitats of the Harbors, Mud Bays, and Floats, while the native species predominated in the less disturbed and more uniform habitats provided by Rocky Headlands and Reefs, and Rocky Bays. Cryptogenic algal species appear to contain a high percentage of ephemeral forms. Hence, their ability to survive in fluctuating environments and perhaps in ballast water and on ship bottoms is high.

Introduced species and their impact. The 5 probable plant NIS discovered during our survey are all isolated (and probably young) populations. Although four of these species do not appear to have wide distribution in Prince William Sound, *Fucus cottonii* does appear to have an expanding range. It was found at 4 of our sites and appears to be prevalent in the supra-littoral of all of these areas. Unique to sloughs and the marsh area of mudflats, this species does not seem to be replacing any of the known marine or estuarine species. However, in Cloudman Bay, it may actually be out-competing some terrestrial plants. Fortunately, none of the probable NIS plants found in Prince William Sound appear to be hazardous to the environment. None are as toxic or as invasive as the Mediterranean introduction *Caulerpa taxifolia* (Lemee et al., 1993; Verlaque and Fritayre, 1994).

The transport mechanisms of these introductions is only partially clear. The two species (*Chroodactylon ramosum, Microspongium globosum*) found on oyster floats could have been brought into the area with the transplantation of oysters for aquaculture purposes. The vector for *Codium* and its epiphyte *Ceramium* is more debatable. The subspecies *Codium fragile fragile* was potenitally transported up from southeast Alaska with *Macrocystis* for the HROK industry. But the only method of transport for the subspecies *Codium fragile tomentasoides* would have to be either ballast water or as fouling on the hulls of ships. The importation mechanism of *Fucus cottonii* is even less clear. Its relatively widespread occurrence in Prince William Sound (and in patchy spots along the west coast) indicates that it is probably not a recent introduction. However, since it is a predominantly unattached species, it is also an excellent candidate for transport by ballast water.

Other potential introductions and their significance. What of the other 70 cryptogenic species which are possibly introductions, but which have less obvious characteristics of invasion? These species are, by definition, wide-ranging and many are abundant, often heavily impacting the communities in which they occur. Proof of the NIS status of these prominent species is possible, but it will require detailed comparative morphological study and world-wide molecular biological tracking of their distributions. Furthermore, knowledge of the impacts of these species on community structure will demand complex physiological and ecological studies of the species in both their introduced and native habitats. These studies are important projects for future investigators who are concerned about the conservation of our native biodiversity.

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Chapter 9C2. Focal Taxonomic Collections: Planktonic Cnidaria, Ctenophora, and Pelagic Mollusca

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Methods

Medusae, ctenophores, and pelagic molluscs were collected at sites in both Prince William Sound and Cook Inlet from August 8–14, 1999 using small plankton nets and a water scoop attached to a long handle. Specimens were examined in the field, relaxed, and fixed for transport to the laboratory. Specimens were reexamined microscopically at the Friday Harbor Laboratories in September 1999, in order to verify or assign species names.

Results

All pelagic Hydrozoa, Scyphozoa, Ctenophora and Mollusca are identified by site in Table 9C2.1. Separate species lists for these groups follow for Prince William Sound (Table 9C2.2) and Cook Inlet (Table 9C2.3). An annotated species list follows (Table 9C2.4), including all species on both lists. In the time allotted to this project, I do not feel that I completed a comprehensive search of the literature for species previously collected in Prince William Sound and Cook Inlet, but no other papers came to mind. I also did not search for unpublished data at the University of Alaska.

A few coelenterates were conspicuously missing from the region. We saw no stauromedusae, no *Epiactis* anemones on eelgrass, no *Chrysaora* or *Phacellophora* scyphomedusae, and no *Anthopleura elegantissima* or *A. xanthogrammica*.

No known nonindigenous species of planktonic Cnidaria or Ctenophora were collected in Prince William Sound or Cook Inlet by our scientific teams in either 1998 or 1999. In the 1999 expedition, 15 species of Hydrozoa were collected (including 3 hydroids [see section 9D. Fouling Communities) for more thorough hydroid work-up] and 14 species of hydromedusae), two scyphomedusae and unidentified scyphozoan polyps (scyphistomae), and two species of ctenophores. Two molluscan species were also taken in the water column.

The following species appear to be new records in the Prince William Sound region:

Hydromedusae
**Aequorea aequorea*
**Aequorea victoria*
**Clytia gregaria* (=*Phialidium gregarium*)
Eperetmus typus
Euphysa sp.
Gonionemus vertens
Halitholus sp.
**Melicertum octocostatum*
**Proboscidactyla flavicirrata*
Sarsia spp.
Tiaropsis multicirrata

Ctenophora:
**Bolinopsis infundibulum*
**Pleurobrachia bachei*

New NAME for common **Scyphomedusa**

Aurelia labiata

* indicates common species whose presence in PWS may be known, but I have not seen reports in print. Dr. Jennifer Purcell (Horn Point Laboratory, University of Maryland) is working with some of these, but her results are unpublished as yet.

Following the annotated species list is a list and discussion of nonindigenous cnidarian species already present in some west coast estuaries that might be positioned to ultimately invade locations in Alaska. This list is accompanied by an Appendix (following the report) titled "Commentary on species of Hydrozoa, Scyphozoa and Anthozoa (Cnidaria) sometimes listed as non-indigenous in Puget Sound", reprinted from Cohen *et al*. (1998). References are given at the end of the main report as well as the Appendix.

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Table 9C2.1. Hydrozoa, Scyphozoa, Ctenophora and pelagic Mollusca by site, 1999. Collections and identifications by Claudia E. Mills.

1999 PWS EXPEDITION C.E. MILLS REPORT	Homer	Sadie Cove	Seward Marina	Lowell Pt Seward	Whit-tier	south of Esther Is.	Fair-moun t Bay	Val-dez Mar ina	Tatit-lek	Bus -by Is.	Cord ova
HYDROZOA											X
Aequorea aequorea v, albida	X			X	X	X		X			X
Aglantha digitale		X									
Bougainvillia ?superciliaris		x									
Clytia gregaria *(=Phialidium gregarium)*		X					X		X	X	X
Eperetmus typus		X					X				
Euphysa sp.							X				
Eutonina indicans	X										
Gonionemus vertens									X		
Halitholus sp.									X		
Leuckartiara sp.		X									
Melicertum octocostatum	X						X				X
Mitrocoma cellularia	X										
Obelia? hydroids	X		X	X							
Proboscidactyla flavicirrata	X + polyps						X		X		X
Sarsia/Coryne sp. hydroids	X										
Sarsia spp. medusae	X	X					X			X	
SCYPHOZOA											
Aurelia labiata											X
Cyanea capillata	X	X			X	X	X		X		X
unidentified scyphistomae (probably *Aurelia* sp.)	X				X						
CTENOPHORA											
Bolinopsis infundibulum									X		
Pleurobrachia bachei									X		
MOLLUSCA											
Melibe leonina							X		X		X
? Clione limacina	X										

Table 9C2..2. Prince William Sound species list. See Table 1 for specific locations. Collections and identifications by Claudia E. Mills, unless otherwise noted.

HYDROZOA	REFERENCE
Aequorea aequorea v. albida	PWS 99; Purcell, 1998
Aequorea victoria/ A. aequorea v. aequorea	Purcell, personal communication 1999
Catablema multicirrata	Bigelow, 1913
Clytia gregaria (=*Phialidium gregarium)*	PWS 99
Eperetmus typus	PWS 98, PWS 99
Euphysa sp.	PWS 99
Gonionemus vertens	PWS 99
Halitholus sp.	PWS 99
Melicertum octocostatum	PWS 99
Obelia longissima	PWS 98
Obelia? spp. hydroids	PWS 99
Proboscidactyla flavicirrata	PWS 99
Sarsia spp. medusae	PWS 99
Staurophora mertensii	Bigelow, 1913
Tiaropsis multicirrata	PWS 98
SCYPHOZOA	
Aurelia"aurita" (Mills quotes)	Purcell, 1998
Aurelia labiata	PWS 99
Cyanea capillata	PWS 99; Purcell, 1998
Unidentified scyphistomae (probably *Aurelia* sp.)	PWS 99
CTENOPHORA	
Bolinopsis infundibulum	PWS 99
Pleurobrachia bachei	PWS 99; Purcell, 1998
MOLLUSCA	
Melibe leonina	PWS 99

* PWS 98 refers to specimens collected by Ruiz *et al*., June 1998 in Cook Inlet.
PWS 99 refers to specimens collected by Greg Ruiz *et al*., August 1999 in Cook Inlet.

Table 9C2.3. Cook Inlet species list.
Collections and identifications by Claudia E. Mills, unless otherwise noted.

HYDROZOA	*REFERENCE AND LOCATION
Aequorea aequorea v. albida	PWS 99 - Homer Marina
Aglantha digitale	PWS 99 - Sadie Cove, Katchemak Bay
Bougainvillia ?superciliaris	PWS 99 - Sadie Cove, Katchemak Bay
Clytia gregaria (=*Phialidium gregarium)*	PWS 99 - Sadie Cove, Katchemak Bay
Eperetmus typus	PWS 99 - Sadie Cove, Katchemak Bay
Eutonina indicans	PWS 99 - Homer Marina
Leuckartiara sp.	PWS 99 - Sadie Cove, Katchemak Bay
Melicertum octocostatum	PWS 99 - Homer Marina
Mitrocoma cellularia	PWS 99 - Homer Marina
Obelia? sp. hydroids	PWS 99 - Homer Marina
Proboscidactyla flavicirrata hydroids	PWS 99 - Homer Marina
Sarsia/Coryne sp. hydroids	PWS 99 - Homer Marina
Sarsia spp. medusae	PWS 99 - Homer Marina, Sadie Cove
SCYPHOZOA	
Cyanea capillata	PWS 99 - Homer Marina, Sadie Cove
Unidentified scyphistomae (probably *Aurelia* sp.)	PWS 99 - Homer Marina
CTENOPHORA	
(none)	
MOLLUSCA	
? Clione limacina	PWS 99 - Homer marina
Melibe leonina	PWS 99 - not collected but told of site at Jakalof Bay by Carmen Field

* PWS 99 refers to specimens collected by Ruiz *et al.*, August 1999 in Cook Inlet.

Table 9C2.4

PRINCE WILLIAM SOUND ANNOTATED SPECIES LIST

(combines both Cook Inlet and Prince William Sound locations)

HYDROZOA

Aequorea aequorea var. albida

Distribution. Most of the *Aequorea* medusae that we saw were beached. Such specimens were seen at the Homer Marina, Lowell Point in Seward, the Whittier Marina, and in Cordova and Valdez. A few were seen in the water while underway south of Esther Island, along with *Cyanea capillata*.

Remarks. This name was applied by Bigelow (1913) to *Aequorea* specimens measuring 120 mm and 165 mm bell diameter, collected in Dutch Harbor. Such very-large *Aequorea* occur throughout southern Alaska, and are accompanied in some places by smaller specimens that seem very similar to *Aequorea victoria* at Friday Harbor (called *Aequorea aequorea var. aequroea* by Bigelow, 1913). Whether they are different sizes of the same species or 2 different species has still not been resolved (even the modern use of "*A. victoria*" as species name for Friday Harbor medusae is controversial). Only large-sized specimens (most 120-160 mm diameter) were seen in Prince William Sound in August 1999. Similar large *Aequorea*s in Prince William Sound were called *A. victoria* by Purcell (1998).

Aequorea victoria or *Aequorea aequorea var. aequorea*

Remarks. We did not collect any smaller specimens of *Aequorea*, but I am told by Dr. Jennifer Purcell, who has been doing a recent plankton study in Prince William Sound that small *Aequorea*s that look like those at Friday Harbor are also present. Bigelow (1913) calls these *A. aequorea var. aequorea*. Arai and Brinckmann-Voss later applied the name *A. victoria* to the same animals. It is not clear to me that *A. victoria* is not a junior synonym to *A. aequorea*.

Aglantha digitale

Distribution. Several *Aglantha digitale* medusae were collected at the head of Sadie Cove, Katchemak Bay, on August 8, 1999, by dipping from a small boat in about 8 feet of water. Most were within a layer of fresher water that occupied the upper 15" of the water column and were dead and decomposing. Many others were seen, but not collected.

Remarks. There is no question about the identification of this material, although why these medusae were in the layer of low salinity water is not clear. This circumpolar species is well known in the North Pacific, North Atlantic and Arctic Oceans, including the Bering Sea.

Bougainvillia ?superciliaris

Distribution. Five *Bougainvillia ?superciliaris* medusae were collected at the head of Sadie Cove, Katchemak Bay, on August 8, 1999, by dipping from a small boat in about 8 feet of water. All were below a layer of fresher water that occupied the upper 15" of the water column. Several others were seen, but not collected.

Remarks. These 6-12 mm high specimens best correspond with the description of *Bougainvillia superciliaris*, having its characteristic prominent peduncle above the manubrium. The Sadie Cove specimens had 36-40 tentacles on each of the four marginal bulbs, which is quite a bit higher than the

10-22 tentacles described for *B. superciliaris* in Kramp (1961). Bigelow (1913) found a single specimen of *B. superciliaris* of the same size off Attu Island in the Aleutians, but also with less than 20 tentacles in each group. This tentacle number discrepancy leads to the question about species identification for the Sadie Cove material.

Catablema multicirrata
Distribution. This species (2 medusae) was collected by Bigelow (1913) off Orca in Prince William Sound on July 19, 1906.

Remarks. We did not find it in August 1999, but did not sample at that location.

Clytia gregaria (=Phialidium gregarium)
Distribution. Many individuals of this species were collected in Sadie Cove, Katchemak Bay and in Fairmount Bay, Tatitlek, off Busby Island and in the Cordova Marina.

Remarks. Most of the specimens correspond well to the description of *Clytia gregaria* (as *Phialidium gregarium*) in Kramp (1961), with about 40 tentacles and a few rudimentary bulbs alternating with marginal vesicles in 12 mm diameter medusae; the gonads were on the distal 1/2 of the radial canals. Some smaller medusae (7 mm diameter), with a few less tentacles and shorter gonads may be *C. gregaria*, or could be *C. lomae*, looking very similar to specimens collected in September 1998 in Puget Sound by Claudia Mills and Erik Thuesen. Seasonal morphological variation with changes in zooplankton prey availability have not been described, so it is difficult to be positive about the species name in some cases. The genus name *Clytia* has typically been applied only to the hydroid form, but it is an older genus name than *Phialidium*, and should be applied to both phases of the life cycle.

Eperetmus typus
Distribution. One *young Eperetmus typus* medusa was collected at the head of Sadie Cove, Katchemak Bay, on August 8, 1999, by dipping from a small boat in about 8 feet of water. It was below a layer of fresher water that occupied the upper 15" of the water column. Three more *Eperetmus typus* medusae were collected in Fairmount Bay, Prince William Sound, in vertical plankton tows taken off the side of the *Kristina* with Jeff Cordell's 130 µm mesh plankton net in about 70- 90 feet of water.

Remarks. These 8-12 mm diameter immature specimens were very lively swimmers, that sank rapidly when they were not swimming. Both locations were protected coves and in both cases the animals may have been fairly near the bottom, but not enough is known to verify whether this species is indeed typical of protected coves and associated with the bottom in the same way as *Gonionemus* or *Polyorchis*.

Euphysa sp.
Distribution. Three small *Euphysa* sp. medusa were collected in Fairmount Bay, Prince William Sound, in vertical plankton tows taken off the side of the *Kristina* with Jeff Cordell's 130 µm mesh plankton net in about 70- 90 feet of water on August 10, 1999.

Remarks. These 1.5–3.5 mm high medusae were found in the lab by Jeff Cordell in his plankton tow material. The two smaller specimens clearly had 3 larger tentacles and either one small tentacle or one bare bulb. The larger specimen had 4 tentacles. There is insufficient information to assign them to species.

Eutonina indicans
Distribution. Six *Eutonina indicans* medusae were collected in the Homer Marina, Katchemak Bay, Cook Inlet on August 8, 1999.

Remarks. I am surprised that we did not find more of this species.

Gonionemus vertens
Distribution. More than 30 *Gonionemus vertens* medusae were seen in a dense eelgrass bed at low tide in front of Tatitlek, near the small town marina, on August 12, 1999.

Remarks. These medusae emerged from within blades of eelgrass in the low intertidal as the tide came in. They were abundant. The pigmentation was less colorful and more brownish that specimens in the San Juan Islands. This species was previously not known north of Sitka (where it is mentioned by Ricketts and Calvin, 1939), except that probably the same species (as *G. agassizii*) was collected early this century by Trevor Kincaid in a salt lake on Unalaska Island, in the Aleutians (Murbach and Shearer, 1903). The same or a very similar species also occurs in Japan and the Russian Far East.

Halitholus sp.
Distribution. Three *Halitholus* sp. medusae were collected at the Tatitlek commercial (ferry) dock on August 11, 1999, in vertical plankton tows taken off the side of the *Kristina* with Jeff Cordell's 130 µm mesh plankton net in about 50 feet of water. Two more of these medusae were seen using a flashlight, but not collected, later the same evening from the small Tatitlek town marina at about midnight.

Remarks. These 7-8 mm high specimens cannot be referred to any described species of *Halitholus*. They are very similar to both *Halitholus* sp. I and *Halitholus* sp. II of Arai and Brinckmann-Voss (1980, pp. 48-52), which were previously known from British Columbia and Washington State.

Leuckartiara sp.
Distribution. Four *Leuckartiara* sp. medusae were collected at the head of Sadie Cove, Katchemak Bay, on August 8, 1999, by dipping from a small boat in about 8 feet of water. All were below a layer of fresher water that occupied the upper 15" of the water column. Several others were seen, but not collected.

Remarks. These approximately 15 mm-high specimens cannot be referred to any described species of *Leuckartiara*. They bear some resemblance to *Leuckartiara foersteri* of Arai and Brinckmann-Voss (1980, pp. 52-53), which is known from British Columbia and Washington State. They had 8 large tentacles and 12 small tentacles, with no additional rudimentary marginal bulbs.

Melicertum octocostatum
Distribution. About ten *Melicertum octocostatum* medusae were found in the Homer Marina, Katchemak Bay, Cook Inlet, Fairmount Bay and the Cordova Marina.

Remarks. This species is well known elsewhere in Alaska as well as in the North Pacific and Atlantic; it probably occurs throughout Prince William Sound. These specimens were relatively small, all being under 12 mm in bell height.

Mitrocoma cellularia
Distribution. Homer Marina, Katchemak Bay, Cook Inlet on August 8, 1999.

Remarks. Only a single small (15 mm diameter) specimen was collected. This specimen was only provisionally identified as *M. cellularia* until it was compared with a comparable-sized living *M. cellularia* in Friday Harbor. The small and large tentacles on the margin are the same, confirming the species identification.

Obelia longissima (Pallas, 1766)
Distribution. Various sites in Prince William Sound, summer 1998.

Remarks. John Chapman sent all of the hydroids he collected in 1998 to Claudia Mills, who passed them on to Dr. Wim Vervoort of the Natural History Museum at Leiden, the Netherlands. Dr. Vervoort identified all of the hydroids that he saw as *Obelia longissima*. John Chapman has both the hydroids and their specific collection information.

Obelia? spp. hydroids
Distribution. These hydroids were collected at least at the Seward Marina and at Lowell Point on August 10 and 11, 1999.

Remarks. In my inexpert opinion, the blackened portions of some of the stems imply that these were probably *Obelia longissima*. I originally guessed that they might be *Garveia franciscana*, but they are not. They should be inspected by a hydroid specialist.

Proboscidactyla flavicirrata
Distribution. The hydroid of *P. flavicirrata* was found at the distal tips of several, 6 cm-long sabellid worm tubes in the Homer Marina, Katchemak Bay, Cook Inlet on August 8, 1999. This hydroid was actively producing medusa buds although no medusae were seen in this marina. Several *P. flavicirrata* medusae were collected in Fairmount Bay, Tatitlek and the Cordova Marina.

Remarks. These medusae are very small; they probably occur throughout Prince William Sound.

Sarsia/Coryne sp. hydroids
Distribution. One or more clumps of hydroids that looked like *Sarsia* were collected by Jeff Goddard in the Homer Marina, Katchemak Bay, Cook Inlet on August 8, 1999.

Remarks. I did not look carefully at this material. If it was reproductive and making medusa buds, it can be assigned to *Sarsia*; if it was reproductive and bearing fixed gonophores, it could be assigned to *Coryne*. *Sarsia* hydroids cannot usually be identified to species without their mature medusae.

Sarsia spp. medusae

Distribution. About ten *Sarsia* medusae were collected from Sadie Cove and the Homer Marina, (Katchemak Bay, Cook Inlet) and Fairmount Bay and Busby Island.

Remarks. *Sarsia* is a typical north-boreal hydrozoan genus. Many conspecific *Sarsia*s are known from the Puget Sound / Strait of Georgia region and the entire life cycle - both hydroid and mature medusa - is usually needed for identification to species. Most of the medusae collected had the apical canal above the manubrium that is seen in *Sarsia princeps* and looked quite a bit like those pictured as *S. princeps* by Bigelow (1920), although they were rather small for that species. A second species seemed to also be present.

Staurophora mertensii
Distribution. This species (5 medusae) was collected by Bigelow (1913) in Prince William Sound - no further site description or date given.

Remarks. We did not find it in August 1999.

Tiaropsis multicirrata
Distribution. Several *Tiaropsis multicirrata* were collected at station PWS 98-21 on June 24, 1998. John Chapman identified this site as Green Island, near Montague Island, on the south side of Prince William Sound.

Remarks. Specimens sent to Claudia Mills for identification, summer 1998.

SCYPHOZOA

Aurelia labiata
Distribution. Only two *Aurelia labiata* were seen, in the Cordova Marina, on August 13, 1999.

Remarks. I would have expected to see this species or its northern congener *Aurelia limbata* (similar, but with a brown rim and tentacles) in many more locations. *Aurelia* tends to occur in dense aggregations at the surface - such "swarms" were described to me by resident kayakers as present in Sheep Bay near Cordova and at Long Bay off Culross Passage near Whittier, but we did not see them. See Wrobel and Mills (1998) for a discussion of the differences between *A. aurita* and *A. labiata*. Purcell (1998) refers to the Prince William Sound species as *A. aurita*, but probably without knowing about the recently rediscovered *A. labiata* name.

Cyanea capillata
Distribution. *Cyanea capillata* was probably the most common medusa in Prince William Sound in August 1999. We saw it in the Homer Marina and Sadie Cove in Cook Inlet, as well as at the Whittier Marina, en route at the south end of Esther Island and south of Eaglek Bay, in Fairmount Bay, at Tatitlek and in the Cordova Marina. A.J. Paul told me that it is common in Resurrection Bay, but further out than the town of Seward.

Remarks. In Prince William Sound this species comes in a range of colors, from red to pink or lilac, to yellowish, to a colorless "white". The size ranged from a couple of cm to about 30-40 cm in bell diameter. It was abundant in open water.

Unidentified scyphozoan polyps

Distribution. Jeff Goddard observed scyphistomae on the docks at both Homer and Whittier.

Remarks. Most scyphistomae on docks on the west coast have proven to be those of *Aurelia* spp. Other species of scyphozoan scyphistomae have not been observed in the field and I assume that they select other types of habitats. If these were *Aurelia*, they may have been either *Aurelia labiata* or perhaps *Aurelia limbata*, which is likely to also occur in the region.

CTENOPHORA

Bolinopsis infundibulum
Distribution. Only one *Bolinopsis* specimen was seen on the PWS 1999 trip. It was collected on August 11, 1999, at the Tatitlek commercial (ferry) dock, in vertical plankton tows taken off the side of the *Kristina* with Jeff Cordell's 130 µm mesh plankton net in about 50 feet of water.

Remarks. I do not hesitate to call this specimen *Bolinopsis infundibulum*, which I have also collected at Dutch Harbor.

Pleurobrachia bachei
Distribution. Only one *Pleurobrachia* specimen was seen on the PWS 1999 trip. It was collected on August 11, 1999, at the Tatitlek commercial (ferry) dock, in vertical plankton tows taken off the side of the *Kristina* with Jeff Cordell's 130 µm mesh plankton net in about 50 feet of water.

Remarks. Examination of this preserved ctenophore left some question about its species identity. This animal was fairly contracted in its preserved state, at which point the funnel canal appeared to be shorter than the pharynx, which is indicative of *Pleurobrachia pileus* (see Bigelow, 1912). This species name should not be applied lightly, however, to a North Pacific specimen, since all those collected from British Columbia to California have been identified as *Pleurobrachia bachei*. Comparison with 3 living *P. bachei* of the same size (about 7 mm) from Friday Harbor, revealed that the pharynx/canal ratios in that species to be similar to the preserved specimen from PWS, so that name is applied here.

MOLLUSCA

?Clione limacina
Distribution. A young pteropod collected in the Homer Marina (Cook Inlet) on August 8, 1999 was probably *Clione limacina*.

Remarks. The identification was not confirmed by careful microscopic examination. This species is found in boreal and temperate regions worldwide.

Melibe leonina
Distribution. Several *Melibe leonina* was observed either swimming in the water column or attached to kelp at each of: Fairmount Bay, Tatitlek and Cordova. In addition, Carmen Field

informed me that this species is common in Jakalof Bay within Katchemak Bay, although we did not confirm that location.

Remarks. This species was seen swimming well up in the water column at Fairmount Bay and over eelgrass at Tatitlek. It was attached to laminarian kelp in the marina at Cordova.

NONINDIGENOUS CNIDARIA, (MOST) ALREADY PRESENT IN SOME WEST COAST ESTUARIES
that might be positioned to ultimately invade locations in Alaska.

CNIDARIA

HYDROZOA

Bougainvillia muscus (Allman, 1863). Hydroid known on the west coast only from Friday Harbor, Washington (Mills, 1981, as *B. ramosa*); possibly the same species of *Bougainvillia* that is a pest/contaminant in some aquariums in California. Temperature tolerances not known. This may actually be a complex of cryptic species rather than one species (Calder, 1988).

Blackfordia virginica Mayer, 1910. Hydroids and medusae on the west coast known from north San Francisco Bay and Coos Bay (J. T. Carlton, personal communication); has a wide salinity and temperature tolerance. Also reported from the Chesapeake Bay and several European and Asian harbors, and its apparent point of origin, the Black Sea. Full temperature tolerances not known, but most of Alaska is north of its known distribution.

Cladonema radiatum Dujardin, 1843. Hydroids and tiny medusae abundant in eelgrass community in Padilla Bay, Washington, not far from Anacortes and Cherry Point oil terminals. Temperature tolerances not known, but this species is found in numerous locations worldwide, including northern and Mediterranean Europe, its putative natural range.

Cordylophora caspia (Pallas, 1771). Hydroid known from the mouth of the Samish River in Samish Bay, not far south of the Cherry Point oil terminals. Is also found in very low salinity tributaries to north San Francisco Bay and elsewhere on the west coast. Requires very low salinity, temperature tolerances not known; assumed to be of Ponto-Caspian origin.

Ectopleura crocea (L. Agassiz, 1862). This Atlantic hydroid is probably established in at least California and British Columbia (see photo attributed to this species in Harbo (1999, p. 32). Species of *Tubularia/Ectopleura* cannot be positively identified without examining the reproductive medusoids, which is rarely done by non-specialists.

Maeotias inexspectata Ostroumoff, 1896. Medusae on the west coast known from low salinity tributaries to north San Francisco Bay, seemingly always in salinities less than 15 psu, maybe to as low as 1-2 psu (Mills and Sommer, 1995). Also known intermittently from the Chesapeake Bay and several European estuaries, and its apparent point of origin, the Black Sea and Sea of Azov. Temperature tolerances not known, but most of Alaska is north of its known distribution. This species was newly collected in the Baltic Sea in Estonia in August 1999 (Risto Vainola, pers. comm.).

Moerisia spp. Several species in this genus have been described from a variety of widely separated locations worldwide, including some rivers emptying into north San Francisco Bay (J.T. Rees, personal communication), in which both polyps and medusae of this genus have been found. Also known from the Chesapeake Bay. It is not clear how many species are involved worldwide. Some populations are known to be single-sexed, inplying a single introduction. Temperature and salinity tolerances not known.

SCYPHOZOA

Aurelia aurita (Linnaeus, 1758). The most commonly-reported species of *Aurelia* worldwide. With its seemingly highly-transportable sessile polyp, there is some reason to assume that this species was carried early to many additional locations, although its home range is so-far not defined - genetic studies are currently underway by several researchers. All *Aurelia* that I have inspected carefully in Alaska appear to be *Aurelia labiata* Chamisso and Eysenhardt, 1821 or *Aurelia limbata* Brandt, 1835 (the latter species known from the Aleutians and the Bering Sea). *A. labiata* was originally described from central California, but seems to range all the way up the North American Pacific coast. It would not be too surprising to find *A. aurita* also living on the west coast. A report of a genetically-different population of *Aurelia* (Greenberg *et al*., 1996) in San Francisco Bay is likely to be such. Because it is more amenable to culture, most public aquariums on the west coast have *Aurelia aurita* on display, providing a possible source of introduction. The name *Aurelia aurita* has been rather indiscriminately applied in the literature, including on the west coast of North America, without careful morphological inspection.

ANTHOZOA

Diadumene lineata Merrill, 1870. Cryptogenic sea anemone known from several locations in Washington and California, as well as worldwide. We searched in seemingly appropriate habitat for this species in several locations including the intertidal at Lowell Point, Seward, but none were found. Temperature tolerances are not known and might be an issue in Alaska.

Nematostella vectensis Stephenson, 1935. Cryptogenic sea anemone known from quiet, low-salinity lagoon habitats in most coastal American states, as well as numerous locations worldwide. This species was not found during the 1999 Prince William Sound Expedition, but we may not have encountered the right kind of habitat. Temperature tolerances are not known and might be an issue in Alaska.

CTENOPHORA

Mnemiopsis leidyi A. Agassiz, 1865. This is apparently the only species of ctenophore known to have invaded a marine habitat outside of its home range (the Black Sea). This genus, whose 3 putative species are not entirely resolved taxonomically, is native to the eastern coast of North America, extending from New England well into Argentina. It has not been found yet in the Pacific Ocean.

NOTE: Many ctenophores are assumed to have very broad global distributions, and it is not known at this time to what extent, if any, their ranges have been extended artificially by man.

Chapter 9C3. Focal Taxonomic Collections: Polychaete Worms

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Summary

Nearly all of the Prince William Sound samples of polychaetes collected during the 1998 Expedition have been examined. Certain taxa, such as the Spirorbinae, have not yet been identified. Excluding the latter subfamily, 61 species have been tentatively identified and partially described. In essence, there appear to be no clearly defined species that could be listed as a NIS. However, at least five species may be new to science (species of *Eumida*, *Scoloplos*, *Exogone*, *Nephtys* and *Glycera*). At least three new range extensions may be noted *for Phyllodoce medipapillata*, *Chaetozone senticosa* and *Rhynchospio glutaea*. Finally, six species that have widespread distributions in the northern hemisphere are represented in the present material, including: *Pholoe minuta*, *Eteone longa*, *Barantolla americana*, *Harmothoe imbricata*, *Capitella capitata* and *Amphitrite cirrata*. The systematics of each of these species is terribly confused and precise identifications are impossible to render presently. For example, *Eteone longa* was originally described from Greenland (1780), and has since been reported from numerous localities in the Arctic, Atlantic and Pacific Oceans where it appears to be phenotypically "identical" wherever it occurs. Of course, this is likely not true since the distributions of most species are restricted spatially and temporally. Resolving such dilemmas falls outside the scope of this study, and these six species are therefore identified as above, pending future revisions. Although all identifications are reasonably precise and non-indigenous species are represented in these samples, all results are based on literature descriptions and are preliminary; present materials must be more carefully compared to known reference specimens.

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Table 9C3.1 POLYCHAETA, PRINCE WILLIAM SOUND, SUMMER 1998

SIGALIONIDAE
Pholoe minuta Fabricius, 1780

PHYLLODOCIDAE
Eteone longa (Fabricius, 1780)
Eulalia bilineata (Johnston, 1840)
Eumida species A (new species)
Phyllodoce medipapillata Moore, 1909
Phyllodoce species

NEREIDIDAE
Chelonereis cyclurus Harrington, 1897
Platynereis species (?bicanaliculata)

CAPITELLIDAE
Barantolla ?*americana* Hartman, 1963

GONIADIAE
Glycinde picta Berkeley 1927

GLYCERIDAE
Glycinde ?*armigera* Moore, 1911

ORBINIIDAE
Scoloplos species A New Species

POLYNOIDAE
Harmothoe imbricata (Linnaeus, 1767)
Harmothoe extenuata (Grube, 1840)
Harmothoinae
Lepidonotinae

CHRYSOPELATIDAE
Chrysopetalum occidentale Johnson, 1897

SYLLIDAE
Exogone cf. *dwisula* Kudenov & Harris, 1995
Sphaerosyllis cf. *californiensis* Hartman, 1961
Trypanosyllis gemmipara Johnson, 1901
?*Eudontosyllis* species A
Tyosyllis alternata (Moore, 1908)
Typosyllis hyalina Grube 1863

Typosyllis pulchra Berkeley & Berkeley, 1938
Typosyllis stewarti Berkeley & Berkeley, 1942
Autoylus (Procerea) cornutus Agassiz, 1863

LUMBRINDERIDAE
Lumbrineris latrielli Audouin & Milne-Edwards, 1834

ORBINIIDAE
Leitoscoloplos pugettensis (Pettibone, 1957)
Naineris dendritica (Kinberg, 1867)

SPIONIDAE
Spio filicornis (Müller, 1776)

OPHELIIDAE
Armandia brevis Hartman, 1938
Ophelia limacina (Rathke, 1843)

NEREIDIDAE
Nereididae (postmetamorphic juvenile)

SPIONIDAE
Prionospio steenstrupi Malmgren, 1867

CIRRATULIDAE
Cirratulus cingulatus Johnson, 1901
Chaetozone senticosa Blake, 1996

CAPITELLIDAE
Capitella capitata (Fabricius, 1780)

NEPHTYIDAE
Nephtys species A (*N. ciliata*)
Nephtys species A (juvenile)
Nephtys species B (juvenile)

ARENICOLIDAE
Abarenicola pacifica Healy & Wells 1959

OWENIIDAE
Owenia fusiformis della Chiaje, 1841

GLYCERIDAE
Glycera cf. *nana* Johnson, 1901

SPIONIDAE
Rhynchospio glutaea (Ehlers, 1887)
?*Prionospio* sp.
Dipolydora cf. *socialis* (Schmarda, 1861)
Dipolydora sp. A (near *bidentata*?) Zachs, 1933
Dipolydora sp. B
Dipolydora sp. C (near *giardi* (Mesnil, 1896))
Polydora ?*limicola* Annenkova, 1934
Diplydora ?*quadrilobata* (Jacobi, 1883)
Polydora sp.

MALDANIDAE
Nicomache personata Johnson 1901

PECTINARIIDAE
Pectinaria granulata Johnson 1901

AMPHARETIDAE
Ampharete species A

TEREBELLIDAE
Amphitrite cirrata Müller. 1771
Polycirrus species III Hobson & Banse, 1981

SABELLIDAE
Laonome cf. *kroyeri* (Malmgren, 1866)
Schizobranchia insignis Bush 1904

SERPULIDAE
Crucigera zygophora (Johnson, 1901)
Serpula vermicularis Linnaeus, 1767
Spirorbis species

Table 3. Polychaeta Collected in 1998 PWS Expedition
Note: Materials listed below as PWS NIS 1998 include Stations followed by the number of specimens in parentheses.

***Pholoe minuta* Fabricius, 1780**
PWS NIS 1998: Sta 1(1 specimen); Sta 5(1); 6 (fragments); Sta 7 (2); Sta (3); Sta 10(4); Sta 11(1); Sta 41(3).

Based on specimens, these are not *Pholoe minuta* sensu Fabricius. Original taxon described as having papillae disbursed over entire ventral and parapodial surfaces. Specimens all have small, close-set, short papillae over entire ventral surface; parapodia with conspicuous digitiform papillae. Whatever "*Pholoe minuta*" represents, it must be a polyphyletic species at the very least. It has a recorded distribution in both the Arctic and south Atlantic Oceans. This species is correctly identified to a single taxon. However its actual identity is questionable in view of its widespread distribution.

***Eteone longa* (Fabricius, 1780)**
PWS NIS 1998: Sta 3(1 specimen); Sta 15(2); Sta 16(3); Sta 17(8); Sta 18(9); Sta 36(1); Sta 41(1).
Technically, the *Eteone longa/flava* group is in severe disarray and is undoubtedly represents a complex taxonomic assemblage of closely related species. Whatever taxon is represented by PWS specimens of "*E. longa*" must remain obscure until a definitive study is published.

***Eulalia bilineata* (Johnson, 1840)**
PWS NIS 1998: Sta 21(1 specimen).
Keys out according to Blake (1996) and Pleijel (1991). Only one specimen, which is poorly preserved used for this identification; therefore it is considered to be tentative.

***Eumida* species A (new species)**
PWS NIS 1998: Sta 21(2 specimens).
Genus identification correct. Prostomium small, with 4 distal and one median unpaired antenna. Dorsal cirri triangular, pointed, lanceolate. Ventral cirri subtriangular, subtly pointed. Segment 1 highly reduced, not fused to segment 2; in largest specimen it actually extends onto prostomium (although this may be artifactual); tentacular cirri lateral to prostomium. Segment 2

with two pairs of tentacular cirri, ventral pair shortest; lacking setae. Segment 3 with one pair tentacular cirri, with fascicle of setae in neuropodium.

Parapodia all distally rounded, without hint of dorsal lobe; all about the same length throughout the body. Ventral cirri asymmetrical, subquadrangular, longest anteriorly and gradually decreasing in length, size posteriorly.

Pygidium lacking appendages (lost).

***Phyllodoce medipapillata* Moore, 1909**
PWS NIS 1998: Sta 21(1); 36(1).
Two beautiful specimens, complete, well preserved with proboscides everted. Key out according to Blake (1994). Present record is a range extension, and potentially also an introduced species to PWS, assuming there are no other records of it between here and central to southern California (0-300 m) where it seems to be restricted.

***Phyllodoce* species**
PWS NIS 1998: Sta 15(2 specimens)
Juvenile individuals, one of which has proboscis everted. Both extremely small, unidentifiable.

***Chelonereis cyclurus* Harrington, 1897**
PWS NIS 1998: Sta 3(3 specimens); Sta 5(4); Sta 6(3); Sta 9(1); Sta 10(1); Sta 11(32); Sta 12(33); Sta 14(1); Sta 16(2); Sta 19(7); Sta 21(65); Sta 22(7); Sta 23(28); Sta 24(14); Sta 24N(2); Sta 25(10); Sta 28(57); Sta 30(8); Sta 31(2); Sta 32(3); Sta 34(35); Sta 35(106); Sta 36(2); Sta 40(1); Sta 41(2); Sta 44(2).
Characteristic species. Notosetae homogomph spinigers. Neurosetae heterogomph spinigers and falcigers. Largest specimen lacks homogomph falcigers in neuropodia.

***Platynereis* species (?*bicanaliculata* (Baird, 1863))**
PWS NIS 1998: Sta 12(1 specimen).
Juvenile lacking tentacular cirri. This identification is highly tentative, based on a single specimen!

Nereididae (postmetamorphic juvenile)
PWS NIS 1998: Sta 6(1 specimen).
Identified as "*Platynereis*?" but the specimen is a postmetamorphic juvenile that is not identifiable to genus.

***Glycinde picta* Berkeley 1927**
PWS NIS 1998: Sta 4(1 specimen); Sta 7(1); Sta 15(1); Sta 16(2); Sta 41(1).
All with ventral arc of micrognaths, characteristic of *Glycinde picta* along Pacific coast of North America.

***Glycinde* ?*armigera* Moore, 1911**
PWS NIS 1998: Sta 13(1 specimen); Sta 23(1).

Identification tentative in light of a dissection performed previously and prior to the present examination that damaged the critical region of macro- and micrognaths.

***Harmothoe imbricata* (Linnaeus, 1776)**
PWS NIS 1998: Sta?5(2 juveniles); Sta?6(2 juveniles); Sta 10(3 specimens); Sta 11(10); Sta 14(2); Sta 19(2); Sta 21(8); Sta 23(4); Sta 24(3) Sta?24(1); Sta 28(7); Sta 30(2); Sta 34(7); Sta 35(17); Sta 36(9).
Another widespread species that must be re-examined critically. Tentatively assigned to *Harmothoe imbricata*.

***Harmothoe extenuata* (Grube, 1840)**
PWS NIS 1998: Sta 35(3 specimens).
Seems to key out well. Some of the specimens included as *H. imbricata* likely identical to this taxon.

Harmothoinae
PWS NIS 1998: Sta 19(1 specimen); Sta 24N(2).
These are most likely "*H. imbricata* " juveniles, and should be referred to above as "?"

Lepidonotinae
PWS NIS 1998: Sta 23(1 specimen); Sta 24N(1); 34(2).
Note that Station 34(2 specimens) contains the best specimens, which seem to key out to Parhalosydna, which seems somewhat of a stretch. Most of the specimens are not well preserved, nearly all lack elytra, and identification can not be made positively.

***Chrysopetalum occidentale* Johnson, 1897**
PWS NIS 1998: Sta 23(1 specimen); 24(1).
Highly characteristic species.

***Exogone* cf. *dwisula* Kudenov & Harris, 1995**
PWS NIS 1998: Sta 19(1 specimen); Sta 21(1); Sta 23(10); Sta 32(1).
This species is very closely allied to *E. dwisula*, and also to *E. gemmifera*. Antennae closely set, laterals about .67-.75x length of median. Pharynx extends through 1.5-2 segments, with anterior unpaired middorsal tooth. Proventriculus extends through 2 segments, with 15 rows muscle cells. Peristomial antennae small, inconspicuous, not visible in dorsal view. Setae number 4-5 per parapodium, of 3 kinds: a) falcigers with deeply incised blades, confined to anterior setigers; b) stout awl-shaped spinigers, numbering 1-2 per anterior parapodium, 1 per median and posterior parapodia; c) dorsal and ventral simple seta, the former present in all setigers, the latter in the last few setigers. Aciculae numbering 1 per parapodium, all terminating in distally enlarged heads (blunt or beaked??)

***Sphaerosyllis* cf. *californiensis* Hartman, 1961**
PWS NIS 1998: Sta 10(1 specimen); Sta 19(1); Sta 19(11); Sta 21(2); Sta 21(2); Sta 23(65); Sta 23(5).
One difference between these specimens and those examined by Kudenov & Harris (1995) is the presence of an additional pair of conspicuous papillae on distal parapodial surfaces; one is

anterior, the other posterior. A most unusual aspect to the setal morphology is the fact that the cutting teeth on blades of compound falcigers are set in 2 rows, members of one row alternating with those of the other row.

This has not been reported for *S. californiensis*. Then again, I don't believe anyone has ever looked closely enough! These specimens will represent a new species if *S. californiensis* lacks these alternating rows of teeth on blade cutting surfaces.

***Trypanosyllis gemmipara* Johnson, 1901**
<u>PWS NIS 1998: Sta 23(1 specimen).</u>
One small specimen, 61 segments. Bidentate falcigers. Trepan with 10 teeth; middorsal tooth absent.

?*Eudontosyllis* species A
<u>PWS NIS 1998: Sta 19(1 specimen); 23(1).</u>
Only 2 specimens, both anterior fragments. Specimen of Sta 19 in 2 pieces, with dorsal cirri; Sta 23 in 1 piece, lacking dorsal cirri. Specimens key out to Eudontosyllis Knox 1960, which according to Fauchald (1977) is represented by a single species.

Essential descriptive elements include: Prostomium reduced, with 2 pairs of large lenticulate; eyes Palps reduced, fused only basally. Paired occipital nuchal organs extending over setiger 1, not fused to dorsum; Antennae very long, smooth basally, terminating in a few distal moniliform elements, each long and cylindrical; Peristomial tentacles long, number 1 pair; Notoacicula present, each conspicuous, with distally bent tips; Notosetae as multispinose capillaries in small inconspicuous tufts. Neurosetal fascicles with bidentate compound falcigers.

The one specimen with notosetal fascicles may be epitokous (Sta 23). Need to check out the specimen from Sta 19 for comparison.

***Tyosyllis alternata* (Moore, 1908)**
<u>PWS NIS 1998: Sta 5(1 specimen); 9(1); Sta?10(1, juvenile).</u>

***Typosyllis hyalina* Grube 1863**
<u>PWS NIS 1998: Sta 21(1 specimen).</u>

***Typosyllis pulchra* Berkeley & Berkeley, 1938**
<u>PWS NIS 1998: Sta 21(1 specimen); 24(1).</u>

***Typosyllis stewarti* Berkeley & Berkeley, 1942**
<u>PWS NIS 1998: Sta 21(5 specimens); 21(1); 23(1).</u>
Characteristic increase in thickness of falcigers in posterior segments. Many of these have lost their blades.

***Autoylus* (*Procerea*) *cornutus* Agassiz, 1863**
A.cornutus Okada, 1933:645-647, figs. 3,4; Pettibone, 1963:144, fig. 37e.
A.cornatus Hartman, 1944:338, pl. 13, fig. 5.

A. (Regulatus) cornutus, Imajima, 1966:49-51, Text-fig. 13a-i.
PWS NIS 1998: Sta 19(1 specimen); Sta 20(2); Sta 25(1).
Only two specimens include in these samples. Specimen (Sta. 19) is small, lacking tentacular and dorsal cirri. Dorsal cirri of setiger 1 longest; those from setiger 2 all shorter and about the same size. Both asexual forms exhibiting stolons between segments 13-14. Trepan with 18 teeth: 9 larger and 9 smaller. Dorsal simple setae thick, distally truncate and serrated. Nuchal organs restricted to posterolateral regions of prostomium; not extended to posterior margin of setiger 1.

The species was originally reported from Atlantic habitats (Labrador to Chesapeake Bay; Plymouth) and has also been reported from Japan to British Columbia-Washington.

Specimens (Sta. 20) are sexual forms for which only the genus is a certain identification. Swarming or sexually swimming stages have not been related to asexual phases, unfortunately, along the Pacific coast of North America (or most other places, except see Gidholm 1965, 1966).

***Nephtys* species A (*N. ciliata*)**
NIW NIS 1998: Sta 10(1 specimen); Sta?11(1); Sta 15(3); Sta 16(1); Sta 16(4); Sta 36(5).
This appears to be a new species. It does not key out to anything in Banse & Hobson (1974) where, in the key, this species drops out of the key at couplet 6 (page 73). The couplet provides a choice between large, postsetal notopodial lobes without a middorsal proboscideal papilla versus medium-sized postsetal notopodial lobes with out without a dorsal median proboscideal papilla.

To couplet 9, the next choice is interramal cirri, proboscis with unpaired dorsal papilla, which leads to a choice between *N. ciliata* or *N. caecoides*.

It is not *N. caecoides*. Key leads to *N. ciliata* which lacks a dorsal pigment pattern. Notopodial postsetal lobe partly covered by acicular lobe, which, in *N. caeca* is large, but is relatively small, compared to the postsetal notopodial lobe. Proboscis proximally with small warts.

In all, this appears to be *N. ciliata*. One principal difference appears to be the size of the postsetal notopodial lobes.

Specimen 11(1) poorly preserved; assignment tentative.

***Nephyts* species A (juvenile)**
NIW NIS 1998: Sta 15(7 specimens); Sta 17(1); Sta 17(1).
All specimens are postmetamorphic or young juveniles and are unidentifiable to species. Note that all have conical acicular lobes and poorly defined postsetal lamellae. Specimen (17(1)) obviously a newly postmetamorphic juvenile; assigned to this taxon for convenience.

***Nephyts* species B (juvenile)**
NIW NIS 1998: Sta 11(3 specimens).

Interramal cirri short, almost straight except for distally curved tip, hanging almost straight down. Interramal cirri beginning from setiger 5. Acicular lobes generally rounded although notopodial lobe slightly bilobed; neuropodial lobe more evenly rounded.

***Glycera* cf. *nana* Johnson, 1901**

<u>NIW NIS 1998: Sta 10(1 specimen); Sta 11(1); Sta 16(1); Sta 24(3); Sta 36(1).</u>

These specimens are mighty peculiar! Postsetal lobes are rounded, with biramous parapodia as per *Glycera*. Ailerons winged as per *Glycera*. Proboscis with 3 kinds of papillae including long, slender and shorter tapering forms plus spherical papillae. Inferior presetal lobe pointed, appearing rather different from that for *Glycera nana*.

Hilbig (1994) describes *Glycera nana* in terms that, compared to the present materials, intimates that the PWS specimens are sufficiently different to represent a new species.

***Lumbrineris latrielli* Audouin & Milne-Edwards, 1834**

<u>PWS NIS 1998: Sta 5(2 specimens); Sta 11(1).</u>

Keys out according to both Banse & Hobson (1974) and also Ruff (1995), particularly in view of the latter's comments. Specimen (Sta. 11) with dental formula: 1+1, 5+4, 2+2, 1+1. Yellow aciculae. Compound falcigers in anterior segments. Posterior pre- and postsetal lobes not elongate. No obvious pigmentation patterns in preserved specimens.

***Scoloplos* species A New Species**

<u>As *Scoloplos armiger* PWS NIS 1998: Sta 4(2 specimens); Sta 10(4); Sta 15(2); Sta 36(1); Sta 41(22).</u>

<u>As *Scoloplos* species PWS NIS 1998: Sta 7(1 specimen); Sta 10(3).</u>

<u>As Orbiniidae PWS NIS 1998: Sta 10(4 specimens); Sta 41(1).</u>

All of these individuals represent a new taxon. There are no subpodial lobes present whatsoever. Number of thoracic segments numbering 14-15. Branchiae from posterior thoracic segments. Thoracic neurosetae with distally smooth, transparent hoods. Abdominal neurosetae include both capillaries and delicate spines. Neuropodial lobes in larger specimens digitiform; smaller specimens notched. These lobes are clearly different from those of both *S. armiger* and *S. acmeceps.*

***Leitoscoloplos pugettensis* (Pettibone, 1957)**

<u>PWS NIS 1998: Sta 5(1 specimen); Sta 15(2); Sta 17(14).</u>

Specimens correctly identified to species. No abdominal subpodial lobes present.

***Naineris dendritica* (Kinberg, 1867)**

<u>PWS NIS 1998: Sta 17(36 specimens).</u>

Agrees well with descriptions. Originally identified as N. quadricuspida on label, however, only one record can be assigned to this species, and even then, Hartman (1961) noted distinct and significant differences between her material compared to those described by Fabricius. In other words, N. quaricuspida does not occur on this coast!

***Spio filicornis* (Müller, 1776)**
PWS NIS 1998**:** Sta 5(2 specimens); Sta 10(1); Sta 15(12); Sta 17(1).
Keys out according to Blake (1996).

***Armandia brevis* Hartman, 1938**
PWS NIS 1998: Sta 5(3 specimens); Sta 7(3); Sta 10(5); Sta 11(12); Sta 11(1*); Sta 15(4).
Everything keys out extremely well to this taxon following Hartman (1969). Need to check out the validity of this genus based on Colin Herman's comments a few years ago. Specimen (Sta. 11(1*)) is poorly preserved, has a pair of prostomial eyespots, and hints of lateral eyespots, and is taken here to represent *Armandia brevis*.

Ophelia limacina (Rathke, 1843)
PWS NIS 1998: Sta 5(1 specimen).
This is a supposedly cosmopolitan species. It has 37 setigers compared to 39 originally described. First 10 setigers abranchiate. Ventral groove present from around setiger 10-11.

***Prionospio steenstrupi* Malmgren, 1867**
PWS NIS 1998: Sta 6(1 specimen); Sta 9(3); Sta 11(10).
Specimens poorly preserved, and trashed in most cases. Gills not well intact, and in a few specimens (Sta. 11) they are of variable lengths. The neuropodial lamella of setiger 2 with the characteristic ventral protuberance; those of setiger 3 squarish to ventrally pointed also.

Identification tentative pending additional specimens.

***Cirratulus cingulatus* Johnson, 1901**
PWS NIS 1998: Sta 6(1 specimen); Sta 11(1); Sta 16(2); Sta 17(8) + Sta 17(3); Sta 24(3); Sta 24N(1).
Specimens agree fairly well with description provided by Blake (1996:350-351). Neurosetal spines begin from setigers 23-26; notosetal spines from setigers 35-37. Specimen from Sta 24N may be a juvenile, with neurosetal spines from setiger 9. and notosetal spines from setiger 16. Eyes present in all specimens as line of 4-6 individual eyespots. The three specimens from Sta 17 are very large and show size-dependent morphology concerning transverse band of tentacles/cirri.

***Chaetozone senticosa* Blake, 1996**
PWS NIS 1998: Sta 15(9 specimens); Sta 17(57).
Keys out according to Blake (1996), although the final identification needs to be confirmed based on methyl green. Specimens with around 60-70 setigers, hooks beginning from around setiger 35-40. Prostomium short, triangular, with a single achaetous annulus.

Originally reported from Central and Northern California. This may be a range extension, assuming the identification is valid.

***Barantolla ?americana* Hartman, 1963**
PWS NIS 1998: Sta 3(1 specimen); Sta 4(1); Sta 9(2); Sta 15(3); Sta 19(1); Sta 41(1).

This is a dubious taxon. Originally described has having capillary setae only in notosetiger 6 and neurosetiger 7; mixed capillaries in notosetiger 7 and neurosetiger 8; hooks only in notosetigers 8-11 and neurosetigers 9-11. In contrast, Fauchald (1977) lists *Barantolla* as having 6 setigers with capillaries followed by 1 mixed capillaries and hooks, and then 4 more with hooks only.

The present specimens are at odds with the above descrepancies. Specimen 3(1) with mixed notosetae on setiger 5; 7(2) with capillaries only in notosetigers 1-5 and neurosetigers 1-6, mixed setae in notosetiger 6 and neurosetiger 7, and hooks only thereafter in notosetigers 7-11 and neurosetigers 8-11; specimen 41(1) with capillaries only in both noto- and neurosetigers 1-6, and hooks only in both noto- and neurosetigers 7-11 (setiger with mixed setae apparently absent).

Capitella capitata **(Fabricius, 1780)**
<u>NIW NIS 1998: Sta 7(3 specimens); Sta 9(1); Sta 15(9); Sta 41(17).</u>
Whatever *Capitella capitata* is, these specimens can be assigned to the stem species. But this is one the "cosmopolitan" species that can be almost anything.

Abarenicola pacifica **Healy & Wells 1959**
<u>NIW NIS 1998: Sta 7(1 specimen); Sta 17(3); Sta 18(9).</u>
One large specimen (Sta. 7), intact; all others are juveniles. No question concerning identity.

Owenia fusiformis della **Chiaje, 1841**
<u>NIW NIS 1998: Sta 7(1 specimen); Sta 41(1).</u>
Only two specimens. Have a collar as per *Owenia collaris*. Setae appear to have configuration found in *Owenia fusiformis*. Refer to recent paper on the family from IP4 (Paris).

Rhynchospio glutaea **(Ehlers, 1887)**
<u>PWS NIS 1998: Sta 10(1 specimen); Sta 10(1).</u>
New record for Alaska. Not particularly surprising.

?*Prionospio* sp.
<u>PWS NIS 1998: Sta 18(12 specimens).</u>
Recheck. One specimen appeared to have gills on middle body segments. These are not polydorids as noted on label.

Dipolydora **cf. *socialis*** **(Schmarda, 1861)**
<u>PWS NIS 1998: Sta 17(1 specimen).</u>
Tentative identification, but not *Dipolydora socialis*. Falcate spines of setiger 5 strongly falcate, with hint of flange; bristle absent. Setiger 1 postsetal lamellae poorly developed. Gizzard-like structure present around setigers 17-18, but not as portrayed by Blake (1996).

Dipolydora **sp. A (near *bidentata*?) Zachs, 1933**
<u>PWS NIS 1998: Sta 17(18 specimens); Sta 19(1); Sta 23(2).</u>
This taxon may be a shell borer. Spines of setiger 5 without distal bristles, with flange-tooth on lateral surface (not on convex surface as fas as I can see). Caruncle to posterior setiger 4.

Notosetae present on setiger 1. Prostomium deeply incised, bifurcate. Posterior notosetae capillaries; spinous packets, modified setae absent. Neurosetae without manubrium, from setiger 7, bidentate to end of body.

***Dipolydora*. sp B**

PWS NIS 1998: Sta 17(1 specimen).
Prostomium incised, strongly bilobed. 4 pairs of eyes. Notosetae setiger 1 present, lobe reduced to papillar lobe. Caruncle to posterior setiger 3. Setiger 5 strongly modified; heavy spines distally falcate, heavy triangular tooth on concave surface, bristles present in notch between tooth and tip of spine. Bidentate neurosetae without manubria, from setiger 7. Branchiae from setiger 7.

Does not key out using Blake 1996…falls out at couplet 10 (10B where choice is presence of 2 accessory teeth) since this specimen has only 1 visible accessory tooth, and appears to lack a cowling.

***Dipolydora* sp. C (near *giardi* (Mesnil, 1896))**

PWS NIS 1998: Sta 21(>100 specimens); Sta?30(1).
Numerous specimens. Prostomium incised, bilobed. No eyes. Setiger 1 complete, notosetae present, notopodium reduced to digitiform lobe. Caruncle to setiger posterior margin setiger 3. Setiger 5 modified; spines with accessory tooth on concave surface, with partial cowling on opposite side of concave surface extending to convex surface; bristles absent.

Branchiae from setiger 9. Neurosetal hooks without manubria, from setiger 7.

***Dipolydora* ?*quadrilobata* (Jacobi, 1883)**

PWS NIS 1998: Sta 15(1 specimen).
Incomplete specimen, and identification is tentative.

***Polydora* ?*limicola* Annenkova, 1934**

PWS NIS 1998: Sta 10(1 specimen); Sta 16(1); Sta 23(1).

Incomplete specimen, and identification is tentative.

***Polydora* sp.**

PWS NIS 1998: Sta 17(1 specimen).
This is a juvenile specimen. It is small and slender. Prostomium entire. Eyes numbering 8. Setiger 5 is not modified. Pygidium 4-lobed. Probably not assignable to any known taxon.

***Nicomache personata* Johnson 1901**

PWS NIS 1998: Sta 11(1 specimen).
Identification certain to this species, although specimen is incomplete. Pigmentation pattern characteristic of species.

***Pectinaria granulata* Johnson 1901**
PWS NIS 1998: Sta 11(5 specimens); Sta 16(3); Sta 17(1); Sta 36(22).
Correct identification.

***Laonome* cf. *kroyeri* (Malmgren, 1866)**
PWS NIS 1998: Sta 17(14 specimens).
Avicular uncini with short bases; companion setae absent. Both capillary and spatulate setae present. Radioles lacking external stylodes; collar bilobed. Need to reconfirm identity.

***Schizobranchia insignis* Bush 1904**
PWS NIS 1998: Sta 19(4 specimen); Sta 23(2) + Sta 23(>20).
Identification correct. Smallest specimen placed into shell vial (Sta. 23) is perhaps a juvenile, with all the setal features consistent. Note that large vial (Sta. 23) mislabeled as Terebellidae (instead of Sabellidae).

***Amphitrite cirrata* Müller, 1771**
PWS NIS 1998: Sta 19(2 specimens); Sta 23(3); Sta 24(2); Sta?35(1); Sta 36(1).
This is another "cosmopolitan" species…at least in the northern hemisphere. A taxonomic black hole similar to Phole minuta and Eteone longa!! Specimen (Sta. 35) is juvenile terebellid, probably *Amphitrite cirrata*; it is not Ampharetidae)!

***Polycirrus* species III Hobson & Banse, 1981**
PWS NIS 1998: Sta 36(1 specimen).
This keys out as per Hobson & Banse (1981). However, as a general comment, the key is extremely poor and relies on imprecise terminology that overlaps features used to describe notosetae! In any case, it would seem appropriate to attach names instead of roman numerals.

***Ampharete* species A**
PWS NIS 1998: Sta 41(1 specimen).
The generic identification is correct. Single specimen lacks a tail, and cannot be identified to species. It is not *Ampharete labrops*, which has eyespots on upper buccal lip; present specimen lacks eyespots in corresponding region.

***Crucigera zygophora* (Johnson, 1901)**
PWS NIS 1998: Sta 19(6 specimens); Sta 23(>20); Sta 24(1).
Identification correct. Present specimens are textbook examples.

***Serpula vermicularis* Linnaeus, 1767**
PWS NIS 1998: Sta 23(3 specimens).
Identification correct. Tentacles solid red or banded red and white, at least in preservative.

***Spirorbis* species**
PWS NIS 1998: Sta 17(>50 specimens).
Dextrally spiraled tubes, 3 thoracic setigers. Species identifications pending examination of remaining materials.

Chapter 9C4. Focal Taxonomic Collections: Peracaridan Crustaceans

John W. Chapman, Department of Fisheries & Wildlife, Hatfield Marine Science Center, Oregon State University

Summary

No clear peracaridan NIS were discovered among the scores of species collected in three surveys of 72 sites in 21 general areas of Prince William Sound and south central Alaska between 1997 and 1999. No NIS were found in UAF samples from the area collected previously. Two peracaridan species previously considered to be introduced are likely to be misidentified. Five species of NIS gammaridean amphipods were found in ballast water of tankers travelling to Prince William Sound, indicating that this is an active mechanism of NIS transport to Alaska, even though they do not appear to have invaded or become established there. Invasions of Alaskan estuaries and marine waters by a broad diversity of peracaridan species have not occurred. The diversities of peracaridan NIS invasions in the northern hemisphere vary with climate, as do invasions by other taxa noted previously. Most marine and estuarine peracaridan NIS thus appear to be incapable of invading Alaska from lower latitudes due to the extreme climate. The risk of invasions by high diversities of NIS of pericaridans thus appears to be extremely low.

These findings do not indicate whether a few NIS could be present at ecologically catastrophic abundances, however. Eight peracaridans that are prominent members of either fouling or benthic communities sampled in the survey, have unclear origins or cannot yet be clearly distinguished from species that are nonindigenous to the northeast Pacific. They are therefore classified as cryptogenic. These cryptogenic peracaridan species occur in the same areas as the soft shell clam, *Mya arenaria* Linnaeus, 1758, which is one of the most clearly documented NIS in south central Alaska. If proven to be NIS, these cryptogenic peracaridan species, would be evidence that even a few NIS capable of invading Alaskan estuaries can increase to ecologically catastrophic densities. They would indicate that surveys of peracaridan NIS diversity, such as this one, are an insufficient basis for estimates of risk. Whether these peracaridan crustaceans are, in fact, native to the region therefore should be tested by analyses of morphological variation, molecular genetics and by crossbreeding viability tests with their presumed original populations.

Introduction

A major objective of the south central Alaskan NIS survey was to determine whether introductions of marine or estuarine species have already occurred. An ultimate objective of the overall risk analysis is to predict whether Alaskan waters are vulnerable to NIS invasions. The survey results and comparisons of climate effects on peracaridan NIS diversity over the northern hemisphere provide a basis for this prediction.

Predicting which nonindigenous species (NIS) can be introduced, where, and the factors that control their survival are major objectives of invasion ecology. These predictions require knowledge of the interactions between dispersal and processes that determine NIS survival. The mechanisms of NIS dispersal among estuaries are becoming well known (*e.g.*, Cangelosi 1999, Cohen 1998, Frey et al.1999, Draheim and Olson 1999, Miller and Chapman 2000, Moy 1999, Ruiz et al. 1999, Thresher 1999), while the processes limiting NIS survival and production among estuaries remain poorly known. The distributions of NIS reveal how survival varies as dispersal occurs and thus indicate the interactions of dispersal, ecology, and survival. Interpreting the geography NIS distributions is thus a necessary part of the search for factors controlling NIS invasions.

NIS are particularly diverse and abundant in estuaries of the northeastern Pacific, including San Francisco Bay, California (Carlton and Geller, 1993, Cohen and Carlton 1995, 1997, Ruiz et al. 1997a, 1997b) and in Europe (Leppakoski, 1994, Leppakoski and Olenin, 1999, Eno, *et al.* 1997). The majority of these NIS have origins from western ocean coasts (Cohen and Carlton 1995, Leppakoski and Olenin, 1999) and progressively fewer NIS are known with increasing latitudes (Carlton 1979, Cohen *et al.* 1998, Mills *et al.* 2000). These geographical patterns do not appear to result entirely from the mechanisms of dispersal or patterns of endemic species diversity. Other processes controlling NIS distributions warrant consideration.

Potential climate effects on east and west and north and south patterns of NIS diversity among estuaries and coastal waters of the northern hemisphere are of paramount concern in any NIS risk analysis for Alaska. The cold temperate climate of Alaska is at the extreme northern range of many northeast Pacific intertidal species (O’Clair 1977, O’Clair and O’Claire 1998). Climate effects are therefore considered in this section. Salinity and temperature variations in estuaries are dominant processes of climate that limit NIS survival. Most estuarine species survive within narrow temperature and salinity ranges. Most chemical, biological, and hydrological processes that also limit the abundances and distributions of estuarine organisms are also controlled by, or closely correlated with, salinity and temperature (*e.g.,* Southward 1969, Green 1971, Ebbesmeyer et al. 1991, Cohen and Carlton 1995 1999, Chapman 1998, Thompson 1998). NIS distributions are therefore influenced by salinity and temperature within local estuaries. In turn, salinity and temperature are affected by climate (Ebbesmeyer et al. 1991, Cayan 1993). Precipitation and air temperature variations (Ebbesmeyer et al. 1991, Cayan 1993) can be interpreted to infer salinity and temperature variations in local estuaries even though direct, long-term measures of these parameters are lacking in most cases.

Amphipods recovered from 34 ballast water samples taken from tankers during 1998 were examined to determine whether amphipods are transported by ballast water traffic from west coast ports and harbors.

Methods

Rapid assessment survey

Prince William Sound, Seward and Homer, Alaska (60^{o} 00' - 61^{o} 00' N) survey results are compared to results of NIS surveys of the native, cryptogenic and introduced peracaridans from Puget Sound, Washington (47^{o} 10' - 49^{o} 00' N) and San Francisco Bay, California (37^{o} 30' - 38^{o} 10' N) to resolve how peracaridan NIS invasions are distributed over a broad range of latitudes.

Collections were made from three sites in Port Valdez in early spring of 1997, 46 sites throughout Prince William Sound in June 1998, and from 23 sites in Prince William Sound, Seward and Homer in 1999 (Ruiz and Hines 1997, Hines and Ruiz 1998) (Figure 9C4.1). Twenty six sites were surveyed in Puget Sound, Washington in September 1998 (Cohen *et al.* 1998). San Francisco Bay was surveyed in early fall, late spring or summer of 1993, 1994, 1996 and 1997 at 25 regular sites plus several irregular sites (Cohen 1998, Cohen and Carlton 1995, 1997, 1998). The three systems are excellent for comparison because they have all received and have been interconnected by significant aquaculture and shipping activities that are vectors of NIS dispersal in at least the last century.

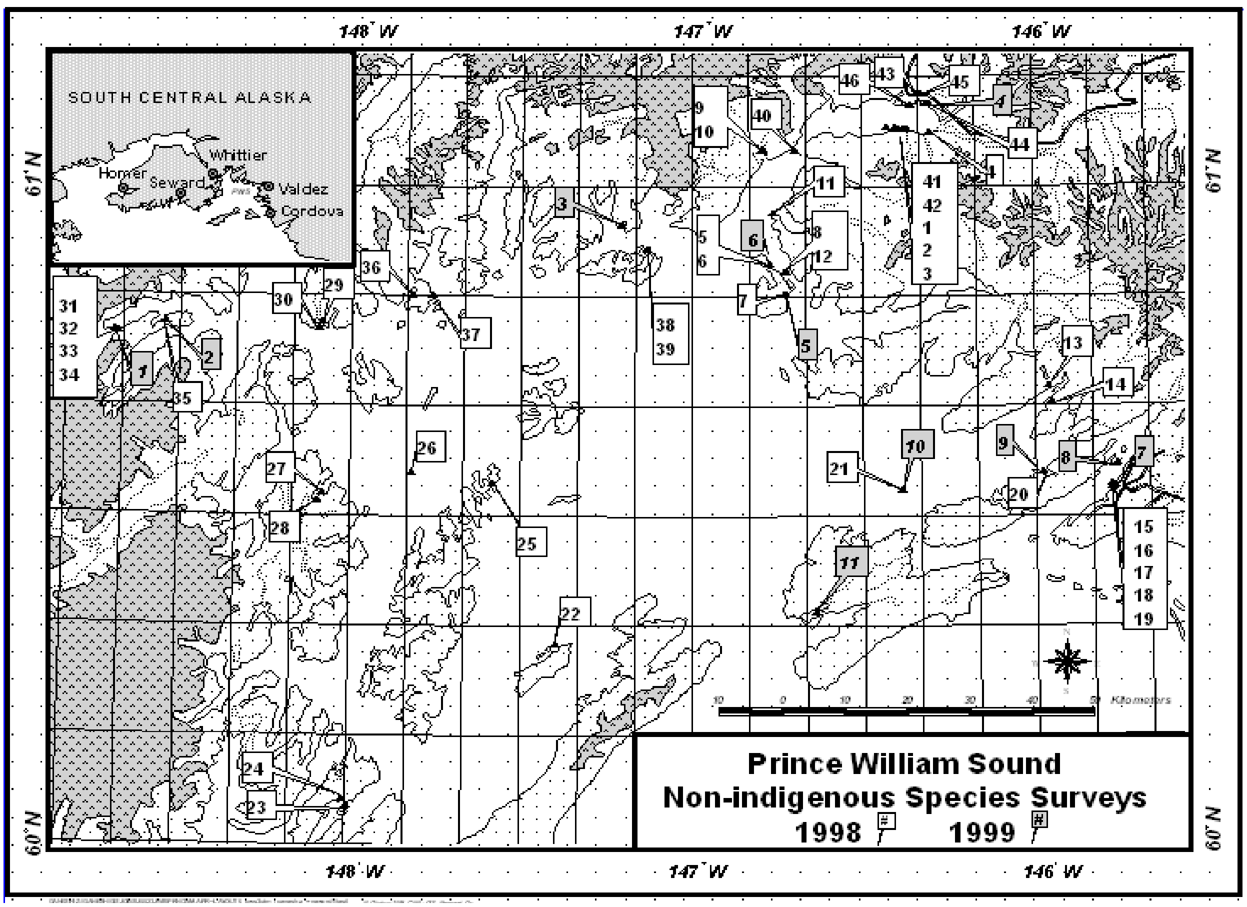

Figure 9C4.1. Prince William Sound, Alaska and south central Alaska rapid assessment sites with open boxes indicating all 46 sampling sites of 1998, inset indicating the five port areas sampled in 1999 and the shaded boxes indicating the eleven general sampling areas of the sound in 1999. (Latitudes longitudes and site descriptions are in appendix table 9C4.5).

Each area was surveyed by the author in the same fashion. Survey samples were collected by hand, scrapings, cores, or dredge as necessary to remove biological communities or substratum from floats, intertidal pilings rocks and intertidal or shallow subtidal mudflats accessible at each collection site. These samples were washed on an 0.5 mm mesh sieve directly or decanted onto an 0.5 mm mesh sieve and washed following vigorous sloshing in buckets of seawater, to suspend organisms from the removed substratum. Harbor float, rock and piling substratums were emphasized in all three survey areas but other available habitats were sampled extensively as available. Organisms were picked directly from substratums during sample collection or from the sieves after washing or from voucher samples of substratums and examined under a stereomicroscope. All collected organisms were fixed in 10% formalin before transfer to 70% ETOH for long-term preservation. All specimens were identified to lowest possible taxonomic category.

Voucher specimens will be deposited in the Los Angeles County Museum, the California Academy of Sciences and the Smithsonian National Museum of Natural History. The precise locality records and notes for each collection site are available from the author. Temperature and salinity was measured at each collection site. Surface salintities ranged between 0 and 33 $^{o}/_{oo}$ in all three survey areas. Surface water temperatures ranged between 8 and 20^{o} C in Prince William Sound, between 10 and 21^{o} C in Puget Sound and between 12 and 30^{o} C in San Francisco Bay. San Francisco Bay is a well mixed estuary. Low surface salinities and clear stratification occur in both sounds in summer and were apparent during the surveys.

All species from the three surveys were collected and examined directly by the author and thus are assumed to be a more standardized sample than would be likely from comparisons of different surveys and sampling methods employed by different investigators. The indigenous origins of species are inferred from previously published records or herein using the criteria of Carlton (1979) and Chapman and Carlton (1991, 1994). The criteria used for cyptogenic species (species that are not clearly native or introduced) are adopted from Carlton (1996a). Only populations of species that have been moved by human activities to new locations, that are reproductive there, and that satisfy the criteria for nonindigenous species are considered here to be NIS.

Alaskan Climate and Peracaridan NIS Invasion Risks

Sources of NIS to Alaskan estuaries are available from a global population. The peracaridan Crustacea of the northern hemisphere considered here are as a sample of that population. Crustacea comprise approximately 25% of the 250 NIS reported from San Francisco Bay (Cohen and Carlton 1995, J. T. Carlton, personal communication), where they are the most diverse NIS taxon. The majority of these crustacean NIS are peracaridans. The Peracarida consist of relatively small, short-lived species that are primarily mysids, amphipods, isopods, tanaidaceans and cumaceans. The Peracarida are prominent in most North Pacific and North Atlantic marine and estuarine NIS communities (Bowman *et al.* 1981, Chapman 1988, 1999, Chapman and Carlton 1991, 1994, Mees and Fockedey 1993, Leppakoski 1994, Cohen and Carlton 1995, 1997, Eno *et al.* 1997, Toft et al. 1999). Both native and nonindigenous Peracarida are diverse, taxonomically well known, and ubiquitous in aquatic environments (*e.g.*, Barnard and Barnard 1983, Barnard and Karaman 1991, Chapman 1988, Cohen and Carlton 1995, Chapman 2000). Peracarida develop directly, without larval dispersal stages or unique life history traits that complicate identifications and interpretations of their geographical distributions. Peracaridans may thus provide clear indications of the patterns of diversity within and among broad geographical regions.

The species selected for the east to west geographical analysis of northern hemisphere peracaridan NIS are common or abundant where they occur and documented either in the literature or by personal observations. Species that are poorly documented, not examined directly, cryptogenic, or that are not introduced across the North Atlantic or North Pacific, were not included. For instance, the amphipod *Chelicorophium curvispinum* (Sars, 1895), which spread from the Black and Caspian Sea to northern Europe (Eno et. al. 1997), and the introduced mysid *Acanthomysis bowmani* Modlin and Orsi, 1997 in San Francisco Bay, which has unknown origins, and many northern NIS that are native to the southern hemisphere are not in the scope of this study and are therefore excluded from the analysis.

Long-term climate conditions in the northeast Pacific, including San Francisco Bay, Puget Sound and Prince William Sound are inferred from monthly average climate time series data for the Pacific Ocean and western Americas (Cayan et al. 1991). These data extend over approximately 100 years up to 1986. Global records of sea surface temperature and precipitation minus evaporation (http://www.cdc.noaa.gov/ 1998) are used for comparisons of temperature among ocean regions. The term "western ocean" is used in reference to the Pacific Ocean bordering the east Asian coast and the Atlantic Ocean bordering the eastern North American coast. The term "eastern ocean" refers to the ocean areas bordering the west coasts of Europe and North Africa and the west coast of North America.

Amphipods in Ballast Water

Ballast water samples were collected in vertical plankton tows from "dedicated" ballast tanks, which are not contaminated by oil. Amphipods retained in the 0.25 mm mesh plankton nets preserved in 5% formalin, subsequently transferred to 70% ethanol for final sorting and identification. Samples were initially sorted under stereo microscopes at the Smithsonian Environmental Research Center or at the field office in Port Valdez and final amphipod identifications were performed at HMSC, Oregon State University.

The origins of the ballast water sampled (Table 9C4.3) were the Los Angeles-Long Beach area, the San Francisco Bay area, Puget Sound (Anacortes) and the open ocean. One ship, from the San Francisco Bay area, exchanged the ballast water at sea during transit. The potential for dispersal of nonindigenous species is assessed from the presence of nonindigenous species in samples.

Results

North - South Climate

The maximum, minimum, mean and range of monthly sea surface temperatures of the eastern Pacific vary by 5^o C or less between 28^o and 52^o N (Figure 9C4.2). The 11 to 14^o C maximum average monthly temperatures of Seward, Kodiak and Sitka, Alaska (between 58 and 60^o N) overlap the Neah Bay, Washington maximum surface temperatures at 48^o N and are similar to the 13^o C average sea surface temperatures adjacent to San Francisco at 38^o N (Figure 2). Nonindigenous species expected to reach south central Alaska might include those that can reproduce within Puget Sound in summer or in average San Francisco temperatures (Figure 9C4.2).

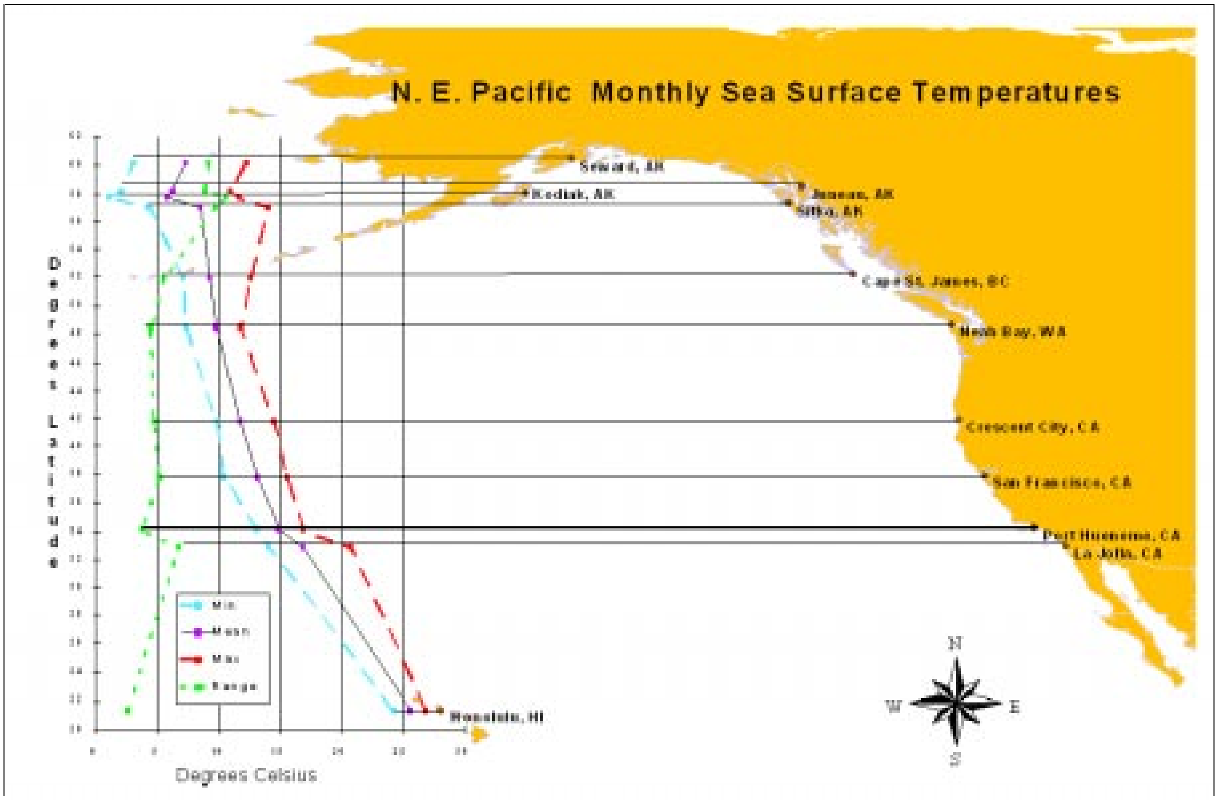

Figure 9C4.2. Sea surface temperature monthly average minimum, mean, maximum and range of northeast Pacific coastal waters estimate over an approximately 100 years up to 1986 (Cayan 1991).

North - South Biodiversity

Of the 106 peracaridan crustacean species identified from the surveys of Prince William Sound, Puget Sound and San Francisco Bay, 54 are native, 14 are cryptogenic and 38 are introduced (Table 9C4.1). Seven peracaridan crustaceans that prominent members of benthic or fouling communities that were recovered in the survey are cryptogenic (Table 9C4.1). They are the tanaidacean *Leptochelia dubia* (Kroyer, 1842) a cosmopolitan species (Miller, 1975); the cumacean *Cumella vulgaris* Hart, 1930 which occurs in Asia (Lomakina 1958) as well as the eastern Pacific; the amphipod *Monocorophium carlottensis* Bousfield and Hoover, 1997 is not clearly distinguished from the nonindigenous amphipods *Monocorophium acherusicum* and *Monocorophium insidiosum* (Ruiz and Hines 1997); the amphipod *Hyale plumulosa* (Stimpson, 1857) is reported also from the western Atlantic (Bousfield 1973); the amphipod *Jassa staudei* Conlan 1990 is extemely similar to the cosmopolitan *Jassa marmorata* Holmes, 1903; the amphipod *Pontogeneia rostrata* Gurjanova, 1938 is reported from the eastern and western Pacific (Gurjanova 1938, 1951, Barnard 1962, 1964); the caprellid *Caprella depranochir* Mayer, 1880 is reported from the eastern and western Pacific (Arimoto 1976, Kozloff and Price1997).

Table 9C4.1. The 106 peracaridan crustaceans identified as nonindigenous, cryptogenic or native, and the records per species collected from San Francisco Bay, California, (w/o "*"), south central Alaska and Prince William Sound (with "*"), or Puget Sound, Washington (underlined). *Gnorimosphaeroma lutea* was collected from San Francisco Bay and Prince William Sound only. No species were collected only in Puget Sound.

Nonindigenous	**Records**	**Cryptogenic**	**Records**	**Native**	**Records**
Mysidacea		Tanaidacea		Mysidacea	
Accanthomysis aspera	1	*eptochelia dubia*	3	*Mysis littoralis**	1
Tanaidacea		Cumacea		Isopoda	
Tanais stanfordi	2	*Cumella vulgaris*	3	*Dynamenella glabra**	2
Isopoda		Gammaridea		*Gnorimosphaeroma lutea*	2
Asellus sp.	1	*Ampithoe lacertosa*	3	*Gnorimosphaeroma oregonense*	3
Dynoides dentisinus	1	*Dulichia sp.*	1	*Ianiropsis kincaidi**	2
Euylana arcuata	1	*Hyale plumulosa*	3	*Idotea montereyensis*	3
Ianiropsis serricadus	1	*Ischyrocerus sp.*	2	*Idotea obscura**	1
Limnoria quadripunctata	1	*Jassa staudei*	3	*Idotea resecata*	2
Limnoria tripunctata	2	*Monocorophium carlottensis**	2	*Idotea wosnsenskii*	3
Munna ubiquita	1	*Pontogeneia rostrata*	3	*Ligia pallasi**	1
Paranthura sp.	1	Caprellidea		*Limnoria lignorum*	2
Sphaeroma quoyanum	1	*Caprella depranochir**	2	Cumacea	
Synidotea laevidorsalis	1	*Caprella laeviuscula*	3	*Diastylis alaskensis**	1
Cumacea		*Caprella penantus*	1	*Diastylis sp.**	1
Nippoleucon hinumensis	2	*Caprella verrucosa*	2	*Lamprops beringi**	1
Gammaridea		*Tritella sp.*	1	*Lamprops quadriplicata**	2
Ampelisca abdita	1			Gammaridea	
Ampithoe valida	2			*Allorchestes angusta*	3
Crangonyx sp.	1			*Americorophium brevis**	2
Eochelidium sp.	2			*Americorophium salmonis**	2
Gammarus daiberi	1			*Americorophium spinicorne*	2
Grandidierella japonica	2			*Ampithoe dalli**	2
Hyalella azteca	1			*Ampithoe kussakini**	1
Jassa marmorata	2			*Ampithoe sectimanus**	1
Laticorophium baconi	2			*Ampithoe simulans**	2
Leucothoe alata	1			*Anisogammarus pugettensis*	3
Melita nitida	2			*Aoroides columbiae*	3
Melita sp.	1			*Aoroides intermedius**	2
Monocorophium acherusicum	2			*Calliopius carinatus**	2
Monocorophium insidiosum	2			*Calliopius pacificus**	2
Monocorophium oaklandense	1			*Eogammarus confervicolus*	3
Monocorophium uenoi	1			*Eogammarus oclairi**	1
Trasorchestia enigmatica	1			*Gammaridae n. gen. n. sp.**	1
Paradexamine sp.	1			*Gnathopleustes pugettensis*	2
Parapleustes derzhavini	1			*Hyale frequens*	3
Senothoe valida	2			*Lagunogammarus setosus**	2
Sinocorophium heteroceratum	1			*Locustogammarus locustoides**	1
Caprellidea				*Megamoera subtener**	2
Caprella acanthogaster	2			*Microdeutopus schmitti*	1
Caprella bidentata	1			*Najna n. sp.**	1
Caprella californica	2			*Paracalliopiella pratti**	2
Caprella equilibra	2			*Parallorchestes ochotensis*	3

Table 9C4.1. Continued

			Paramoera bousfieldi*	2
			Paramoera mohri*	1
			Parampithoe humeralis.*	2
			Parampithoe mea*	1
			Photis brevis	2
			Pontogeneia inermis	3
			Pontogeneia ivanovi*	1
			Pontoporeia femorata*	2
			Spinulogammarus subcarinatus*	1
			Trasorchestia traskiana	3
			Caprellidea	
			Caprella alaskana*	1
			Caprella gracilior*	1
			Caprella irregularis*	2
			Metacaprella kennerlyi*	2
Total Species	38	14		54
Records/Species	1.4	2.1		1.8

The diversity of species collected is nearly nearly constant among sites (66 to 60 and 59, respectively, between San Francisco, Puget Sound and Prince William Sound). Of the 54 native species collected in Alaska, 52 (96%) were collected also in San Francisco Bay or Puget Sound (Table 9C4.1). The common pool of native species and the similar species diversities collected among the three areas both indicate that the habitat selection, collection and sample processing methods of the rapid assessment surveys were consistent among the three areas. Little variation in NIS diversity among these three sample sets was therefore likely to result from sample biases.

From San Francisco Bay north to Puget Sound and Prince William Sound, introduced peracaridan species declined from 38 to 15 to 0 (Figure 9C4.3, $X^2 > 27.01$; $p < 0.0001$; $df = 2$), while the frequencies of cryptogenic peracaridan species were nearly constant at 11, 10 and 8, respectively ($X^2 = 2.0$; $p > 0.73$; $df = 2$). In contrast, the frequencies of native species increased to the north from 17 to 35 and 52 (Figure 9C4.3, $X^2 > 27.01$; $p < 0.0001$; $df = 2$). All peracaridan NIS and all but two of the cryptogenic peracaridan species at any site also occurred in San Francisco Bay while only 17 of the 54 native species were recovered from San Francisco Bay (Table 9C4.1, Figure 9C4.3). The peracaridan NIS that managed to invade northeast Pacific estuaries thus have adaptations to lower latitude climates than do the native species. The affinities of peracaridan NIS for low latitude climates closely corresponds to a pattern that would be expected if the peracaridan NIS are poorly adapted to cold water conditions or other factors of climate that vary with latitude.

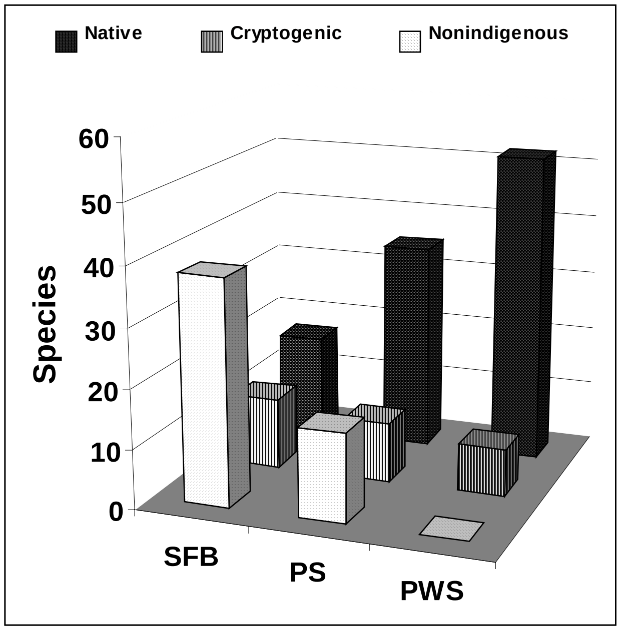

Figure 9C4.3. Native, cryptogenic, nonindigenous and total species in samples from San Francisco Bay, California, Puget Sound, Washington and Prince William Sound, Alaska (SFB, PS and PWS, respectively).

Some NIS may be among the 8 cryptogenic peracaridan species of Prince William Sound (Figure 9C4.3). Six of these cryptogenic Alaskan peracaridan species have broad thermal tolerance ranges and occur also in Puget Sound and San Francisco Bay (Table 9C4.1). The nearly complete faunal peracaridan overlap between Alaska and the two more southern sites indicate that the low diversity of Alaskan NIS peracaridans are not likely to result from unique types of NIS peracaridans that were not collected in the survey. The nearly uniform pool of native peracaridan species and uniform pool of NIS peracaridans among the areas require few qualifications or assumptions to arrive at conclusions of the patterns of diversity. The possibility of overlooking populations of nonindigenous peracaridan crustaceans in Alaska that occur at similar diversities and abundances as in Puget sound or San Francisco Bay, by these rapid assessment methods, is remote. The presence of peracaridan NIS that are not among the cryptogenic species of peracardans in Alaskan estuaries and marine waters is not significantly different from zero.

These results are not surprising. The extreme climate of Alaska was previously assumed to limit the survival of nearly all NIS peracaridans. However, these data include only a single coast and three major areas of reference. NIS pericarican diversity was therefore compared between other geographical regions with climates that vary similarly to the variation that occurs between San Francisco and south central Alaska as a further test of the climate pattern.

East -West Climate

Sea surface temperatures are relatively constant between latitudes of 25^{o} and 50^{o} N in eastern oceans compared to western ocean areas (Figures 9C4.4 and 9C4.5). Eastern ocean species from 32^{o} to 50^{o} N evolved in temperature ranges that span only latitudes 40 to 42^{o} N in western oceans (Figure 9C4.6). Eastern ocean species thus have not evolved in conditions that would create broad temperature tolerance ranges. In contrast, most western ocean organisms survive temperature ranges exceeding the total temperature range of broad eastern ocean areas. Eastern oceans below 50^{o} N, are thus broad thermal targets for western ocean species over space and time while western ocean coasts are narrow thermal targets for eastern ocean species.

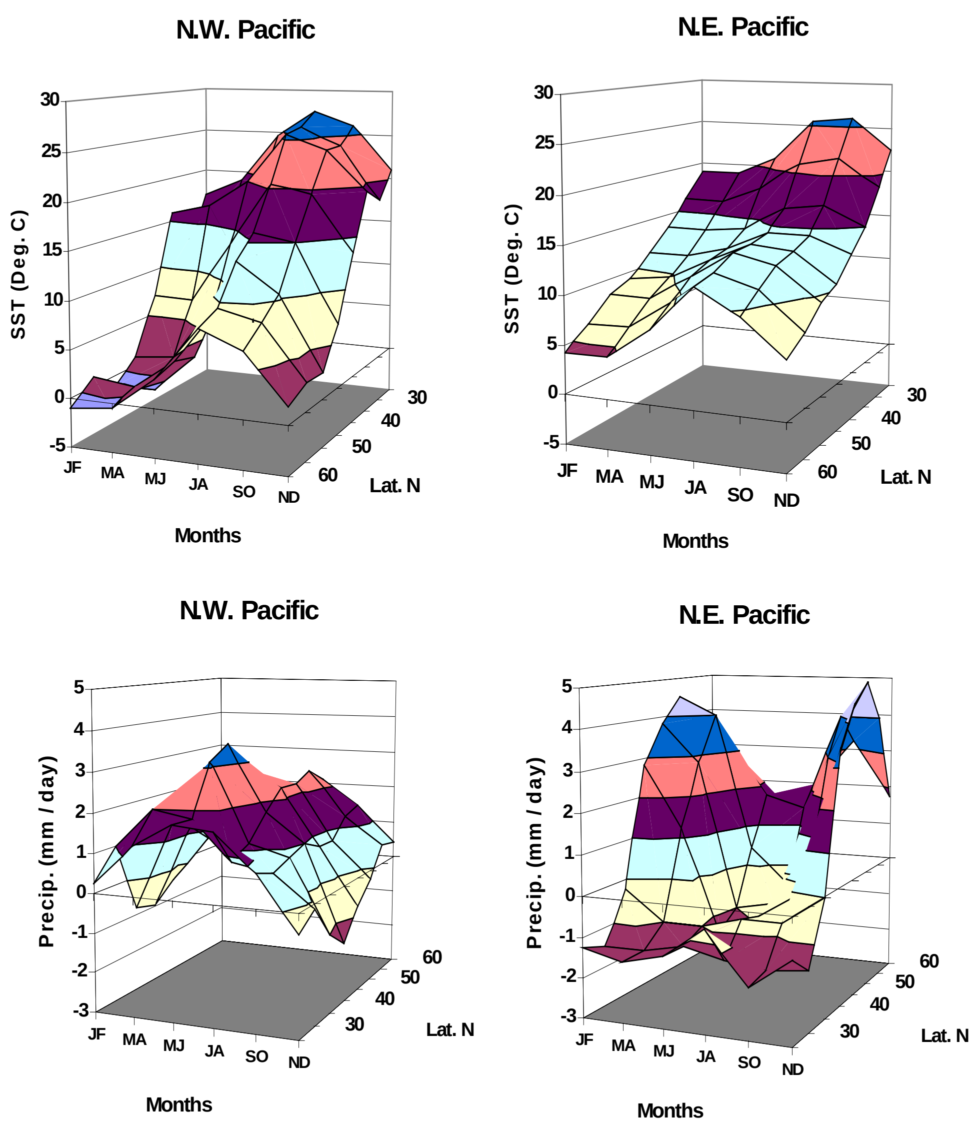

Figure 9C4.4. Northwest and northeast Pacific sea surface temperature in degrees Celsius and bimonthly precipitation minus evaporation in mm^{-d} at ten degree latitude intervals for the bimonthly periods of Jan-Feb, Mar-Apr, May-Jun, Jul-Aug, Sep-Oct and Nov-Dec. (Note: axes of latitude are reversed between graphs of temperature and

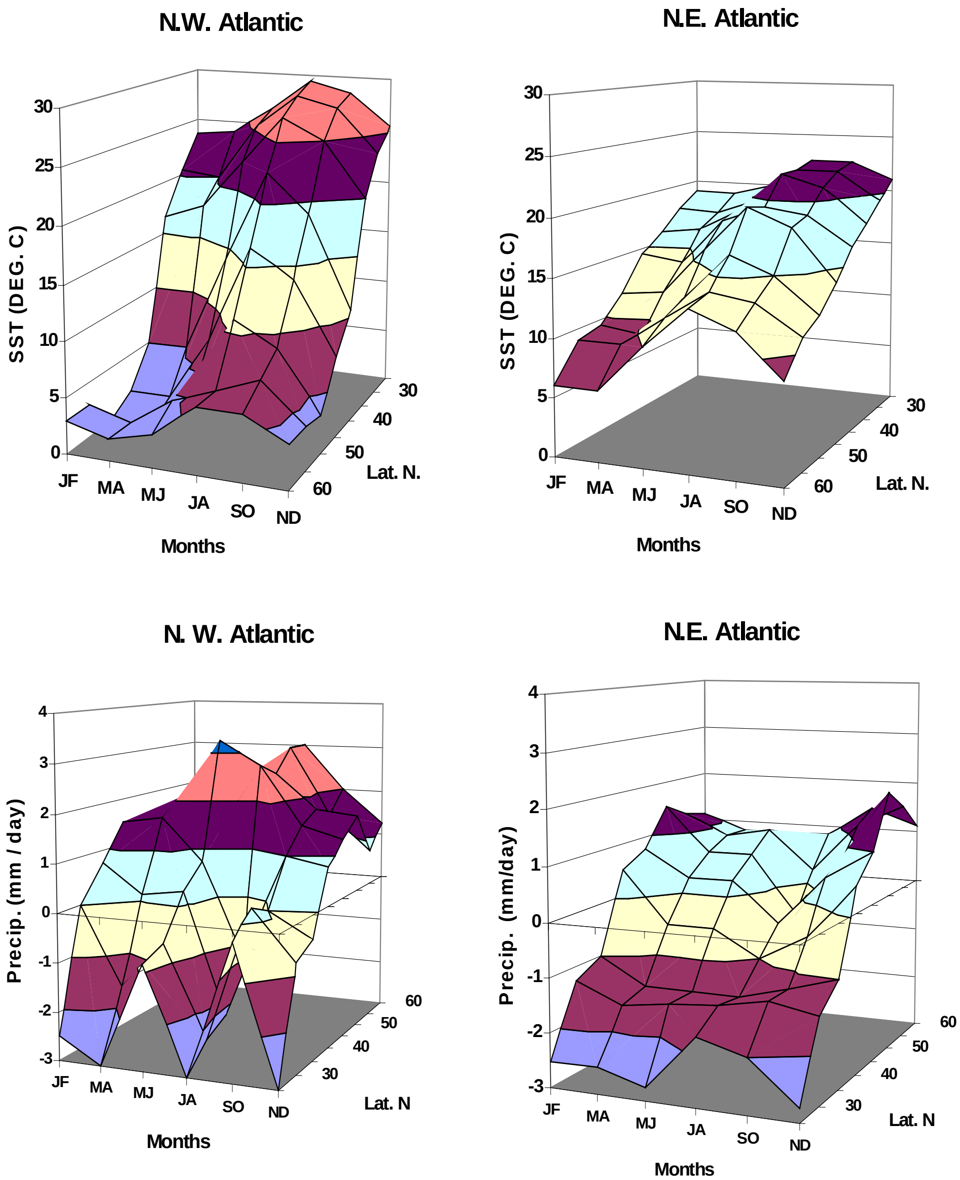

Figure 9C4.5. Northwest and northeast Atlantic sea surface temperature in degrees Celsius and bimonthly precipitation minus evaporation in mm^{-d} at ten degree latitude intervals for the bimonthly periods of Jan-Feb, Mar-Apr, May-Jun, Jul-Aug, Sep-Oct and Nov-Dec. (Note: axes of latitude are reversed between graphs of temperature and precipitation.)

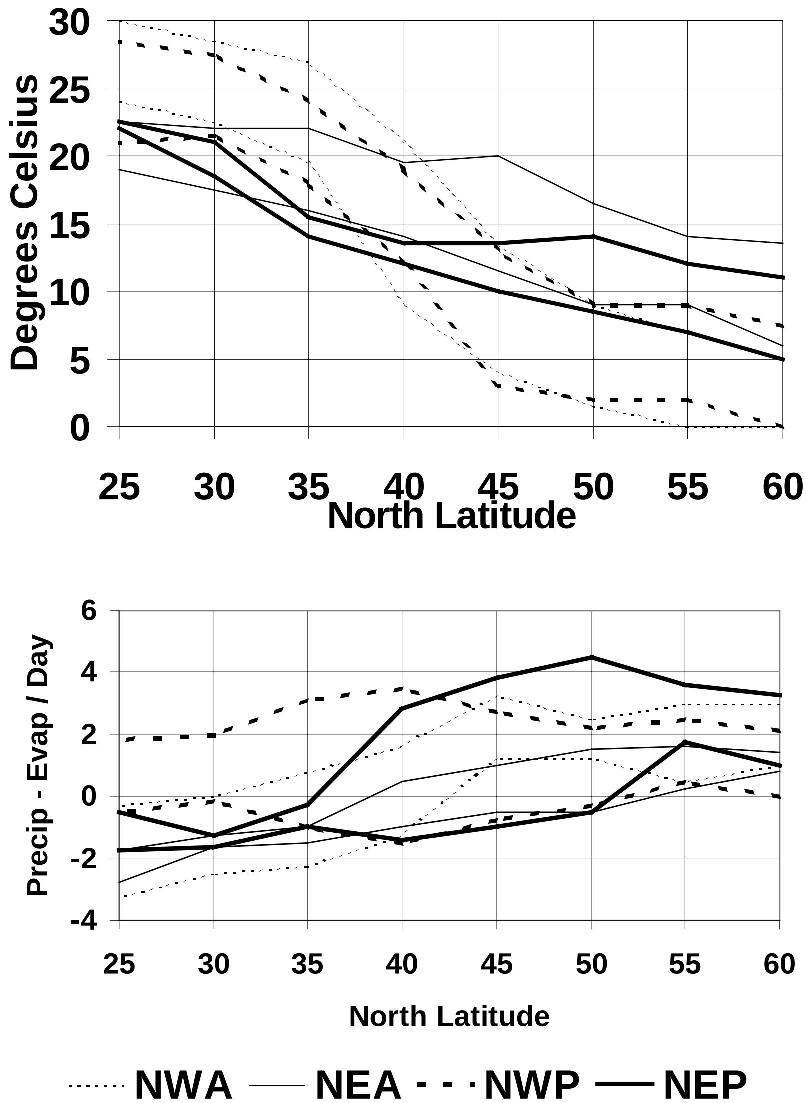

Figure 9C4.6. Maximum and minimum monthly sea surface temperature in degrees Celsius (A) and monthly precipitation minus evaporation in mm d^{-1} (B) at ten degree latitude intervals for the northwest (dashed lines) and northeast (solid lines) Atlantic (thin lines) and Pacific (thick lines). Northeast Pacific, northwest Pacific, northeast Atlantic and northwest Atlantic are NEP, NWP, NEA and NWA, respectively.

Precipitation, and thus salinity in estuaries, also vary from east to west in patterns that resemble the south to north pattern from San Francisco to Alaska. The broadest ranges of precipitation occur in the eastern Pacific north of 35^o N. Lat. (Figure 9C4.4). The narrowest ranges of precipitation and negative net precipitation (desert conditions) occur in the eastern Pacific and Atlantic south of 35^o N. Lat. (Figure 9C4.4). Desert conditions do not occur at low latitudes in the northwest Pacific and occur in the northwest Atlantic only below 30^o N (Figure

9C4.4). The latitudinal range and areal extent of low salinity estuaries is therefore less in eastern oceans than in western oceans and the climates are more uniform.

The seasonal patterns of precipitation (Figures 9C4.4 and 9C4.5) also differ consistently between eastern and western oceans. More precipitation occurs in western oceans during summer when temperatures are maximum while most precipitation occurs in eastern oceans in winter when temperature are low (Figures 9C4.4 and 9C4.5). Where snow-melt is not important, and in the absence of major water impoundments, the salinity-temperature pattens of eastern and western ocean estuaries are out of synchrony. In high latitude regions, such as Alaska, runoff varies most with snow-melt and salinity is lower in warm seasons in correspondence with western ocean climates.

East and West Biodiversity

Peracaridan NIS diversity varied among the four northern hemisphere ocean coasts (X^2 = 17.27, p = 0.001 df = 3), with five times as many introductions to eastern ocean coasts (Table 9C4.2; X^2 = 16.05, p = 0.001 df = 1). Except for the gammaridean amphipods *Orchestia gammarella* (Pallas, 1766) and *Corophium volutator* (Pallas, 1766) in the tidal mudflats and marshes of the Bay of Fundy, peracaridan NIS abundance and diversity in western Atlantic estuaries appeared to be low. Similarly, of the 28 peracaridan species included in the east to west analysis, only 2 - 3 NIS were in the northwest Pacific, compared to 20-23 in the northeastern Pacific and 10-12 in the northeast Atlantic (Table 9C4.2). None of the common northeast Pacific peracaridans were introduced to other areas of the world. Only 2 of the northeast Atlantic species were clearly introduced to other regions compared to13 from the northwest Pacific and 14 from the northwest Atlantic (Table 9C4.2). Remarkably, 5 - 9 of the 28 NIS (Table 9C4.2) have been reported on two coasts and 4 of these species have been discovered on 3 coasts.

Climate and NIS Diversity

The ranks of climates from least to most similar based on overall temperature variation and seasonal precipitation (Figures 9C4.2, 9C4.3 and 9C4.4) were, northeast Pacific, northeast Atlantic, northwest Pacific and northwest Atlantic (NEP, NEA, NWP and NWA, respectively). The ranks of NIS invaders of these regions (Imports, Table 1) were from highest to lowest: NEP, NEA, NWP and NWA. The ranks of native species that have been introduced to other regions (Exports, Table 1) were from lowest to highest: NEP, NEA, and NWP and NWA. The east and west variations in NIS imports and exports were thus correlated with climate variation (Kendall coefficient of concordance W = 1.0; X^2 = 8.2; p < 0.02; df = 2) (Siegal 1956) in a similar pattern to the south to north pattern of NIS between San Francisco Bay and Prince William Sound.

Table 9C4.2. The east and west destinations and sources of common introduced peracaridan crustaceans of the Northwest Pacific Northeast Pacific, Northwest Atlantic and Northeast Atlantic (NWP, NEP NWA and NEA, respectively), their native, introduced, or probable introduced status (N, I, and I?, respectively) and the numbered reference sources.

Common Introduced Nonindigenous Estuarine Peracaridan Crustaceans of the Northern Hemisphere

	NWP	NEP	NWA	NEA	Sources
Mysidacea					
Acanthomysis aspera	**N**	**I**			**1,2**
Cumacea					
Nippoleucon hinumensis	**N**	**I**			**1,3**
Isopoda					
Asellus communis		**I?**	**N**	**I**	**4**
Caecidotea racovitzai		**I**	**N**		**7**
Dynoides dentisinus	**N**	**I**			**1**
Ianiropsis serricatus	**N**	**I**			**1,8**
Paranthura sp.	**N**	**I**			**1**
Synidotea laevidorsalis	**N**	**I**	**I**	**I**	**1,5**
Amphipoda					
Ampelisca abdita		**I**	**N**		**1,6,10**
Ampithoe valida		**I**	**N**		**1,9,10**
Apocorophium lacustre			**N**	**I**	**13,14**
Caprella acanthogaster	**N**	**I**		**I**	**1,10,11**
Corophium sp.	**N**			**I?**	**15,16**
Corophium volutator			**I**	**N**	**13,14,17**
Crangonyx floridanus		**I**	**N**		**7**
Crangonyx pseudogracilis			**N**	**I**	**18**
Gammarus daiberi		**I**	**N**		**1,7**
Gammarus tigrinus			**N**	**I**	**13,14,18,19**
Grandidierella japonica	**N**	**I**		**I**	**10,20,21**
Jassa marmorata	**I**	**I**	**N**	**I**	**10,22,23**
Leucothoe alata	**N**	**I**			**1,24**
Melita nitida	**I?**	**I**	**N**		**1,6,10**
Microdeutopus gryllotalpa		**I**	**N**	**I**	**13,25**
Moncorophium uenoi	**N**	**I**			**9,10**
Monocorophium acherusicum	**I**	**I**	**N**	**I**	**1,9,10**
Monocorophium insidiosum	**I**	**I**	**N**	**I**	**1,9,10**
Orchestia gammarella			**I?**	**N**	**13,14,19**
Parapleustes derzhavini	**N**	**I**			**1,6,10**
Sinocorophium heteroceratum	**N**	**I**			**1,12**
Total Natives (Exports)	**13**	**0**	**14**	**2**	
Total NIS (Imports)	**1 - 3**	**21 - 23**	**2 - 3**	**10 - 12**	

N = native; I = introduced; ? = distribution not completely resolved but probable

1) Cohen and Carlton 1995; 2) Modlin and Orsi 1997; 3) Watling 1991; 4) Williams 1972; 5) Chapman and Carlton 1991, 1994; 6) Chapman 1988; 7) Toft et al. 1999; 8) Kussakin 1988; 9) Barnard 1975; 10) Carlton 1979; 11) Platvoet et al. 1995; 10) Carlton 1979; 12) Chapman and Cole In Prep.; 13) Bousfield 1973; 14) Lincoln 1979; 15) Hirayama 1984, 1986; 16) Janta 1995; 17) Chapman and Smith In prep.; 18) Costello 1993; 19) Watling 1979; 20) Chapman and Dorman 1975; 21) Smith et al. 1999; 22) Conlan 1990; 23) Mills et al. 1999; 24) Nagata 1965a-d; 25) Chapman and Miller In Prep.

BW Source	Temperature	Salinity	Ship ID #	Sample Date	Vessel	Ampelisca abdita	Argissa hamatipes	Corophium acherusicum	Corophium heteroceratum	Cyphocharis challengeri	Eogammarus confervicous	Gammarus daiberi	Gibberosus longimerus	Grandidierella japonica	Hartmanodes harmanni	Hyperia cf medusarum	Melphisana bola	Pontogeneia rostrata	Tiron sp.	Westwoodilla caecula
Port Valdez	6	34	TN-6-1	3/12/98	Alyeska Benth-4					2										
Port Valdez	7	30	CN-4-2	3/11/99	Dock side															1
Benicia/Ocean	19	33	130 1-1	8/27/98	S/R Northslope											12				
Anacortes	6	29	037-1-1	1/23/98	SR Benicia											2				
Anacortes	7	30	177-1-2	12/22/98	S/R Baytown											1				
Anacortes	8	32	82-1-1	5/10/98	S/R Benicia											12				
Anacortes	8	32	82-1-1	5/10/98	S/R Benicia													1		
Anacortes	9	32	086-1-1	5/21/98	Sea River											5				
Anacortes	12	30	103-1-2	6/25/98	Sea Rr, San Franscisco											3				
Anacortes	13	30	116-1-2	7/25/98	S/R/ Baton Rouge											1				
Anacortes	13	31	137-1-2	8/18/98	???											2				
Anacortes	14	30	1331-2	9/10/98	Baytown											5				
Martinez	7	0	073-1-1	4/15/98	Sea River							3								
Benicia	9	4	083-1-1	5/16/98	Sea River, Baton Rouge							1								
Benicia	9	5	077-1-1	4/26/98	Sea River/North Slope						1									
Benicia	9	5	75-1-1	4/19/98	Sea River, Long Beach							5								
SF Bay	10	23	081-1-1	5/7/98	Sea River							4								
Benicia	13	2	101-1-2	6/22/98	S/R Benicia							3								
Benicia	13	2	097-1-1	6/11/98	S/R Long Beach							1								
Benicia	13	3	0881-1	5/23/98	???						3									
Richmond	13	20	104-1-2	7/1/98	Denali	1														
Richmond	15	22	113-1-2	7/17/98	Denali	1		1												
Richomod	16	24	126 1-2	8/19/98	BT Alaska						1			1						
Santa Monica	7	25	070-1-2	8/4/98	Prince William Sound	1														
El Segundo	8	35	170-1-1	12/10/98	Columbia	1						3								
Long Beach	8	35	176-1-2	12/19/98	Arco Spirit										2					
Long Beach	9	35	173-1-1	12/12/98	Arco Independence								1		1					
Long Beach	10	35	169-1-2	12/1/98	Arco Spirit				1											
Long Beach	10	35	076-1-2	4/22/98	Arco Independence		1						1		5		5			
Long Beach	10	35	169-1-2	12/1/98	Arco Spirit										3				1	
Long Beach	10	35	169-1-2	12/1/98	Arco Spirit								3							
Long Beach	10	35	164-1-2	11/24/98	Arco Independence										2					
Long Beach	11	32	026-1-1	12/28/97	Arco Independence										1					
Long Beach	14	35	162-1-1	11/15/98	Arco Spirit										2		1			
Long Beach	14	35	148-1-1	10/12/98	Arco Spirit										3					
Long Beach	15	35	102-1-1	6/24/98	Arco Indin (LB)		1								12		2			

Table 9C4.3. Ballast and Port Valdez amphipos zooplankton samples subdivided into major source areas (Port Valdez, Benicia water exchanged at sea, San Francisco Bay area and southern California, respectively).

Amphipods in Ballast Water

The 125 specimens recovered include one hyperiid species and fourteen species and ten families of gammaridean amphipods. Five of the gammaridean amphipods are NIS in the northeast Pacific and were present in ballast tanks discharged into waters of Port Valdez. These preliminary data indicate that ballast water traffic is a potential mechanism for transporting amphipods among harbors and coastal U. S. waters. The amphipod diversity in these samples (Table 9C4.4) is high given the small number of specimens involved. Except for the Ocean exchanged water and the water from Anacortes, Puget Sound, the heterogeneity among zooplankton sources is almost complete with a significant difference among the four species represented by more than 8 specimens (O^2 ; $p < 0.001$, df = 12). Only *Ampelisca abdita* and *Gammarus daiberi* occurred in more than one zooplankton source. Descriptions of the amphipods in these records are given in Appendix Table 94C. 8. The occurrence of amphipod species as a function of temperature and salinity of ballast water is shown in Figures 9C4.7 and 9C4.8, respectively.

		Water Source					
		Port Valdez	Open Ocean	Puget Sound	San Francisco Bay	Southern California	
	Temperature	6.5	19.0	10.0	11.5	10.5	
	Salinity	32.0	33.0	30.7	10.0	34.0	Total
	Samples	2	1	9	11	13	36
Species	**Origin**						
Pontogeneia rostrata	C			1			1
Ampelisca abdita	I				2	2	4
Monocorophium acherusicum	I				1		1
Sinocorophium heteroceratum	I					1	1
Gammarus daiberi	I				17	3	20
Grandidierella japonica	I				1		1
Argissa hamatipes	N					2	2
Cyphocharis challengeri	N	2					2
Eogammarus confervicous	N				5		5
Gibberosus longimerus	N					5	5
Hartimanodes hartmannae	N					31	31
Hyperia cf. medusarum	N		12	31			43
Melphisana bola	N					8	8
Tiron sp.	N					1	1
Westwoodilla caecula	N	1					1
	Cryptogenic (C)	0	0	1	0	0	1
	Introduced (I)	0	0	0	21	6	27
	Native (N)	3	12	31	5	47	98
	Total	3	12	32	26	53	126

Table 9C4.4. The average salinities, teperatures, subtotals, cryptogenic, introduced and native origins and total numbers of amphipod Crustacea collected in Port Valdez waters and from dedicated ballast tanks containing water exchanged at sea, or entrained from Puget Sound, San Francisco Bay or southern California.

Discussion

Most estuarine peracaridan NIS of the northeast Pacific are from the western sides of the Pacific or the Atlantic oceans. Peracaridan crustacean NIS diversity coincided with particular climates between 25 and 60^{o} N. Lat. Annual sea surface temperatures at latitudes below 50^{o} N vary less along northeast Pacific and Atlantic coasts than along western ocean coasts and, also in contrast to western ocean coasts, low salinity conditions occur in winter months rather than the summer months.

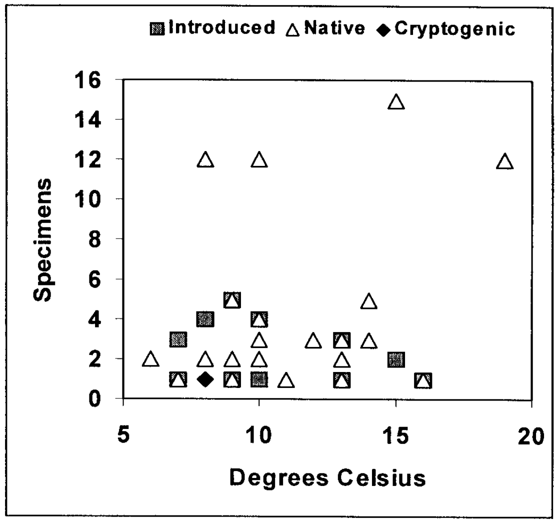

Figure 9C4.7. Native, introduced and cryptogenic amphipod numbers with temperature from 34 ballast water samples.

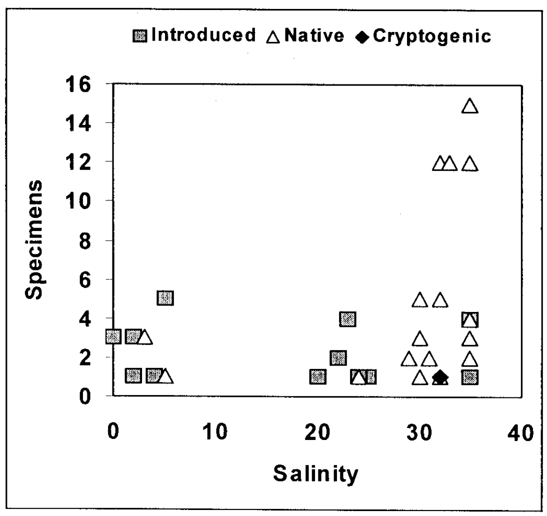

Figure 9C4.8. Native, introduced and cryptogenic amphipod numbers with salinity from 34 ballast water samples.

The great diversity of invading species in northeast Pacific estuaries may thus result, in part, from the great diversity of climates that invading species are adapted to relative to the narrow range of climates in the region. The low diversity of native northeast Pacific species that invade other areas may also result, in part, from the relatively broad range of climate variations they must endure to survive elsewhere. The decline of northeast Pacific NIS diversity from south to north coincides with fewer introductions occurring where greater annual variations in temperature occur and where low salinity conditions occur during warm water periods.

All of the peracaridan NIS known from Puget Sound occurred also in San Francisco Bay. The absence of cold water NIS in Southern Alaska is consistent with a pattern of introductions occurring less in continental climates of high temperature variations and low summer salinities. The overall pattern of NIS peracaridan diversity in the northern hemisphere strongly suggests that northeast Pacific estuarine peracaridan NIS of San Francisco Bay and north are predominantly from lower latitudes. Few of the presently known recognized northeast Pacific NIS peracaridans are thus likely to become established in southern Alaskan waters, even though Alaskan weather variations resemble western ocean climates from where most NIS originate.

Aquatic species with nearly any life history and from nearly any taxon can be introduced (e.g. Carlton 1985, Cohen and Carlton 1995, Eno et al. 1997, Smith *et al.* 1999, Hewitt et al. 1999).   The many vectors, directions, distributions, routes of introduction (e.g., Carlton 1979, 1985, 1987, 1999, Carlton and Geller 1993, Ruiz *et al.* 1997) and taxa available for introductions over the last 500 years (e.g. Carlton 1992, Carlton and Hodder 1995, Ruiz et al. 1997) have moved broad diversities of species to many suitable and unsuitable areas. The present distributions of NIS are a mosaic of surviving populations composed of a broad diversity of taxa and life histories. These surviving nonindigenous populations are surrounded by unsuitable areas in which they were also introduced but failed to survive. The patterns of transport mechanisms superimposed on this mosaic reveal where introductions fail. Resolution of this global pattern can reveal sources, destinations, targets and vectors of NIS and which ecosystems are most vulnerable.

The probability of particular species introductions from one region to another cannot be determined from these data. NIS invasions in northern hemisphere estuaries, even confined to peracaridan crustaceans, are more complex than Tables 9C4.1 and 9C4.2 indicate. Additionally many evolutionary and ecological processes that are likely to contribute to the patterns of NIS invasions are not addressed. Western ocean estuaries may be older, with more diverse biotas and could be less intensely altered by human activities, for instance, than eastern ocean estuaries. When and how climates control NIS distributions are complicated by other processes including human and natural disturbances, and the timing, geography and magnitude of transport vectors. Also, the complexity of climate variations are drastically simplified in Figure 9C4.2, and Figures 9C4.4 - 9C4.6 on the assumption that large populations distributed over broad geographic areas are more likely to reflect average conditions over extended periods. However, other time intervals for integration could be better than the one and two month averages selected here for climate analyses. These simplifications may reduce the fit between biogeographical boundaries and climate and thus obscure interactions between NIS distributions and climate.

These correlations between west ocean to east ocean NIS peracaridan invasions and climate nevertheless deserve close inspection. Source and destination climates for peracaridan NIS may be easier to identify than particular species that are likely to be introduced by particular dispersal vectors. Moreover, peracaridans appear to be a sufficient taxon to sample NIS biogeography. Similar east to west patterns of other NIS taxa have also been noted (Cohen and Carlton 1995, Leppakoski and Olin 2000, Miller and Chapman 2000). Moreover, the patterns of NIS invasions must correspond to climate patterns if climate is an important ecological and evolutionary mechanism controlling the geography species.

The correlations between marine and estuarine peracaridan NIS invasions with temperature and salinity conditions may reveal where, and perhaps how, climates control NIS distributions. NIS peracaridans are unlikely to be as suited to local climates as native species that have had more evolutionary time to adapt. From a maximum possible of 3, the average occurrence of NIS between San Francisco Bay, Puget Sound and Prince William Sound is 1.4 compared to 1.8 records per native species (Table 9C4.2). This restriction of NIS peracaridan distributions in the northeast Pacific relative to native peracaridan species may result from their different adaptations to climate. NIS peracaridan dispersal vectors are sufficient to move NIS peracaridans to Prince William Sound. Port Valdez is the third largest ballast water port in the U.S. and the associated nonindigenous ballast water species that it receives are diverse and abundant (Hines *et al.* 1999) but none of these peracaridan species have been discovered in Prince William Sound. At the same time, the same nonindigenous ballast water species are invading San Francisco Bay at an accelerating rate (Cohen and Carlton 1998). The greater diversity of NIS in San Francisco Bay (Figure 9C4.1), the complete overlap between Puget Sound NIS and San Francisco Bay NIS and the absence of NIS in the Prince William Sound collections (Table 9C4.1), indicate that peracaridans have warm water origins and survive poorly in the cold-water areas of the northeast Pacific.

The introductions of *Corophium volutator* and *Orchestia gammarellus* (Table 9C4.2) from Europe to eastern North America are exceptions to the western ocean to eastern ocean pattern of introductions listed here. *Corophium volutator* is confined in North America to the Bay of Fundy. *Orchestia gammarellus* is confined in North America to the Bay of Fundy and the outer coasts north to Newfoundland (Bousfield 1973, Watling 1979). The climates of these areas are isolated from the Gulf Current and have narrower temperature ranges than areas either to the north or south (Bousfield 1973). The successes of these two species, and other European species such as the green crab *Carcinus maenus* and the European littorine snail *Littorina littorea* in this region, and the Bay of Fundy in particular, may result from the closer match between the climate of this region and the climate of northern Europe.

The occurrence of 5 NIS species of amphipods in segregated ballast water of tankers discharging into Port Valdez indicates that this is an active mechanism of transport introduding NIS arriving to Prince William Sound, even though none of these species appears to have become established yet.

Conclusions

These results reveal that climate and evolution interact to prevent estuarine peracaridan NIS from invading south central Alaska. Western ocean introductions of peracaridans to eastern ocean estuaries are common while few eastern ocean peracaridan species spread in the opposite direction. Unless Arctic Ocean passages of ballast water from the north Atlantic become possible, or global climate changes significantly, or massive shipping from high latitudes of the southern hemisphere occurs, ballast water sources NIS peracaridans from climates similar to south central Alaska are too remote to pose a significant risk.

Like a lock and key, the adaptations of successful invaders must be sufficient to survive in climates and types of disturbances that occur in the new invaded areas. Thermal adaptations of western ocean species may thus fit eastern ocean climates while the thermal adaptations of most eastern ocean species may be insufficient for western ocean climates. By the same mechanism, seasonal salinity disturbances may confine western ocean NIS peracaridans in eastern ocean estuaries to areas where the most stable salinity conditions occur and control which taxonomic groups of NIS peracaridans predominate in particular estuaries. This pattern of invasion appears to be consistent among many taxa even though the particular interacting mechanisms of climate and adaptation creating the pattern remain unresolved and the particular species that invade remain unpredictable. However, predicting where species can survive provides a means to identify, particular mechanisms of introduction, source regions for NIS of greatest concern, the likely secondary dispersal routes of newly introduced species and the possible role of climate changes on further invasions.

Seasonal temperature variations are difficult for shallow water organisms to avoid. The extreme high and low temperature ranges of western ocean climates (Figures 9C4.4 and 9C4.5) create adaptations that span most eastern ocean temperature ranges. The reverse is less likely and must prevent survival of many western ocean introductions of eastern ocean species. The entire sea surface temperature range of the northeast Pacific between 35 and 50^{o} N is overlapped by the temperature ranges of the western ocean coasts between 37 and 42^{o} N (Figure 9C4.6).

Thermal limits for the NIS peracaridans at 60^{o} N (Prince William Sound) are apparent also for the Pacific oyster, *Crassostrea gigas* (Thunberg, 1795), native to the western Pacific and cultured commercially in Asia as far north as Hokkaido, Japan (Quayle, 1969) at about 44^{o} N. *Crassostrea* grows but does not spawn in the low temperatures of Prince William Sound or south central Alaska (Foster 1991, Hines and Ruiz 1997). The minimum monthly temperatures of Prince William Sound match western Atlantic and western Pacific minimum temperatures as far south as 44^{o} N (Figure 9C4.6). Thus, lethal low temperatures might not be encountered in the sound by western ocean NIS peracaridans from 44^{o} N or even slightly farther south. However, maximum northeast Pacific sea surface temperatures at 60^{o} N match western Atlantic and western Pacific maximums only as far south as 48^{o} N (Figure 9C4.6) the inability of *C. gigas* to spawn in Alaska is therefore not surprising.

The poor match of seasonal precipitation across oceans (Figures 9C4.4 and 9C4.5) may also affect the patterns of introduction. The range of coinciding temperature and salinity tolerances that peracaridan species require to survive and reproduced in south central Alaska may prohibit NIS peracaridans that also survive in Long Beach, San Francisco or Puget Sound. The low summer salinities in Prince William Sound (Hines and Ruiz 1997) due to snow melt, more closely matches a western ocean climate (Figures 9C4.4 and 9C4.5). Only the largest eastern ocean estuaries or estuaries with impounded freshwater sources, such as San Francisco Bay, are likely to have stable haloclines in summer that match those of western ocean estuaries.

The high diversity and predominance of benthic peracaridan NIS in the northeast Pacific (Table 9C4.1) may result in part from their superior adaptive responses to large salinity ranges

(Figure 9C4.6). All peracaridan life stages are highly mobile, and their short reproductive cycles allow dispersal away from unsuitable conditions and rapid recruitment when conditions improve (*e.g.,* Watkin 1941). Peracaridans can avoid rapid changes in salinity (Figures 9C4.4 and 9C4.5) by migrating short vertical distances or by swimming into water masses in which transport them to higher or lower salinity areas.

San Francisco Bay may be particularly suited to NIS peracaridans that cannot avoid or quickly adapt to changing salinities. The particular predominance and high diversity of large, long-lived, suspension feeding NIS in San Francisco Bay (Carlton 1979, Nichols et al. 1990, Thompson 1998) may result from human water impoundments that limit major freshwater runoff events. San Francisco Bay is the largest estuary of the eastern Pacific. Massive water diversions and impoundments in the San Francisco Bay watershed, aided by its large size, create a stable salinity structure more typical of western ocean estuaries. Sedentary, long-lived species, including molluscs (Nicholls et al. 1990), burrowing decapods (Posey et al. 1991, Grosholz and Ruiz 1995, Cohen and Carlton 1997) and sedentariate polychaetes (Pearson and Rosenberg 1978) predominate in benthic communities in the absence of major salinity disturbances. These taxa can control the trophic dynamics in estuaries (Nichols *et al.* 1986, Kimmerer *et al.* 1994, Barber 1997, Thayer *et al.* 1997, Thompson 1998) but are slow to repopulate areas following disturbances.

The vulnerability of estuaries to invasion and the potentials of particular taxa and life history types to become invasive may be increasing globally and increase the risk of NIS invasions of Alaskan waters in the future. Water diversions and impoundments and land use practices on western coasts combined with global temperature increases are reducing the differences between climates of eastern and western ocean estuaries. The convergence of climates will increase the potential for biological exchanges.

The predominantly western ocean to eastern ocean direction of peracaridan invasions and south to north gradient in peracaridan invasions support a lock and key hypothesis in which peracaridan NIS cannot be introduced outside of their tolerance ranges. Obvious predictions of this hypothesis that should be tested are: 1) sources of eastern ocean invaders are from a narrow range of western ocean latitudes; 2) eastern ocean invaders of western oceans have restricted geographical ranges; 3) specific physiological tolerances and life history adaptations of most NIS exceed the stresses experienced in the climates invaded; 4) southern hemisphere NIS invasions superimpose on and are superimposed upon by northern hemisphere NIS when their origins are from similar climates; 5) climates affect the life histories and taxonomic composition of invaders and; 6) invaders of western to western or eastern to eastern oceans have broader ecological and geographical ranges than mixed climate invaders.

The analysis of climates and the geography of introductions must include more species and taxa in more detail than is possible here. However, failure to determine the origins of the cryptogenic peracaridan species (Table 9C4.1) are a more critical short-coming of this risk analysis. The eight cryptogenic peracaridans are abundant over broad ecological distributions within the south central Alaska. Even though none of the cryptogenic peracaridan species appear to be associated with ballast water as a means of introduction, these species are abundant and wide spread. If introduced, they are proof that even a few NIS invaders of Alaskan estuaries can increase to ecologically catastrophic densities. Moreover surveys of NIS diversity, such as this one, are an insufficient for estimating ecological risks if these species are introduced. Due to the potential for a single species to produce massive impacts, conclusions of risk from global patterns of diversity of diversity and climate therefore could conflict with conclusions of risk based on presence of even a single NIS in a system. The occurrence of 5 NIS species of amphipods in segregated ballast water of tankers discharging into Port Valdez indicates that this is an active mechanism of transport introduding NIS arriving to Prince William Sound, even though none of these species appears to have become established yet.

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Appendix Table 9C4.5. Site Descriptions

1999 PRINCE WILLIAM SOUND NIS SURVEY ITINERARY AND GENERAL SITE DESCRIPTIONS

DATE	AREA	SITE	LOCATION	LAT/LON	TEMP (°C)	SAL (0/00)	DESCRIPTION
Aug 8	Homer	1	Homer Boat Harbor Floats	*61° 05' 12"N* *146° 23' 30"W*	10	27	Cement floats
Aug 8	Homer	2	Homer, harbor benthos grab	*61° 05' 10"N* *146° 22' 28"W*	10	27	Dense plant debris, anoxic
Aug 8	Homer	3	Homer Mudflats	*61° 05' 10"N* *146° 21' 55"W*	10	27	Rock/cobble intertidal wash
Aug 9	Seward	4	Seward Floats and benthic grab	*61° 04' 54"N* *146° 19' 00"W*	11	7	Cement floats and silt benthos
Aug 9	Seward	5	Seward Lowell Point	*60° 52' 55"N* *146° 46' 29"W*	11	11	Rock/cobble intertidal.
Aug 10	1	6	Whittier Harbor	*60° 46' 37"N* *148° 41' 24"W*	11	23	Floats and benthic grab
Aug 10	2	7	Shotgun Cove Fouling	*60° 47' 26"N* *148° 32' 30"W*	12	9	Fouling on oil-barge mooring buoy
Aug 11	3	8	Fairmont Bay Oyster floats	*60° 53' 40"N* *146° 26' 03"W*	14	25	Fouling on oyster float, nets and line
Aug 11	4	9	Duckflat & Port Valdez Harbor	*61° 07' 28"N* *146° 18' 00"W*	10	5	Mudflat of sparse Zostera, shallow pools, and small meandering intertidal stream
Aug 12	5	10	Cloudman Bay, Busby Is Mudflats and Zostera	*61° 03' 23"N* *146° 47' 25"W*	13	14	Mudflat of dense Zostera, split by glacial-fed stream
Aug 12	6	11	Busby Reef High rocky intertidal	*60° 57' 36"N* *146° 45' 36"W*	15	19	Rock and cobble wash
Aug 13	7	12	Cordova Harbor 1 & 2	*60° 52' 12"N* *146° 43' 48"W*	13	24	Low intertidal mudflats with shell & rock Highly polluted
Aug 13	7	13	Cordova Harbor #4	*60° 41' 47"N* *145° 57' 22"W*	20	0	Compacted silt above creek drainage

(SITE ITINERARY AND DESCRIPTION CONTINUED)

Appendix Table 9C4.5. Continued

DATE	AREA	SITE	LOCATION	LAT/LON	(°C)	(*0/00*)	DESCRIPTION
Aug 13	7	14	Cordova #5	*60° 40' 21"N* *145° 57' 06"W*	20	11	Mud / silt bank next to drainage channel
Aug 13	7	15	Cordova #6	*60° 32' 30"N* *145° 46' 28"W*	15	0	Creek bed cobble upper edge mudflat
Aug 13	7	16	Cordova Harbor	*60° 32' 28"N* *145° 46' 28"W*	11	20	Benthic grabs, anoxic sediments
Aug 13	7	17	Cordova Harbor Benthic grab	*60° 32' 48"N* *145° 46' 27"W*	12	28	Anoxic mud
Aug 13	7	18	Cordova Harbor Floats	*60° 32' 27"N* *145° 46' 26"W*	16	5	Rocky intertidal
Aug 13	8	19	Green Buoy "12" Cordova Harbor entrance	*60° 32' 40"N* *145° 45' 59"W*	11	22	Fouling
Aug 13	9	20	Windy Bay, Hawkins Is.	*60° 33' 54"N* *145° 58' 38"W*	14	28	Fouling on oyster float, nets and line
Aug 13	10	21	Red Buoy "2" Middle Ground Shoal, Hinchenbrook	*60° 32' 52"N* *146° 22' 06"W*	14	28	Drift Zostera
Aug 14	11	22	Constantine Harbor Hinchenbrook Is.	*60° 20' 25"N* *146° 37' 00"W*	11	30	

Appendix Table 9C4.6. Peracardian Crustacea August 1999

South Central Alaska Fouling survey Homer, Seward and Prince William Sound, August 6-16, 1999

Area						1	2	3	4	5	6	7	7	7	7	7	7	7	8	9	10	11
Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
General location	Homer	Homer	Homer	Seward	Seward	Whittier	Shotgun Cove	Fairmont Bay	Valdez	Cloudman Bay	Busby Is.	Cordova	Cordova Mudflat	Cordova	Cordova mudflat	Cordova mudflat	Cordova	Cordova	Cordova	Windy Bay	Mid. Grnd	Constantin e
Specific location	floats		Harbor	Benthos	Rocky-Pt.	Floats	mooring	Oyster	Mudflats	mudflats	rocks	high tide	mudflat	mudflat	mudflat	mudflat	benthos	Harbor	entrance	oyster	Shoal	Harbor
Substratum	cobble	mudflat	benth grb	floats	rocks	Benth	buoy	nets	cobble	Zostera	cobble	mud pool	1&2	#4	#5	#6	benth grab	floats	Buoy "12"	net	Buoy "2"	Benthos
Collection Date	08-Aug-99	08-Aug-99	8-Aug-99	08-Aug-99	09-Aug-99	10-Aug-99	10-Aug-99	11-Aug-99	11-Aug-99	12-Aug-99	12-Aug-99	13-Aug-99	13-Aug-99	13-Aug-99	13-Aug-99	13-Aug-99	13-Aug-99	13-Aug-99	13-Aug-99	13-Aug-99	13-Aug-99	14-Aug-99
Mysidacea																						
Mysis littoralis																						x
Tanaidacea																						
Leptochelia savignyi											x											
Isopoda																						
Gnorimosphaeroma lutea																x						
Gnorimosphaeroma oregonensis		x		x	x	x			x		x											x
Ianiropsis kincaidi											x											
Idotea obscura					x																	x
Idotea wosensenskii				x	x	x			x		x							x				
Ligia pallasii									x													
Limnoria lignorum																						x
Cumacea																						
Cumella vulgaris		x							x		x		x									x
Diastylis alaskensis			x										x									
Lamprops beringi					x																	
Lamprops quadriplicata			x																			
Gammaridea																						
Allorchestes angusta						x			x				x						x			x
Americorophium brevis																						x
Americorophium salmonis													x	x	x							
Americorophium spinicorne			x												x	x						
Ampithoe kussakini		x			x	x	x				x		x									x
Ampithoe sectimanus	x																					
Ampithoe sp.									x													
Anisogammarus pugettensis		x		x	x								x									
Aoroides sp.			x																			
Calliopiella sp.						x			x										x			
Calliopius carinatus					x																	
Eogammarus confervicolus						x			x	x						x	x					x
Eogammarus oclairi				x																		
Hyale frequens											x											
Hyale plumulosa											x											
Ischyrocerus sp.								x														
Jassa staudei										x	x		x				x			x	x	
Lagunogammarus setosus				x					x										x			
Locustogammarus locustoides	x	x			x								x									
Megamorea subtener													x									x
Monocorophium carlottensis	x			x		x		x										x				x
Paramoera bousfieldi									x													
Paramoera mohri					x																	
Perampithoe humeralis																				x		
Perampithoe mea	x																					
Pontogeneia ivanovae					x																	
Pontogeneia rostrata	x					x																
Pontoporeia femorata									x													x
Spinulogammarus subcarinatus		x			x				x													
Caprellidea																						
Caprella depranochir													x									x
Caprella laeviuscula	x						x			x												
Caprella sp.		x									x								x			
Metacaprella kennerlyi										x			x									

Appendix Table 9C4.7. UAF unidentified Amphipoda

University of Alaska Museum unidentified Amphipod collections examined, 1999

Site	ST	TR	QD	Sample	Date	UAFID	*Monocorophium carlottensis*	*Megamoera dentata*	*Ampithoe kussakini*	*Ampithoe sp.*	*Limnoria lignorum*
26	1	3	1	A-7	07/11/91	Corophium sp.	1				
26	1	3	2	A-8	07/11/91	Corophium sp.	3				
26	1	3	2	A-8	07/11/91	Corophium sp.					
15	3	3	2	136-138	02/24/93	Corophium sp.	5				
15	3	1	2	119-121	07/24/93	Corophium sp.	2				
26	2	1	2	I4(3)		Melita sp.		3			
15	1	3	2	137	07/24/91	Corophium sp.	24				
15	1	3	2	137	07/24/91	Corophium sp.					
15	3	3	2	141		Corophium sp.	3				
14	3	3	2	105-106	07/23/93	Corophium sp.	10				
15	2	3	1	129-130	09/24/93	Corophium sp.	2				
15	3	1	2	119-121	07/24/93	Melita sp.		3			
34	3	5	2	65		Ampithoe sp.			3		
26	1	1	1	1	07/11/91	Melita sp.		1			
111	3	3	1	47-48		Corophium sp.	1				
18	1	1	1	156	02/07/91	Melita sp.		1			
11	3	3	2	49-50		Limnoidae					1
15	3	3	1	140	07/24/91	Corophium sp.	3				
34	2	3	2	63	07/15/91	Ampithoe sp.			6		
14	2	3	2	101-102	07/23/93	Ampithoe sp.				2	
26	3	3	2	12	07/11/91	Corophium sp.	2				
15	2	3	1	138		Ampithoe sp.			1		
15	3	3	2	141		Ampithoe sp.				1	
34	3	3	2	65		Corophium sp.	35				
15	1	3	2	125-128	07/24/93	Corophium sp.	13				
15	1	1	1	107-108	07/24/93	Melita sp.		3			
15	1	1	1	107-108	07/24/93	Melita sp.					
15	1	3	1	123-124	02/24/93	Ampithoe sp.			4		
15	2	1	1	112-113	07/24/93	Melita sp.		1			
14	3	3	2	105-106	07/23/93	Melita sp.		3			
14	3	3	2	105-106	07/23/93	Melita sp.					
14	3	3	2	105-106	07/23/93	Ampithoe sp.				1	
26	2	3	1	9		Corophium sp.	1				
18	2	3	1	165	07/28/91	Corophium sp.	3	3			
15	1	1	1	127	07/23/91	Corophium sp.	1				
15	2	1	1	129		Corophium sp.	10				
15	2	1	1	129		Melita sp.		2			
15	2	1	1	129		Melita sp.					
RBA 1-3 UAH					09/02/82	Limnoria lignorum					1

Aquatic Coll. 1994-5 Rocky Bay, Montague Is. PWS HY033 RBA001 72 m

APPENDIX TABLE 9C4.8 Descriptions of Amphipod Species Identified in Ballast Water Tanks.

Hyperidae
Hyperidae

Hyperia cf. ***medusarum*** (Bowman 1973:6-10, figs. 2-6 and references therein; Brusca 1981:21, fig. 9e; Vinogradov et al. 1996:323-327, fig. 131 and references therein). *Hyperiaa medusarum* is a morphologically variable bipolar pelagic species of cold and moderately cold water marine regions of both hemispheres, occurring in the Bering Sea, the Gulf of Alaska and the coastal waters of Canada and the western U. S. (Vinogradov et al. 1996). Specimens of this study are all less than 4 mm in length, and none are mature. Gnathopods, mandibles and pereopods closely resemble *H. medusarum* but the identifications are tentative. The sutures between pereonites 1 and 2 and between coxal plates and pereionites are faint. Their appearance only in the Anacortes samples and in the open ocean exchanged ballast water samples (Table 1) are consistent with the life history of typical hyperiids and this species is very likely native to the region.

Gammaridea
Ampeliscidae

Ampelisca abdita Mills, 1964a; Northeast Pacific records of *Ampelisca milleri* are: Jones 1961:253-254; Filice 1959a:183; Filice 1959b:10; Chapman and Dorman 1975:107, 106; Chapman 1988:365-368, fig. 2 (and references therein); Dickensen 1982:15-17, fig. 9; (not Barnard 1954b:9-11). The range of *A. abdita* on the east coast of the U.S.extends from Maine to the eastern Gulf of Mexico (Mills, 1967, Bousfield 1973, Chapman 1988).

Ampelisca abdita from San Francisco Bay, Bolinas Lagoon and Tomales Bay was confused with *Ampelisca milleri* Barnard 1954 for 40 years and was probably introduced into San Francisco Bay from the eastern U. S. with shipments of the eastern oyster *Crassostrea virginica*(Chapman 1988). The species dominates soft, subtidal sedimentst's of San Francisco Bay at salinities between 10 and 25 PSU and must occasionally occur as zooplankton in massive numbers as it seasonally exits and repopulates shallow subtidal an intertidal mudflats (Mills 1967).

Arigissidae

Argissa hamatipes (Norman 1869); *Syrrhoe hamatipes* Norman 1869:279; Boeck 1871:125; *Argissa stebbingi* Bonnier 1896:626-630, pl.36, fig.4; Argissa typica Sars 1895:141-142, pl.48; Chevreux & Fage 1925:90, figs.81-82; Ruffo 1982:159-161, figs. 106-107; *Argissa hamatipes* Walker 1904:246; Stebbing 1906:277; Shoemaker 1930:37-40, figs.15-16; Stephensen 1935:140; Stephensen 1940:41; Stephensen 1944:52; Gurjanova 1951:327-328, fig.193; Gurjanova 1962:392-393; J.L. Barnard 1962c:151; J.L. Barnard 1964a:218-219; Nagata 1965:154-155, fig.7; J.L. Barnard 1966a:61; J.L. Barnard 1967a:14-15, fig.1d-i; J.L. Barnard 1969b:159, fig. 65; J.L. Barnard 1971b:9; Bousfield 1973:121-122, pl.XX; Griffiths 1975:; Lincoln 1979:334, fig.157; Ledoyer 1982:144-146, fig. 50; Hirayama 1983:147-149, figs.38-41; Barnard & Barnard 1983:607-608; Thomas & McCann 1997:22, fig.2.1.

Argissa hamatipes is an entirely marine, nearly cosmopolitan species with an extensive bathymetric distribution that ranges throughout coastal north Pacific shelf regions from southern California to southern Japan and the north Atlantic from North Carolina Greenland and Iceland, throughout northern Europe and the western Mediterranean, Madagascar and South Africa. Many of the the synonymies are unclear. This extremely dispersed species is likely to be a species complex and the identity of the North Pacific population is probably incorrect. Nevertheless, the very broad open ocean distribution in the northeast Pacific population strongly indicates that it is a native to the region.

Corophiidae

Monocorophium acherusicum *Podacerus cylindricus* Lucas 1842:232; *Corophium cylindricum* Smith 1873:566; Paulmier 1905:167, fig. 37; Holmes 1905:521-522, fig. ; ?C. cylindricus Stebbing 1914:372-373; Kunkel 1918:171-173, fig. 52; *Corophium contractum* Thompson 1881:220-221, fig. 9; *Corophium bonnellii* K. H. Barnard 1932:244 (in Crawford 1937); *Corophium acherusicum* 1853:178; Costa 1857:232, Fig. 1827; Bate 1862:282; Heller 1867:51-52, pl 4 fig. 14; DeElla Valle 1893:364-367, pl. I, Fig. II, Pl. 8, figs. 17, 18, 20-41; Sowinsky 1897:9; Sowinsky 1898:455; Chevreux 1900a:109; Graeffe 1902:20; Holmes 1905:521-522, fig. ; Stebbing 1906:692-740; Chevreux 1911:271; K. H. Barnard 1916:272-274; Stebbing 1917a:448; Ussing and Stephensen 1924:78-79; Chevreux 1925c:271; Chevreux and Fage 1925:368, fig. 376; Chevreux 1926:392; Cecchini 1928e:8, pl. 1, fig. 6a; Cecchini 1928b:309-312, fig. 1; Schellenberg 1928:672;Schijfsma 1931a:22-25; Monod 1931a:499; Fage 1933:224; Candeias 1934:3; Shoemaker 1934c:24-25; Cecchini-Parenzan 1935:227-229, fig. 52; Shoemaker 1935c:250; Crawford 1936:104; Schellenberg 1936c:21; Schijsfma 1936:122-123; Crawford 1937:617-620, 650, fig. 2; Monod 1937:13; Miloslavskaya 1939:148-149; K. H. Barnard 1940:482; Bassindale 1941:174; Stephensen 1944a:134; Shoemaker 1947:53, figs. 2, 3; Shoemaker 1949a:76; Soika 1949:210-211; Gurjanova 1951:977-978, fig. 680; Reid 1951:269; Stock and Bloklader 1952:4-5; J.L. Barnard 1954a:36; Hurley 1954e:442-445, figs. 35-39; J. L. Barnard 1955a:37; Irie 1957:5-6, fig. 6; Irie 1958c:145; Irie 1959: tab. 4; J.L.Barnard 1959:38; Nayar 1959:43-44, pl. XV, figs. 14-20; Irie In Okada and Ochida et al. 1960:122, pl. 61, fig. 12; Nagata 1960:177; J. L. Barnard 1961:182; Irie and Nagata 1962:20; Nagata 1964:10; Barnard 1964a:111, chart 5; Nagata 1965c:317; Nagata 1966:334; Kikuchi 1966:, tab 21; Kikuchi 1968:179; Reish and J. L. Barnard 1967:16; Ledoyer 1968:214; Fearn-Wannan 1968b:134-135; Mordhukai-Boltovskoi 1969:485, pl. 25, fig. 2; Sivaprakasam 1969d:156, fig. 14; Bellan-Santini 1971:260-261; J. L. Barnard 1971a:59; J. L. Barnard 1972b:48; Bousfield 1973:201, Pl. LXII.2; Griffiths 1974:181-182;Griffiths 1974b:228; Griffiths 1974c:281; Griffiths 1975:109; Fox and Bynum 1975:225; Hirayama 1984:13, fig. 50; Azuma 1986:77; Sudo et al. 1987:1570; Inaba 1988:141; *Monocorophium acherusicum* Bousfield and Hoover 1997:111-114, figs. 26-27.

Monocorophium acherusicum could be the most widely distributed and widely introduced estuary invertebrate in the world, occurring in fouling and benthic mud communities of shallow and intertidal areas on all continents except Antarctica. *C. acherusicum* has been reported at all latitudes between 60^o North and South. However, many of the records of this species at latitudes greater than 60^o, including all records from Alaska are doubtful (Hines et al. 1999) due likely confusion with other species. *M. acherusicum* was not found in the present surveys of south central Alaska, including Port Valdez and Prince William Sound. Parthenogenic populations of an extremely similar species, that closely resembles *Monocorophium carlottensis* Bousfield and Hoover, 1997, occurs in nearly all fouling communities of these areas (Chapman 1999, Peracarida and Decapoda). All Alaskan records of the nonindigenous species, *M. insidiosum* and *M. acherusicum* are probably referrable to *M. carlottensis*.

Sinocorophium heteroceratum (Yu, 1938) *Corophium heteroceratum* Yu 1938:93-101, figs. 7-11; *Sinocorophium heteroceratum* Bousfield and Hoover 1997:75, 78.

Sinocorophium heteroceratum was introduced into San Francisco Bay and Los Angeles Harbor from Asia in the mid 1980s where it presumed to have been transported with ballast water traffic (Cohen and Carlton 1995). This species occurs predominantly in soft sediments in high salinity, sub-tidal areas of San Francisco Bay and Los Angeles Harbor (Chapman and Cole, MS in preparation). *Sinocorophium heteroceratum* are also unlikely to have been introduced with aquaculture industries, or ship fouling in San Francisco Bay or Los Angeles Harbor because its lack of association with fouling communities.

Grandidierella japonica Stephensen, 1938:179-184; Nagata 1960:179; Nagata 1965c:320-321; Chapman and Dorman 1975:104-108, 4 figs., Nagata 1984:15, fig. 53-56; Muir 1997; Smith et al. 1999:8-9, fig. 3.

Grandidierella japonica occurs in salinities from 5-40 PSU predominantly in warm intertidal areas of nearly all estuaries from Puget Sound to San Diego. Dense populations are especially common in low-salinity tidepools and seepage areas; mixed sediment. The species has been introduced to Hawaii (Muir 1997) England (Smith et al. 1999), and estuaries of the northeast Pacific between Puget Sound and San Diego (Chapman and Dorman 1975, Staude 1997, Bay et al. 1988). *Grandidierella* was most likely introduced to the northeast Pacific with Pacific oysters from Japan between the 1930s and 1950s (Chapman and Dorman 1975). Its recent arrival in Europe (Smith et al. 1999) is more likely to be associated with ballast water. It was misidentified in Hawaii for 25 years as *Neogamphopus cabinae* (Muir 1997) where the mechanism of its introduction is unclear. The massive ballast water traffic from San Francisco Bay to Hawaii is a possible mechanism for its introduction there.

Cyphocharidae

Cyphocharis challengeri Stebbing 1888: ;Birstein and Vinogradov 1955:212 (with references); J. L. Barnard 1961b:31; Bowman and McCain 1967:1-14, figs. 1-9 (with references).

The most common epipelagic gammaridean amphipod in sub-Arctic offshore and coastal waters of the North Pacific is *Cyphocharis challengeri* (Bowman and McCain 1967). Bousfield and McCain (1967) demonstrated that most of the variation in the anterior protrusion of pereonite 1 varies with size. The species is endemic to the North Pacific but has been reported from a broad range of latitudes in the Atlantic and Indian Ocean. .

Eusiridae

Pontogeneia rostrata Gurjanova, 1938; Gurjanova, 1938:330,398, fig.39; Gurjanova, 1951:719, fig.500; Nagata 1960:171-173, pl.14; J.L.Barnard, 1962b:81; J.L.Barnard, 1964b:114-116, fig.20; Nagata 1965b:185, fig. 26; Nagata 1965e:563; Nagata 1966:334; J.L.Barnard, 1969a:111,112,114; Itoh 1970:29; Mukai 1971:178; Itoh, Honma and Kakimoto 1972:25; Honma and Kitami 1978:40; Azuma 1980:28; Barnard 1979a:49, figs. 25-27 (part); Imada et al. 1981:127; Itoh 1981:24; Itoh, Honma and Kitami 1982:41; Hirayama 1985a:28; Azuma et al. 1985:4; Azuma 1986:74; Sudo et al. 1987:1570; Inaba 1988:146; Ariyama 1988:129, fig. 13f; Barnard and Karaman 1991:334; Ishimaru 1994:45.

A widely reported species in the North Pacific from Bahia de San Quintin, Mexico (Barnard 1964) to Alaska and down the Asian coast to southern Japan (Ishimaru, 1994). *Pontogeneia rostrata* was recovered in the nonindigenous species surveys of Prince William Sound (Hines 1999). However, *P. rostrata* can easily be confused with species of *Accedemorea* its extremely broad range in the Northeast Pacific and uncertain taxonomic status prevents clear resolution of whether it is endemic or introduced. This species is cryptogenic (Carlton 1996).

Gammaridae

Gammarus daiberi Bousfield, 1969; Bousfield 1969:10(1)4-8, figs. 1& 4; Bousfield 1973:52, pl. IV.2; Toft et al. 1999:36.

A probable 1980s ballast water introduction into San Francisco Bay from the eastern Unites States. *Gammarus daiberi* is an estuarine species most abundant in the low salinity ranges between 1.5 and 15 PSU and is largely pelagic. Except for this report, this species is unknown in the northeast Pacific outside of San Francisco Bay. Its range in the eastern U.S. extends from Delaware Bay to South Carolina (Bousfield 1973). *Gammarus daiberi* is a probable ballast water introduction into San Francisco Bay that arrived in the 1980s.

Eogammarus confervicolus *Mara confervicola* Stimpson 1856:90; *Gammarus confervicolus* Stimpson 1857:520-521; Bate 1862:218, pl. 38, fig. 9; Holmes 1904:239; *Melita confervicola* Stebbing 1906:428; *Anisogammarus confervicolus* Saunders 1933:248 (in part); J.L. Barnard 1954a:9-12, pls.9-10; Shoemaker 1964:423, figs. 14-15; Pamamat 1968:211; Bousfield and Hubbard 1968:3; *Anisogammarus (Eogammarus) confervicolus* Schellenberg 1937a:274; Tzvetkova 1975:145-147, fig. 57; Bousfield 1958a:86, fig. 10; *Eogammarus confervicolus* Bousfield 1979:317-319, fig.4.

Eogammarus confervicolus is the only native species recovered from ballast water that was also collected in the Prince William Sound nonindigenous species survey (Chapman 1999). *Eogammarus confervicolus* is extremely euryhaline and is occasionally pelagic. It occurs mainly in estuaries and protected coastal shores. *Eogammarus confervicolus* is the most common and widely distributed gammaroidean amphipod of the North American Pacific coast (Bousfield 1979).

Megaluropidae

Gibberosus longimerus Hoek; *Megaluropus longimerus*; J.L.Barnard 1962b:103, figs.20-21; J.L.Barnard, 1964a:224; J.L. Barnard 1966b:19; J.L.Barnard, 1969a:126; J.L. Barnard 1971b:15; *Gibberosus myersi* (McKinney 1980); *Megaluropus myersi* McKinney 1980; *Megaluropus longimerus* of Cadien *et al.* NEP (in part); (not Schellenberg 1925:151-153, fig.14).

The genus is poorly studied north of northern California (Cadien et al. 1997). Schellenberg (1925) figured only two appendages from his specimens from Lagos, Nigeria and the type specimens have not been compared to California material. The possibility of these populations comprising a single species seems remote. The common occurrence of this species over a broad range of coastal and nearshore waters (Barnard 1962) indicates that it is endemic.

Melphidipiidae

Melphisana bola Barnard 1962b:81-82, fig.7; Thomas & McCann 1997:42, fig.2.20.

This native species is limited to depths no greater than 130 m on the southern California coastal shelf (Barnard 1962b, Thomas and McCann 1997). Appendages are usually missing this species on recovery from benthic samples (Barnard 1962b, Thomas and McCann 1997) greatly complicating identifications. These specimens are in excellent condition is in sharp contrast ot previous material on which the species is described.

Oedicerotidae

Hartmanodes hartmanae *Monoculodes hartmanae* J.L. Barnard 1962:363, figs. 6-7; Barnard & Karaman 1991:560; *Hartmanodes hartmannae* Bousfield & Chevrier 1996:92-93, fig. 10. Bousfield and Chevrier (1996) did not find this species in their 200 samples from the shelf benthos and coastal waters of Canada and it is not listed in by Staude (1997). This species is native to southern California marine waters where it occurs at less than 40 m depths (Barnard 1962). *Hartmanodes hartmannae* is the most abundant gammaridean amphipod found in the samples.

Westwoodilla caecula *Halimedon caecula* Bate 1857:140; *Halimedon Molleri* Boeck 1871:169-170; *Halimedon Mulleri* Sars 1895:327-329, pl.115; *Halimedon acutifrons* Sars 1895:329-330, pl.116, fig.1; *Westwoodilla caecula* Enequist 1950:333-338, figs.40-56; Gurjanova 1951:541-543, pl. 357; Mills 1962:5-9, fig.1; J.L. Barnard 1962e:370; J.L. Barnard 1964a:235; J.L. Barnard 1966a:80 (forma *acutifrons*); J.L. Barnard 1966b:27; J.L. Barnard 1971b:51; Lincoln 1979:354, fig.167; Thomas & McCann 1997:58, figs. 2.37, 2.38; Beare, D. J. and P. G. Moore 1998.

This species may not be part of a complex of similar species distributed around the Arctic Ocean, the Japan Sea, the north east Pacific from British Columbia to southern California and the North Atlantic from Greenland to the Gulf of St. Lawrence and northern Europe. This extremely widespread, common, species in offshore marine soft-sediment environments is most likely endemic to cold water areas of the northeast Pacific. Its occurrence in Port Valdez zooplankton samples is not surprising.

Synopiidae

Tiron sp.

The short dactyls, spineless telson, tiny mandibular palp, smooth dorsal urosome of this single specimen do not agree with either of the local species ***Tiron tropakis*** J. L. Barnard, 1972 or ***Tiron biocellata*** J. L. Barnard, 1962. Pelagic dispersal of benthic peracaridans usually occurs as adults and often is preceded by slight morphological changes that are adaptive for swimming. These changes are poorly understood. The low morphological correspondence of this single specimen with a known species is therefore not surprising. The specimen is therefore considered more likely to be a member of one of the above native species than an introduced species.

References for Appendix Table 9C4.8 (Descriptions of Amphipod Species Identified in Ballast Water Tanks:

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Barnard, J. L. 1962c. Benthic marine Amphipoda of southern California: Families Amphilochidae, Leucothoidae, Stenothoidae, Argissidaem, Hyalidae, Pac. Nat., 3(3):116-163

Barnard, J. L. 1962f. Benthic marine Amphipoda of southern California: Family Oedicerotidae, Pac. Nat., 3(12):351-371

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Chapter 9C5. Focal Taxonomic Collections: Copepod Crustaceans

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Methods

Copepods were identified from three types of samples. The first method consisted of sweeps that were made through algal and fouling assemblages on the underside of docks, using a small hand-held net consisting of 130 µm mesh material attached to a stainless steel hoop of approximately 15 cm diameter. An effort was made to disturb algal and bivalve holdfasts in order to capture copepods from those microhabitats. The second type of samples taken were vertical water column plankton hauls made either off a dock or from a small boat in the harbor with a 0.25 m diameter 250 µm mesh plankton net. The net was lowered to the bottom, and after waiting approximately 1 minute for disturbance to dissipate, the net was slowly pulled to the surface. The third type of samples were taken from settling plates used for collecting fouling macro-invertebrates by briefly soaking plates in 5% formaldehyde solution in a plastic tub and washing the residue through 130 µm mesh.

In the laboratory, each sample was examined under a dissecting microscope, and several representatives of each species of copepod were removed. Each species was then further examined under a compound microscope. Identification was made as far as possible without dissection of individuals (with the exception of occasional removal of the abdomen to facilitate viewing the fifth leg).

Results and Discussion

We identified 68 species of harpacticoid copepods, six calanoids, four cyclopoids, and several unidentified poecilostomatoid species (Table 9C5.1). Of these, none is a confirmed introduced species.

For harpacticoids, our results were similar to those of Kask et al. (1982) for the Nanaimo estuary in southern British Columbia in both the number of species found (75 in B.C.) and in that most of the species that were identified were either northern Pacific, broadly distributed boreal species (i.e., Pacific and Atlantic records), or probably undescribed species. Kask et al. (1982) speculated that the presence of many of the species that they found might have been the result of introductions from ship fouling communities. Harpacticoid copepods may be particularly likely to be transported and introduced because as a group they have successfully occupied almost all benthic and epibenthic habitats. Also, many species have multiple life history modes (e.g., resting and planktonic stages) that may also increase their chance of being transported and introduced. However, these same factors may also explain wide natural distributions. The paucity of studies of harpacticoid taxonomy in the northeastern Pacific makes it nearly impossible to determine whether or not a given species has been introduced without extensive distribution or genetic studies. Many of the species described in Lang's monograph on the harpacticoids of central California (Lang, 1965) occur in Puget Sound (J. Cordell, unpublished data) and southern British Columbia (Kask et. al., 1982), and Lang's species that also occur in Prince William Sound (Table 9C5.2) probably have continuous distributions. Other species that we encountered have Arctic and circumboreal distributions. An example of this is the important

Table 9C5.1. Copepoda

Order Harpacticoida
Fam. Ameiridae
Ameira longipes Boeck, 1865
Ameira sp. 1
Ameira sp. 2
Ameiridae, unid. sp. 1
Fam. Ancorabolidae
Arthropsyllus serratus Sars, 1909
Fam. Canthocamptidae
Mesochra pygmaea (Claus, 1863)
Mesochra sp. 1
Fam. Canthocamptidae, incertae sedis
Leimia vaga Willey, 1923
Fam. Cletodidae
Acrenhydrosoma sp.
Fam. Danielsseniidae
Danielssenia typica
Fam Diosaccidae
Diosaccus spinatus Lang, 1965
Diosaccus sp. 1
Amphiascopsis cinctus
Amphiascus minutus
Amphiascus sp. 1
Amphiascoides cf. debilis
Amphiascoides sp. 1
Amonardia perturbata Lang, 1965
Amonardia normani
Robertsonia sp.
Stenhelia peniculata Lang, 1965
Fam. Ectinosomatidae
Ectinosoma sp.
Halectinosoma sp. 1
Halectinosoma sp. 2
Halectinosoma sp. 3
Microsetella norvegica
Fam. Tachidiidae
Microarthridion littorale (Poppe, 1881)

Table 9C5.1. (continued) Copepoda

Fam. Harpacticidae
Harpacticus uniremis Kröyer, 1842
Harpacticus septentrionalis Klie, 1941
Harpacticus compressus Frost, 1967
Harpacticus sp.- *uniremis* group 1
Harpacticus sp.- *obscurus* group 1
Harpacticus sp.- obscurus group 2
Zaus sp.
Fam. Laophontidae
Echinolaophonte sp.
Heterolaophonte discophora (Willey, 1929)
Heterolaophonte longisetigera Klie, 1950
Heterolaophonte variabilis Lang, 1965
Heterolaophonte sp. 1
Laophonte elongata Boeck, 1872
Laophonte applanata
Laophonte sp. 1
Pseudonychocamptus spinifer Lang, 1965
Paralaophonte cf. congenera (Sars, 1908)
Paralaophonte pacifica Lang, 1965
Paralaophonte perplexa (T. Scott, 1898)
Paralaophonte hyperborea (Sars, 1909)
Paralaophonte sp. 1
Laophontidae, unid.
Fam. Longipediidae
Longipedia sp.
Fam. Parastenheliidae
Parastenhelia sp. 1
Parastenhelia sp. 2
Fam. Tegastidae
Tegastes sp. 1
Tegastes sp. 2
Fam. Thalestridae
Idomene sp.
Diarthrodes sp. 2
Parathalestris sp. 1
Parathalestris sp. 2
Parathalestris sp. 3
Dactylopusia vulgaris Sars, 1905
Dactylopusia glacialis Sars, 1909
Dactylopusia cf. *glacialis*
Dactylopusia paratisboides Lang, 1965
Dactylopusia sp. 1
Paradactylopodia sp. 1

Table 9C5.1. (continued) Copepoda

Fam. Tisbidae
Tisbe cf. *furcata* (Baird, 1837)
Tisbe spp.
Scutellidium arthuri Poppe, 1884
Order Cyclopoida
Fam. Cyclopinidae
Fam. Cyclopidae
Euryte sp.
Halicyclops sp.
Fam. Oithonidae
Oithona similis Claus, 1863
O. spinirostris Claus, 1863

Order Poecilostomatoida
Unidentified spp.

Order Calanoida
Fam. Acartiidae
Acartia cf. clausi Giesbrecht, 1889
Acartia longiremis (Lilljeborg, 1853)
Fam. Centropagidae
Centropages abdominalis Sato, 1913
Fam. Paracalanidae
Paracalanus sp.
Fam. Pseudocalanidae
Pseudocalanus spp.
Fam. Temoridae
Eurytemora herdmani Thompson and Scott, 1897

Table 9C5.2. Copepods Collected at 6 Locations in Southcentral Alaska in August 1999.

1999 Copepoda	Homer	Whittier	Cordova	Valdez	Seward	Shotgun Cove
Order Harpacticoida						
Fam. Ameiridae						
Ameira longipes	x					
Ameira sp. 1	x	x	x			x
Ameira sp. 2	x		x			
Family Ancorabolidae						
Arthropsyllus serratus			x			
Fam. Canthocamptidae						
Mesochra pygmaea		x				x
Mesochra sp. 1						x
Fam. Canthocamptidae, incertae sedis						
Leimia vaga			x			
Fam. Danielsseniidae						
Danielssenia typica	x					
Fam Diosaccidae						
Diosaccus spinatus	x		x			
Amphiascopsis cinctus	x		x			x
Amphiascus minutus	x	x	x			x
Amphiascus sp. 1	x	x				
Amphiascoides sp. 1	x					
Amonardia perturbata	x	x				
Fam. Ectinosomatidae						
Ectinosoma sp.						
Fam. Harpacticidae						
Harpacticus uniremis	x	x	x		x	x
H. septentrionalis	x					
H. compressus	x					
H. unidentified sp.	x					
Harpacticus sp. A- uniremis group					x	
Harpacticus sp.- obscurus group 1	x		x			x
Harpacticus sp.- obscurus group 2						x
Zaus sp.						
Fam. Laophontidae						
Unidentified sp.						x
Heterolaophonte discophora	x	x				
Heterolaophonte longisetigera	x	x	x			
Laophonte elongata	x					
Pseudonychocamptus spinifer	x	x				
Paralaophonte cf. congenera			x			
Paralaophonte pacifica	x					
Paralaophonte perplexa	x		x			x
Paralaophonte sp. 1						x
Family Parastenheliidae						
Parastenhelia sp. 1						x
Parastenhelia sp. 2						x

Table 9C5.2. (continued) Copepods Collected at 6 Locations in Southcentral Alaska in August 1999.

1999 Copepoda	Homer	Whittier	Cordova	Valdez	Seward	Shotgun Cove
Fam. Tegastidae	x					
Tegastes sp. 1			x			x
Tegastes sp. 2						
Fam. Thalestriade						
Diarthrodes sp. 1	x					
Diarthrodes sp. 2						x
Parathalestris sp. 1	x					
Parathalestris sp. 2						x
Parathalestris sp. 3						x
Dactylopusia vulgaris	x	x	x			x
Dactylopusia cf. glacialis						x
Paradactylopodia sp.			x			
Fam. Tisbidae						
Tisbe cf. furcata			x			x
Tisbe sp.	x	x	x			x
Scutellidium arthuri	x		x			
Order Cyclopoida						
Family Cyclopinidae			x			
Family Cyclopidae						
Euryte sp.	x		x			x
Halicyclops sp.				x	x	
Order Poecilostomatoida						x
Total Number of Taxa	28	11	20	1	3	23

juvenile salmon prey species *Harpacticus uniremis*, which occurs in the arctic and as far south as the English Channel in the Atlantic (Kask et al. 1982) and La Jolla, California in the Pacific (Gunnill, 1982).

Settling plates appear to be a good way to sample the diversity of harpacticoid and other epibenthic/epiphytic copepods. In each case where we had dock sweep samples to compare with settling plate samples, more species were collected from the settling plates. Only one species, the algal blade dwelling *Scutellidium arthuri* was found only in the dock sweep samples. Reduced numbers of copepod taxa in the dock sweep samples was probably due to low and/or highly fluctuating surface salinities and/or temperatures. This assertion is supported by the fact that dock sweep samples taken in harbors with high freshwater input (e.g., Valdez, Seward) had extremely low taxa numbers, and those without much freshwater (Homer, Shotgun Cove) had the highest number of taxa.

One species of harpacticoid copepod that we found in dock sweep collections, *Leimia vaga*, may be regarded as “probably introduced”. This species, which was described from Nova Scotia, is also abundant in many estuaries in Oregon and Washington, where it is restricted to brackish reaches (J. Cordell, unpublished data); however, this species was not reported from the Nanaimo estuary by Kask (1982). The fact that *L. vaga* has restricted habitat requirements and apparently disjunct populations on the Pacific coast may indicate that it has been introduced.

Although a number of Asian planktonic copepods have become established in California, Oregon, and Washington estuaries (e.g., Cordell and Morrison, 1996, Orsi and Ohtsuka, 1999), we found no introduced species in the vertical haul samples. In fact, overall planktonic copepod diversity was quite low, and almost all of the copepod numbers were made up of only three taxa: *Acartia longiremis*, *Pseudocalanus* spp., and *Oithona similis*. Also, we did not encounter several taxa that have been previously reported from ballast water arriving to Prince William Sound (Ruiz and Hines, 1997; Hines et al., 1998; Chapt. 3 Biological Characteristics of Ballast Water). As with dock-associated harpacticoids, our shallow sampling depths that were probably subject to large fluctuations in salinity and temperature may have decreased diversity of planktonic copepods in our samples.

References

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Orsi, J.J., and S. Ohtsuka. 1999. Introduction of the Asian copepods *Acartiella sinensis*, *Tortanus dextrilobatus* (Copepoda: Calanoida), and *Limnoithona tetraspina* (Copepoda: Cyclopoida) to the San Francisco estuary, California, USA. Plank. Biol. Ecol., 46 (2): 128-131.

Chapter 9C6. Focal Taxonomic Collections: Decapod Crustaceans

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Results

We collected a total of 21 species of decapods, including 12 species of brachyuran crabs, 3 species of lithodid crabs, 3 species of hermit crabs, and 5 species of caridean shrimp (Table 9C6.1). All of these species were collected by hand or dip net in the intertidal and shallow subtidal zones, or on float fouling communities. None of these species is a new record for the region (Jensen, 1995).

We also noted parasitic castrators (rhizocephalan cirripedes, entoniscid isopods) of decapods in the collections during August 1999. Several of the samples of the hermit crab *Pagurus hirsutiusculus* exhibited infections by rhizocephalan parasites. The crab *Lophopanopeus bellus* also has a high prevalence of infection by the rhizocephalan "*Loxothylacus panopaei*" at Tatitlek. (Note: The name given to this rhizocephalan in the literature by Boschma (1955) for the west coast of North America is undoubtedly incorrect and should be renamed, as this is not the same species that is found in xanthid crabs of the eastern and gulf coasts.) The population of the shore crab *Hemigrapsus oregonensis* also had high prevalence of the entoniscid isopod *Portunion conformis*.

References

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Table 9C6.1. Decapod Crustaceans in Field Surveys

Decapod Crustaceans **1997; 1998; 1999**	Homer	Sew-ard	Whit-tier	Port Valdez	Saw-Mill Bay	Rocky Pt., Gallena Bay	Bus-by Is.	Tatit-lek	Cor-dova	Gla-cier Is.	Green Island	Consta-Tine Harbor	Port Chal-mers
Brachura													
Cancer magister	X	X			X				X			X	
Cancer oregonensis	X	X				X	X	X	X	X	X		X
Cancer productus							X	X					
Cancer gracilis									X				
Chionoecetes bairdi (molts)							X						
Chorilla longipes								X					
Hemigrapsus oregonensis		X	X	X	X	X	X,9	X,4	X,7			X	X
Lophopanopeus bellus						X	X	X,5			X		X
Oregonia gracilis	X					X			X	X			
Pugettia gracilis						X	X	X					
Scyra acutifrons	X												
Telmessus cheiragonus	X	X			X		X	X	X	X	X		X
Anomura													
Cryptolithodes typicus						X							
Hapalogaster grebnitzii	X						X	X			X		
Phyllolithodes papillosus						X							
Pagurus beringanus	X							X					
Pagurus granosimanus						X	X	X			X		
Pagurus hirsutiusculus	X,1	X,2	X	X,3	X	X	X	X,6	X,8	X	X	X	X
Caridea													
Eualus b9iunguis							X						
Hyppolyte clarki				X	X								
Heptacarpus stimpsoni	X			X					X				
Spirontocaris ochotensis					X		X	X					X
Spirontocaris prionota						X					X		

Parasite Notes:
Aug 1999:
1 = 7/9 with bopyrid isopod
2 = 1/32 with rhizocephalan *Peltogaster paguri; 1/32 with rhizocephalan Peltogasterella gracilis*
3 = 0/9 infected
4 = 30/45 with entoniscid isopod *Portunion conformis*
5 = 19/44 with rhizocephalan *Loxothylacus panopei*
6 = 1/6 with bopyrid isopod; 2/6 with rhizocephalan *Peltogaster paguri*; 1/6 with isopod and *P. paguri*
7 = 0/13 with *Portunion conformis*
8 = 3/30 with *Peltogaster paguri; 1/30 with Peltogasterella gracilis*
June 1998: 9 = 2/93 with rhizocephalan

Chapter 9C7. Focal Taxonomic Collections: Shelled Molluscs

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Methods

Molluscs were collected and identified by N. Foster at sites in Prince William Sound during June 20-28, 1998 and August 8-14, 1999. In 1999 the field survey was expanded to include sites in Homer, Seward, and Hinchinbrook Entrance (see Fig. 9A.2 above). Also, J. Goddard and L. Schickel participated in the second year's field collecting and identification, providing expertise in opisthobranch taxonomy (see Chapt 9C8. Opisthobranch Molluscs).

Site information. Site information was collected by J. Chapman & T. Miller (see Chapt 9B).

Sampling and processing. Presence and relative abundance (recorded as abundant, common, or rare) of the easily identified and abundant species were recorded in the field. Field notes were then transferred to spreadsheets maintained by J. Chapman. Voucher specimens of small or rare, mollusks were collected and or were preserved in 10% formalin. Identifications were made by N. Foster at the University of Alaska Museum Aquatic Collection.

Identifications and distributions. No comprehensive reference is available for Alaskan marine mollusca. Major references used for both identifications and distribution records include Foster (1991) , Coan and Scott (unpublished draft), Baxter (1987), Turgeon (1998), Kozloff (1996), and Harbo (1997). Voucher collections form this study will be accessioned into the UAM Aquatic Collection as accession 1998-003 and 1999-001.

Results

Seventy-nine mollusc species were collected or identified from 27 sites in 1998 (Table 9C7.1). Sixty- six three species were collected or identified from 16 sites in 1999 (Table 9C7.2). Mollusks were collected from three general types of habitats:

1. Human-made structures, including oyster lantern nets, and associated floats and buoys, and docks. Characteristic mollusks from fouling communities are *Mytilus trossulus*, *Lacuna vincta*, *Hiatella arctica*. This represented the richest habitat for nudibranchs, including 12 new records. Small mytilids were examined, to look for *Musculista stenhousia*.
2. Mudflats. Upper intertidal areas of mudflats, near Cordova and Valdez and Homer were dominated by *Mya arenaria*. A search was made for *Nuttalia obscurata*, *Batillaria cumingi*, *Ilyanassa obsoleta*, and *Nassa fratercula*, but these potenial NIS were not found at any site of our surveys.
3. Rocky intertidal zones of beaches, sheltered bays with eelgrass. Fauna of rocky intertidal areas, both in bays and headlands is fairly well documented. It is the habitat that is richest in species, but has fewest NIS candidates or new collecting records.

In combination for the two years, 115 species of molluscs were sampled (Table 9C7.3). Of these species, the soft-shelled clam *Mya arenaria* is an NIS (Strasser 1999) that was widely distributed as a self-sustaining population in intertidal soft sediments of protected bays throughout Prince William Sound. Recently, Foster examined archaeological evidence for

	Harbors			Mud bays					Headlands & Reefs			Rocky Bays	Fouling														
Table 9C7.1. Shelled Molluscs 1998 Survey	**Valdez**	**Cordova**	**Whittier**	**Valdez**	**Bligh Island**	**Valdez Arm**	**Growler Island**	**Cordova**	**Valdez Arm**	**Busby Island**	**Green Island**	**Northwest Bay**	**Valdez**	**Cordova**	**Whittier**	**Bligh Island**	**Eagilik Bay**	**Evans Island**	**Knight Island**	**Lake Bay**	**Main bay**	**Sheep Bay**	**Shotgun Cove**	**Squaw Bay**	**Port Valdez**	**Valdez Arm**	**Windy Bay**
Gastropoda																x											
Acmaea mitra									x		x	x															
Acteocina harpa									x																		
Aglaja ocelligera																											
Alia gauspata									x	x	x											x					
Alvania sp.		x							x	x		x											x				
Archidoris montereyensis					x	x											x						x				
Barleeia sp.											x																
Buccinum baeri		x					x			x																	
Cerithiidae											x																
Cerithiopsis sp.									x		x																
Crepidula dorsata											x																
Crepidula perforans										x																	
Crepidula sp.										x																	
Cryptobranchia concentrica							x																				
Cryptonatica affinis			x							x																	
Dendronotus																											
Dendronotus ?albopunctatus																x											
Dendronotus frondosus															x			x									
Diplodonta impolita												x															
Dorid nudibranch																		x			x		x				
Doridella steinbergi															x	x							x				
Eubranchus olivaceous																					x	x					
Fusitriton oregonensis										x																	
Granulina margaritula											x																
Haminoea virescens		x			x																	x					
Hermissenda crassicornis															x	x	x							x			x
Lacuna sp.					x	x			x	x		x				x		x									
Lacuna marmorata		x			x				x	x	x																
Lacuna vincta										x	x	x			x	x				x			x				
Lepeta caeca									x																		

	Harbors			Mud bays					Headlands & Reefs			Rocky Bays	Fouling														
Table 9C7.1. (Continued) Shelled Molluscs 1998 Survey	**Valdez**	**Cordova**	**Whittier**	**Valdez**	**Bligh Island**	**Valdez Arm**	**Growler Island**	**Cordova**	**Valdez Arm**	**Busby Island**	**Green Island**	**Northwest Bay**	**Valdez**	**Cordova**	**Whittier**	**Bligh Island**	**Eagilik Bay**	**Evans Island**	**Knight Island**	**Lake Bay**	**Main bay**	**Sheep Bay**	**Shotgun Cove**	**Squaw Bay**	**Port Valdez**	**Valdez Arm**	**Windy Bay**
Lepetidae?									x																		
Lirularia lirulata									x																		
Littorina scutulata		x	x		x				x	x		x								x							
Littorina sitkana					x	x	x	x	x		x		x	x		x	x							x			
Lottia pelta	x	x	x	x	x	x	x		x	x		x						x		x						x	
Lottia sp.		x	x	x	x	x	x		x	x		x								x							
Margarites berhigensis									x		x																
Margarites helicinus									x			x															
Margarites pupilliis			x				x		x	x	x	x								x	x						
Margarites sp.																											
Nassarius mendicus									x	x																	
Neptunea lyrata		x																									
Nucella lamellosa		x							x	x	x	x															
Nucella lima							x			x		x															
Ocenebra interfossa											x																
Odostomia spp.									x																		
Olivella baetica		x							x	x																	
Onepota spp.									x	x																	
Scabrotrophon maltzani										x																	
Searlesia dira									x		x	x															
Tectura fenestrata	x												x														
Tectura persona		x	x		x		x					x	x							x						x	
Tectura scutum	x		x			x	x		x	x										x							
Trichotropis cancellata									x	x	x																
Trichotropis insignis											x	x															
unidentified Turridae										x																	
Velutina rubra											x																
Bivalvia																											
Axinopsida sp.		x																									
Bankia setacea												x	x														
Chlamys rubida							x				x					x							x				
Clinocardium nuttalli	x	x			x	x	x			x																	
Crassostrea gigas										x																	

	Harbors			Mud bays					Headlands & Reefs			Rocky Bays	Fouling														
Table 9C7.1. (Continued) Shelled Molluscs 1998 Survey	Valdez	Cordova	Whittier	Valdez	Bligh Island	Valdez Arm	Growler Island	Cordova	Valdez Arm	Busby Island	Green Island	Northwest Bay	Valdez	Cordova	Whittier	Bligh Island	Eagilik Bay	Evans Island	Knight Island	Lake Bay	Main bay	Sheep Bay	Shotgun Cove	Squaw Bay	Port Valdez	Valdez Arm	Windy Bay
Gari californica											x																
Hiatella arctica		x	x	x	x	x	x		x	x	x	x	x	x	x	x		x		x	x		x	x			
Macoma balthica		x	x	x	x		x	x		x			x														
Macoma inquinata	x	x				x	x		x	x		x															
Macoma nasuta		x								x																	
Macoma sp.		x																								x	
Modiolus modiolus									x	x																	
Montacutidae					x							x															
Musculus vernicosus					x				x	x						x										x	
Mya arenaria		x		x	x					x																	
Mya pseudoarenaria							x																				
Mya sp.		x				x	x						x														
Mya truncata	x	x					x			x																	
Mysella tumida		x			x				x																		
Mytilus trossulus	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x		x	x	x			x	
Pododesmus macroschisma	x				x	x				x	x	x									x						
Protothaca staminea	x	x					x		x	x	x	x															
Pseudopythinia compressa					x															x							
Saxidomus giganteus	x	x			x	x	x		x	x	x	x								x							
Serripes groenlandicus			x				x													x						x	
Serripes laperousii							x																				
Tresus capax		x								x																	
Turtonia minuta										x		x															
Yoldia hyperborea							x																				
Polyplacophora																											
Cryptochiton stelleri												x															
Katherina tunicata										x																	
Lepidozona interstinctus												x															
Mopalia ciliata			x				x													x							
Mopalia lignosa		x			x					x		x		x													
Mopalia sp.		x										x															
Schizoplax brandtii					x		x																				
Tonicella insignis										x		x															
Tonicella lineata									x	x		x															

Table 9C7.2. Shelled Molluscs 1999 Survey	**Homer**			**Seward Lowell Pt**	**Whittier**	**Shot-gun Cove**	**Fairmont Bay**	**Valdez**		**Cloudman Bay**	**Busby Is.**	**Cordova**		**Windy Bay**	**Constan-tine Harbor**	**Tatitlek**
a = abundant c = common r = rare p = present	**floats**	**benthic**	**homer spit**	**benthic**	**floats**	**float**	**fouling**	**benthic**	**grab**	**benthic**		**benthic**	**floats**	**floats**	**benthic**	
Gastropoda																
Alia gauspata											r					
Archidoris montereyensis											r					
Boreotrophon											r					
Buccinum baeri											c					
Cerithiidae											r					
Collisella digitalis				c												
Collisellla strigatellla				c						c						
Crepipatella dorsata															r	
Cryptobranchia alba		r	r								r				r	
Cryptonatica offinis											r	r				
dorid nudibranch														c	c	
Granulina margaritula																r
Haminoea vesicula										c		r	r		c	
Hermissenda crassicornis														c		
Lacuna vincta	c				c	c	c	c						c		
Littorina sitkana		a		c				c		a	c	r			c	
LIttoria scutulata										c					c	
Lottia pelta		a		c						c	c				c	
Lottia strigatella															r	
Margarites pupillis				r							r					
Melibe leonina														c		
Nassarius mendicus										r						
Neptunea lyrata		p														
Nucella lamellosa											c				r	
Nucella lima				c						c					r	
Ocinebrina interfossa											r					
Odostomia sp.	r	r													r	
Oenopota sp											r					
Olivella baetica				r							r					
Onchidoris bilammelata							c									
Polycera zosterae														c		
Tectura fenestrata								c								
Tectura persona				c						c						
Tectura scutum		c			c						c					
Trichotropis cancellata	c			r												
Velutina plicatilis	r															
Polyplacophora																
Mopalia cf *M. imporcata*	r															
Mopallia cf. *M.spectabilis*													r			
Moplalia ciliata	r														r	
Schizoplax brandtii															r	
Tonicella lineata	r												r			
Tonicella rubra	r															
Bivalvia																
Bankia setacea	p															
Chlamys rubida	r						r									
Clinocardium californiense		r														
Clinocardium nuttalli		c		c						c		c				
Clinocardium sp.		c		p												
Crassicardia crassidens															r	
Cryptomya californica											r					

Table 9C7.2. (Continued) Shelled Molluscs 1999 Survey	**Homer**			**Seward Lowell Pt**	**Whittier**	**Shot-gun Cove**	**Fairmont Bay**	**Valdez**		**Cloudman Bay**	**Busby Is.**	**Cordova**		**Windy Bay**	**Constan-tine Harbor**	**Tatitlek**
a = abundant c = common r = rare p = present	**floats**	**benthic**	**homer spit**	**benthic**	**floats**	**float**	**fouling**	**benthic**	**grab**	**benthic**		**benthic**	**floats**	**floats**	**benthic**	
Cyclocardia sp.			r												r	
Hiatella acrtica		c		c	c	c	c		p				c	c	c	
Humilaria kennerleyi															r	
Macoma balthica		a		c				a		c		a			c	
Macoma calcarea									p							
Macoma inquinata		c		c				a			c	c			c	
Macoma lama			r													
Macoma obliqua		r	r													
Macoma sp.		p		p												
Modiolus modiolus			r								r					
Mya arenaria										c		a			c	
Mya pseudoarenaria		c								c						
Mya sp.									p							
Mya truncata		c	c												r	
Mytilus trossulus	a	a		a	a	c	a			a	a		a	a	a	
Neaeromya compressa											r					
Pododesmus macroschisma															r	
Protothaca staminea		c		c					p			c				
Saxidomus giganteus		c		c					p			c				
Serripes groenlandicus									p		r					
Serripes laperousii			r													
Siliqua patula		p	p													
Spisula polynyma		c										c			c	
Tresus capax												c			c	
Vilasina vernicosa							c			c					c	
Yoldia myalis									p							

Table 9C7.3. All Mollusks from Both 1998 and 1999

Species	Distribution	NIS status
Acmaea mitra	NE Pac	
Acteocina harpa	NE Pac	
Aglaja ocelligera	NE Pac	new record
Astyris gauspata	NE Pac	
Alvania sp.		
Archidoris montereyensis	NE Pac	
Axinopsida sp.		
Bankia setacea	NE Pac	
Barleeia sp. ?		
Boreotrophon		
Buccinum baeri	NE Pac	
Cerithiidae		
Cerithiopsis?		
Chlamys rubida	NE Pac	
Clinocardium californiense	NE Pac	
Clinocardium nuttallii	NEW Pac	
Clinocardium sp.		
Lottia digitalis	NE Pac	
Lottia strigatellla	NE Pac	
Cyclocardia crassidens	NEW Pac	
Crassostrea gigas		introduced
Crepidula sp.		
Crepipatella dorsata	NE Pac	
Cryptobranchia alba	NE Pac	
Cryptobranchia concentrica	NEW Pac	
Cryptomya californica	NEW Pac	
Cryptonatica affinis	arctic circumboreal	
Cyclocardia sp.		
Dendronotus frondosus	northern hemisphere	
Dendronotus sp.		
Diplodonta impolita	NE Pac	
dorid nudibranch		
Acanthodoris?		
Doridella steinbergi	NE Pac	
Eubranchus olivaceous	NE Pac	new record
Fusitriton oregonensis	NE Pac	
Gari californica	NE Pac	
Granulina margaritula	NE Pac	
Haminoea vesicula	NE Pac	
Haminoea virescens	NE Pac	
Hermissenda crassicornis	NE Pac	
Hiatella arctica	northern hemisphere	
Humilaria kennerleyi	NE Pac	
Lacuna marmorata	NE Pac	
Lacuna sp.		
Lacuna vincta	amphiboreal	
Lepidozona interstinica	NE Pac	
Lepetidae?		
Lirularia lirulata	NE Pac	

Table 9C7.3. (Continued) All Mollusks from Both 1998 and 1999		
Species	**Distribution**	**NIS status**
Littorina scutulata	NE Pac	
Littorina sitkana	NE Pac	
Lottia pelta	NE Pac	
Lottia sp		
Lottia strigatella	NE Pac	
Macoma balthica	circumboreal	poss. cryptogenic
Macoma calcarea	ampiboreal	
Macoma inquinata	NE Pac	
Macoma lama	NEW pac	
Macoma nasuta	NE Pac	
Macoma obliqua	NE Pac	
Macoma sp.		
Margarites beringensis	AK	
Margarites helicinus	circumboreal	
Margarites pupillus	NE Pac	
Margarites sp.		
Melebe leonina	NE Pac	
Modiolus modiolus	circumboreal	
Montacutidae		
Mopalia cf *M. imporcata*	NE Pac	
Mopalia ciliata	NE Pac	
Mopalia lignosa	NE Pac	
Moplalia cf. *M.spectabilis*	NE Pac	
Mya arenaria	amphiboreal	introduced
Mya pseudoarenaria	NE Pac	
Mya sp.		
Mya truncata	amphiboreal	
Mysella tumida	NE Pac	
Mytilus trossulus	NE Pac	
Nassarius mendicus	NE Pac	
Neaeromya compressa	NE Pac	
Neptunea lyrata	NE Pac	
Nucella lamellosa	NE Pac	
Nucella lima	NE Pac	
Ocinebrina interfossa	NE Pac	
Odostomia spp.		
Oenopota sp.		
Olivella baetica	NE Pac	
Onchidoris bilamellata	amphiboreal	
Onchidoris sp.?		
Pododesmus macroschisma	NE Pac	
Polycera zosterae	NE Pac	
Protothaca staminea	NE Pac	
Saxidomus giganteus	NE Pac	
Scabrotrophon maltzani	NE Pac	
Schizoplax brandtii	NEW Pac	
Searlesia dira	NE Pac	
Serripes groenlandicus	circumboreal	
Serripes laperousii	circumboreal	
Siliqua patula	NE Pac	

Table 9C7.3. (Continued) All Mollusks from Both 1998 and 1999		
Species	**Distribution**	**NIS status**
Spisula polynyma	amphiboreal	
Tectura fenestrata	NE Pac	
Tectura persona	NE Pac	
Tectura scutum	NE Pac	
Tonicella insignis	AK	
Tonicella lineata	NE Pac	
Tonicella rubra	circumboreal	
Tresus capax	NE Pac	
Trichotropis cancellata	NE Pac	
Trichotropis insignis	NEW Pac	
Turtonia minuta	amphiboreal	
Velutina plicatilis	arctic circumboreal	
Velutina rubra	AK	
Vilasina vernicosa	NEW Pac	
Yoldia hyperborea	circumboreal	
Yoldia myalis	amphiboreal	

occurrence of Mya arenaria in Alaskan waters before the 1890s. No *M. arenaria* were found in samples from shell middens from Sitka (1070-470 yr BP) (Foster, unpublished data) and S. Hawkins Island (500-200 yr BP and 2150-1380 yr BP) (Yarborough, unpublished data), and faunal lists from two other Prince William Sound sites (ca. 400-200 yr BP) (Yarborough, unpublished data), and from Resurrection Bay and Aialik Bay (1700s –1800s AD) (Yarborough, unpublished data). These negative findings are consistent with *M. arenaria* being an invasive species that was introduced in the late 1880s. In addition, the Asian oyster *Crassostrea gigas* was also widely distributed in protected bays of Prince William Sound and Katchemak Bay, where it is cultured abundantly in nets suspended vertically in the water column. However, it is sustained as an aquaculture species by importation of laboratory produced spat, and is not a self-sustaining population, probably because water temperatures are too cold for gonad development and spawning. The common clam *Macoma balthica* may be viewed as a cryptogenic species that may be introduced from the north Atlantic; but because of its circumboreal distribution and variation in shell morphology, it is difficult to reconstruct the history of this species' biogeography.

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Chapter 9C8. Focal Taxonomic Collections: Opisthobranch Molluscs

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Introduction

The Smithsonian Environmental Research Center, in conjunction with the University of Alaska, U.S. Fish and Wildlife Service and Prince William Sound Advisory Council, conducted in August 1999 a survey of Prince William Sound for non-indigenous marine species. Owing to the abundance of opisthobranch molluscs observed in a similar survey the previous summer, I was invited to help identify members of this taxon in the 1999 survey. The following report summarizes the 1999 collection of opisthobranch molluscs and attempts to identify non-indigenous and cyptogenic members of the fauna.

Methods

Specimens were collected by hand from floating docks, intertidal mudflats and rocky shores, jetties, and from settling panels deployed earlier in the year. Observations were made of living animals, either with a dissecting microscope in the laboratory, or with a hand lens while traveling to the next collecting station. Voucher specimens were fixed in either 5 to 10 % formalin or 70 % ethanol. Specimens not identified during the expedition were examined, dissected and identified in the laboratory at UCSB.

Results

Twenty-eight species were found, consisting primarily of dorid nudibranchs. These are listed below with notes on their classification, habitats, and prey; an asterisk marks range extensions. Distributions and abundance in our field collections are summarized in Table 9C8.1 following the list.

Cephalaspidea

Aglaja ocelligera (Bergh, 1894)
Numerous specimens were found on the intertidal mudflats west of the Cordova marina.

Haminoea sp. (either *vesicula* or *virescens*)
Egg masses of this species were abundant on *Zostera* in the Cordova marina, where Nora Foster collected a single specimen.

Melanochlamys diomedea (Bergh, 1894)
Adults and egg masses of this species were abundant on mudflats just west of the Cordova marina.

Sacoglossa

**Alderia modesta* (Loven, 1844)
Adults and their egg masses were abundant on *Vaucheria* sp. on the high intertidal mudflats immediately west of the Cordova marina. Range extension from Vancouver Island, British Columbia (Millen, 1980).

**Olea hansineensis* Agersborg, 1923
One specimen of this opisthobranch egg eating sacoglossan was found on the egg masses of *Melanochlamys diomedea* on the mudflat west of the Cordova marina. Range extension from Sechelt Inlet, British Columbia (Millen, 1980).

Nudibranchia, Doridacea

Acanthodoris nanaimoensis O'Donoghue, 1921
A specimen about 35 mm long was found in the low intertidal on the jetty at the Cordova marina. This species was recently collected from Little Green Island, Prince William Sound (Nora Foster, personal communication, 1999).

Acanthodoris pilosa (Abildgaard, 1789)
Three specimens, 2.2 to 5 mm long, were found on drift pieces of a large, unidentified, fleshy, orange-brown colored ctenostome bryozoan on the mudflats just west of the Cordova marina. Note: unidentified species of cheilostome bryozoans were growing on the above ctenostome and may have been the prey of these specimens of *A. pilosa*. Two additional specimens, 5.5 and 7 mm long, were found on settling panels in the Cordova marina.

**Adalaria jannae* Millen, 1987
This species was abundant, along with its ribbon shaped egg masses, on *Membranipora* sp. growing on *Laminaria* on the docks at Whittier and on the moored buoy at Shotgun Cove. *A. jannae* closely resembles *Onchidoris muricata*, but lacks the medial radular teeth found in the latter; *A. jannae* also has 4 to 6 small lateral teeth on each half row of the radula, as well as a ribbon shaped egg masses (Millen, 1987). The radular formula from an 8 mm long (preserved) specimen from Shotgun Cove was 30 (4.1.0.1.4.). Range extension from Sointula, British Columbia (Millen, 1987).

Adalaria proxima (Alder & Hancock, 1854)
Two specimens, 3 mm long (alive) and 10 mm long (preserved) were found on the unidentified ctenostome bryozoan mentioned above for *Acanthodoris pilosa* and on the jetty, respectively, at Cordova (the above note for the prey of *Acanthodoris pilosa* also applies to this species). The radular formula for these two specimens was 30 (7.1.1.1.7) and 36 (9.1.1.1.9), respectively, and the changes in shape of the teeth with increasing body size match that described for this species by Thompson & Brown (1984). Note: previous Alaskan records of this species can be found under the names *Adalaria albopapillosa*, *A. pacifica*, and *A. virescens* (see Lee & Foster, 1985:444), all three of which Millen (1987) considered junior synonyms of *A. proxima*.

**Adalaria* sp. 1 of Behrens (1991) and Millen (1987:2701)
One specimen, 3.3 mm long (preserved) of this distinctive species was found on the low intertidal rocky shore at Tatitlek. Range extension from Ketchikan, Alaska (Millen, 1989).

Adalaria sp.
Two specimens, 2 and 3 mm long, were found on the same fleshy ctenostome bryozoan that *Acanthodoris pilosa* was found at Cordova (and the same note on prey also applies here). An

additional specimen, 3 mm long, was found on a settlement panel at Valdez. The radular formula (24 x 4.1.0.1.4 in a 3 mm specimen), tooth shape, and bipinnate gills inserted in separate pits place this onchidoridid in the genus *Adalaria*, but the presence of long slender dorsal papillae lacking spicules does not appear to match any described species.

**Ancula pacifica* MacFarland, 1905
A single specimen, lacking orange lines on the body, was found on the floating docks in the Cordova marina. This species (or the color form of *A. pacifica* lacking orange lines on the body) may be a junior synonym of *Ancula gibbosa* (Risso, 1818). Range extension from Grant Island, Ketchikan, Alaska (Millen, 1989).

Archidoris montereyensis (Cooper, 1863)
Two specimens were found eating the sponge *Halichondria panicea* growing on oysters in Fairmont Bay, and two specimens were found in the marina at Cordova.

Doridella steinbergae (Lance, 1962)
This species was found on its prey, *Membranipora* sp., *on Laminaria* on the floating docks at Whittier, and on drift *Laminaria* on the mudflats at Cordova. The range of this species was extended by Foster (1987) northward to Prince William Sound and more recently westward to Mink Island, Katmai National Park (Nora Foster, personal communication, 1999).

**Geitodoris heathi* (MacFarland, 1905)
Four specimens were found on the low intertidal rocky shore at Tatitlek. Range extension from Ketchikan, Alaska (Millen, 1989).

Onchidoris bilamellata (Linnaeus, 1767)
This circumboreal species feeds on *Balanus* spp. and was abundant, along with its egg masses, in the Homer marina, on the settling panels at Fairmont Bay and Tatitlek, and on rocks in and around the Cordova marina.

Onchidoris muricata (Müller, 1776)
Atotal of five small specimens were found, two on settling panels at Valdez, and three on settling panels at Cordova. Note: previous Alaskan records of this species can be found under the names *O. hystricina* and *O. varians* (see Lee & Foster, 1985:444), which Millen (1985) synonomized with *O. muricata*.

**Palio zosterae* (O'Donoghue, 1924)
Adults and egg masses were abundant on the bryozoan *Membranipora* sp. growing on *Laminaria* on the floating docks at Whittier; a few specimens were also found on the buoy at Shotgun Cove and on the docks at Cordova. *P. zosterae* may be a junior synonym of *P. pallida* Bergh, 1880; if not these specimens represent a small westward range extension from Hawkins Island, Prince William Sound (Nora Foster, personal communication, 1999).

Triopha catalinae (Cooper, 1863)
Three specimens were found under cobbles in the low intertidal at Tatitlek.

Nudibranchia, Dendronotacea

Dendronotus frondosus (Ascanius, 1774)
Specimens were found on *Obelia*-like hydroids on settling panels at Seward, Fairmont Bay, Potato Point in Valdez narrows, and Tatitlek. Adults and egg masses were also common on the docks at Cordova.

Melibe leonina (Gould, 1852)
Specimens were found on *Zostera* in Fairmont Bay, on a settling panel at Tatitlek, and on the docks at Cordova.

Nudibranchia, Arminacea

Dirona albolineata MacFarland in Cockerell & Eliot, 1905
Four small specimens were found on the floating docks in the Cordova marina, an additional juvenile specimen was found on a settling panel at Tatitlek.

**Janolus fuscus* (O'Donoghue, 1924)
Two specimens, 60 to 70 mm long, were found with their egg masses on *Bugula* sp. on docks in the Homer marina. Range extension from Klu Bay, Revillagigedo Island, Alaska (Robilliard & Barr, 1978).

Nudibranchia, Aeolidacea

Aeolidia papillosa (Linnaeus, 1761)
One 70 mm long specimen was found on the docks at Homer.

**Cuthona albocrusta* (MacFarland, 1966)
A single specimen of this distinctive species was found on the docks at Cordova. Range extension from White Rock, southern British Columbia (Millen, 1983).

**Cuthona pustulata* (Alder & Hancock, 1864)
Four specimens, 4 to 5 mm long, were found feeding on the hydroid *Sarsia* sp. on a dock in the marina at Homer. These specimens resembled Gosliner & Millen's (1984) description of *Cuthona pustulata* from British Columbia, especially with regard to overall shape of the body, cerata, and head tentacles. Our specimens differed however by lacking large white spots on the cerata (they did have smaller opaque white flecks) and by having slightly fewer rows of cerata with fewer cerata per row. The radula and shape of the radular teeth of our specimens are virtually identical to that described by Gosliner & Millen (1984) but differed in having 4 to 5 lateral denticles, compared to 5 to 9. Range extension from Galiano Island, British Columbia (Gosliner & Millen, 1984).

**Eubranchus olivaceus* (O'Donoghue, 1922)
This distinctive aeolid was found with its egg masses on *Obelia*-like hydroids on the docks at Homer and at Whittier. Range extension from Prince William Sound (Nora Foster, personal communication, 1999).

Hermissenda crassicornis (Eschscholtz, 1831)
Hermissenda was found at Whittier, Shotgun Cove, Fairmont Bay, Tatitlek, and in the Cordova marina. Specimens were small at all sites except Cordova, where they were up to 35 mm long.

Discussion
Most of the opisthobranchs collected during this survey are cold-temperate species endemic to the northern Pacific Ocean, especially the northeastern Pacific. The remainder are circumboreal species, a few of which (e.g., *Dendronotus frondosus* and *Onchidoris bilamellata*) penetrate the Arctic Ocean (see information on distributions in Marcus, 1961; McDonald, 1983; Thompson & Brown, 1984; Behrens, 1991). To my knowledge, none of the species collected in our survey are non-indigenous in the Prince William Sound region. While native/non-native status can not be assigned with certainty to the unidentified species of *Adalaria* or the tentatively identified specimens of *Cuthona pustulata*, the radiation of both of these genera in boreal waters suggests that both of these species are probably also indigenous to Prince William Sound.

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Table 9C8. 1. Numbers of opisthobranch molluscs collected at 8 sites on the Kenai Peninsula and in Prince William Sound, Alaska, August 1999. A number followed by (S) means those specimens were found on fouling plates only.

Table 9C8.1 Opisthobranch Molluscs 1999	Homer		Seward		Whittier	Shotgun	Fairmont		Tatitlek	Cordova	
Species	marina	mudflat	marina	Lowell Pt.	marina	Cove	Bay	Valdez	rocky shore	mudflats	marina
Aeolidia papillosa	1										
Eubranchus olivaceus	>10				1						
Cuthona pustulata	4										
Janolus fuscus	2										
Onchidoris bilamellata	>10						>10(S)		3(S)	>10*	>10
Melanochlamys diomedea		1								>100	
Dendronotus frondosus			7(S)				>10	2(S)	>1(S)		>10
Palio zosterae					>100	>1					>1
Adalaria jannae					>100	>10					
Hermissenda crassicornis					5	>10	>10		>1		>10
Doridella steinbergae					2					>10*	
Archidoris montereyensis							1				2
Melibe leonina							1		>1(S)		1
Onchidoris muricata								2(S)			3(S)
Adalaria sp.								1(S)		2*	
Adalaria sp. 1 of											
Behrens (1991)									1		
Geitodoris heathi									4		
Triopha catalinae									3		
Aglaja ocelligera										>10	
Acanthodoris pilosa										3*	2(S)
Adalaria proxima										1*	1
Alderia modesta										>10	
Olea hansineensis										1	
Haminoea sp.											1
Acanthodoris nanaimoensis											1
Dirona albolineta									1(S)		4
Ancula pacifica											1
Cuthona albocrusta											1
Number of species per site	5	1	1	0	5	3	5	3	8	9	14

* specimens found on cobbles, drift kelp, or drift bryozoans lying on the mudflat.

Chapter 9C9. Focal Taxonomic Collections: Echinoderms

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Results

Echinoderm collections over the two years of field sampling included 4 species of holothuroid, 1 species of ophiuroid, 6 species of asteroid, and 1 species ophiurioid (Table 9C9.1). No crinoid species were collected. All of these species are reported as native to Alaska. However, *Asterias amurensis*, a northwest Pacific seastar, was found at Homer spit of Kachemak Bay, off Cook Inlet. This is a range extension form the Shumagin Islands (Fisher 1930) and from the Kodiak Shelf and Izhut Bay, Kodiak Island, and Bering and Chukchi Seas, where it was found by Jewett and Feder (1981). Specimens of *A. amurenis* are not represented in the University of Alaska Museum's collections for trawl surveys in either the Gulf of Alaska (Foster, 1999 pers. comm.) or Cook Inlet (Feder and Paul 1981, Feder et al. 1981). The survey of Cook Inlet also included scuba surveys. It would have been very unusual for such collections to miss a large conspicuous sea star (30 cm from ray tip to ray tip). Prior experienced naturalists working in Kachemak Bay reported the sudden recent appearance of this species. This species is an invasive species in Tasmania, where it was probablyintroduced by ballast water (it has a long-lived planktotrophic larva). In Tasmania it is having adverse impacts on native bivalves and is considered to be a serious pest. We consider this species to be cryptogenic in Cook Inlet, with characteristics that are very suspicious of an NIS. Because it is a voracious predator, it could have a major impact on benthic communities.

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Table 9C9.1. Echinoderms 1998, 1999

	Homer	Seward	Whittier	Growler Island	Sawmill Bay	Port Valdez	Rockey Point	Busby Island	Tatitlek	Cloudman Bay	Cordova	Constantine Harbor	Port Chalmers	Green Island	Chenega	Northwest Bay	Main Bay
Eupentacta pseudoquesemita	X																
Cucumaria frondosa japonica	X																
Psolus chitonoides							X	X									
Cucumaria vegae								X									
Ophiopholis aculeata							X	X						X			
Pycnopodia helianthoides	X			X	X	X	X	X	X		X		X	X	X	X	X
Evasterias troschelii	X	X		X				X	X						X		
Pisaster ochraceus						X		X	X								
Asterias amurensis	X																
Dermasterias imbricata								X	X				X	X			
Leptasterias sp.								X	X					X			
Strongylocentrotus droebachiensis								X			X		X				

Chapter 9C10. Focal Taxonomic Collections: Ascidians

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Results

A total of 12 species of ascidians were collected during this expedition. The highest number of species and of individuals was at Homer, Tatitlek and Cordova, the three locations with the highest salinity. No ascidians were recorded from Seward or Whittier, or the floats at Valdez, where the salinity was only 10-12 parts per thousand, although fouling panels at Valdez, submerged at about 7m, did have some ascidians. Ascidians require at least 25-27 parts per thousand and prefer a salinity of 30 or higher. Three of the 12 species are colonial, the other 9 are solitary forms. Although there were not a large number of species collected, they do represent a good diversity. Both orders and all three suborders of the class Ascidiacea are represented and include a total of 6 families. Seven of the 12 species are known to brood their embryos and release swimming tadpoles; all 7 of these did harbor mature embryos. At the end of this report is a list of the ascidian voucher specimens collected in 1998; there were no additional species to the 1999 collections.

The collection includes an undescribed species of *Distaplia*, a colonial form in the suborder Aplousobranchia. It is surprising that this species is very abundant at both Homer and Cordova marinas, yet has gone unrecognized for nearly a century. It is possible that if Ritter (1901) or Huntsman (1912) collected it, they may have considered it merely a variant of *Distaplia occidentalis*. On the other hand, this species may have been much rarer during Ritter's and Huntsman's time. Its preferred habitat is apparently sheltered surfaces, shallow but never exposed at low tide and away from very much light. It is thus "pre-adapted" for the huge surface area and specialized environment provided by marina floats and the many submerged ropes up to 3m. in length that are often suspended from floats. Before the building of large marinas, this particular type of habitat was not abundant. The marina environment is also somewhat unstable, subject to changing seasonal conditions. Many ascidians are well adapted to take advantage of this instability. *Distaplia* spp., like most aplousobranchs, are very fast growing, reach sexual maturity in a few weeks, reproduce and then die back to a dedifferentiated basal portion than can survive until environmental conditions are again suitable for rapid growth. This new species is somewhat similar to a cold-water form from the Kamchatka Peninsula of Russia, and an analysis and description of it is being prepared in collaboration with Dr. Karen Sanamyan of the Kamchatka Institute of Science.

Two species of the genus *Ascidia* were collected and present a taxonomic problem. One corresponds to *Ascidia adhaerens* Ritter, 1901, the other to *Ascidiopsis columbiana* Huntsman, 1912. (The genus Ascidiopsis is no longer valid; it was synonymized under the genus *Ascidia*.) Van Name (1945) synonymized these two NE Pacific species under *Ascidia callosa*, probably incorrectly; *A. callosa* was described in 1852 by Stimpson from U.S. east coast specimens from Massachusetts. The recent genetic analysis of many Atlantic and Pacific species of various taxa that closely resemble each morphologically and were originally lumped into the same species has resulted in many cases in their separation into different species (R. Strathmann pers. comm.). However, a recent re-examination of Stimpson's syntypes of Ascidia callosa and Ritter's paratypes of Ascidia adhaerens, borrowed from the Smithsonian National Museum of Natural

History, has confirmed that these are the same species. Thus, Ascidia adhaerens remains a synonym under A. callosa. The type specimen of Huntsman's Ascidiopsis columbiana was borrowed from the Royal Ontario Museum in Toronto. I was able to confirm that this species is indeed distinct from Ascidia callosa and thus should be resurrected as a valid species, which will be done in a publication now in preparation.

Botrylloides violaceus is not native to Alaska, or to any part of the NE Pacific. It is a Japanese species that appeared on the U.S. Pacific coast about 20 years ago (J. Carlton pers. comm.). Since that time it has spread and become extremely abundant from southern California to British Columbia (Lambert and Lambert, 1998). This is the first report of its presence in any part of Alaska, however. Although large colonies were not observed, the fouling panels at Tatitlek contained numerous newly settled zooids most of which appeared healthy. Thus somewhere close to the panels there had to be mature colonies which were supplying the short-lived tadpoles that settled on the panels. *B. violaceus* incubates its embryos; the tadpoles that are released are huge, complex, and usually swim for just a very brief period, perhaps only a few minutes, before settling. The unusual tadpole morphology allows for easy recognition of this invasive species (Saito et al., 1981).

Molgula retortiformis and *Ascidia callosa* are apparently the only species collected on this expedition that occur in both the North Pacific and North Atlantic (Van Name, 1945). *Chelyosoma productum, Corella inflata* and *C. willmeriana, Distaplia occidentalis, Pyura haustor* and *Styela truncata* have been recorded only from the NE Pacific. *Halocynthia hilgendorfi* is known from both the NW and NE Pacific.

Sixty-five species of ascidians are known to occur in Alaskan waters. Most of these were obtained by dredging many decades ago and may be restricted to the Bering Sea or the Arctic Ocean. The ascidian fauna of Alaska is still mostly unexplored, and probably there exist a number of undescribed species.

Publication of the present work, including a description of the new *Distaplia* species and redescription of the two *Ascidia* species, is in preparation with Dr. Karen Sanamyan of the Kamchatka Institute of Ecology.

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Table 9C10.1 Sites visited:

1. Aug. 8 Homer Marina, Kachemak Bay, Cook Inlet
   Salinity 27 $\%_o$ 1 ft. depth, 30 $\%_o$ at 2m depth; Temp. 10 ^{o} C
   Most of the following records are from suspended ropes.

Ascidia callosa--common esp. about halfway between the inner and outer ends of the marina. Some contain brooded larvae in atrial chamber. Two small specimens from fouling panel: one from E1 and one from OH--2-P2.
Corella inflata--reported by John Chapman but not personally seen in spite of extensive sampling of floats and ropes. Samples lost; record not verified.
Distaplia new sp. very abundant at most locations in the marina, esp. on ropes 1-2 m. deep. A few small colonies on fouling panel.
Molgula retortiformis: 2 large and 8 small specimens on ropes. Two small specimens on fouling plate E1. The large animals contain brooded embryos in the atrial chamber.
Styela truncata - 1 small individual.

2. Aug. 9: Seward Marina.
   Salinity 11 $\%_o$ about a foot down.
   Temperature 11.5 ^{o} C.
   No ascidians either at the marina or Lowell Pt. rocky intertidal (11 $\%_o$, 11.5 ^{o} C.)

3. Aug. 10, 1999 Whittier marina.
   No sal. or temp. readings taken. Sal. very low; no ascidians on floats.

4. Aug. 10, 1999 Fairmont Bay oyster farm, Prince Wm. Sound.
   Salinity 25 $\%_o$ about a foot down.
   Temperature 14 ^{o} C.

Ascidia columbiana--numerous small specimens on concrete blocks of the fouling panels and one large one on bottom of submerged 4 ft long oyster bag.

5. Aug. 11, 1999 Valdez Marina
   No salinity or temp. readings taken
   No ascidians observed on marina floats or suspended ropes.

6. Aug. 11-12, 1999 Tatitlek
   Salinity 27 $\%_o$ about a foot down.
   Temperature 17 ^{o} C. surface
   a) Fouling panels and frames, 3m depth:

Ascidia columbiana -- a few small specimens on the concrete blocks for the fouling panels and one on panel PL3-l.
Botrylloides violaceus -- numerous very small zooids on panels. Largest one with 2 zooids in colony. Youngest appeared to be only hours post metamorphosis.
Corella inflata -- common on both the panels and frames about 3m depth, with brooded larvae in the atrial chamber.

Table 9C10.1 (Continued) Sites visited:

b) Intertidal rocks, low tide, morning Aug. 12
Ascidia columbiana -- one large specimen coll. by J. Goddard.
Chelyosoma productum -- about 12 seen, 2 collected.
Halocynthia igaboja -- one very small immature specimen coll. by J. Goddard.
Pyura haustor -- 4 seen, one incomplete specimen collected. Difficult to collect; wedged tightly into rock crevices.

c) oyster cages from across bay: one small *Corella inflata*.

7. Aug. 13, 1999 Cordova Marina. Tide just beginning to come in.
Salinity 27 $‰_o$ about a foot down.
Temperature 13 ^{o} C. surface
Ascidia callosa-- numerous on floats and especially on suspended ropes. Some contain brooded larvae in atrial chamber.
Corella inflata -- large, common, full of brooded larvae in atrial chamber.
<u>*Distaplia*</u> new sp. --abundant colonies, with many mature larvae.
Distaplia occidentalis -- common; several color morphs, large heads, with mature larvae.
Styela truncata -- numerous. Some contain brooded larvae in atrial chamber.

b) Fouling panels
Ascidia callosa -- 12 small specimens from I dock, Pl. 3, 3 in a second vial.
Corella inflata -- one small specimen from I dock, Pl. 3; two in a second vial.
Corella willmeriana-- (specimens identified on site, not saved apparently.)
Distaplia new sp. -- numerous small colonies from I dock Pl. 3, one in a second vial.
Styela truncata -- 8 on fouling panels in voucher collection in one vial, 3 in another.

8. Aug. 14, 1999 Valdez fouling panels, Berth 5
Corella willmeriana -- 3 individuals, 1 large and 2 small. Specimens identified on site; not saved apparently.
Ascidia columbiana -- one small specimen from fouling panel (or perhaps the concrete block anchoring the panels) at 20 ft. (sampled 8/14).

<u>Table 9C10.2 Ascidian vouchers from fouling panels 1998, identified Sept. 1999</u>

Data taken from jar labels.
Homer 3/9/98 -- *Styela truncata* (1)
Homer: 9/3/98 -- *Ascidia callosa* (1)
Homer Oct. 1998 -- *Distaplia* new sp. collected by G. Sonnevil. Colonies without gonads or larvae.
Homer 5/11/99 -- *Distaplia* new sp. collected by G. Sonnevil. Colonies small, immature.

Chenega 7/9/98 -- *Corella inflata* (2) Port San Juan, Chenega sm. boat hbr
Chenega 9/7/98 -- *Ascidia callosa* (1)
Chenega no date -- *Corella inflata* (7) panel MI - 05 - ? (can’t read label)

Valdez 9/8/98 -- *Corella inflata* (2) at Alyeska berths

No location given -- *Ascidia* sp. (1) too small to ID to species. Panel WH-04-P3.

Table 9C10.3 Systematics

Class Ascidiacea

OrderAplousobranchia
Family Holozoidae
Distaplia occidentalis Bancroft, 1899
Distaplia new species
Order Phlebobranchia
Family Corellidae
Chelyosoma productum Stimpson, 1864
Corella inflata Huntsman, 1912
Corella willmeriana Herdman, 1898
Family Ascidiidae
Ascidia callosa Stimpson, 1852
Ascidia columbiana (Huntsman, 1912)

Order Stolidobranchia
Family Styelidae
Botrylloides violaceus Oka, 1927
Styela truncata Ritter, 1901
Family Pyuridae
Halocynthia igaboja Oka, 1906
Pyura haustor (Stimpson, 1864)
Family Molgulidae
Molgula retortiformis Verrill, 1871

Table 9C10. 4 Ascidian References by Depth and Habitat

Depth(m)	**Selected References**
intertidal, floats;to 10m	Ritter '01, '13; VName 45; PWS Expedition 1999
us. 0-60m	Ritter'01,Huntsman'12,VName45,Abbott66,O'Clair98;PWS Exped.'99
0-few m.	Saito et al 81,Lambert & Lambert 98, PWS Exped. 1999
intertidal - 50m	Huntsman '12,VName 45,O'Clair98; PWS Exped. '99
0-50m	Huntsman '12,VName 45; PWS Exped. '99
0-few m.	Huntsman '12,VName 45; PWS Exped. '99
float	PWS Expedition 1999
floats; intertidal-few m.	VName 45, O'Clair 98, PWS Expedition 1999
to 57m	VName 45, Nishikawa 91,Sanamyan 96,O'Clair98, PWS Exped. '99
4-75m; floats	Ritter 01,VName 45,Abbott66,Sanamyan 93, PWS Exped. '99
intertidal - 114m	VName 45, Sanamyan 96,O'Clair98; PWS Exped. '99
ropes on floats;0-20m	Ritter '01, Van Name 45, PWS Exped. '99

Table 9C10.5 Ascidan Species Distribution in Alaska

Genus	Species	Author/date	Family	Distribution in Alaska
Ascidia	callosa	Stimpson, 1852	Ascidiidae	Homer;PWS:Fairmont Bay oyster farm,Tatitlek,Cordova,Valdez, Chenega
Ascidia	columbiana	(Huntsman, 1912)	Ascidiidae	Arctic coast to Alask. Penin. & SE Alaska
Botrylloides	violaceus	Oka, 1927	Styelidae	PWS: Tatitlek
Chelyosoma	productum	Stimpson, 1864	Corellidae	PWS: Tatitlek; Sitka Sound:Passage Is.
Corella	willmeriana	Herdman, 1898	Corellidae	PWS: Cordova, Valdez
Corella	inflata	Huntsman, 1912	Corellidae	PWS: Tatitlek, Cordova, Valdez, Chenega
Distaplia	new sp.		Holozoidae	Cook Inlet: Homer Marina; PWS: Cordova Marina
Distaplia	occidentalis	Bancroft, 1899	Holozoidae	PWS: Cordova Marina; Chichagof Is.
Halocynthia	igaboja	Oka, 1906	Pyuridae	Gulf of Alaska: Kodiak Is.;Chichagof Is.; PWS: Tatitlek; Prince Rupert BC
Molgula	retortiformis	Verrill, 1871	Molgulidae	SE Bering Sea to Sitka; Canoe Bay; SE Chukchi Sea; Homer Marina
Pyura	haustor	(Stimpson, 1864)	Pyuridae	Alaska Gulf:Sanak Is., Shumagin Is.; Sitka Sound:Alice Is.; PWS: Tatitlek
Styela	truncata	Ritter, 1901	Styelidae	Yakutat Bay; Cook Inlet: Homer Marina; PWS: Cordova Marina

9D. Fouling Community Surveys

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9D1. Purpose

Fouling communities in many bays, harbors and estuaries are frequently invaded by NIS associated with shipping traffic (Cohen & Carlton 1995, Hewitt 1993, Coles et al. 1999). Fouling communities have major impact on ships and floating structures, ranging from buoys and floats to aquaculture pens and nets, as well as surfaces of oysters and mussels themselves. Consequently, fouling communities are well-studied in many parts of the world, but they have received little study in Alaskan waters. We conducted surveys of fouling communities in Prince William Sound, Seward and Homer using experimental fouling plates. The use of fouling plates provides a replicated standardized assay for NIS in a community that is prone to invasions, but which has received little prior ecological analysis in Alaska. We also surveyed fouling communities on floats, pilings, and buoys to compare these substrates with our experimental plates.

9D2. Methods

We conducted two surveys that focused on fouling communities that settled on natural surfaces and experimental plates, which we deployed in earlier spring months at an array of sites in Homer, Seward and Prince William Sound. We sampled these fouling plates in 7-17 September 1998 and in 8-16 August 1999.

The team for the fouling community surveys consisted of:

- Greg Ruiz (SERC), molluscs, parasites, fouling communities;
- Anson Hines (SERC), barnacles and decapod crustaceans;
- James Carlton (Mystic Seaport), marine/estuarine invertebrates and global NIS
- Melissa Frey (SERC); technical and field assistance
- George Smith (SERC); technical and field assistance
- Lea Ann Henry (University of Ontario??), hydroid identifications;
- Judy Winston (Virginia Museum of Natural History), bryozoan identifications.

We deployed arrays of fouling plates at 12 locations, including 2 on the Kenai Peninsula (Homer, Seward) and 10 in Prince William Sound (Table 9D.1). At each site we deployed 5 arrays suspended at depths of either 1 meter (3 arrays) or 3 meters (2 arrays) below mean low water level. Each array consisted of settling plates attached to a frame made of 2 crossed pieces of pvc pipe (20 mm diameter, 50 cm long), which was suspended in a horizontal position by a line attached to a dock or float and weighted by a concrete block. Settling plates made of 14 cm x 14 cm x 7 mm thick pvc (3 plates) or plywood (1 plate) were attached to each of the 4 ends of the cross in a horizontal position. The horizontal orientation assured that sediment would not accumulate on the underside, providing a clean surface addition to several irregular surfaces of the frame and top surfaces for settlement. To maximize the chance of detecting possible NIS within each site, the 5 arrays were dispersed as widely as possible to sample the range of microhabitats present. We deployed the plates during April-May of each year and retrieved them in August-September, providing a “soak time” of about 4 months.

Table 9D.1. Sampling Locations for Fouling Community Surveys.

Site	1998	1999
Kenai Sites		
Homer	X	X
Seward	X	X
Prince William Sound		
Port Valdez		
Marine Terminal	X	X
Valdez Area	X	X
Growler Island	X	
Whittier	X	
Chenega	X	
Port Chalmers	X	
Fairmont Bay		X
Tatitlek		
Oyster Culture		X
Docks		X
Cordova		X

At the time of retrieving the arrays, the fouling plates were removed from their frame and placed individually into ziplock plastic bags for transport to a laboratory. Each plate was examined under a dissecting microscope and sessile and motile species were scored as present or absent. Voucher specimens were preserved and sent to taxonomic experts for authoritative identification. At the present stage of this project, we have used the fouling plates to develop an inventory of species. However, using this technique, the occurrence and abundance of species can be quantified and compared statistically for frequency of plates with species present. This type of comparison will proceed in new work during 2000 and 2001 as we sample other locations in Alaska and the major ports of western North America along the lower 48 states.

9D3. Results

During the soak time of ca. 4 months, the fouling plates accumulated dense community assemblages with large biomasses of mussels, barnacles, ascidians, hydroids, and bryozoans (Table 9.D.2). The fouling communities were rich in species, particularly for bryozoans, hydroids, nudibranchs, and ascidians Combining the 2 years of study across the12 sampling locations, we recorded more than 107 taxa/species on the fouling plates (Table 9D.2), including: 8 families of polychaete worms, 13 species of acidians, 34 species of bryozoans, 1 species of sea anemone, 3 species of barnacle and 13 taxa of motile crustacea, 2 species of echinoderms, 12 species of hydroids, 29+ taxa of molluscs, and 1 species of protozoan. Diversity of hydroids was particularly high at Homer (11 species). Byozoans were most diverse at Chenega (10 species), Homer (13 species), Port Valdez (14 species), and Tatilek (13 species). Acidians were most diverse at Homer (6 species) and Cordova (6 species).

Table 9D.2. Taxa Recovered on Fouling Plates. Asterisk denotes NIS. x denotes presence in 1998 and or 1999. Site Key: AL=Alyeska terminal; CH=Chenega Bay; GR=Growler Isl.; HO=Homer, MI=Montague Isl.; SE=Seward;VA=Port Valdez; WH=Whittier; CORD=Cordova; FRMNT=Fairmount Bay; PTOPT=Potato Pt. TAT=Tatitlek

		Site											
		AL	**CH**	**GR**	**HO**	**MI**	**SE**	**VA**	**WH**	**CORD**	**FRMNT**	**PTOPT**	**TAT**
Protozoan	*Foliculina*	x	x		x		x	x	x	x	x		x

		AL	**CH**	**GR**	**HO**	**MI**	**SE**	**VA**	**WH**	**CORD**	**FRMNT**	**PTOPT**	**TAT**
Cnidaria	*Metridium senile*				x								
	Metridium sp.	x			x				x				

		AL	**CH**	**GR**	**HO**	**MI**	**SE**	**VA**	**WH**	**CORD**	**FRMNT**	**PTOPT**	**TAT**
Hydroids	*Calycella syringa*				x								
	Clytia hemispherca				x								
	Clytia kincaidi									x			
	Companulina rugosa				x								
*	*Garveia franciscana*				x								
	Gonoththyraea clarki				x		x			x	x		
	Obelia longissima		x	x	x		x	x		x	x		x
	Obelia sp.	x	x	x	x	x	x	x	x				
	Opercularella lacerata				x								
	Sarsia eximia				x								
	Sarsia tubulosa				x								
	Sertularia robusta				x								

		AL	**CH**	**GR**	**HO**	**MI**	**SE**	**VA**	**WH**	**CORD**	**FRMNT**	**PTOPT**	**TAT**
Annelida	Capitellidae	x				x		x		x			
	Cirratulidae				x					x			
	Nereidae	x	x	x	x	x	x	x	x		x		
	Polynoidae	x	x	x	x	x			x	x	x		x
	Sabellidae									x	x		x
	Serpulidae	x	x	x	x	x		x	x	x	x		x
	Spirorbidae	x	x	x	x	x	x	x	x	x	x		x
	Syllidae	x		x		x				x	x		x
	Terebellidae									x			

		AL	**CH**	**GR**	**HO**	**MI**	**SE**	**VA**	**WH**	**CORD**	**FRMNT**	**PTOPT**	**TAT**
Mollusca	*Acanthodoris sp.*					x							
	Acmaeidae					x							
	Aelolididae						x						
	Alvania sp.	x	x			x				x			x
	Chlamys sp.	x						x					x
	Clinocardium sp.				x								
	Dendronotus frondosus						x	x					
	Dendronotus sp				x						x		
	Fusitron oregonensis	x											
	Haminoea sp.	x							x				x
	Hermissenda sp.	x	x	x		x	x	x	x	x	x		x
	Hiatella arcitca	x	x	x	x	x	x	x	x	x	x		x
	Hinnites sp.	x											
	Lacuna sp.		x	x		x							x
	Lacuna vincta												x
	Limacina helicina							x					

Table 9D.2. Continued

		AL	CH	GR	HO	MI	SE	VA	WH	CORD	FRMNT	PTOPT	TAT
Mollusca cont.	*Lottia sp.*									x			
	Margarites helinicus												x
	Margarites pupillis	x			x								
	Mytilus trossulus				x		x						
	Mytilus sp.	x	x	x	x	x	x	x	x	x	x	x	x
	Odostomia sp.		x	x		x		x					
	Onchidoris sp.							x		x	x		x
	Onchidoris murricata	x						x					
	Onchidoris sp.	x	x	x	x			x	x				
	Pododesma macroshisma									x			
	Pododesmus sp.	x						x					
	Sacoglossan sp.			x						x			
	Tritonia sp.		x										
	Vilisina vernicosa												x

		AL	CH	GR	HO	MI	SE	VA	WH	CORD	FRMNT	PTOPT	TAT
Crustacea	*Ampithoe sp.*					x							
	Balanus cariosus		x	x		x		x		x		x	x
	Balanus crenatus	x	x	x	x	x	x	x	x	x	x	x	x
	Semibalanus carriosus	x									x		x
	Cancer magister						x	x					
	Caprellidae		x	x		x				x	x		x
	Corophium sp.	x							x		x		x
	Eogammarus sp.	x											
	Gnorimosphaeroma oregonense	x				x	x	x	x				
	Harpacticus uniramus						x						
	Jassa sp.		x			x							
	Munna sp.		x										
	Oregonia gracilis				x								
	Scyra acutifems				x								
	Spirontocaris sp.		x										

		AL	CH	GR	HO	MI	SE	VA	WH	CORD	FRMNT	PTOPT	TAT
Bryozoa	*Alcyonidium sp.*	x			x	x				x	x		x
	Alcyonidium hirsutum										x		x
	Bugula californica				x					x			
	Bugula pacifica				x		x	x					
	Bugula sp.	x	x		x		x	x	x	x			x
	Calloporella craticula							x			x		x
	Calloporella "lineata"		x										
	Cauloramphus pseudospinifer						x						
	Celleporella hyalina		x		x		x	x			x		x
	Cribrilina sp.	x	x										
	Cribrilina corbicula		x		x			x	x	x			x
	Cribrilina sp.	x	x		x			x		x	x		x
	Crisia serrulata		x										
	Cryptosula okadai						x						
	Electra sp.		x		x	x							
	Fenestruloides eopacifica							x					x
	Filicrisia franciscana							x		x			x
	Harmeria scutulata							x					
	Hippothoa sp.		x		x			x					
	Lichenopora sp.		x										

Table 9D.2. continued

		AL	CH	GR	HO	MI	SE	VA	WH	CORD	FRMNT	PTOPT	TAT
Bryozoa cont.	*Membranipora menbrenacea*				x								
	Membranipora sp.											x	x
	Microporella germana							x					
	Parasmittina trispinosa	x											
	Phidolopora pacifica							x					x
	Porella major	x						x					
	Rhamphostomella gigantea				x								
	Rhamphostomella hincksi	x											
*	*Schizoporella "unicornis"*												x
	Tegella armifera								x				
	Tegella aquilirostris				x								
	Tubulipora tuba	x						x					x
	Tubulipora sp.										x		

		AL	CH	GR	HO	MI	SE	VA	WH	CORD	FRMNT	PTOPT	TAT
Echino-dermata	*Psolus sp.*				x								
	Strongylocentrotus sp.								x				x

		AL	CH	GR	HO	MI	SE	VA	WH	CORD	FRMNT	PTOPT	TAT
Ascidia	*Ascidia sp.*								x				
	Ascidia callosa			x	x					x			
	Ascidia columbiana							x			x		x
*	*Botrylloides violaceus*												x
	Corella sp.	x	x		x								
	Corella inflata	x	x							x			x
	Corella willmariana	x						x					
	Distaplia sp. (new)				x					x			
	Distaplia alaskensis				x								x
	Molgula retortiformis				x								
	Molgula sp.				x					x			
	Ritterella sp.				x			x		x			
	Styela truncata									x			

Among these species, there were 3 NIS: the ascidean *Botrylloides violaceus*, the bryozoan *Schizoporella unicornis*, and the hydroid *Garvieia franciscana*. These are the first records for two of these species (*B. violaceus* and *G. franciscana*) in Alaska. *Botrylloides violaceus* (=*Botryllus aurantius* is a colonial tunicate that is native to the northwest Pacific (Japan), and may have been first found on the West Coast in 1973, in San Francisco Bay (Cohen and Carlton 1995). It is now widespread, from southern California to British Columbia (Cohen et al. 1998; Lambert and Lambert 1998). *B. violaceus* was abundant on fouling plates in Prince William Sound in 1999 (G. Lambert 1999 pers. comm.). *Schizoporella unicornis* is a bryozoan found in the northwest Pacific but was first collected in the Eastern Pacific in 1927, in Puget Sound (Carlton 1979; Cohen and Carlton 1995). Its first Alaska collection was made between 1944 and 1949, in Kodiak (U. S. Navy 1951; Carlton, pers. comm.). *Schizoporella unicornis* may have been introduced in ship fouling or with plantings of Pacific Oysters (Cohen and Carlton 1995). In 1999, it was found in Tatilek. This form, while definitely introduced to the Pacific coast, may actually be a complex of several species (Winston 1999 pers. comm.). *Garveia franciscana* (Rope Grass Hydroid) has been found in many estuaries around the world, but its origin is uncertain. The Indo-Pacific and the Black--Caspian Sea basin have been suggested as possible native regions (Cohen and Carlton 1995; Calder 1997 pers. comm.) It was first described from San Francisco Bay in 1902, which was its only known location on the west coast of North America (Cohen and Carlton 1995), until we found it near Homer in 1999 (Lea-Anne Henry pers. comm. 1999). In other regions of the world, this hydroid has been an economically important fouling organism, adversely affecting ships, power plants and fishing gear (Simkina 1963; Andrews 1973; McLean 1972). In addition, fouling plates at Homer and Cordova had large biomasses of the new/undescribed ascidian, *Distaplia* sp. nov, which has many suspicious characteristics of NIS. *Diastaplia* sp. nov. is a new, undescribed species of tunicate, which is very abundant in fouling communities on floats and man-made substrates in marinas at Homer and Cordova. It was first collected in 1998 in Homer and was found in both Homer and Cordova in 1999. It was not found at other sites within Prince William Sound where other, native species of tunicate were common in fouling communities but lack similar shipping/boating traffic (e.g., Tatitlek, Chenega, Port Chalmers). Its appearance is also suspicious, because it was not found in 1901 when tunicates were collected in the region at nearby sites. This tunicate could be a formerly rare native species that has taken advantage of the newly created marina habitat, or a recent introduction (G. Lambert 1999 pers. comm.).

Fouling communities on the plates suspended at 1m depth were greatly diminished at Seward, Whittier and Port Valdez during the summer, when snow and glacial melt produced markedly low salinities in the surface waters and also thick sediment deposits that covered the plates. Fouling plate arrays at 3 m depth in these locations experienced higher salinities, but still suffered from heavy sediment deposits. It was evident, however, that these plates had developed rich fouling communities prior to the summer season of greatest freshwater runoff and siltation.

Species composition of fouling communities on the experimental plates were generally quite similar to the composition on surrounding surfaces (floats, pilings, lines, oysters, etc) at comparable tidal levels. Since the arrays were suspended below mean low water, the main groups of specie s that the plates did not sample adequately were species on pilings in the intertidal zone, such as *Balanus glandula*, *Semibalanus balanoides*, and various species of acmaeid limpets.

Chapter 9E. Re-Examination of Museum, Reference, and Voucher Specimens

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9E1. Purpose

As a result of environmental assessment work in Port Valdez during the 1970's for construction of the Valdez Marine Terminal, and the Exxon Valdez oil spill (EVOS), a large ecological database exists for Prince William Sound. Through a careful scrutiny of both the species lists and specimens archived in museum, reference and voucher collections for the past work, this part of our study was intended to test the idea that this extensive prior work in Prince William Sound should have detected NIS. However, in spite of the amount of sampling done in Prince William Sound, some species lists were developed without input from taxonomic experts, so that the biota is still poorly known. Few prior surveys have focused on biogeography or taxonomy, and until this study, none has specifically looked for NIS.

9E2. Methods

Literature sources for Prince William Sound invertebrates include:

- Reports on marine fauna of the northeastern Gulf of Alaska, compiled as a result of the Outer Continental Shelf Environmental Assessment Project (OCSEAP);(Feder and Matheke, 1980; Feder and Jewett, 1988);
- Thesis by M. Hoberg (1986);
- Project reports on the Port Valdez environment (Cooney and Coyle, 1988; Feder et al., 1976; Feder and Bryson-Schwafel, 1988; Feder and Keiser, 1980; Jewett and Feder, 1977);
- Eyerdam's (1924) species lists;
- Haven (1971); and
- Several taxonomic references (Butler, 1980; Hart, 1982; Lambert, 1981; 1991; Behrens, 1991 and others) for additional distribution records in Alaskan waters.

A vast array of preserved biological samples from Prince William Sound and adjacent Gulf of Alaska are housed in the Aquatic Collection of the University of Alaska Museum (UAM). The major part of these are collections made as part of the OCSEAP projects in the mid-1970's, environmental monitoring of Port Valdez, and Max Hoberg's thesis material from three bays in the outer part of the Sound. Intertidal and benthic biota from the soft bottom communities of Prince William Sound are well represented in the collection. Species lists for this material were generated using the museum accession records.

<u>EVOS Specimen Archives</u>

The specimens collected as part environmental surveys after the 1989 Exxon Valdez oil spill supplement the UAM collection. Subtidal invertebrates in 1,154 lots have been transferred to the UAM from warehouse storage for examination. These represent sampling conducted during 1990, 1991, 1993, and 1995, from 15 selected unoiled sites. The collections provide samples of shallow subtidal fauna from silled fjords, eelgrass beds, and habitats dominated by *Laminaria*. With limited resources, each specimen from this large number of samples cannot be examined individually, so it has been necessary to select subset of specimens for careful re-examination.

The subset of reference and voucher specimens examined as part of this study was selected by first compiling a list of 88 invertebrate taxa by comparing the lists of known taxa from Prince William Sound (discussed above) with lists of known NIS from west coast source ports: Puget Sound, San Francisco Bay, southern California, and other localities (see Ruiz & Hines, 1997). This compilation of 88 species includes:

- species that may be confused with known NIS in Alaska;
- NIS known from western North America (especially those extending to higher latitudes);
- taxonomically difficult species and species complexes;
- biogeographic outliers; and
- range extensions.

For example, polychaete specimens of most *Boccardia* and *Polydora*, were removed for re-examination because for their resemblance to *Polydora ligni*. Similarly, capitellid and many syllid polychaetes were selected to check for the presence of *Barontolla americana*, *Capitella capitata*, and *Decamastus* spp. The gastropod slipper shell *Crepidula* was partitioned from the collections to check for *Crepidula fornicata* and *C. plana*. Specimens of the amphipod *Corophuim* were selected to check for several NIS *Corophium* reported from Puget Sound. This original list was considered a working document and has been refined as the project has progressed (Table 9.E.1).

Table 9.E.1. Museum and Reference Samples Selected for Re-Examination

Family	Genus	Species	Specimen Source
Amphitoidae	Amphitoe	sp.	Jewett samples
Amphitoidae	Amphitoe	simulans	Jewett samples
Corophidae	Corophium	sp.	Jewett samples
Corophidae	Corophium	brevis	Jewett samples
Gammaridae	Melita	sp.	UAM uncataloged
Gammaridae	Gammarus	sp.	Jewett samples
Gammaridae	Jassa	sp.	Jewett samples
Gammaridae	Melita	dentata	UAM uncataloged
Cardiidae	Clinocardium	fucanum	Jewett samples
Glycymeridae	Glycymeris	septentrionalis	Jewett samples
Kelliidae	Pseudopythina*	compressa	Jewett samples
Kelliidae	Pseudopythina*	rugifera*	Jewett samples
Mytilidae	Dacrydium	vitreum*	Jewett samples
Mytilidae	Dacrydium	pacificum*	UAM cataloged
Ungulinidae	Diplodonta	orbella	Port Valdez uncataloged
Ungulinidae	Diplodonta	impolita	UAM cataloged
	Adontorhina	sp.	Jewett samples
	Cryptosula	okaidai	Jewett samples
Atyidae	Haminoea	virescens	Little Green Island
Atyidae	Haminoea	vesicula	PWS 98 samples
Atyidae	Haminoea	sp.	Jewett samples
Calyptraeidae	Crepidula	dorsata*	Jewett samples
Calyptraeidae	Crepidula	sp.	Jewett samples
Calyptraeidae	Crepidula	grandis	Jewett samples
Calyptraeidae	Crepidula	sp.	Jewett samples
Diaphanidae	Diaphana	minuta*	Jewett samples

Table 9.E.1. Continued

Diaphanidae	Diaphana	brunnea	Jewett samples
Diaphanidae	Diaphana	sp.	UAM cataloged
Fissurellidae	Puncturella	cooperi*	Jewett samples
Lacunidae	Lacuna	sp.	UAM cataloged
Lacunidae	Lacuna	vincta*	Jewett samples
Lacunidae	Lacuna	variegata*	UAM cataloged
Lacunidae	Lacuna	marmorata*	UAM cataloged
Lamellariidae	Velutina	sp.	UAM cataloged
Rissoidae	Barleeia	acuta*	Jewett samples
Scaphandridae	Cylichna	alba	UAM cataloged
Scaphandridae	Cylichna	occulta	UAM cataloged
Scaphandridae	Cylichna	sp.	UAM cataloged
Scaphandridae	Cylichna	attonsa	Jewett samples
Scaphandridae	Cylichnella	culcitella	Jewett samples
Scaphandridae	Cylichnella	harpa	Jewett samples
Scaphandridae	Cylichnella	sp.	Jewett samples
Turridae	Kurtziella	plumbea	Jewett samples
Turridae	Taranis	strongi	Jewett samples
Limnoriidae	Limnoria	lignorum	Jewett samples
Limnoriidae	Limnoria ?		Jewett samples
Capitellidae	Barantolla	americana	Jewett samples
Capitellidae	Barantolla	sp.	Jewett samples
Capitellidae	Capitella	sp.	Jewett samples
Capitellidae	Capitella	capitata	Jewett samples
Capitellidae	Decamastus	sp.	Jewett samples
Capitellidae	Decamastus	sp.	Jewett samples
Capitellidae	Heteromastus	sp.	Jewett samples
Capitellidae	Heteromastus	filliformis	Jewett samples
Capitellidae	Mediomastus	sp.	Jewett samples
Capitellidae	Notomastus	sp.	Jewett samples
Nereidae	Platynereis	bicanaliculata	Jewett samples
Polynoidae	Harmothoe	imbricata	Jewett samples
Spionidae	Malacoceros	sp.	Jewett samples
Spionidae	Nerine	cirratulus	Jewett samples
Spionidae	Polydora	sp.	Jewett samples
Spionidae	Polydora	cf P.bracycephalata	Jewett samples
Spionidae	Polydora	socialis	Jewett samples
Spionidae	Prionospio	cirrifera	Jewett samples
Spionidae	Prionospio	sp.	Jewett samples
Spionidae	Prionospio	steenstrupi	Jewett samples
Spionidae	Prionospoi	malmgreni	Jewett samples
Spionidae	Pygospio	sp.	Jewett samples
Spionidae	Pygospio	elegans	Jewett samples
Spionidae	Rhynchospio	glutaeus	Jewett samples
Spionidae	Scolelepis	sp.	Jewett samples
Spionidae	Scolelepis	squamata	Jewett samples
Spionidae	Spio	cirrifera	Jewett samples
Spionidae	Spio	fillicornis	Jewett samples
Spionidae	Spio	sp.	Jewett samples
Spionidae	Spiophanes	berkeleyorum	Jewett samples
Spionidae	Spiophanes	bombyx	Jewett samples
Spionidae	Spiophanes	sp.	Jewett samples

Table 9.E.1. Continued

Spionidae	Sternapsis	scutata	Jewett samples
Syllidae	Typosyllis	armillaris	UAM uncataloged
Syllidae	Typosyllis	fasciata	Jewett samples
Syllidae	Typosyllis	harti	UAM uncataoged
Syllidae	Typosyllis	sp.	UAM uncataoged Jewett samples

Biological Technician Max Hoberg (UAF) used the suspect list to remove 1,154 specimens for screening: 154 crustaceans, 1081 polychaetes, 307 molluscs, 30 bryozoans. From these, specimens in the best condition were removed for further study. Thirty-five small crustacea were loaned to focal taxonomic expert J. Chapman (OSU), and similarly polychaete specimens were loaned to focal taxonomic expert J. Kudenov (UA Anchorage). Analyses of these specimens (presently on-going) will be reported in the 2000 final report for the University of Alaska Sea Grant.

9E3. Results

Mollusc Taxa, including One Known NIS

Most east Pacific records of the soft shell clam, *Mya arenaria*, are the result of its accidental introduction along with Atlantic oysters, starting in San Francisco Bay in 1869, and Puget Sound in 1888 or 1889. We found that the clam was abundant in mud sediments in Cordova. We also found it in Port Valdez, Tatitlek, Constantine Harbor, Homer and Seward. *Mya arenaria* is also documented in Alaska from Nunivak Island, Norton Sound, and Kodiak Island (UAM collection records) as well as southeastern Alaska.

Nora Foster examined mollusc specimens from both the EVOS specimens and cataloged and uncataloged specimens the UA Museum, selecting the following taxa for re-examination:

- small venerids and *Turtonia*, were examined as possibly misidentified specimens of potential NIS *Protamcorbicula amurensis*, *Venerupsis philipinarium*, or *Nuttalia obscurata*;
- small individuals of *Musuculus* spp. were reexamined as possibly misidentified specimens of the potential NIS *Musculista stenhousei*;
- Cerithiidae were re-examined were reexamined as possibly misidentified specimens of the potential NIS *Battilaria*;
- *Ocenibrina* were reexamined as possibly misidentified specimens of the potential NIS *Urosalpinx cineria* and *Ocenebra inornata*, two introduced oyster drills; and
- *Crepidula* specimens were reexamined as possibly misidentified specimens of the potential NIS *Crepidula fornicata*.

None of these potential NIS taxa were found. However, to date it has been possible to examine carefully only a small subsample of the collections, and we are faced with the situation of there being too many samples and too little time.

University of Alaska Sea Grant funding for this analysis of existing museum and reference collections continues until June 30, 2000. The goals for this remaining time frame are to:

- Incorporate information from additional taxonomic experts and ecologists.

- Check database against additional grey literature sources (e.g., O'Clair & Zimerman,1987).
- Add to the database a biogeographical descriptor, indicating whether the PWS record represents a range extension, and a reference source for the animal's distribution.
- Publish with J. Goddard an analysis of our 1999 collections of opisthobranch molluscs of Prince William Sound (see also focal taxonomic subsection 9C8 Opisthobranch Molluscs, above).
- Incorporate of additional specimens collected as part of this assessment of EVOS collections into the UAM Aquatic Collection.

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Chapter 10. Biodiversity of Prince William Sound

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10A. Summary

Basic taxonomic, biogeographic, and habitat information for 1876 species of marine plants and animals of Prince William Sound were compiled into structured data sets. This species inventory is intended as a baseline from which biodiversity responses to future environmental changes can be assessed measured. The data sets include 39 possibly undescribed species, 89 range extensions, and 17 nonindigenous species. Two hundred thirty-one marine plant species, mostly algae, are present. Twenty invertebrate phyla are represented, and Annelida, Mollusca, and Crustacea account for over 60% of the invertebrates. Vertebrates include 175 fish, 14 mammal, and 113 bird species. The fauna and flora of Prince William Sound is a mixture of species with biogeographic affinities that overlap the northeastern and northwestern Pacific as well as the Arctic and Atlantic regions.

10B. Purpose

A single inventory of Prince William Sound biodiversity is currently lacking. This gap in taxonomic and biogeographic knowledge is an impediment to efforts to monitor environmental change, to understand the diversity of plant and animal life and to clarify biogeographic relationships among the living organisms in the rich waters of Prince William Sound and the adjacent shelf of the northern Gulf of Alaska. (Hines et al. 2000) The purpose of this report is to compile a database for the plant and animal species of Prince William Sound. The project is one component of a research project on potential introductions of nonindigenous species into Prince William Sound, especially through the discharge of ballast water from oil tankers traveling into Port Valdez. Annotated species lists were developed for the project to help taxonomic experts establish a current baseline for the status of nonindigenous species in Prince William (Hines et al. 2000).

Working versions of the data sets were compiled by M. Fry and expanded by N. Foster with assistance by M. Hoberg, and review by K. Coyle (zooplankton), J. Goddard (opisthobranch gastropods), J. Kudenov (polychaete annelids), G. Lambert (urochordates), P. Lambert (echinoderms), C. Mecklenberg (fishes), C. Mills (Cnidaria and Ctenophora), J. Norenburg (nemerteans) and others. Additional polychaete identifications were accomplished for this report by J. Kudenov. The draft versions of the data sets were included in the final project report (Hines et al. 2000).

10C. Scope

Taxonomic

The data sets list free-living macrophytes and animals . Protists and most endoparasites are outside the scope of the project.

Geographic

Prince William Sound waters are well-defined We have used literature and collecting records from Port Bainbridge east to Orca Inlet, and south and east to the outer coasts of

Montague and Hinchinbrook islands. However, for some taxa, (e.g. Bryozoa), the fauna of adjacent areas (northeastern Gulf of Alaska and Kodiak Island waters) are better documented and some records for those areas are included. Migratory birds and marine mammals that inhabit Prince William Sound waters seasonally are included in the data set. Planktonic Cnidaria and Crustacea from the northern Gulf of Alaska listed in the data sets occur in Prince William Sound rarely, with their presence dependent on oceanographic conditions.

10D. Methods

Literature sources

A large number of species included in the data sets are based on their listing in the environmental surveys of the Gulf of Alaska, Prince William Sound, and Port Valdez in the late 1970’s and early 80’s. We compiled species lists from Cooney et al. (1973) and Cooney and Coyle (1988):plankton, Feder et al. (1976):sediments, Feder and Bryson-Schwafel (1988):the intertidal zone, Feder and Jewett(1987):subtidal benthos, Feder and Keiser (1980):intertidal biology, Feder and Matheke (1980):benthic infauna, Feder et al. (1979):benthos of Resurrection and Aialik bays, Feder and Paul (1973):the intertidal zone, Feder and Paul (1980):Cook Inlet, Hoberg (1986):benthic infauna, Jewett and Feder (1977):Port Valdez, and Rogers et al. (1986):nearshore fishes.

Species names from field guides and taxonomic revisions of characteristic northeastern Pacific taxa have been added, for example Banse and Hobson (1968) (benthic errantiate polychaetes), Barnard (1969) (gammaridean amphipods), Butler (1980) (shrimp), Coan et al. (2000) (bivalve mollusks), Dick and Ross (1988) (Bryozoa), Lambert (1981, 1997) (sea stars and sea cucumbers), and Schultz (1969) (isopods). For detailed information on the geographical ranges, we have relied on the same taxonomic revisions and regional publications. However, this information in a consistent format has been difficult to obtain for many species. When specific reference to a species’ occurrence in Prince William Sound was not available, we used Austin (1985). We have also deleted inaccurate records that have crept into the literature, and have made changes in nomenclature based on reviews and taxonomic revisions accomplished after the environmental surveys mentioned above.

Biogeographic analyses presented here use conventions based on a global system developed by the World Conservation Union and described in Kelleher et al. (1995) (Figures 10.1 and 10.2). The biogeographic summaries are based on numbers of species for which we have confident identifications, leaving out unidentified or undescribed species. Some of the analyses exclude birds, because the migratory habits of some species fit poorly into the bioregional classification used for algae, invertebrates and fishes.

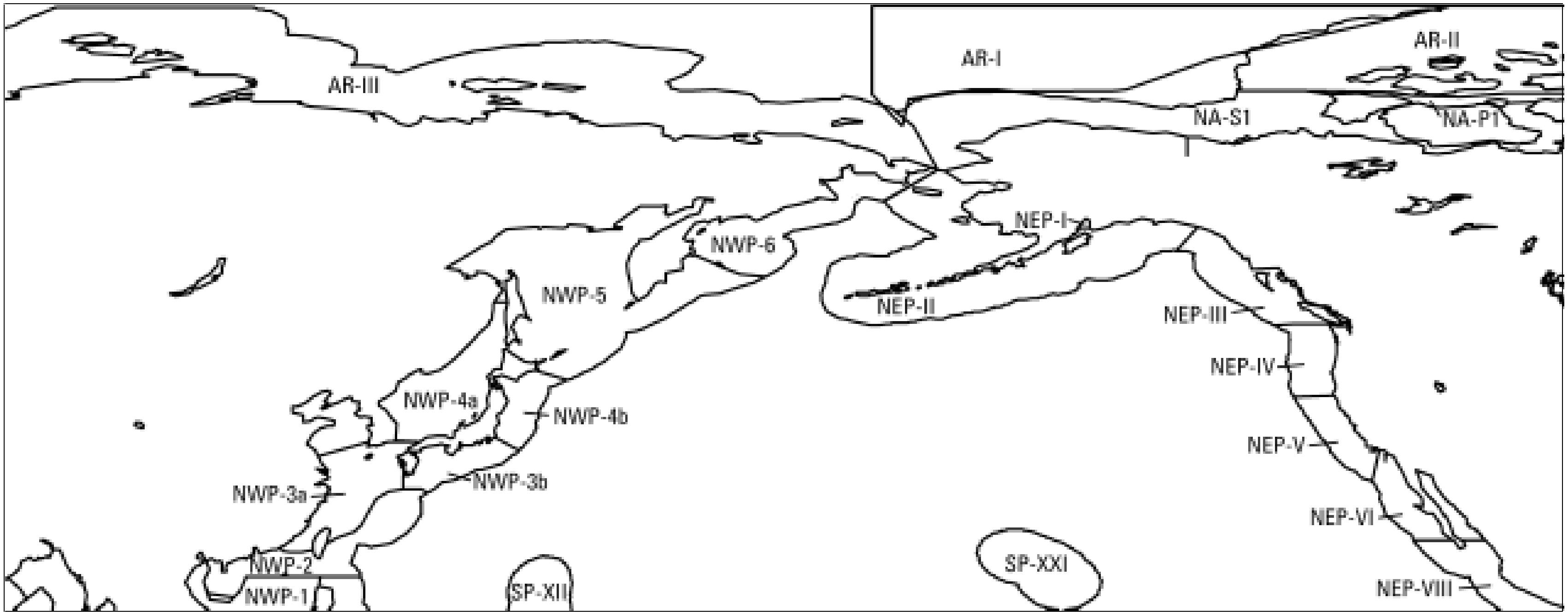

Figure 10.1. Biogeographic areas of the North Pacific.

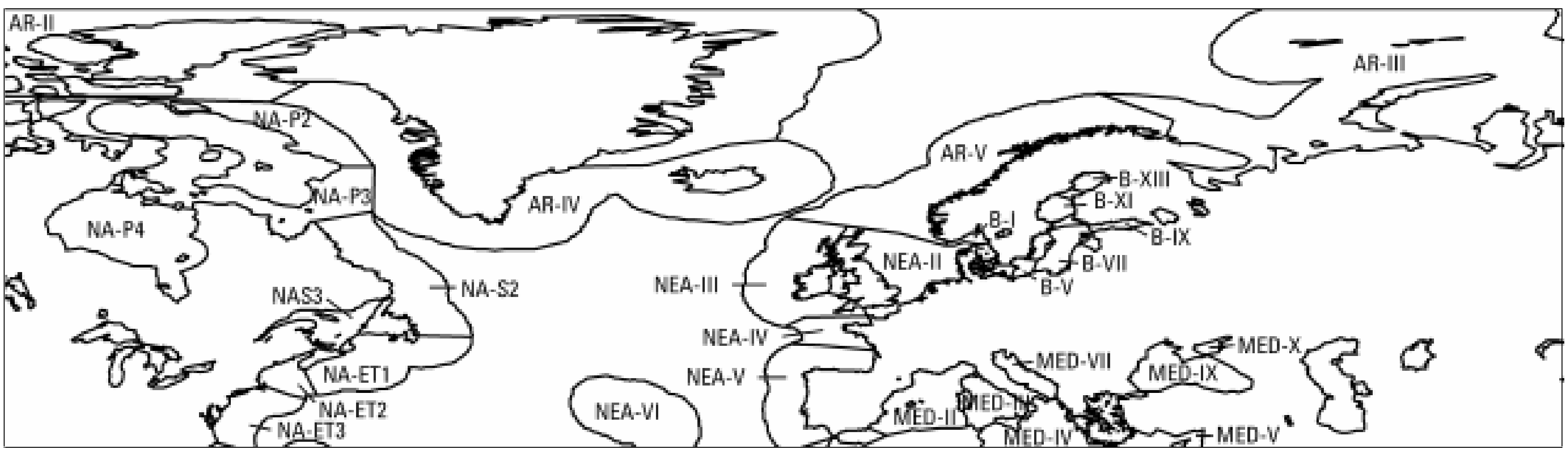

Figure 10.2. Biogeographic areas of the North Atlantic.

Specimens and observations

The second major source for names of Prince William Sound species is the collections of the University of Alaska Museum (UAM). Names of algae, mollusks, bryozoans, and fishes were entered from specimen catalogues. Voucher specimens for many of the species listed in the environmental studies are in the UAM Aquatic Collection, but may not be catalogued. A large number of specimens was also collected in 1990-1995 by Dr. Stephen Jewett as part of damage assessment after the 1989 Exxon Valdez oil spill. While not accessioned into the UAM, these specimens were available for this study . Each species entry should be traceable to a specimen identified to the species level by an expert. Citing specimens from other museum collections, however, goes beyond the scope of the project.

Rapid community assessments, focal taxonomic collections, and fouling plate surveys in Prince William Sound in 1998 and 1999 were intended to detect well-established nonindigenous species, especially in areas at risk for invasion (Hines and Ruiz 2000). Taxonomic experts who participated in the field work in Prince William Sound and the Kenai Peninsula contributed names and distribution information for marine plants (G. Hansen), Cnidaria and Ctenophora (C. Mills), opisthobranch gastropods (J. Goddard), polychaete annelids (J. Kudenov), Crustacea (J. Chapman and J. Cordell), Bryozoa (J. Winston), and urochordates (G. and C. Lambert).

Results

The data sets

The data sets comprising the bulk of this report are in the form of separate Excel™ worksheets for algae and vascular plants, Cnidaria and Ctenophora, Annelida, Mollusca, Arthropoda , Bryozoa, Echinodermata, miscellaneous invertebrate taxa, fishes, birds, mammals (Tables 10.1 – 10.11). Data are presented in tabular form, one species per row.

The following data fields, as columns, are common to all data sets:

- **Family, Genus, Species**
  An attempt has been made to use the currently accepted name

- **Other Name**
  The column contains family, genus or species names under which the taxon has appeared in the cited literature, museum catalogs, or specimens labels, which may not reflect revisions made in the past 20 years.

- A **Source** for the name
  UAM specimen available in the University of Alaska Museum Aquatic Collection
  EVOS specimen archived as part of Exxon Valdez oil spill damage assessment studies
  Other sources are in Literature Cited section of this report.

- **Habitat**
  For most invertebrates the following conventions are used:
  I intertidal Inf infauna P plankton
  ST subtidal Epi epifauna

Abbreviations used in the fish, bird and mammal sections will be given with the Summary Information for those taxa.

- **Bioregion**
  An "x" marks the presence of a species in the large scale bioregions: Northwestern Pacific (NWP), Arctic (AR), and Northeastern Atlantic (NWA) (Figures 1, 2). Occurrence of each species with in the northeastern Pacific bioregion is further designated by Roman numerals denoting a small scale bioregion (Figure 3).

- **Origin**
  For species that represent a new collecting record or nonindigenous species, "origin" indicates the area closest to Prince William Sound from which the species is likely to have spread.

- **NIS status**

nr	range extension within Alaska to Prince William Sound
NR	new record for Alaska
C	cryptogenic
definite	definite nonindigenous species
possible	likely a nonindigenous species

- **Reference to Distribution**
  Literature source for distributional information.

Summary information for major taxa

Marine Plants

Red, brown, and green algae account for over 90% of the 231 marine plants listed in the data set (Table 10.1). Ten taxa could not be determined to the species level. The non-vascular plant species lists is based on G. Hansen's (2000) report and cataloged UAM specimens. Records of Chrysophyta and Ascomycota are based on Feder and Keiser 1980, and Feder and Bryson-Schwafel 1988. Additional distribution information is derived from Scagel et al. 1986 and Lindstrom 1977. Ten vascular plants species are included. The surfgrasses and eelgrass are obvious vascular plants, but a few other species are included because of their presence in the upper intertidal and splash zones. Sources used are Scheel et al. 1997; Hulten 1968, and Hansen 2000. Hansen (2000) found 17 new distributional records for marine plants in Prince William Sound. There is one undescribed species, a *Coilodesme* and six species are possibly introduced.

Table 10.1. Marine plants.

PHYLUM	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	COMMUNITY	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Ascomycota	Verrucaricaea	*Verrucaria*	*mucosa*		Feder and Bryson-Schwafel 1988	I	II III IV	x		x		C	Hansen 2000
Ascomycota	Verrucaricaea	*Verrucaria*	*maura*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Chlorophyta	Acrosiphoniaceae	*Acrosiphonia*	*saxitilis*	*Spongomorpha*	Hansen 2000	I	II III IV	x					Hansen 2000
Chlorophyta	Acrosiphoniaceae	*Acrosiphonia*	*arcta*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Chlorophyta	Acrosiphoniaceae	*Acrosiphonia*	*coalita*		Hansen 2000	I	II III IV						Hansen 2000
Chlorophyta	Acrosiphoniaceae	*Urospora*	*penicilliformis ?*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Capsosiphonaceae	*Capsosiphon*	*fulvescens*		Hansen 2000	I	II III IV	x		x	BC	NR, C	Hansen 2000
Chlorophyta	Chlorocystidaceae	*Halochlorococcum*	*moorei*		Hansen 2000	I	II III IV	x		x	BC	NR, C	Hansen 2000
Chlorophyta	Cladophoraceae	*Chaetomorpha*	*capillaris/ cannabina*		Hansen 2000	I	II III IV	x		x			Hansen 2000
Chlorophyta	Cladophoraceae	*Chaetomorpha*	*recurva*		Hansen 2000	I	II III IV				WA	NR	Hansen 2000
Chlorophyta	Cladophoraceae	*Cladophora*	*sericea*	*C. gracilis*	Hansen 2000	I	II III IV			x		C	Hansen 2000
Chlorophyta	Cladophoraceae	*Cladophora*	*albida*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Chlorophyta	Cladophoraceae	*Cladophora*	*hutchinsiae*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Chlorophyta	Cladophoraceae	*Cladophora*	*stimpsonii*		Hansen 2000	I	II III IV						Hansen 2000
Chlorophyta	Cladophoraceae	*Rhizoclonium*	*implexum*	*R. implexum*	Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Cladophoraceae	*Rhizoclonium*	*riparium*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Cladophoraceae	*Rhizoclonium*	*tortuosum*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Codiaceae	*Codium*	*fragile* subsp. *fragile*		Hansen 2000	I	II III IV V VI				SE Alaska	nr	Hansen 2000
Chlorophyta	Codiaceae	*Codium*	*fragile* subsp. *tomentosoides ?fragile*		Hansen 2000	I	x	x	x	x	WA	probable	Hansen 2000
Chlorophyta	Collinsiellaceae	*Collinsiella*	*tuberculata*		Feder and Bryson-Schwafel 1988	I	II III IV						Scagel et al. 1986
Chlorophyta	Gayraliaceae	*Gayralia*	*oxyspermum*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Chlorophyta	Monostromataceae	*Monostroma*	*fractum*		Hansen 2000	I	II III IV				WA	NR	Hansen 2000
Chlorophyta	Monostromataceae	*Monostroma*	*grevillei/arcticum*	*M. arcticum*	Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Chlorophyta	Ulotrichaceae	*Ulothrix*	*flacca*	*U. pseudoflacca*	Feder and Bryson-Schwafel 1988	I	II III IV	x		x		C	Scagel et al. 1986
Chlorophyta	Ulotrichaceae	*Ulothrix*	*implexa* (non *flacca)*		Hansen 2000	I	II III IV		x	x		C	Scagel et al. 1986
Chlorophyta	Ulvaceae	*Blidingia*	*chadefauldi*		Hansen 2000	I	x	x		x		C	Hansen 2000
Chlorophyta	Ulvaceae	*Blidingia*	*marginata*		Hansen 2000	I	x	x	x	x	BC	NR, C	Hansen 2000
Chlorophyta	Ulvaceae	*Blidingia*	*minima*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Ulvaceae	*Blidingia*	*subsalsa*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Chlorophyta	Ulvaceae	*Enteromorpha*	*compressa*		Feder and Bryson-Schwafel 1988	I	x	x	x	x		C	Scagel et al. 1986
Chlorophyta	Ulvaceae	*Enteromorpha*	*clathrata*	*E. crinita*	Hansen 2000	I	x	x	x	x		C	Scagel et al. 1986
Chlorophyta	Ulvaceae	*Enteromorpha*	*intestinalis*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Ulvaceae	*Enteromorpha*	*linza*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Ulvaceae	*Enteromorpha*	*prolifera/torta*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Ulvaceae	*Kornmannia*	*leptoderma*		Hansen 2000	I/epilithic	II III IV	x		x	North Atlantic	NR, C	Hansen 2000

Table 10.1. Continued.

PHYLUM	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	COMMUNITY	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Chlorophyta	Ulvaceae	*Kornmannia*	*zostericola*		Hansen 2000	I/epiphytic	II III IV	x		x		C	Hansen 2000
Chlorophyta	Ulvaceae	*Ulva*	*fenestrata*	*U. lactuca*	Feder and Bryson-Schwafel 1988	I	II III IV	x					Scagel et al. 1986
Chlorophyta	Ulvaceae	*Ulva*	*fenestrata/expansa/ lactuca*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Chlorophyta	Ulvaceae	*Ulvaria*	*obscura*	*Monostroma fuscum*	Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Chlorophyta	Ulvellaceae	*Ulvella*	*setchelli*		Hansen 2000	I/epiphytic/endophytic	II III IV V VI	x				C	Hansen 2000
Chlorophyta	Cladophoraceae	*Percursaria*	*percursa*		Hansen 2000	brack/I	x	x	x	x		C	Hansen 2000
Cyanophyta		*Calothryx*	*crustacea*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Cyanophyta		*Rivularia*	*atra*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Phaeophyta	Alariaceae	*Alaria*	*prelonga/marginata*		Hansen 2000	I/ST	II III IV V	x					Hansen 2000
Phaeophyta	Alariaceae	*Alaria*	*taeniata/augusta/ crispa*		Hansen 2000	I/ST	II III IV	x					Hansen 2000
Phaeophyta	Alariaceae	*Alaria*	*tenuifolia/pylaii/ membranacea*		Hansen 2000	I/ST	II III IV	x					Hansen 2000
Phaeophyta	Chordaceae	*Chorda*	*filum*		Hansen 2000	I/ST	II III IV	x		x			Hansen 2000
Phaeophyta	Chordariacea	*Chordaria*	*flagelliformis*		Hansen 2000	I/ST	II III IV	x	x	x		C	Hansen 2000
Phaeophyta	Chordariacea	*Chordaria*	*gracilis*		Hansen 2000	I/ST	II III IV	x				C	Hansen 2000
Phaeophyta	Chordariaceae	*Eudesme*	*virescens*		Hansen 2000	I	II III IV	x		x			Hansen 2000
Phaeophyta	Chordariaceae	*Saundersella*	*simplex*		UAM	I/epiphytic	II III IV	x					Scagel et al. 1986
Phaeophyta	Coilodesmaceae	*Coilodesme*	*bulligera*	*C. polygnampta*	Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Phaeophyta	Coilodesmaceae	*Coilodesme*	*californica*		Hansen 2000	I/ST/ epiphytic	II III IV V VI						Hansen 2000
Phaeophyta	Coilodesmaceae	*Coilodesme*	undescribed		Hansen 2000	I	II III			x			Hansen 2000
Phaeophyta	Cystoseiraceae	*Cystoceria*	*germinata*		Hansen 2000	I/ST	II III IV	x					Hansen 2000
Phaeophyta	Desmarestiaceae	*Desmarestia*	*lingulata*		UAM	I/ST	II III IV V VI						Scagel et al. 1986
Phaeophyta	Desmarestiaceae	*Desmarestia*	*viridis*	*D. media*	UAM	I/ST	II III IV V VI	x		x		C	Scagel et al. 1986
Phaeophyta	Desmarestiaceae	*Desmarestia*	*viridis*		Hansen 2000	I/ST	II III IV V VI	x		x			Hansen 2000
Phaeophyta	Desmarestiaceae	*Desmarestia*	*aculeata*	*D. intermedia*	UAM	I/ST	II III IV	x		x		C	Hansen 2000
Phaeophyta	Dictyosiphonaceae	*Dictyosiphon*	*foeniculaceus*		Hansen 2000	I	II III IV		x	x		C	Hansen 2000
Phaeophyta	Dictyosiphonaceae	*Dictyosiphon*	*sinicola*		UAM	I	II III IV						Scagel et al. 1986
Phaeophyta	Ectocarpaceae	*Ectocarpus*	*parvus*		Hansen 2000	I	II III IV V VI						Hansen 2000
Phaeophyta	Ectocarpaceae	*Ectocarpus*	*siliculosus*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Phaeophyta	Ectocarpaceae	*Ectocarpus*	*acutus*		Hansen 2000	I	II III IV V				BC	nr	Hansen 2000
Phaeophyta	Ectocarpaceae	*Ectocarpus*	*dimorpha*	*E. dimorphus*	Hansen 2000	I	II III IV V				BC	nr	Hansen 2000
Phaeophyta	Ectocarpaceae	*Ectocarpus*	sp. *(Acinetospora?)*		Hansen 2000	I	II III IV V						Hansen 2000
Phaeophyta	Ectocarpaceae	*Pilayella*	*littoralis*		Hansen 2000	I	x	x	x	x			Hansen 2000

Table 10.1. Continued.

							BIOREGION						
PHYLUM	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	COMMUNITY	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Phaeophyta	Ectocarpaceae	*Pilayella*	*littoralis/ washingtoniensis*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Phaeophyta	Ectocarpaceae	*Pilayella*	unidentified		Hansen 2000	I/epiphytic	II						Hansen 2000
Phaeophyta	Ectocarpiaceae	*Spongonema*	*tomentosum*		Hansen 2000	I/epiphytic	II III IV V VI	x	x	x		C	Hansen 2000
Phaeophyta	Elachistaceae	*Elachista*	*fucicola*		Hansen 2000	I/epiphytic	II III IV V	x		x			Hansen 2000
Phaeophyta	Elachistaceae	*Elachista*	*lubrica*		Hansen 2000	I/epiphytic	II III		x	x			Hansen 2000
Phaeophyta	Fucaceae	*Fucus*	*gardneri/distichus/ evanensis*		Hansen 2000	I	II III IV V					C	Hansen 2000
Phaeophyta	Fucaceae	*Fucus*	*cottoni*		Hansen 2000	I	II III IV	x		x	North Atlantic	probable	Hansen 2000
Phaeophyta	Fucaceae	*Fucus*	*spiralis*		UAM	I	II III IV					C	Hansen 2000
Phaeophyta	Heterochordariaceae	*Analipus*	*japonicus*		UAM	I	II III IV V	x					Scagel et al. 1986
Phaeophyta	Laminariaceae	*Agarum*	*clathratum (cribrosum)*		Hansen 2000	ST	II III IV	x		x		C	Hansen 2000
Phaeophyta	Laminariaceae	*Costaria*	*costata*		Hansen 2000	I	II III IV	x					Hansen 2000
Phaeophyta	Laminariaceae	*Cymathere*	*triplicata*		Hansen 2000	ST	II III IV	x					Hansen 2000
Phaeophyta	Laminariaceae	*Hedophyllum*	*sessile*		UAM	I	II III IV V						Scagel et al. 1986
Phaeophyta	Laminariaceae	*Laminaria*	*groenlandica*		Feder and Bryson-Schwafel 1988	I/ST	II III IV						Scagel et al. 1986
Phaeophyta	Laminariaceae	*Laminaria*	*"groenlandica"/ bongardiana*		Hansen 2000	ST	II III IV	x	x				Hansen 2000
Phaeophyta	Laminariaceae	*Laminaria*	*dentigera*		UAM	ST	II III IV	x					Scagel et al. 1986
Phaeophyta	Laminariaceae	*Laminaria*	*longipes*		UAM	I/ST	II III IV	x					Scagel et al. 1986
Phaeophyta	Laminariaceae	*Laminaria*	*yezoensis*		Hansen 2000	I	II III IV	x					Hansen 2000
Phaeophyta	Laminariaceae	*Laminaria*	*saccharina*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Phaeophyta	Laminariaceae	*Pleurophycus*	*gardneri*		UAM	ST	II III IV V						Scagel et al. 1986
Phaeophyta	Leathesiaceae	*Leathesia*	*difformis*		Feder and Bryson-Schwafel 1988	I	x	x	x	x		C	Scagel et al. 1986
Phaeophyta	Leathesiaceae	*Leathesia*	*nana*		Hansen 2000	I	II III IV V VI						Hansen 2000
Phaeophyta	Lessoniaceae	*Macrocystis*	*integrifolia*		UAM	ST	II III IV V VI VII VIII IX				SE Alaska	definate	Hansen 2000
Phaeophyta	Lessoniaceae	*Nereocystis*	*leutkeana*		UAM	ST	II III IV V						Scagel et al. 1986
Phaeophyta	Punctariaceae	*Delamarea*	*attenuata*		Hansen 2000	I	II III IV	x		x	Commander Islands	NR, C	Hansen 2000
Phaeophyta	Punctariaceae	*Myelophycus*	*intestinalis*	*Melanosiphon*	Feder and Bryson-Schwafel 1988	I	II III IV	x		x		C	Scagel et al. 1986
Phaeophyta	Punctariaceae	*Punctaria*	*latifolia (Desmotrichium)*		Hansen 2000	ST	II III IV	x		x	SE Alaska	nr	Hansen 2000
Phaeophyta	Punctariaceae	*Punctaria*	*lobata*		Hansen 2000	E/ST/ epiphytic	II III IV						Hansen 2000
Phaeophyta	Punctariaceae	*Punctaria*	*plantagenea*		Hansen 2000	I	II III IV	x		x	Japan	NR, C	Hansen 2000

Table 10.1. Continued.

PHYLUM	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	COMMUNITY	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Phaeophyta	Punctariaceae	*Punctaria*	*tenuimissima*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Phaeophyta	Punctariaceae	*Soranthera*	*ulvoidea*		Hansen 2000	I	II III IV	x					Hansen 2000
Phaeophyta	Punctariaceae	*Soranthera*	*ulvoidea* f. *difformis*		Hansen 2000	I/epiphytic	II III IV	x					Hansen 2000
Phaeophyta	Ralfsiaceae	*Microspongium*	*globosum*		Hansen 2000	I/epiphytic	II III IV	x		x	Japan	probable	Hansen 2000
Phaeophyta	Ralfsiaceae	*Ralfsia*	*fungiformis*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Phaeophyta	Scytosiphonaceae	*Colpomenia*	*peregrina*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Phaeophyta	Scytosiphonaceae	*Colpomenia*	*bullosa*		Hansen 2000	I/epiphytic	II III IV	x					Hansen 2000
Phaeophyta	Scytosiphonaceae	*Petalonia*	*fascia*		Hansen 2000	I/ST	x	x	x	x			Hansen 2000
Phaeophyta	Scytosiphonaceae	*Scytosiphon*	*lomentaria*		Feder and Bryson-Schwafel 1988	I	x	x	x	x			Scagel et al. 1986
Phaeophyta	Scytosiphonaceae	*Scytosiphon*	*simplicissima*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Phaeophyta	Sphacelariaceae	*Sphacelaria*	*racemosa*		Hansen 2000	I/ST	II III IV	x		x		C	Hansen 2000
Phaeophyta	Sphacelariaceae	*Sphacelaria*	*rigidula*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Rhodophyta	Acrochaetiaceae	*Acrochaetium*	unidentified		UAM	I						C	
Rhodophyta	Acrochaetiaceae	*Audouienlla*	*membranaceum*	*Rhodochorton membranaceum*	UAM	I	x	x	x	x		C	Scagel et al. 1986
Rhodophyta	Acrochaetiaceae	*Audouinella*	*purpurea*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Rhodophyta	Bangiaceae	*Bangia*	*atropurpurea*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Rhodophyta	Bangiaceae	*Porphyra*	*cuneiformis*		Hansen 2000	I/ST	II III IV						Hansen 2000
Rhodophyta	Bangiaceae	*Porphyra*	*miniata*		Hansen 2000	I/ST	II III IV	x		x	Commander Islands	NR	Hansen 2000
Rhodophyta	Bangiaceae	*Porphyra*	*mumfordii*		Hansen 2000	I/ST	II III IV						Hansen 2000
Rhodophyta	Bangiaceae	*Porphyra*	*nereocystis*		Hansen 2000	ST/ epiphytic	II III IV						Hansen 2000
Rhodophyta	Bangiaceae	*Porphyra*	*perforata*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Bangiaceae	*Porphyra*	*purpureo-violacea?*		Hansen 2000	I/ST	II III IV	x		x	North Atlantic	NR, C	Hansen 2000
Rhodophyta	Bangiaceae	*Porphyra*	*rediviva*		Hansen 2000	I	II III IV				WA	NR	Hansen 2000
Rhodophyta	Bangiaceae	*Porphyra*	cf. *P. thuretti*		Feder and Bryson-Schwafel 1988	I	II III IV						Scagel et al. 1986
Rhodophyta	Bangiaceae	*Porphyra*	*torta/abbottae*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Ceramiaceae	*Antithamnion*	*dendroideum*		UAM	ST	II III IV V VI VII VIII IX						Scagel et al. 1986
Rhodophyta	Ceramiaceae	*Antithamnionella*	*pacifica*		Hansen 2000	ST/ epiphytic	II III IV						Hansen 2000
Rhodophyta	Ceramiaceae	*Antithamnionella*	*spiriographidis*		Hansen 2000	I	II III IV	x	x	x		C	Scagel et al. 1986
Rhodophyta	Ceramiaceae	*Callithamnion*	*acutum*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Ceramiaceae	*Callithamnion*	*pikeanum* v. *laxum*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Ceramiaceae	*Callithamnion*	*pikeanum* v. *pikeaum*		Hansen 2000	I	II III IV						Hansen 2000

Table 10.1. Continued.

							BIOREGION						
PHYLUM	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	COMMUNITY	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Rhodophyta	Ceramiaceae	*Callophyllis*	unidentified		Feder and Bryson-Schwafel 1988	I	II III IV						
Rhodophyta	Ceramiaceae	*Ceramium*	*gardneri*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Ceramiaceae	*Ceramium*	*pacificum/ washingtoniensis*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Ceramiaceae	*Ceramium*	*rubrum/kondoi*		Hansen 2000	I	x	x	x	x			Hansen 2000
Rhodophyta	Ceramiaceae	*Ceramium*	*cimbricum*		Hansen 2000	I	II III IV	x		x			Hansen 2000
Rhodophyta	Ceramiaceae	*Ceramium*	*sinicola ?*		Hansen 2000	I	II III IV				CA	probable	Hansen 2000
Rhodophyta	Ceramiaceae	*Ceramium*	*rubrum*		UAM	I	x	x	x	x			Scagel et al. 1986
Rhodophyta	Ceramiaceae	*Hollenbergia*	unidentified		UAM	I/ST							Scagel et al. 1986
Rhodophyta	Ceramiaceae	*Hollenbergia*	*subulata*		UAM	I/ST	II III IV V						Scagel et al. 1986
Rhodophyta	Ceramiaceae	*Microcladia*	*borealis*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Ceramiaceae	*Neoptilota*	*asplenioides*		Hansen 2000	I/ST	II III IV	x					Hansen 2000
Rhodophyta	Ceramiaceae	*Platythamnion*	*pectinatum*		Hansen 2000	ST	II III IV						Hansen 2000
Rhodophyta	Ceramiaceae	*Plenosporium*	cf. *P. vancouverianum*		Hansen 2000	ST	II III IV	x					Hansen 2000
Rhodophyta	Ceramiaceae	*Ptilota*	*serrata (* incl. *pectinata)*		Hansen 2000	I/ST	II III IV	x		x		C	Hansen 2000
Rhodophyta	Ceramiaceae	*Ptilota*	*californica*		UAM	I/ST	II III IV	x				C	Scagel et al. 1986
Rhodophyta	Ceramiaceae	*Ptilota*	*plumosa*	*P. p* v. *filicina*	UAM	I/ST	II III IV V VI	x				C	Abbott and Hollenberg 1976
Rhodophyta	Ceramiaceae	*Ptilota*	*filicina*	*P. tenuis*	Hansen 2000	I/ST	II III IV						Hansen 2000
Rhodophyta	Ceramiaceae	*Scagiella*	*americana*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Rhodophyta	Choreocolacaceae	*Leachiella*	*pacifica*		Hansen 2000	I	II III IV V VI	x					Hansen 2000
Rhodophyta	Cladophoraceae	*Chroodactylon*	*ramosus*		Hansen 2000	I	II III IV	x		x	CA	probable	Hansen 2000
Rhodophyta	Corallinaceae	*Bossiella*	*chiloensis*		UAM	I/ST	II III IV						Scagel et al. 1986
Rhodophyta	Corallinaceae	*Bossiella*	*cretacea*		UAM	I/ST	II III IV	x					Scagel et al. 1986
Rhodophyta	Corallinaceae	*Bossiella*	*plumosa*		UAM	I	II III IV						Scagel et al. 1986
Rhodophyta	Corallinaceae	*Calliarthron*	unidentified		UAM	I							Scagel et al. 1986
Rhodophyta	Corallinaceae	*Clathromorphum*	*reclinatum*			I/epiphytic	II III IV V VI	x					Scagel et al. 1986
Rhodophyta	Corallinaceae	*Corallina*	*frondescens*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Corallinaceae	*Corallina*	*officianalis* v. *chilensis*		Hansen 2000	I/ST	II III IV V VI VII VII VIII IX	x					Hansen 2000
Rhodophyta	Corallinaceae	*Corallina*	*vancouverensis*		UAM	I	II III IV						Scagel et al. 1986
Rhodophyta	Corallinaceae	*Lithophyllum*	*dispar*		Hansen 2000		II III IV						Hansen 2000
Rhodophyta	Corallinaceae	*Lithothamnion*	unidentified			I							Scagel et al. 1986
Rhodophyta	Corallinaceae	*Mesophyllum*	*lamellatum*		Scagel 1986	I	II III IV V VI						Scagel et al. 1986
Rhodophyta	Delesseriacaea	*Delesseria*	*decipiens*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Delesseriaceae	*Phycodrys*	*riggii*		Hansen 2000	I/ST	II III IV	x					Hansen 2000
Rhodophyta	Delesseriaceae	*Tokidadendron*	*kurilensis*	*T. bullata*	Hansen 2000	I	II III IV	x					Hansen 2000

Table 10.1. Continued.

PHYLUM	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	COMMUNITY	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Rhodophyta	Dumontiacaea	*Cryptosiphonia*	*woodii*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Dumontiacaea	*Weeksia*	*coccinea*		Hansen 2000		II III IV						Hansen 2000
Rhodophyta	Dumontiaceae	*Constantinea*	*subulifera*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Dumontiaceae	*Constantinea*	*simplex*		Feder and Bryson-Schwafel 1988	I	II III IV V						Scagel et al. 1986
Rhodophyta	Dumontiaceae	*Dumontia*	*simplex*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Dumontiaceae	*Dumontia*	*contorta*	*D. incrassata*	Hansen 2000	I	II III IV	x	x			C	Hansen 2000
Rhodophyta	Dumontiaceae	*Farlowia*	*mollis*		UAM	I/ST	II III IV V VI	x					Scagel et al. 1986
Rhodophyta	Dumontiaceae	*Neodilsea*	unidentified		UAM	I							Hansen 2000
Rhodophyta	Endocladiaceae	*Endocladia*	*muricata*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Endocladiaceae	*Gloiopeltis*	*furcata*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Erythropeltidaceae	*Erythrotrichia*	*carnea*		Hansen 2000	I	x	x	x	x			Hansen 2000
Rhodophyta	Erythropeltidiaceae	*Smithoria*	*naiadum*		Hansen 2000	ST/ epiphytic	II III IV					C	Hansen 2000
Rhodophyta	Gigartinaceae	*Gigartina*	unidentified		UAM	I/ST							Hansen 2000
Rhodophyta	Gigartinaceae	*Iridaea*	*cordata*		UAM	I/ST	II III IV	x					Scagel et al. 1986
Rhodophyta	Gigartinaceae	*Iridaea*	*cornucopiae*		Feder and Bryson-Schwafel 1988	I	II III IV	x					Scagel et al. 1986
Rhodophyta	Gigartinaceae	*Rhodoglossum*	*latissimum*		UAM	I	II III IV						Scagel et al. 1986
Rhodophyta	Halemeniaceae	*Cryptonemia*	*obovata*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Halemeniaceae	*Cryptonemia*	*borealis*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Helminthocladiaceae	*Nemalion*	*helminthoides*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Rhodophyta	Hildenbrandiaceae	*Hildenbrandia*	*rubra*	*H. prototypus*	Hansen 2000	I	x	x	x	x		C	Scagel et al. 1986
Rhodophyta	Nemastomataceae	*Neodilsea*	*borealis*	*N. americana/ Schizymenia*	UAM	I	II III IV						Scagel et al. 1986
Rhodophyta	Palmariaceae	*Devaleraea*	*ramentacea*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Rhodophyta	Palmariaceae	*Halosaccion*	*glandiforme*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Palmariaceae	*Halosaccion*	*firmum*		Hansen 2000	I	II III IV		x				Hansen 2000
Rhodophyta	Palmeriaceae	*Palmaria*	*mollis/palmata*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Rhodophyta	Palmeriaceae	*Palmaria*	*calophylloides/ stenogona*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Palmeriaceae	*Palmaria*	*hecatensis*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Petrocelidaceae	*Mastocarpus*	cf. *M. pacificus?*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Petrocelidaceae	*Mastocarpus*	*papillatus* complex		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Petrocelidaceae	*Mastocarpus*	*papillatus*	*Gigartina cristata*	UAM	I	II III IV V VI VII VII VIII IX						Scagel et al. 1986
Rhodophyta	Phyllophoraceae	*Ahnfeltia*	*plicata*		UAM	I	II III IV		x	x			Scagel et al. 1986
Rhodophyta	Phyllophoraceae	*Ahnfeltia*	*fastigata*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Rhodophyta	Phyllophoraceae	*Ahnfeltiopsis*	*gigartinoides*	*Arnfeltia*	Hansen 2000	I	II III IV						Hansen 2000

Table 10.1. Continued.

PHYLUM	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	COMMUNITY	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*brodiaei*		Hansen 2000	I	x	x	x	x		C	Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*eastwoodae*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*hendryi* v. *deliquescens*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*hendryi* v. *hendryi*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*hendryi* v. *luxurians*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*hendryi* v. *pacifica*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*pacifica v. determinata?*		Hansen 2000	I/ST	II III IV						Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*pacifica v. pacifica*		Hansen 2000	I/ST	II III IV						Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*pungens*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*hendryi*	*P. collinsii*	UAM	I	II III IV			x			Scagel et al. 1986
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*pacifica*		Feder and Bryson-Schwafel 1988	I	II III IV						Scagel et al. 1986
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*senticulosa*		Hansen 2000	I	II III IV				SE Alaska	nr	Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*stricta (ureceolata)*		Hansen 2000	I	II III IV	x		x			Hansen 2000
Rhodophyta	Rhodomelaceae	*Polysiphonia*	*ureceolata*		Hansen 2000	I	x	x	x	x			Hansen 2000
Rhodophyta	Rhodomelaceae	*Pterosiphonia*	*bipinnata*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Rhodomelaceae	*Rhodomela*	*lycopodioides*		Hansen 2000	I	II III IV	x		x		C	Hansen 2000
Rhodophyta	Rodomelaceae	*Neorhodomela*	*larix*	*Rhodomela*	Hansen 2000	I/ST	II III IV	x					Hansen 2000
Rhodophyta	Rodomelaceae	*Neorhodomela*	*aculaeta*		Hansen 2000	I/ST	II III IV	x					Hansen 2000
Rhodophyta	Rodomelaceae	*Neorhodomela*	*oregona*		Hansen 2000	I/ST	II III IV	x					Hansen 2000
Rhodophyta	Rodomelaceae	*Odonthalia*	*floccosa*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Rodomelaceae	*Odonthalia*	*kamtschatica*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Rodomelaceae	*Odonthalia*	*setacea*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Rhodymeniaceae	*Rhodymenia*	*pertusa*		Hansen 2000	I	II III IV		x				Hansen 2000
Rhodophyta	Solieriaceae	*Opuntiella*	*californica*		Hansen 2000	ST	II III IV						Hansen 2000
Rhodophyta	Gigartinaceae	*Mazzaella*	*heterocarpa*		Hansen 2000	I	II III IV						Hansen 2000
Rhodophyta	Gigartinaceae	*Mazzaella*	*phyllocarpa*		Hansen 2000	I	II III IV	x					Hansen 2000
Rhodophyta	Gigartinaceae	*Mazzaella*	*splendescens*		Hansen 2000	I	II III IV						Hansen 2000
Xanthophyta		*Vaucheria*	*longicaulis (?)*		Hansen 2000	I	II III IV	x		x	BC	NR	Hansen 2000
vascular plant	Caryophyllaceae	*Honchneya*	*peploides*		Scheel et al. 1997	I	II III IV	x					Hulten 1968
vascular plant	Cyperaceae	*Carex*	unidentified		Feder and Bryson-Schw	I							Hulten 1968
vascular plant	Gramineae	*Puccinellia*	*nutkaensis*		Scheel et al. 1997	I	II III IV						Hulten 1968
vascular plant	Gramineae	*Puccinellia*	*plumila*		Hulten 1968	I	II III IV						Hulten 1968
vascular plant	Primulaceae	*Glaux*	*maritima*		Scheel et al. 1997	I	II III IV	x		x			Hulten 1968
vascular plant	Rosaceae	*Potentilla*	unidentified		Feder and Bryson-Schw	I							Hulten 1968
vascular plant	Sparganiaceae	*Phyllospadix*	*scouleri*		Hansen 2000	I/ST	II III IV						Hulten 1968
vascular plant	Sparganiaceae	*Phyllospadix*	*serrulatus*		Hansen 2000	I/ST	II III IV						Hulten 1968
vascular plant	Sparganiaceae	*Zostera*	*marina*		Hansen 2000	I/ST	II III IV	x		x			Hulten 1968

Cnidaria and Ctenophora

One hundred two species of Cnidaria and Ctenophora are listed in this report (Table 10.2). Twenty-seven of the taxa have been identified to the generic level, and not to species. Anthozoa are probably under-counted, because they are difficult to identify based on preserved specimens. The hydrozoans and scyphozoans include 34 species, four of which, the hydrozoans *Tiaropsis multicirrata*, *Eperetmus typus*, *Gonionemus vertens* and *Proboscidactyla flavicirrata*, are distributional range extensions (Mills 2000). Thirty species records are derived from T. Cooney's (1987) compilation of Gulf of Alaska plankton.

Table 10.2. Cnidaria and Ctenophora.

							BIOREGION						
PHYLUM/ CLASS	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Cnidaria: Anthozoa	Actiniidae	*Anthopleura*	*artemesia*		Feder and Bryson-Schwafel 1988	I	II III IV						Austin 1985
Cnidaria: Anthozoa	Actiniidae	*Cribirnopsis*	unidentified		Rosenthal 1977	ST/Epi							
Cnidaria: Anthozoa	Actiniidae	*Urticina*	*crassicornis*		Feder and Jewett 1987	I/ST/Epi	II III IV		x				Austin 1985
Cnidaria: Anthozoa	Actinostolidae	*Stomphia*	unidentified		Scheel et al. 1997	ST/Epi							
Cnidaria: Anthozoa	Carophllidae	*Carophyllia*	*alaskensis*		UAM	ST	II III IV						Austin 1985
Cnidaria: Anthozoa	Cerianthidae	*Pachycerianthus*	unidentified		UAM	ST							
Cnidaria: Anthozoa	Epizoanthidae	*Epizoanthus*	unidentified		UAM	ST							
Cnidaria: Anthozoa	Halcalvidae	*Peachia*	unidentified		Feder and Matheke 1980	ST							
Cnidaria: Anthozoa	Metridiidae	*Metridium*	*senile*		Feder and Jewett 1987	I/ST/Epi	II	x	x	x			Austin 1985
Cnidaria: Anthozoa	Metridiidae	*Metridium*	unidentified		NRF observation	ST							
Cnidaria: Anthozoa	Pennatulidae	*Ptilosarcus*	*gurneyi*		Feder et al. 1979	ST	II III IV						Austin 1985
Cnidaria: Anthozoa	Primnoidae	*Callogorgia*	unidentified		UAM	ST							
Cnidaria: Anthozoa	Primnoidae	*Primnoa*	unidentified		UAM	ST							
Cnidaria: Anthozoa	Virgularidae	*Acanthoptilum*	*ptile?*		Feder and Matheke 1980	ST	II III						
Cnidaria: Anthozoa	Virgularidae	*Stylatula*	*elongata?*		Rosenthal 1977	ST	II III IV V				British columbia	NR?	Austin 1985
Cnidaria: Hydrozoa	Aeginidae	*Aegina*	*citrea*	*A. rosea*	Cooney 1987	P	II III IV V VI	x		x			Austin 1985
Cnidaria: Hydrozoa	Aequoreidae	*Aequorea*	*aequorea* v. *albida*		Mills 2000	ST	II III IV						Wrobel and Mills 1998
Cnidaria: Hydrozoa	Aequoreidae	*Aequorea*	unidentified		Cooney:SEA	ST							
Cnidaria: Hydrozoa	Aequoreidae	*Aequorea*	*victoria/ A. aequorea* v. *aequorea*		Mills 2000	ST	II III IV						Wrobel and Mills 1998
Cnidaria: Hydrozoa	Agalmidae	*Agalma*	*elegans*		Cooney 1987	P	II III			x			Austin 1985
Cnidaria: Hydrozoa	Agalmidae	*Nanomia*	unidentified		Cooney 1987	P							
Cnidaria: Hydrozoa	Bougainvilliidae	*Bougainvillia*	*superciliaris*		Mills 2000	ST	II III IV	x					Austin 1985
Cnidaria: Hydrozoa	Bougainvilliidae	*Garveia*	*franciscana*		Mills 2000	ST	x	x	x	x	uncertain	definate	Hines and Ruiz 2000
Cnidaria: Hydrozoa	Calycopsidae	*Calycopsis*	*simulans*		Wrobel and Mills 1998	P	x						Wrobel and Mills 1998
Cnidaria: Hydrozoa	Campanulariidae	*Clytia*	*gregaria*	*Phialidium gregarium*	Mills 2000	I	II III IV						Wrobel and Mills 1998
Cnidaria: Hydrozoa	Campanulariidae	*Clytia*	*hemispherca?*		Hines and Ruiz 2000	ST/Epi	II III IV V VI			x			Austin 1985
Cnidaria: Hydrozoa	Campanulariidae	*Clytia*	*kincaidi*		Mills 2000	ST	x	x	x	x			Austin 1985
Cnidaria: Hydrozoa	Campanulariidae	*Gonothyraea*	*clarki*		Mills 2000	I	II III IV	x					Austin 1985
Cnidaria: Hydrozoa	Campanulariidae	*Obelia*	*longissima*		Mills 2000	I	II	x		x			Austin 1985
Cnidaria: Hydrozoa	Campanulariidae	*Obelia*	*borealis*	*O. dichotoma*	Cooney 1987	P	II III IV V	x					Austin 1985
Cnidaria: Hydrozoa	Campanulariidae	*Obelia*	unidentified		Mills 2000	I							
Cnidaria: Hydrozoa	Campanulariidae	*Obelia*	spp. (hydriods)		Mills 2000	I							
Cnidaria: Hydrozoa	Campanulariidae	*Phialidium*	*gregarium*	*P. languidum*	Cooney 1987	P	II III IV V						Austin 1985

Table 10.2 continued.

PHYLUM/ CLASS	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Cnidaria: Hydrozoa	Campanulariidae	*Verticillina*	*verticillata*		Feder and Matheke 1980	ST	II III IV V	x		x			
Cnidaria: Hydrozoa	Clausophyidae	*Chuniphyes*	*multidentata*		Cooney 1987	P	II III IV V VI						Austin 1985
Cnidaria: Hydrozoa	Corymorphidae	*Euphysa*	*japonica*		Cooney 1987	P	II III IV	x	x	x			Wrobel and Mills 1998
Cnidaria: Hydrozoa	Corymorphidae	*Euphysa*	unidentified		Mills 2000	I/ST/Epi							
Cnidaria: Hydrozoa	Corynidae	*Sarsia*	spp. (medusae)		Mills 2000	I/ST/Epi							
Cnidaria: Hydrozoa	Corynidae	*Sarsia*	*tubulosa*		Mills 2000	I/ST/Epi	x	x	x	x			Austin 1985
Cnidaria: Hydrozoa	Corynidae	*Sarsia*	*eximia*		Mills 2000	I/ST/Epi	II	x		x			Austin 1985
Cnidaria: Hydrozoa	Corynidae	*Sarsia*	*princeps*		Cooney 1987	P	II III IV	x					Austin 1985
Cnidaria: Hydrozoa	Corynidae	*Sarsia*	*rosaria*		Cooney 1987	P	II III IV			x			Austin 1985
Cnidaria: Hydrozoa	Corynidae	*Sarsia/Coryne*	sp. (hydroids)		Mills 2000	I/ST/Epi							
Cnidaria: Hydrozoa	Cuninidae	*Cunina*	*globosa*		Cooney 1987	P	II III IV						Cooney 1987
Cnidaria: Hydrozoa	Diphyidae	*Dimophyes*	*arctica*		Cooney 1987	P	II III IV V VI VII VIII	x	x	x			Austin 1985
Cnidaria: Hydrozoa	Diphyidae	*Lensia*	*concoidea*		Cooney 1987	P	II III IV V VI	x		x			Austin 1985
Cnidaria: Hydrozoa	Diphyidae	*Muggiaea*	*atlantica*		Cooney 1987	P	II III	x		x			Austin 1985
Cnidaria: Hydrozoa	Eirenidae	*Eutonina*	*indicans*		Wrobel and Mills 1998	P	II III IV			x			Wrobel and Mills 1998
Cnidaria: Hydrozoa	Eutimidae	*Eutonima*	*indicans*		Mills 2000	ST	II III IV						Austin 1985
Cnidaria: Hydrozoa	Haleciidae	*Grammaria*	*immersa*		Rosenthal 1977	ST	II III			x			Austin 1985
Cnidaria: Hydrozoa	Halicreatidae	*Halicreas*	unidentified		Cooney:SEA	P							
Cnidaria: Hydrozoa	Halimedusidae	*Halimedusa*	*typus*		Cooney 1987	P	II III IV						Austin 1985
Cnidaria: Hydrozoa	Hippopodiidae	*Vogtia*	*serrata*	*V. pentacantha*	Cooney 1987	P	II III	x		x			Austin 1985
Cnidaria: Hydrozoa	Laodicidae	*Cuspidella*	unidentified		Cooney:SEA	P							
Cnidaria: Hydrozoa	Laodicidae	*Staurophora*	*mertensii*		Mills 2000	ST	II	x		x			Austin 1985
Cnidaria: Hydrozoa	Laodicidae	*Stegopoma*	*plicatile*		Feder and Matheke 1980	ST	II	x		x			Austin 1985
Cnidaria: Hydrozoa	Lovenellidae	*Calycella*	*springe*		Mills 2000	I	II	x		x			Austin 1985
Cnidaria: Hydrozoa	Melicertidae	*Melicertum*	*campanula*		Cooney:SEA	ST	II III IV	x		x			Austin 1985
Cnidaria: Hydrozoa	Melicertidae	*Melicertum*	*octocostatum*		Mills 2000	ST	II	x		x			Wrobel and Mills 1998
Cnidaria: Hydrozoa	Mitrocomidae	*Mitrocoma*	*cellularia*	*Halistaura*	Mills 2000	ST	II III IV V						Wrobel and Mills 1998
Cnidaria: Hydrozoa	Mitrocomidae	*Tiaropsidium*	unidentified		Cooney 1987	P							
Cnidaria: Hydrozoa	Mitrocomidae	*Tiaropsis*	*multicirrata*		Mills 2000	I/ST/Epi	II III IV	x		x	SE Alaska	nr	Wrobel and Mills 1998
Cnidaria: Hydrozoa	Olindiasidae	*Eperetmus*	*typus*		Mills 2000	ST	II III IV				SE Alaska	nr	Wrobel and Mills 1998
Cnidaria: Hydrozoa	Olindiasidae	*Gonionemus*	unidentified		Cooney:SEA	ST							
Cnidaria: Hydrozoa	Olindiasidae	*Gonionemus*	*vertens*		Mills 2000	ST	II III IV				SE Alaska	nr	Wrobel and Mills 1998

Table 10.2 continued.

PHYLUM/ CLASS	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Cnidaria: Hydrozoa	Pandeidae	*Catablema*	*multicirrata*		Mills 2000	ST/Epi	II III IV	x					Austin 1985
Cnidaria: Hydrozoa	Pandeidae	*Halitholus*	unidentified		Mills 2000	ST							
Cnidaria: Hydrozoa	Pandeidae	*Leuckartiara*	*breviconis*	*Neoturris*	Cooney 1987	P	II III IV						Austin 1985
Cnidaria: Hydrozoa	Pandeidae	*Leuckartiara*	*nobilis*	*Catablema nodulosa*	Cooney 1987	P	II III IV						Austin 1985
Cnidaria: Hydrozoa	Pandeidae	*Leuckartiara*	*octona*		Cooney 1987	P	II III IV						Austin 1985
Cnidaria: Hydrozoa	Pandeidae	*Leuckartiara*	unidentified		Mills 2000	I/ST/Epi							
Cnidaria: Hydrozoa	Pandeidae	*Neoturris*	*breviconis*		Wrobel and Mills 1998	P	II II III IV V						Wrobel and Mills 1998
Cnidaria: Hydrozoa	Pandeidae	*Perigonimus*	unidentified		Cooney:SEA	P							
Cnidaria: Hydrozoa	Pandeidae	*Stomotoka*	*atra*		Wrobel and Mills 1998	P	II III						Wrobel and Mills 1998
Cnidaria: Hydrozoa	Periphyllidae	*Periphylla*	*periphylla*	*P. hyacinthina*	Cooney 1987	P	II III IV V VI			x			Wrobel and Mills 1998
Cnidaria: Hydrozoa	Phialellidae	*Campanulina*	*rugosa*		Mills 2000	ST	II III IV						Austin 1985
Cnidaria: Hydrozoa	Phialellidae	*Opercularella*	*lacerata*		Mills 2000	ST	II	x		x			Austin 1985
Cnidaria: Hydrozoa	Polyorchidae	*Polyorchis*	*penicillatus*		Wrobel and Mills 1998	P	II III IV V VI						Wrobel and Mills 1998
Cnidaria: Hydrozoa	Prayidae	*Nectopyramis*	*diomedeae*		Cooney 1987	P	II III IV V VI			x			Austin 1985
Cnidaria: Hydrozoa	Prayidae	*Praya*	*reticulata*	*Nectodroma*	Cooney 1987	P	II III IV V VI VII VIII						Austin 1985
Cnidaria: Hydrozoa	Proboscidactylidae	*Proboscidactyla*	*flavicirrata*		Mills 2000	I/ST/Epi	II	x		x	SE Alaska	nr	Wrobel and Mills 1998
Cnidaria: Hydrozoa	Protohydridae	*Protohydra*	unidentified		Feder and Bryson-Schwafel 1988								
Cnidaria: Hydrozoa	Rathkeidae	*Rathkea*	*jaschnowi*		Cooney:SEA	P	II	x			Bering Sea	nr?	Naumov 1960
Cnidaria: Hydrozoa	Rathkeidae	*Rathkea*	*octopunctata*	*R. blumenbachii*	Cooney 1987	P	II III IV	x		x			Wrobel and Mills 1998
Cnidaria: Hydrozoa	Rathkeidae	*Rathkea*	unidentified		Cooney:SEA	P							
Cnidaria: Hydrozoa	Rhopalonematidae	*Aglantha*	*digitale*		Cooney and Coyle 1988	P/ST	II III IV	x	x				Wrobel and Mills 1998
Cnidaria: Hydrozoa	Rhopalonematidae	*Pantachogon*	*haekeli*		Cooney 1987	P	II III IV			x			Austin 1985
Cnidaria: Hydrozoa	Sertulariidae	*Sertularia*	*robusta*		Mills 2000	ST	II	x		x			Austin 1985
Cnidaria: Hydrozoa	Tubularidae	*Hybocodon*	*prolifer*		Cooney 1987	P	II III			x			Austin 1985
Cnidaria: Hydrozoa	Tubularidae	*Plotocnide*	*borealis*		Cooney:SEA	P	II III IV	x		x			Austin 1985
Cnidaria: Hydrozoa	Tubularidae	*Tubularia*	*prolifera*		Cooney:SEA	P	II	x	x	x			Austin 1985
Cnidaria: Scyphozoa	Cyaneidae	*Cyanea*	*capillata*		Mills 2000	ST	II	x		x			Wrobel and Mills 1998
Cnidaria: Scyphozoa	Pelagiidae	*Chrysaora*	*melangaster*		Cooney 1987	P	II III IV V VI	x					Wrobel and Mills 1998
Cnidaria: Scyphozoa	Ulmariidae	*Aurelia*	*aurita*		Mills 2000	ST	II	x		x			Wrobel and Mills 1998
Cnidaria: Scyphozoa	Ulmariidae	*Aurelia*	*labiata*		Mills 2000	ST	II III IV	x					Wrobel and Mills 1998
Cnidaria: Scyphozoa	Ulmariidae	*Aurelia?*	unidentified		Mills 2000	P							
Cnidaria: Scyphozoa	Ulmariidae	*Phacellophora*	*camtschatica*	*Catablema*	Cooney:SEA	P	II III IV V VI	x		x			Wrobel and Mills 1998
Ctenophora	Beroidae	*Beroe*	unidentified		Cooney 1987	P							
Ctenophora	Bolinopsidae	*Bolinopsis*	*infundibulum*		Mills 2000	ST	II	x		x			Wrobel and Mills 1998
Ctenophora	Mertensiidae	*Mertensia*	sp. *(ovum)*		Cooney and Coyle 1988	P	II	x		x			Austin 1985
Ctenophora	Pleurobranchiidae	*Hormiphora*	*cucumis*		Wrobel and Mills 1998	P	II III	x					Wrobel and Mills 1998
Ctenophora	Pleurobranchiidae	*Pleurobrachia*	*bachei*		Mills 2000	ST	II III IV						Wrobel and Mills 1998

Annelida

The region's polychaete annelid fauna is particularly rich, with 233 species in 46 families. Kudenov (2000) has noted three range extensions, for *Phyllodoce medipapillata*, *Chaetozone senticosa*, and *Rhynchospio glutaea*. Some species of *Eumida*, *Scoloplos*, *Exogone*, *Nephtys*, *Glycera*, and the archaeannelid *Polygordius* are likely to be undescribed. Seven taxa, including members of the Spirorbidae have not been identified below the generic level. Nineteen new records from the UAM collection and Exxon Valdez oil spill specimens represent range extensions.

Hirudinea and Oligochaeta are not included in the data sets (Table 10.3), because we lack reliable identifications for specimens found in Prince William Sound. At least one species of marine leech is present in UAM samples from the adjacent Gulf of Alaska. Kozloff (1987) lists 14 leech species with distributions from Oregon north. Oligochaetes have been collected, but no effort has been made to identify them to family or lower taxon. Austin (1985) lists eight oligochaete species whose ranges include Alaska or southeast Alaska.

Information on distribution, habitat, and nomenclatural changes have been drawn from Austin (1985), Banse and Hobson (1968), Berkeley and Berkeley (1948, 1952), Hobson and Banse (1981), Kudenov (2000) and Ushakov (1955).

Table 10.3. Annelida.

					BIOREGION						
GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Ampharete	*acutifrons*		EVOS	ST/Inf	II III IV						Austin 1985
Ampharete	*finmarchia*	*A. arctica*	Feder et al. 1979	ST/Inf	II III IV	x	x	x			Austin 1985
Amphicteis	*gunneri*		Feder and Matheke 1980	ST/Inf	II III IV	x					Ushakov 1955
Amphicteis	*scaphobranchiata*		Feder et al. 1979	ST/Inf	II III IV						Austin 1985
Anobothrus	*gracilis*		Feder et al. 1979	ST/Inf	II III IV		x				Austin 1985
Lysippe	*labiata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Melinna	cf. *M. cristata*		Feder et al. 1979	ST/Inf	II III IV		x				Austin 1985
Melinna	*cristata*		Feder and Matheke 1980	ST/Inf	II III IV		x				Austin 1985
Melinna	*elisabethae*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Pseudosabellides	*lineata*	*Asabellides*	EVOS	ST/Inf	II III IV		x				Austin 1985
Pseudosabellides	*sibirica*	*Asabellides littoralis*	UAM	ST/Inf	II III IV						Austin 1985
Sosanella	unidentified		UAM								
Aphrodita	*japonica*		UAM	ST/Inf	II III IV	x					Austin 1985
Drilonereis	*falcata minor*		Feder and Matheke 1980	ST/Inf	II III IV				British Columbia	NR	Austin 1985
Drilonereis	*longa*		UAM	ST/Inf	II	x		x	British Columbia	NR	Austin 1985
Abarenicola	*pacifica*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV	x					Austin 1985
Barantolla	*americana*		EVOS	I/ST/Inf	II III IV					C	Austin 1985
Capitella	*capitata*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II	x	x	x		C	Austin 1985
Heteromastus	*filiformis*		EVOS	ST/Inf	II III IV V		x	x		possible	Austin 1985
Mediomastus	unidentified		EVOS	I/ST/Inf							
Mesochaetopterus	*taylori*		EVOS	ST/Inf	II III IV				British Columbia	NR	Austin 1985
Spiochaetopterus	*costarum*		Feder and Matheke 1980	ST/Inf	x	x	x	x			Austin 1985

Table 10.3 continued.

GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Chrysopetalium	*occidentale*		Kudenov 2000		II III IV V VI	x					Kudenov 2000
Chaetozone	*senticosa*		Kudenov 2000	ST/Inf	II IV V				California	NR	Kudenov 2000
Chaetozone	*setosa*		Feder and Matheke 1980	ST/Inf	x	x	x	x			Austin 1985
Cirratulus	*cingulatus*		Kudenov 2000	ST/Inf	II III IV						Kudenov 2000
Cirratulus	*cirratus*		EVOS	ST/Inf	x	x	x	x	British Columbia	NR	Austin 1985
Tharyx	*monilaris*		Feder and Bryson-Schwafel 1988	ST/Inf	II III IV						Austin 1985
Tharyx	*multifilis*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV						Austin 1985
Tharyx	*parvus*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Tharyx	*secundus*		EVOS	ST/Inf	II III IV				British Columbia	NR	Austin 1985
Cossura	*longocirrata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Dorvillea	*rudolphi*		EVOS	ST/Inf	II III IV						
Dorvillea	*pseudorubrovittata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Protodorvillea	*gracilis*		EVOS	ST/Inf	II III IV						Austin 1985
Schistomeringos	unidentified		UAM	ST							
Eunice	*valens*	*E. kobiensis*	UAM	ST/Inf	II III IV	x					Austin 1985
Brada	*granulata*		Feder and Matheke 1980	ST/Inf	II III IV	x					Austin 1985
Flabelligera	*affinis*		EVOS	ST/Inf	II III IV		x				Austin 1985
Pherusa	*plumosa*		EVOS	I/ST/Inf	II III IV		x				Austin 1985
Pherusa	*papillata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Glycera	sp. undescribed		Kudenov 2000								Kudenov 2000
Glycera	cf. *G. nana*		Kudenov 2000								
Glycera	*nana*	*G. capitata*	Feder and Bryson-Schwafel 1988	ST/Inf	II III IV	x					Austin 1985
Hemipodus	*borealis*		EVOS	I/ST/Inf	II III IV						Austin 1985
Glycinde	*armigera*		EVOS	ST/Inf	II III IV	x					Austin 1985
Glycinde	*picta*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV						Austin 1985
Goniada	*annulata*		Feder and Jewett 1988	ST/Inf	II III IV						Austin 1985
Goniada	*maculata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Microphthalmus	*sczelkowii*		Feder and Bryson-Schwafel 1988	ST/Inf	II	x		x	California	NR	Austin 1985
Micropodarke	*dubia*		EVOS	ST/Inf	II III IV						Austin 1985
Podarkeopsis	*glabrus*	*Gyptis brevipalpa*	Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Pelagobia	*longicirrata*		Cooney 1987	P	II III IV V VI	x		x			Austin 1985
Lumbrineris	*latreilli*		Feder et al. 1979	ST/Inf	II III IV V VI VII VIII IX	x					Austin 1985
Lumbrineris	*limicola*		UAM	ST/Inf	II III IV				SE Alaska	nr	
Lumbrineris	*luti*		Feder and Jewett 1988	ST/Inf	II III IV				British Columbia	NR	Austin 1985
Lumbrineris	*similabris*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Lumbrineris	*zonata*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV						Austin 1985
Ninoe	*gemmea*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Ninoe	*simpla*		Feder et al. 1979	ST/Inf	II III IV						Austin 1985
Magelona	*berkeleyi*		EVOS	ST/Inf	II III IV				British Columbia	NR	Austin 1985
Magelona	*hobsonae*	*M. pitekai*	Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV				British Columbia	NR	Austin 1985

Table 10.3 continued.

GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Metasychis	*disparidentata*	*Asychis*	Feder et al. 1979	ST/Inf	II III IV	x					Austin 1985
Nicomache	*personata*		UAM	ST/Inf	II III IV						Austin 1985
Notoproctus	*pacificus*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Petaloproctus	*borealis*	*P. tenuis*	EVOS	ST/Inf	II III IV		x				Austin 1985
Praxillella	*praetermissa*		EVOS	ST/Inf	II III IV	x					Austin 1985
Praxillella	*gracilis*		Feder and Jewett 1988	ST/Inf	II III IV						Austin 1985
Praxillella	*pacifica*	*P. affinis*	Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Rhodine	*bitorquata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Aglophamus	*rubella anops*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Nephtys	*cornuta cornuta*		UAM	ST/Inf	II III IV						Austin 1985
Nephtys	*ferruginea*		EVOS	ST/Inf	II III IV						Austin 1985
Nephtys	*punctata*		Feder and Jewett 1988	ST/Inf	II III IV		x				Austin 1985
Nephtys	*caeca*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV V	x	x	x			Austin 1985
Nephtys	*ciliata*		EVOS	I/ST/Inf	II	x		x			Austin 1985
Nephtys	*cornuta*		Feder and Matheke 1980	I/ST/Inf	II III IV						Austin 1985
Nephtys	*cornuta franciscana*		Feder and Matheke 1980	I/ST/Inf	II III IV						Austin 1985
Nephtys	sp. undescribed		Kudenov 2000								
Chelonereis	*cyclurus*		Kudenov 2000	ST/Inf	II III IV V	x					Austin 1985
Nereis	*grubei*		UAM	I/ST/Inf	II III IV	x					Austin 1985
Nereis	*pelagica*		UAM	I/ST/Inf	II III IV						Austin 1985
Nereis	*procera*		Feder and Matheke 1980	ST/Inf	II III IV V VI						Austin 1985
Nereis	*vexillosa*		Feder and Bryson-Schwafel 1988	I/inf	II III IV V VI						Austin 1985
Nereis	*zonata*		Feder and Matheke 1980	ST/Inf	II III IV V VI		x				Austin 1985
Platynereis	*bicanaliculata*	*P. agassizi*	EVOS	I/ST/Inf	II III IV						Austin 1985
Onuphis	*iridescens*		UAM	ST/Inf	II III IV	x					Austin 1985
Onuphis	*conchylega*		Feder and Matheke 1980	ST/Inf	II III IV	x					Banse and Hobson 1968
Onuphis	*geophiliformis*		Feder and Matheke 1980	ST/Inf	II III IV	x					Austin 1985
Onuphis	*parva*		Feder and Matheke 1980	ST/Inf	II III IV	x					Banse and Hobson 1968
Onuphis	*stigmatis*			ST/Inf	II III IV						Austin 1985
Armandia	*brevis*		EVOS	ST/Inf	II III IV						Austin 1985
Ophelia	*limacina*		Feder and Bryson-Schwafel 1988	I/ST/Inf	x	x	x	x			Austin 1985
Ophelina	*acuminata*	*Amnotrypane aulogaster*	Feder and Matheke 1980	ST/Inf	II III IV V VI			x			Austin 1985
Travisia	*forbesii*		Feder et al. 1979	ST/Inf	II	x	x	x			Austin 1985
Leitoscoloplos	*panamensis*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV						Austin 1985
Leitoscoloplos	*pugettensis*	*L. elongatus*	Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Naineris	*dendritica*		Kudenov 2000	ST/Inf	II III IV V						Austin 1985
Naineris	*drenritica*	*N. laevigata*	UAM	ST/Inf	II III IV						Austin 1985
Naineris	*uncinata*		EVOS	ST/Inf	II III IV						Austin 1985
Naineris	unidentified		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Scoloplos	*acmeceps*		EVOS	ST/Inf	II III IV						Austin 1985
Scoloplos	*armiger*		EVOS	ST/Inf	II III IV	x	x				Austin 1985
Scoloplos	sp. undescribed		Kudenov 2000								
Myriochele	*oculata*	*M. heeri*	Feder and Matheke 1980	ST/Inf	II III IV		x				Austin 1985
Owenia	*fusiformis*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV	x	x				Austin 1985
Aricidea	*ramosa*		EVOS	ST/Inf	II III IV	x					Austin 1985

Table 10.3 continued.

GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Aricidea	*lopezi*		Feder and Jewett 1988	ST/Inf	II III IV	x					Austin 1985
Aricidea	*neosuecica*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Aricidea	*nolani*	*A. suecica*	UAM	ST/Inf	II III IV						Austin 1985
Cirrophoras	*lyra*		EVOS	ST/Inf	II III IV						Austin 1985
Cirrophoras	*branchiatus*		UAM	ST/Inf	II III IV						Austin 1985
Paraonis	*gracilis*		Feder and Matheke 1980	ST/Inf	II III IV	x	x				Austin 1985
Amphictene	*moorei*	*A. auricoma*	Feder and Matheke 1980	I/ST/Inf	II III IV		x				Austin 1985
Cistenides	*granulata*	*C. brevicoma*	Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV		x				Austin 1985
Pectinaria	*californiensis*		EVOS	ST/Inf	II III IV						Austin 1985
Pholoides	*asperus*	Polyodontidae: *Peisidice*	Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Anaitides	*groenlandica*	*Phyllodoce*	UAM	ST/Inf	II III IV	x	x				Austin 1985
Anaitides	*mucosa*		Feder and Matheke 1980	ST/Inf	II III IV		x				Austin 1985
Anaitides	*maculata*		Feder and Matheke 1980	ST/Inf	II III IV	x					Austin 1985
Eteone	*longa*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV	x				C	Austin 1985
Eulalia	*viridis*		UAM	ST/Inf	II III IV	x					Austin 1985
Eumida	sp. undescribed		Kudenov 2000	ST/Inf							
Hypoeulalia	*bilineata*	*Eulalia*	UAM	ST/Inf	II III IV	x	x				Austin 1985
Mysta	*barbata*		UAM	ST/Inf	II	x	x		Chukchi Sea	nr	Ushakov 1955
Nereiphylla	*castanea*	*Phyllodoce, Genetylus*	UAM	ST/Inf	II III IV	x					Austin 1985
Notophyllum	*tectum*		UAM	ST/Inf	II III IV						Austin 1985
Phyllodoce	*medipapillata*		Kudenov 2000	ST/Inf	II III IV V				California	NR	Kudenov 2000
Ancistrosyllis	*hamata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Polygordius	sp. undescribed		UAM	ST/Inf							Kudenov 2000
Antinoella	*sarsi*		Feder and Matheke 1980	ST/Inf	II III IV	x	x				Ushakov 1955
Arcteobia	*spinelytris*		Feder and Matheke 1980	ST/Inf	II III IV	x					Austin 1985
Byglides	*macrolepidus*	*Antinoella*	Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Eunoe	*depressa*		UAM	ST/Inf	II III IV	x					Austin 1985
Eunoe	*oerstedi*		EVOS	ST/Inf	II III IV						Austin 1985
Eunoe	*senta*		UAM	ST/Inf	II III IV						Austin 1985
Gattyana	*ciliata*		Feder and Matheke 1980	ST/Inf	II III IV	x					Austin 1985
Gattyana	*cirrosa*		Feder and Matheke 1980	ST/Inf	II III IV	x	x				Austin 1985
Gattyana	*treadwelli*		Feder and Matheke 1980	ST/Inf	II III IV		x				Austin 1985
Halosydna	*brevisetosa*		UAM	ST/Inf	II III IV						Austin 1985
Harmothoe	*extenuata*		UAM	ST/Inf	II III IV	x	x				Austin 1985
Harmothoe	*imbricata*		EVOS	I/ST/Inf	II III IV	x	x			C	Austin 1985
Hesperonoe	*complanata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Lepidonotus	*helotypus*		UAM	ST/Inf	II III IV						Ushakov 1955
Lepidonotus	*squamatus*		Feder and Matheke 1980	ST/Inf	x	x	x	x			Austin 1985
Nemida	*tamarae*		UAM	ST/Inf	II				Bering Sea	nr	Ushakov 1955
Polynoe	*canadensis*		Feder et al. 1979	ST/Inf	II III IV		x				Austin 1985
Idanthyrsus	*armatus*		Feder and Matheke 1980	ST/Inf	II III IV V VI VII VIII IX						Austin 1985
Idanthyrsus	*ornamentatus*		EVOS	ST/Inf	II III IV						Austin 1985
Chone	*magna*		EVOS	ST/Inf	II III IV						Austin 1985
Chone	*cincta*		UAM	ST/Inf	II III IV	x					Austin 1985
Euchone	*hancocki*		EVOS	ST/Inf	II III IV						Austin 1985
Euchone	*longifissuirata*		UAM	ST/Inf	II III IV	x	x				Ushakov 1955
Euchone	*analis*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV	x	x				Ushakov 1955
Fabricia	*sabella*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II	x		x			Austin 1985

Table 10.3 continued.

					BIOREGION						
GENUS	**SPECIES**	**OTHER NAMES**	**SPECIMEN or SOURCE**	**HABITAT**	**NEP**	**NWP**	**AR**	**NWA**	**ORIGIN**	**NIS STATUS**	**REFERENCE to DISTRIBUTION**
Laonome	*kroyeri*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II	x		x			Berkeley and Berkeley 1952
Myxicola	*infundibulum*		Feder and Matheke 1980	ST/Inf	II III IV	x					Austin 1985
Potentilla	*ocellata*		UAM	ST/Inf	II III IV						Austin 1985
Schizobranchia	*insignis*		Kudenov 2000		II III IV V						Austin 1985
Scalibregma	*inflatum*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Crucigera	*irregularis*		Feder and Matheke 1980	ST/Epi	II III IV						Austin 1985
Crucigera	*zygophora*		UAM	ST/Epi	II III IV	x					Austin 1985
Pseudochitinopoma	*occidentalis*		EVOS	ST/Epi	II III IV						Austin 1985
Serpula	*vermicularis*		Kudenov 2000	ST/Epi	II III IV	x					Kudenov 2000
Pholoe	sp. *"minuta"*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV	x	x			C	Austin 1985
Sphaerodoropsis	*minuta*		EVOS	ST/Inf	II III IV	x					Austin 1985
Sphaerodoropsis	*sphaerulifer*		EVOS	ST/Inf	II III IV	x					Austin 1985
Sphaerodorum	*papillifer*		EVOS	ST/Inf	II	x	x	x			Austin 1985
Dipolydora	cf. *D. bidentata*		Kudenov 2000								Kudenov 2000
Dipolydora	cf. *D. giardi*		Kudenov 2000								Kudenov 2000
Dipolydora	cf. *D. socialis*		Kudenov 2000								Kudenov 2000
Laonice	*cirrata*		EVOS	ST/Inf	x	x	x	x			Austin 1985
Rhynchospio	*glutaea*	*Malacoceros*	EVOS	ST/Inf	II	x		x		nr	Berkeley and Berkeley 1952
Polydora	*limicola ?*		Kudenov 2000	ST/Inf	II III IV V						Austin 1985
Polydora	cf. *P.brachycephalata*		UAM	ST/Inf	II III IV						Austin 1985
Polydora	*ciliata*	*P. pygidialis*	Feder and Bryson-Schwafel 1988	I/ST/Inf	x	x	x	x			Austin 1985
Dipolydora	*quadrilobata*		EVOS	I/ST/Inf	II III IV					C	Austin 1985
Polydora	*socialis*	*Dipolydora*	UAM	ST/Inf	II III IV V VI VII VIII IX						Austin 1985
Prionospio	*cirrifera*		EVOS	ST/Inf	II III IV		x				Austin 1985
Prionospio	*steenstrupi*		EVOS	I/ST/Inf	x	x	x	x			Austin 1985
Pygospio	*elegans*		EVOS	I/ST/Inf	II	x		x			Austin 1985
Scolelepis	*squamata*	*Nerine cirratulus*	EVOS	ST/Inf	II III IV						Austin 1985
Spio	*filicornis*		EVOS	ST/Inf	x	x	x	x			Austin 1985
Spiophanes	*berkeleyorum*		EVOS	ST/Inf	II III IV	x					Austin 1985
Spiophanes	*bombyx*		EVOS	ST/Inf	x	x	x	x			Austin 1985
Spiophanes	*cirrata*	*S. kroyeri*	Feder et al. 1979	ST/Inf	II	x		x			Austin 1985
Circeis	*spirillum*		Feder and Bryson-Schwafel 1988	I/Epi	II III IV						Austin 1985
Dexiospira	unidentified		Feder and Bryson-Schwafel 1988	I/Epi	II III IV						Austin 1985
Spirorbis	unidentified		Feder and Matheke 1980	ST/Epi	II III IV	x	x				Austin 1985
Sternaspis	*scutata*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Autolytus	*alexandri*	*A. verrilli*	UAM	ST/Inf	II III IV						Austin 1985
Autolytus	*cornatus*	*A. prismaticus*	UAM	ST/Inf	II	x	x	x			Austin 1985
Eusyllis	*bloomstrandi*		Feder and Matheke 1980	ST/Inf	II	x		x			Austin 1985
Exogone	sp. undescribed		Kudenov 2000								
Exogone	cf. *E. dwisula*		Kudenov 2000								Kudenov 2000
Exogone	*lourei*		Feder and Bryson-Schwafel 1988	ST/Inf	II III IV						Austin 1985
Exogone	*naidina*	*E. gemmifera*	Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV	x					Austin 1985
Exogone	*verugera*		Feder and Matheke 1980	ST/Inf	x	x	x	x			Austin 1985
Sphaerosyllis	cf. *C. californiensis*		Kudenov 2000								Kudenov 2000

Table 10.3 continued.

					BIOREGION						
GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Sphaerosyllis	*erinaceous*		Feder and Bryson-Schwafel 1988	ST/Inf	II III IV	x					Banse and Hobson 1968
Syllis	*armillaris*	*Typosyllis*	Feder and Matheke 1980	ST/Inf	II III IV V VI	x	x	x			Austin 1985
Syllis	*fasciata*	*Typosyllis*	EVOS	ST/Inf	II III IV						Austin 1985
Syllis	*harti*	*Typosyllis*	EVOS	ST/Inf	II III IV				British Columbia	NR	Austin 1985
Syllis	*harti armillaris*	*Typosyllis*	Feder and Matheke 1980	ST/Inf	II III IV						
Syllis	*harti unguicula*	*Typosyllis*	UAM	ST/Inf	II III IV				British Columbia	NR	
Syllis	*heterochaeta*	*Langerhansia cornuta*	Feder and Matheke 1980	ST/Inf	II III IV	x					Austin 1985
Syllis	*hyalina*	*Typosyllis*	Kudenov 2000	I/ST/Inf	x	x	x	x			Austin 1985
Trypanosyllis	*gemmipara*		Kudenov 2000		II III IV V						Austin 1985
Typosyllis	*stuarti*		Kudenov 2000		II III						Austin 1985
Typosyllis	*alternata*		Kudenov 2000	I/ST/Inf	II III IV	x					Austin 1985
Amphitrite	*cirrata*		Kudenov 2000		II III IV V			x		C	Austin 1985
Artacama	*conifera*		UAM	ST/Inf	II III IV						Austin 1985
Artacama	*proboscidea*		Feder et al. 1979	ST/Inf	II III IV		x				Austin 1985
Lanassa	*venusta*		EVOS	ST/Inf	II III IV	x	x				Austin 1985
Laphania	*boecki*		EVOS	ST/Inf	II	x		x			Austin 1985
Leana	*abranchiata*		UAM	ST/Inf	II III IV	x	x				Austin 1985
Lysilla	*loveni*		Feder and Matheke 1980	ST/Inf	II	x		x			Austin 1985
Pista	*cristata*		Feder and Matheke 1980	ST/Inf	II	x		x			Austin 1985
Pista	*vinogradovi*	*P. pacifica*	Feder and Jewett 1988	ST/Inf	II III IV	x					Austin 1985
Polycirrus	*medusa*		UAM	ST/Inf	II	x		x			Austin 1985
Proclea	*graffi*		UAM	ST/Inf	II III IV						Austin 1985
Terbellides	*stroemi*		Feder and Jewett 1988	ST/Inf	x	x	x	x			Austin 1985
Tomopteris	*septentrionalis*		Cooney 1987	P	x	x		x			Austin 1985
Tomopteris	*pacificus*		Cooney 1987	P	II III IV V	x					Austin 1985
Tomopteris	unidentified		Cooney and Coyle 1988	P							
Trichobranchus	*glacialis*		Feder and Matheke 1980	ST/Inf	II	x	x	x			Austin 1985
Disoma	*carica*	Disomidae:Trichochaeta	UAM	ST/Inf	II III IV	x					Austin 1985
Disoma	*multisetosum*	Disomidae:Trichochaeta	UAM	ST/Inf	II III IV	x					Austin 1985
Typhloscolex	*mulleri*		Cooney: SEA	ST	II III IV	x		x	NE Pacific	NR?	Austin 1985

Mollusca

Three hundred fifteen mollusk species, representing all classes except monoplacophorans, are included in the data set (Table 10.4). There is one aplacophoran, and 108 bivalves, 179 gastropods, 17 polyplacophorans, three scaphopods, and eight cephalopods. Mollusks in the UAM comprise one of the chief sources for the data set. Information on nomenclature and distribution derives form Austin (1985), Baxter (1987), Behrens (1991), Coan et al. (2000), and Turgeon et al. (1998).

The shelled fauna is quite well known, but opisthobranchs, because they require special techniques to collect and preserve, have not been adequately documented in Alaska. It is not surprising to find potentially undescribed species and geographical range extensions within the Prince William Sound fauna. A paper describing range extensions for 11 species of opisthobranchs is in preparation by J. Goddard and N. Foster.

Table 10.4. Mollusca.

GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Chaetoderma	*robustum*		UAM	ST/Inf	II III IV						Baxter 1987
Pododesmus	*macroschisma*		UAM	ST/Epi	II III IV						Coan et al. 2000
Astarte	*borealis*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Astarte	*compacta*	*A. polaris*	UAM	ST/Inf	II III IV						Coan et al. 2000
Astarte	*elliptica*	*A. alaskensis*	UAM	ST/Inf	II	x		x			Coan et al. 2000
Astarte	*esquimaulti*		UAM	ST/Inf	II III	x					Coan et al. 2000
Astarte	*ovata*	*A. borealis*	UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Clinocardium	*blandum*	*C. fucanum*	Coan et al. 2000	I/ST/Inf	II III IV						Coan et al. 2000
Clinocardium	*californiense*		UAM	I/ST/Inf	II III IV	x					Coan et al. 2000
Clinocardium	*ciliatum*		UAM	I/ST/Inf	II	x	x	x			Coan et al. 2000
Clinocardium	*nuttallii*		UAM	I/ST/Inf	II III IV	x					Coan et al. 2000
Serripes	*groenlandicus*		UAM	I/ST/Inf	II	x	x	x			Coan et al. 2000
Serripes	*laperousii*		UAM	I/ST/Inf	II	x	x	x			Coan et al. 2000
Serripes	*notabilis*		UAM	ST/Inf	II III IV	x					Coan et al. 2000
Cyclocardia	*crebricosta*		UAM	ST/Inf	II III IV	x					Coan et al. 2000
Cyclocardia	*ventricosa*		UAM	ST/Inf	II III IV						Coan et al. 2000
Miodontiscus	*prolongata*		Coan et al. 2000	ST/Inf	II III IV	x					Coan et al. 2000
Cardiomya	*behringensis*		Coan et al. 2000	ST/Inf	II III IV	x					Coan et al. 2000
Cardiomya	*pectinata*		UAM	ST/Inf	II III IV						Coan et al. 2000
Cardiomya	*planetica*		UAM	ST/Inf	II III IV						Coan et al. 2000
Glycymeris	*septentrionalis*		EVOS	ST/Inf	II III IV						Coan et al. 2000
Hiatella	*arctica*		UAM	I/ST/Epi/Inf	x	x	x	x			Coan et al. 2000
Panomya	*ampla*		Coan et al. 2000	ST/Inf	II III IV	x					Coan et al. 2000
Panomya	*norvegica*	*P. arctica*	UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Kellia	*suborbicularis*	*Kelliidae*	Coan et al. 2000	ST/Inf	II III IV						Coan et al. 2000
Mysella	*planata*		Coan et al. 2000	ST/Inf	II III IV	x					Coan et al. 2000
Neaeromya	*compressa*	*Pseudopythina*	UAM	I/ST/Inf	II III IV						Coan et al. 2000
Rochefordia	*tumida*	*Mysella*	UAM	ST/Inf	II III IV						Coan et al. 2000
Limatula	*attenuata*	*L. subauriculata*	Coan et al. 2000	ST/Epi	II III IV	x					Coan et al. 2000
Lucina	*tenuisculpta*	*Parvilucina*	UAM	ST/Inf	II III IV						Coan et al. 2000
Lucinoma	*annulatum*		UAM	ST/Inf	II III IV						Coan et al. 2000
Entodesma	*navicula*	*E. saxicola*	UAM	I/Epi/Inf	II III IV	x					Coan et al. 2000
Lyonsia	*bracteata*		UAM	ST/Inf	II III IV						Coan et al. 2000
Mactromeris	*polynyma*		UAM	I/ST/Inf	II			x			Coan et al. 2000
Tresus	*capax*		Coan et al. 2000	I/ST/Inf	II III IV						Coan et al. 2000
Tresus	*nuttallii*		UAM	I/ST/Inf	II III IV						Coan et al. 2000
Malletia	*pacifica*	*M. cuneata*	UAM	ST/Inf	II III IV						Coan et al. 2000
Cryptomya	*californica*		Coan et al. 2000	I/ST/Inf	II III IV	x					Coan et al. 2000
Mya	*arenaria*		UAM	I/Inf	II III IV			x	N Atlantic	definate	Coan et al. 2000
Mya	*truncata*		UAM	I/ST/Inf	II	x	x	x			Coan et al. 2000
Crenella	*decussata*		UAM	I/ST/Epi	II	x	x	x			Coan et al. 2000
Dacrydium	*vitreum*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Modiolus	*modiolus*		UAM	ST/Inf	II	x		x			Coan et al. 2000
Musculus	*discors*		UAM	ST/Inf	II	x		x			Coan et al. 2000
Musculus	*glacialis*	*M. corrugatus*	UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Musculus	*niger*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Mytilus	*trossulus*	*M. edulis*	UAM	I/ST/Epi	II III IV						Coan et al. 2000
Solamen	*columbianun*	*Megacrenella*	Coan et al. 2000	ST/Inf	II III IV	x					Coan et al. 2000
Vilasina	*seminuda*	*Musculus*	Coan et al. 2000	ST/Epi	II III IV	x					Coan et al. 2000
Vilasina	*vernicosa*	*Musculus*	UAM	ST/Epi	II III IV	x					Coan et al. 2000
Nuculana	*conceptionis*	*Perrisonota*	UAM	ST/Inf	II III IV						Coan et al. 2000
Nuculana	*minuta*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Nuculana	*navisa*		Coan et al. 2000	ST/Inf	II III IV						Coan et al. 2000
Nuculana	*pernula*	*N. fossa*	UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Eunucula	*tenuis*	*Nucula*	UAM	ST/Inf	II	x		x			Coan et al. 2000
Crassostrea	*gigas*		UAM	I/ST/Epi	II III IV	x			NW Pacific	definate	Coan et al. 2000
Pandora	*wardiana*	*P. grandis*	UAM	ST/Inf	II III IV	x					Coan et al. 2000
Pandora	*bilirata*		Coan et al. 2000	ST/Inf	II III IV	x					Coan et al. 2000
Pandora	*filosa*		Coan et al. 2000	ST/Inf	II III IV						Coan et al. 2000
Pandora	*glacialis*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Chlamys	*rubida*		UAM	ST/Epi	II III IV	x					Coan et al. 2000
Crassdoma	*gigantea*	*Hinnites*	Coan et al. 2000	ST/Epi	II III IV						Coan et al. 2000
Delectopecten	*vancouverensis*	*D. randolphi*	UAM	ST/Epi	II III IV	x					Coan et al. 2000
Parvamussium	*alaskense*		UAM	ST/Epi	II III IV						Coan et al. 2000
Patinopecten	*caurinus*		UAM	ST/Epi	II III IV						Coan et al. 2000
Periploma	*aleuticum*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Siliqua	*alta*	Solenidae*: S. sloati*	UAM	I/ST/Inf	II III IV	x					Coan et al. 2000
Siliqua	*patula*	Solenidae	Coan et al. 2000	I/Inf	II III IV						Coan et al. 2000
Philibrya	*setosa*		Coan et al. 2000	ST/Inf	II III IV						Coan et al. 2000
Penitella	*penita*		Coan et al. 2000	I/ST/Inf	II III IV						Coan et al. 2000

Table 10.4 continued.

					BIOREGION						
GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Gari	*californica*		UAM	I/Inf	II III IV	x					Coan et al. 2000
Macoma	*dexioptera*		UAM	ST/Inf	II						Coan et al. 2000
Macoma	*elimata*		UAM	ST/Inf	II III IV						Coan et al. 2000
Macoma	*moesta*		UAM	ST/Inf	II III IV		x	x			Coan et al. 2000
Macoma	*balthica*		UAM	I/Inf	x	x	x	x		C	Coan et al. 2000
Macoma	*brota*		UAM	ST/Inf	II III IV						Coan et al. 2000
Macoma	*calcarea*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Macoma	*carlottensis*		UAM	ST/Inf	II III IV						Coan et al. 2000
Macoma	*expansa*		UAM	I/ST/Inf	II III IV						Coan et al. 2000
Macoma	*golikovi*	*M. obliqua*	UAM	I/ST/Inf	II III IV						Coan et al. 2000
Macoma	*inquinata*		UAM	I/ST/Inf	II III IV						Coan et al. 2000
Macoma	*lipara*		Coan et al. 2000	ST/Inf	II III IV						Coan et al. 2000
Macoma	*nasuta*		UAM	I/ST/Inf	II III IV						Coan et al. 2000
Tellina	*modesta*		UAM	ST/Inf	II III IV						Coan et al. 2000
Bankia	*setacea*		UAM	ST/Inf	II III IV	x					Coan et al. 2000
Thracia	*challisiana*		Coan et al. 2000	ST/Inf	II III IV						Coan et al. 2000
Thracia	*condoni*		Coan et al. 2000	ST/Inf	II III IV						Coan et al. 2000
Thracia	*myopsis*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Thracia	*trapeziodes*		UAM	ST/Inf	II III IV						Coan et al. 2000
Adontorhina	*cyclia*		UAM	I/ST/Inf	II III IV	x					Coan et al. 2000
Axinopsida	*serricata*		UAM	I/ST/Inf	II	x	x	x			Coan et al. 2000
Conchocoele	*bisecta*	*Thyasira*	Coan et al. 2000	ST/Inf	II III IV	x					Coan et al. 2000
Mendicula	*ferruginosa*	*Odontogena borealis*	UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Thyasira	*flexuosa*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Turtonia	*minuta*		UAM	I/Inf	II			x			Coan et al. 2000
Diplodonta	*impolita*		UAM	I/Inf	II III IV						Coan et al. 2000
Compsomyax	*subdiaphana*		UAM	ST/Inf	II III IV						Coan et al. 2000
Humilaria	*kennerleyi*		UAM	I/ST/Inf	II III IV						Coan et al. 2000
Liocyma	*fluctuosa*		UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Nutricola	*lordi*	*Psephidia ovalis*	UAM	I/Inf	II III IV						Coan et al. 2000
Nutricola	*tantilla*	*Transenella*	UAM	I/ST/Inf	II III IV						Coan et al. 2000
Protothaca	*staminea*		UAM	I/ST/Inf	II III IV	x					Coan et al. 2000
Saxidomus	*gigantea*		UAM	I/Inf	II III IV						Coan et al. 2000
Yoldia	*hyperborea*	*Y. amygdalea*	UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Yoldia	*montereyensis*	*Megayoldia martyria/ M. secunda/ M. beringiana*	UAM	ST/Inf	II III IV						Coan et al. 2000
Yoldia	*myalis*		UAM	ST/Inf	II			x			Coan et al. 2000
Yoldia	*seminuda*	*Y. scissurata*	UAM	ST/Inf	II III IV	x					Coan et al. 2000
Yoldia	*thraciaeformis*	*Megayoldia*	UAM	ST/Inf	II	x	x	x			Coan et al. 2000
Gonatus	unidentified		Feder and Jewett 1988	P							
Benthoctopus	*leioderma*		Scheel- possible for PWS	ST/Epi	II III IV						Austin 1985
Octopus	*dofleini*	*Enteroctopus*	Scheel et al. 1997	ST/Epi	II III IV						Austin 1985
Octopus	*rubescens*		Scheel- observation	ST/Epi	II III IV						Austin 1985
Rossia	*pacifica*		UAM	ST/Epi	II III IV	x					Austin 1985
Chiroteuthis	*veranayi*	*C. calyx*	Cooney 1987	P	II III IV V VI						Austin 1985
Gliteuthis	*armata*	*G. phyllura*	Cooney 1987	P	II III IV V VI	x					Austin 1985
Acanthodoris	*hudsoni*		Lee and Foster 1985	I/ST/Epi	II III IV						Lee and Foster 1985
Acanthodoris	*nanaimoenisis*		Goddard 2000	I/ST/Epi	II III IV						Lee and Foster 1985
Acanthodoris	*pilosa*		Lee and Foster 1985	I/ST/Epi	II	x		x			Behrens 1991
Acmaea	*mitra*		UAM	I/Epi	II III IV						Austin 1985
Aeolidia	*papillosa*		Lee and Foster 1985	I/ST/Epi	x	x	x	x			Behrens 1991
Aglaja	*ocelligera*	*Melanochlamys*	Goddard 2000	I/ST/Epi	II III IV						Lee and Foster 1985
Melanochlamys	*diomedea*	*Aglaja*	Feder and Bryson Schwafel 1988	I/ST/Epi	II III IV				SE Alaska	nr	Lee and Foster 1985

Table 10.4 continued.

GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Archidoris	*montereyensis*			I/ST/Epi	II III IV						Lee and Foster 1985
Archidoris	*odhneri*		Lee and Foster 1985	I/ST/Epi	II III IV						Lee and Foster 1985
Armina	*californica*		Lee and Foster 1985	ST/Epi	II III IV						Lee and Foster 1985
Haminoea	*vesicula*		Foster 2000	I/ST/Epi	II III IV						Lee and Foster 1985
Haminoea	*virescens*		Baxter 1987	I/ST/Epi	II III IV						Lee and Foster 1985
Barleeia	*subtenuis*		UAM	I/Inf	II III IV						Baxter 1987
Barleeia	*haliotiphila*		Baxter 1987	I/Inf	II III IV						Baxter 1987
Pseudodiala	*acuta*	*Barleeia*	UAM	I/Inf	II III IV				British Columbia	NR	Baxter 1987
Ancistrolepis	*eucosmuis*		UAM	ST/Epi	II III IV						Baxter 1987
Beringius	*kennicotti*		UAM	ST/Epi	II III IV						Austin 1985
Buccinum	*baerii*		UAM	I/Epi	II III IV						Austin 1985
Buccinum	*plectrum*		UAM	ST/Epi	II III IV		x	x			Austin 1985
Colus	*aphelus*	*C. hypolispus*	UAM	ST/Epi	II III IV		x	x			Turgeon et al. 1998
Colus	*halli*		UAM	ST/Epi	II III IV						Austin 1985
Lirabuccinum	*dira*	*Searlesia*	UAM	I/ST/Epi	II III IV						Baxter 1987
Lussivolutopsius	*filosa*	*Volutopsius*	UAM	I/ST/Epi	II III IV						Baxter 1987
Neptunea	*lyrata*		UAM	ST/Epi	II III IV		x	x			Austin 1985
Neptunea	*pribiloffensis*		UAM	ST/Epi	II III IV	x					Austin 1985
Pyrulofusus	*harpa*	*Volutopsius*	UAM	I/ST/Epi	II III IV						Austin 1985
Volutopsius	undescribed sp.		Baxter 1987	I/ST/Epi	II III IV						Turgeon et al. 1998
Caecum	*crebricinctum*	*Micranellum*	UAM	I/ST/Inf	II III IV						Baxter 1987
Caecum	*occidentale*	*Fartulum*	UAM	I/Inf	II III IV						Baxter 1987
Calliostoma	*ligatum*	Trochidae	UAM	I/ST/Epi	II III IV						Baxter 1987
Calyptraea	*fastigiata*		UAM	I/ST/Epi	II III IV						Baxter 1987
Crepidula	*perforans*		Baxter 1987	I/ST/Epi	II III IV						Austin 1985
Crepipatella	*lingulata*	*Calyptraea fastigiata/ Crepiptella dorsata*	UAM	I/ST/Epi	II III IV						Baxter 1987
Admete	*viridula*	*A. couthouyi*	UAM	ST/Inf	II	x	x	x			Baxter 1987
Neadmete	*modesta*		UAM	ST/Inf	II III IV						Baxter 1987
Trichotropis	*borealis*	Trichotropidae	UAM	I/ST/Epi	II	x					Baxter 1987
Trichotropis	*cancellata*	Trichotropidae	UAM	I/ST/Epi	II III IV						Baxter 1987
Trichotropis	*insignis*	Trichotropidae	UAM	I/ST/Epi	II III IV	x					Baxter 1987
Stylidium	*eschrichti*	*Bittium*	Baxter 1987	I/Inf	II III IV						Austin 1985
Cadlina	*luteomarginata*		Rosenthal 1977	ST/Epi	II III IV V VI				SE Alaska	nr	Behrens 1991
Clione	*limacina*		Cooney and Coyle 1988	P	x	x	x	x			Wrobel and Mills 1998
Cocculina	*baxteri*		UAM	ST/Epi	II III						Baxter 1987
Alia	*carinata*	*Mitrella*		I/ST/Epi	II III IV						Baxter 1987
Amphissa	*columbiana*		UAM	I/ST/Inf	II III IV						Baxter 1987
Amphissa	*reticulata*		UAM	ST/Epi	II III IV						Baxter 1987
Astrys	*gauspata*	*Alia*	UAM	I/ST/Inf	II III IV						Baxter 1987
Grantotoma	*incisula*	Turridae: *Oenopota*	UAM	ST/Inf	II			x			Baxter 1987
Kurtziella	*plumbea*	Turridae	EVOS	I/ST/Epi	II III IV						Austin 1985
Oenopota	*bicarinata*	Turridae	UAM	ST/Inf	II			x			Austin 1985
Oenopota	*excurvata*	Turridae	UAM	ST/Inf	II III IV						Austin 1985
Oenopota	*krausei*	Turridae	UAM	ST/Inf	II III IV						Austin 1985
Oenopota	*rugulata*	Turridae	UAM	ST/Inf	II			x			Austin 1985
Oenopota	*turricula*	Turridae	UAM	ST/Inf	II			x			Austin 1985
Propebela	*arctica*	Turridae: *Oenopota viridula*	UAM	ST/Inf	II			x			Baxter 1987
Pseudotaranis	*strongi*	Turridae: *Tarais*	EVOS	ST/Epi	II III IV						Austin 1985
Doridella	*steinbergi*	*Suhinia*	EVOS	ST/Epi	II III IV						Behrens 1991
Flabellina	*trophina*	*F. fusca*	Lee and Foster 1985	ST/Epi	II III IV						Lee and Foster 1985
Flabellina	*salmonacea*		Lee and Foster 1985	ST/Epi	II	x	x	x			Lee and Foster 1985
Euclio	*pyamidata*	*Clio*	Cooney 1987	P	x	x	x	x			Austin 1985
Granulina	*margaritula*	*Marginellidae*	UAM	I/ST/Epi	II III IV						Baxter 1987

Table 10.4 continued.

GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Dendronotus	*albus*		Lee and Foster 1985	ST/Epi	II III IV						Behrens 1991
Dendronotus	*frondosus*		Lee and Foster 1985	ST/Epi	II			x			Behrens 1991
Dendronotus	*iris*		Lee and Foster 1985	ST/Epi	II III IV						Behrens 1991
Diaphana	*minuta*		Lee and Foster 1985	ST/Inf	II			x			Turgeon et al. 1998
Diaphana	*brunnea*		UAM		II III IV						Lee and Foster 1985
Dirona	*albolineata*		Lee and Foster 1985	ST/Epi	II III IV						Behrens 1991
Dirona	*aurantia*		Lee and Foster 1985	ST/Epi	II III IV						Behrens 1991
Anisodoris	*lentigenosa*		Lee and Foster 1985	ST/Epi	II III IV						Behrens 1991
Anisodoris	*nobilis*		Lee and Foster 1985	ST/Epi	II III IV						Behrens 1991
Dialula	*sandiegensis*		Lee and Foster 1985	ST/Epi	II III IV						Behrens 1991
Geitodoris	*heathi*		Goddard 2000	ST/Epi	II III IV				British Columbia	NR	Behrens 1991
Eubranchus	*olivaceous*		Goddard 2000	ST/Epi	II III IV				SE Alaska	nr	Behrens 1991
Melanella	*columbiana*	*Vitreolina*	UAM		II III IV						Baxter 1987
Melanella	*micrans*	*Balcis*	UAM	ST/Epi	II III IV						Baxter 1987
Hermissenda	*crassicornis*		Goddard 2000	I/ST/Epi	II III IV						Behrens 1991
Diadora	*aspera*		Baxter 1987	I/ST/Epi	II III IV						Austin 1985
Puncturella	*cooperi*		UAM	ST/Epi	II III IV						Austin 1985
Puncturella	*galeata*		UAM	ST/Epi	II III IV						Austin 1985
Puncturella	*noachina*		UAM	ST/Epi	II III IV		x	x			Austin 1985
Gastropteron	*pacificum*		Feder and Bryson Schwafel 1988	I/Epi	II III IV						Behrens 1991
Ancula	*pacifica*		Goddard 2000	ST/Epi	II III IV				SE Alaska	nr	Behrens 1991
Alderia	*modesta*		Goddard 2000	ST/Epi	II			x	British Columbia	NR	Behrens 1991
Cryptobranchia	*alba*		UAM	I/ST/Epi	II III IV	x					Baxter 1987
Cryptobranchia	*concentrica*		UAM	I/ST/Epi	II III IV	x					Baxter 1987
Lepeta	*caeca*		UAM	ST/Epi	II III IV	x					Baxter 1987
Limacina	*helicina*		Cooney and Coyle 1988	P	x	x	x	x			Wrobel and Mills 1998
Lacuna	*carinata*	*Lacunidae*	UAM	I/ST/Epi	II III IV						Austin 1985
Lacuna	*marmorata*	*Lacunidae*	Baxter 1987	I/ST/Epi	II III IV						Baxter 1987
Lacuna	*variegata*	*Lacunidae*	Baxter 1987	I/ST/Epi	II III IV						Baxter 1987
Lacuna	*vincta*	*Lacunidae*	UAM	I/ST/Epi	II			x			Austin 1985
Littorina	*scutulata*		UAM	I/Epi	II III IV						Austin 1985
Littorina	*sitkana*		UAM	I/Epi	II III IV						Austin 1985
Lottia	*borealis*		UAM	I/Epi	II III IV						Austin 1985
Lottia	*instabilis*		Baxter 1987	I/ST/Epi	II III IV						Austin 1985
Lottia	*ochracea*		UAM	I/ST/Epi	II III IV						Baxter 1987
Lottia	*pelta*		UAM	I/ST/Epi	II III IV						Austin 1985
Lottia	*triangularis*		Baxter 1987	I/ST/Epi	II III IV						Austin 1985
Lottia	*digitalis*		UAM	I/Epi	II III IV						Baxter 1987
Tectura	*fenestrata*		UAM	I/Epi	II III IV						Austin 1985
Tectura	*persona*		UAM	I/Epi	II III IV						Austin 1985
Tectura	*scutum*		UAM	I/ST/Epi	II III IV						Austin 1985
Tectura	*testudinalis*		Baxter 1987	I/ST/Epi	II			x			Austin 1985
Boreotrophon	*clathratus*		UAM	I/ST/Epi	II	x	x	x			Baxter 1987
Boreotrophon	*multicostata*		UAM	I/ST/Epi	II III IV						Turgeon et al. 1998
Boreotrophon	*truncatus*	*B. pacificus/ B. beringi*	UAM	I/ST/Epi	II	x	x	x			Turgeon et al. 1998
Nucella	*canaliculata*		UAM	I/Epi	II III IV						Baxter 1987
Nucella	*lamellosa*		UAM	I/Epi	II III IV						Austin 1985
Nucella	*lima*		UAM	I/Epi	II III IV	x					Baxter 1987
Ocenebrina	*interfossa*	*Ocenebra*	UAM	I/Epi	II III IV						Baxter 1987
Ocenebrina	*lurida*	*Ocenebra*	UAM	I/Epi	II III IV						Austin 1985
Scabrotrophon	*maltzan*	*Trophonopsis lasius*	UAM	I/Epi	II III IV						Baxter 1987

Table 10.4 continued.

					BIOREGION						
GENUS	**SPECIES**	**OTHER NAMES**	**SPECIMEN or SOURCE**	**HABITAT**	**NEP**	**NWP**	**AR**	**NWA**	**ORIGIN**	**NIS STATUS**	**REFERENCE to DISTRIBUTION**
Nassarius	*mendicus*		UAM	I/ST/Inf	II III IV						Austin 1985
Cryptonatica	*affinis*	*Natica russa/ Natica aleutica/ Natica clausa*	UAM	I/ST/Inf	II III IV	x	x	x			Austin 1985
Euspira	*pallida*	*Polinices pallidus*	UAM	I/ST/Inf	II	x	x	x			Austin 1985
Olea	*hansinensis*		Goddard 2000	ST/Epi	II III IV				British Columbia	NR	Behrens 1991
Olivella	*baetica*		UAM	I/ST/Inf	II III IV						Baxter 1987
Onchidella	*borealis*		Lee and Foster 1985	I/Epi	II III IV						Lee and Foster 1985
Adalaria	*jannae*		Goddard 2000	ST/Epi	II III IV				British Columbia	NR	Behrens 1991
Adalaria	*proxima*		Lee and Foster 1985	ST/Epi	II	x		x			Lee and Foster 1985
Adalaria	sp. 1 of Behrens		Goddard 2000	ST/Epi	II III IV				SE Alaska	nr	Behrens 1991
Onchidoris	*bilamellata*		Lee and Foster 1985	ST/Epi	II	x		x			Lee and Foster 1985
Onchidoris	*muricata*		Goddard 2000	ST/Epi	II	x		x			Lee and Foster 1985
Policera	*zosterae*		Goddard 2000	ST/Epi	II III IV				SE Alaska	nr	Behrens 1991
Triopha	*catalinae*	Triophidae	Lee and Foster 1985	ST/Epi	II III IV	x					Lee and Foster 1985
Cyclostremella	*concordia*	Cyclostremellidae	UAM		II III IV						Baxter 1987
Odostomia	*angularis*		UAM	I/ST/Inf	II III IV						Austin 1985
Odostomia	*arctica*		UAM	I/ST/Inf	II	x		x	Arctic	nr	Turgeon et al. 1998
Odostomia	*iliuliukensis*		UAM	I/ST/Inf	II III IV						Austin 1985
Odostomia	*cassandra*		Feder and Matheke 1980	I/ST/Inf	II III IV						Austin 1985
Odostomia	*pesa*		Baxter 1987	I/ST/Inf	II III IV						Baxter 1987
Turbonilla	*canadensis*		Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Turbonilla	*eyerdami*		Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Turbonilla	*lordii*		Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Turbonilla	*lyalli*		Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Turbonilla	*middendorffi*		Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Turbonilla	*rinella*		Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Fusitriton	*oregonensis*	*Cyamatiidae*	UAM	I/ST/Epi	II III IV						Baxter 1987
Retusa	*obtusa*	*R. perteuis/ R. semen*	UAM	I/ST/Inf	II			x	Bering Sea	nr	Lee and Foster 1985
"Rissoella"	*alaskensis*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV						Austin 1985
Alvania	*compacta*		UAM	I/ST/Inf	II III IV						Baxter 1987
Alvania	*moerchi*		Baxter 1987	I/ST/Inf	II	x	x	x			Baxter 1987
Alvania	*rosana*		UAM	I/ST/Inf	II III IV						Baxter 1987
Boreocingula	*martyni*	*Cingula katherenae*	Feder and Bryson Schwafel 1988	I/ST/Inf	II III IV						Austin 1985
Falsicingula	*aleutica*	Falsicingulidae	UAM	I/ST/Inf	II III IV						Baxter 1987
Onoba	*dalli*	*Alvania*	Baxter 1987	I/ST/Inf	II III IV						Baxter 1987
Onoba	*cerinella*		Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Onoba	*kyskensis*		Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Onoba	*montereyensis*	*Alvania carpenteri*	Baxter 1987	I/ST/Inf	II III IV						Austin 1985
Acteocina	*culcitella*	*Cylichnella*	EVOS	I/ST/Inf	II III IV						Austin 1985
Acteocina	*harpa*	*A. oldroydi*	Lee and Foster 1985	I/ST/Inf	II III IV						Behrens 1991
Cylichna	*attonsa*		UAM	I/ST/Inf	II III IV						Austin 1985
Cylichna	*occulta*		UAM	I/ST/Inf	II			x			Lee and Foster 1985
Cylichna	*alba*		UAM	I/ST/Inf	II	x	x	x			Austin 1985
Siphonaria	*thirsites*		UAM	I/Epi	II III IV						Baxter 1987
Hermaea	*vancouverensis*	*Hermaeidae*	Foster 1987	ST/Epi	II III IV						Behrens 1991
Cuthona	*albocrusta*		Goddard 2000	ST/Epi	II III IV				Washington	NR	Goddard 2000
Cuthona	*pustulata*		Goddard 2000	ST/Epi	II III IV				British Columbia	NR	Goddard 2000
Melibe	*leonina*		Lee and Foster 1985	P	II III IV						Lee and Foster 1985

Table 10.4 continued.

					BIOREGION						
GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Tritonia	*diomedea*		Lee and Foster 1985	ST/Epi	II III IV	x					Lee and Foster 1985
Tritonia	*festiva*		Lee and Foster 1985	ST/Epi	II III IV						Lee and Foster 1985
Trochuina	*tetraquetra*		Lee and Foster 1985	ST/Epi	II III IV	x					Lee and Foster 1985
Cidarina	*cidaris*		UAM	ST/Epi	II III IV						Baxter 1987
Lirularia	*succincta*		UAM	I/Inf	II III IV						Austin 1985
Margarites	*beringensis*		UAM	I/Inf	II III IV						Baxter 1987
Margarites	*helicinus*		UAM	ST/Inf	II	x	x	x			Austin 1985
Margarites	*pupillus*		UAM	ST/Inf	II III IV						Austin 1985
Solariella	*varicosa*		UAM	ST/Inf	II			x			Baxter 1987
Solariella	*obscura*		UAM	ST/Inf	II			x			Austin 1985
Spiromoellaria	*kachemakens*		UAM	I/ST/Epi	II III IV						Baxter 1987
Aforia	*circinata*		UAM	ST/Inf	II III IV						Baxter 1987
Tachyrhynchus	*erosus*		Baxter 1987	ST/Inf	II			x			Austin 1985
Tachyrhynchus	*reticulatus*		Baxter 1987	ST/Inf	II III IV						Austin 1985
Velutina	*plicatilis*		Baxter 1987	ST/Epi	II			x			Austin 1985
Velutina	*prolongata*		Baxter 1987	ST/Epi	II III IV						Austin 1985
Velutina	*rubra*		Foster 2000	I/Epi	II III IV						Austin 1985
Velutina	*undata*		Baxter 1987	ST/Epi	II	x	x	x			Austin 1985
Volumitra	*alaskana*		UAM	ST/Epi	II III IV						Baxter 1987
Arctomelon	*stearnsii*		UAM	ST/Epi	II III IV						Austin 1985
Janolus	*fuscus*		Goddard 2000	ST/Epi	II III IV				SE Alaska	nr	Goddard 2000
Clio	*pyramidata*		Cooney 1987	P	x	x		x			Turgeon et al. 1998
Cryptochiton	*stelleri*		UAM	I/ST/Epi	II III IV						Baxter 1987
Lepidozona	*interstincta*	*Ischnochiton*	UAM	ST/Epi	II III IV						Baxter 1987
Stenonemus	*albus*	*Ischnochiton*	UAM	ST/Epi	II			x			Baxter 1987
Leptochiton	*rugatus*		UAM	I/ST/Epi	II III IV	x					Austin 1985
Katherina	*tunicata*		UAM	I/Epi	II III IV						Baxter 1987
Mopalia	*laevior*		UAM	I/ST/Epi	II III IV						Austin 1985
Mopalia	*lignosa*		UAM	I/ST/Epi	II III IV						Baxter 1987
Mopalia	*ciliata*		UAM	I/ST/Epi	II III IV						Baxter 1987
Mopalia	*cirrata*		UAM	I/ST/Epi	II III IV						Baxter 1987
Mopalia	*mucosa*		UAM	I/ST/Epi	II III IV						Baxter 1987
Mopalia	*spectabilis*		Baxter 1987	I/ST/Epi	II III IV						Baxter 1987
Mopalia	*swanii*		UAM	I/ST/Epi	II III IV						Austin 1985
Placiphorella	*rufa*		UAM	I/ST/Epi	II III IV						Austin 1985
Schizoplax	*brandtii*		UAM	I/Epi	II III IV	x					Austin 1985
Tonicella	*insignis*	Ischnochitonidae	Foster 2000	I/ST/Epi	II III IV						Baxter 1987
Tonicella	*lineata*	Ischnochitonidae	UAM	I/ST/Epi	II III IV						Baxter 1987
Tonicella	*rubra*	Ischnochitonidae	UAM	I/ST/Epi	II			x			Baxter 1987
Rhabdus	*rectius*	*Dentalium dalli*	UAM	ST/Inf	II III IV						Baxter 1987
Pulsellum	*salishorum*		UAM	ST/Inf	II III IV						Baxter 1987
Polyschides	*tolmei*	*Cadulus stearnsi*	UAM	ST/Inf	II III IV						Baxter 1987

Arthropoda

Chelicerata and Pycnogonida are relatively scarce in Prince William Sound compared to Crustacea. Seven of the ten pycnogonid species are included in the data set based on UAM specimens, One Acarina and one pseudoscorpion are frequently observed in the high intertidal zone of southeastern and south-central Alaska.

Crustacea make up about 28% of the animal species listed in the data set (Table 10.5). We list 172 copepods, (including planktonic species from the Gulf of Alaska which may be present occasionally in Prince William Sound), 105 decapods, 105 amphipods, 21 cumacean, 19 isopods, and smaller numbers of others.

Several taxa (e.g. Ostracoda) are probably very much under-counted. Six copepods, one amphipod, and two ostracods are identified to the family level, and no further. A large number of small crustacea, mostly harpacticoid copepods and amphipods have not been identified to species. Two species, the amphipod *Jassa* sp./*marmorata* and the copepod *Leimia vaga* are possible NIS, but this number probably represents an underestimate. Cordell (2000) pointed out that "Harpacticoid copepods may be particularly likely to be transported and introduced because as a group they have successfully occupied almost all benthic and epibenthic habitats. … The paucity of studies of harpacticoid taxonomy in the northeastern Pacific makes it nearly impossible to determine whether or not a given species has been introduced without extensive distribution or genetic studies." We have not included an inventory of parasitic cirripedia or isopods, but several species of these were recorded by Hines et al. (2000).

Sources for information of Crustacea include Barnard 1969 (amphipods), Butler 1980 (shrimp), Hart 1982 (crabs), and Schultz 1969 and Squires and Figueria 1974 (isopods). J. Chapman (2000) contributed to the information on Pericarida, and J. Cordell (2000) to our knowledge of the harpacticoid Copepoda. Records for the planktonic crustacea derive from unpublished data compiled from T. Cooney's Sound Ecosystem Analysis project of 1994-1998. We found eleven new records for the occurrence of Crustacea.

The third major group of Arthropoda, marine and brackish water insects, have not been surveyed in any detail in the area. For insects, Austin (1985) lists eight Coleoptera, and 12 Diptera with ranges that include Alaska.

Table 10.5. Arthropoda.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Arachnida: Acarina		*Nemolgus*	*littoralis*		Foster/Hoberg-observation	I/Epi							
Arachnida: Pseudoscorpionida		unidentified	unidentified		UAM	I/epi							
Crustacea: Amphipoda	Acanthonotozomatidae	*Odius*	*carinatus*		EVOS	ST/Epi	II			x			Austin 1985
Crustacea: Amphipoda	Ampeliscidae	*Ampelisca*	*birulai*		Feder and Matheke 1980	I/ST/Inf	II III IV	x	x				Coyle and Highsmith 1994
Crustacea: Amphipoda	Ampeliscidae	*Ampelisca*	*brevisimulata*		EVOS	ST	II III IV						Austin 1985
Crustacea: Amphipoda	Ampeliscidae	*Ampelisca*	*caryei*		EVOS	ST	II III IV						Austin 1985
Crustacea: Amphipoda	Ampeliscidae	*Ampelisca*	*pugetica*		EVOS	ST	II III IV						Austin 1985
Crustacea: Amphipoda	Ampeliscidae	*Ampelisca*	*eschrichti*		Feder and Matheke 1980	ST/Inf	II III IV	x					Austin 1985
Crustacea: Amphipoda	Ampeliscidae	*Ampelisca*	*macrocephala*	*A. careyi*	Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985
Crustacea: Amphipoda	Ampeliscidae	*Haploops*	*tubicola*		Feder and Matheke 1980	ST/Inf	II	x		x			Austin 1985
Crustacea: Amphipoda	Amphitoidae	*Ampithoe*	*kussakini*		Chapman 2000	I/Inf	II III IV	x					Chapman 2000
Crustacea: Amphipoda	Amphitoidae	*Ampithoe*	*sectimanus*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Amphitoidae	*Ampithoe*	*simulans*		Feder and Bryson-Schwafel 1988	I/ST	x	x	x	x			Austin 1985
Crustacea: Amphipoda	Amphitoidae	*Peramphithoe*	*eoa*	*Ampithoe mea*	Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Amphitoidae	*Peramphithoe*	*humeralis*	*Ampithoe*	Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Anisogammaridae	*Anisogammarus*	*pugettensis*		EVOS	ST/Epi	II III IV	x					Chapman 2000
Crustacea: Amphipoda	Anisogammaridae	*Eogammarus*	*confervicolus*	*Anisogammarus*	Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Anisogammaridae	*Eogammarus*	*oclairi*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Anisogammaridae	*Eogammarus*	unidentified		Chapman 2000	I/ST							
Crustacea: Amphipoda	Anisogammaridae	*Locustogammarus*	*locustoides*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Anisogammaridae	*Spinulogammarus*	*subcarinatus*		Chapman 2000	I?	II III IV						Chapman 2000
Crustacea: Amphipoda	Aoridae	*Aoroides*	*columbiae*		EVOS	ST	II III IV	x					Austin 1985
Crustacea: Amphipoda	Atylidae	*Atylus*	*collingi*		EVOS	ST	II III IV	x					Austin 1985
Crustacea: Amphipoda	Calliopiidae	*Calliopiella*	unidentified	*Paracalliopiella*	Chapman 2000	I/Inf							

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Amphipoda	Calliopiidae	*Calliopius*	*behringi*		Cooney 1987	I/ST	II III	x	x	x			Gur'yanova 1951, 1962
Crustacea: Amphipoda	Calliopiidae	*Calliopius*	*carinatus?*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Calliopiidae	*Calliopius*	*laeviuscula*		Cooney 1987	P	III IV V VI	x		x			Austin 1985
Crustacea: Amphipoda	Caprellidae	*Caprella*	*drepanochir*		Chapman 2000	I/Inf	II III IV	x				C	Chapman 2000
Crustacea: Amphipoda	Caprellidae	*Caprella*	*laeviuscula*		Chapman 2000	I/Inf	II III IV	x					Chapman 2000
Crustacea: Amphipoda	Caprellidae	*Caprella*	unidentified		Chapman 2000	I/Inf							
Crustacea: Amphipoda	Caprellidae	*Metacaprella*	*kennerlyi*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Corophidae	*Neohela*	unidentified		Feder and Matheke 1980	ST/Inf							
Crustacea: Amphipoda	Corophidae	*Americorophium*	*brevis*	*Corophium*	Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Corophidae	*Americorophium*	*salmonis*	*Corophium*	Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Corophidae	*Americorophium*	*spinicore*	*Corophium*	Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Corophidae	*Corophium*	unidentified		EVOS	ST							
Crustacea: Amphipoda	Corophidae	*Monocorophium*	*carlottensis?*		Chapman 2000	I/Inf	II III IV					C	Chapman 2000
Crustacea: Amphipoda	Dexamidae	*Guernea*	unidentified		EVOS	ST							
Crustacea: Amphipoda	Eusiridae	*Eusiriella*	*multicalceola*	*Gracilipes*	Cooney 1987	P	II III						Austin 1985
Crustacea: Amphipoda	Eusiridae	*Pontogeneia*	unidentified		EVOS	ST							
Crustacea: Amphipoda	Eusiridae	*Rhachotropis*	*natator*		Cooney 1987	P	II III IV V			x			Austin 1985
Crustacea: Amphipoda	Gammaridae	*Lagunogammarus*	*setosus*		Chapman 2000	I/Inf	II III IV		x				Chapman 2000
Crustacea: Amphipoda	Haustoriidae	*Ericthonius*	*hunteri*	*E. rubricornis*	Feder and Matheke 1980	I/ST/Inf	II	x		x			Austin 1985
Crustacea: Amphipoda	Hyalellidae	*Najna*	unidentified	*Najnidae*	EVOS	I/St							
Crustacea: Amphipoda	Hyalidae	*Allorchestes*	*angusta*		Chapman 2000	I/Inf	II III IV	x					Chapman 2000
Crustacea: Amphipoda	Hyalidae	*Hyale*	*frequena*		Chapman 2000	I/Inf	II III IV						Chapman 2000

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Amphipoda	Hyalidae	*Hyale*	*plumulosa*		Chapman 2000	I/Inf	II	x		x		C	Chapman 2000
Crustacea: Amphipoda	Hyperiidae	*Euprimno*	*macropa*	*Primno abyssalis*	Cooney: SEA	P	II III IV V VI VII VIII IX	x		x			Austin 1985
Crustacea: Amphipoda	Hyperiidae	*Euprimno*	unidentified	*Primno*	Cooney 1987	P							
Crustacea: Amphipoda	Hyperiidae	*Hyperia*	*medusarum hystryx*		Cooney 1987	P	II III IV V VI			x			Austin 1985
Crustacea: Amphipoda	Hyperiidae	*Hyperia*	unidentified		Cooney 1987	P							
Crustacea: Amphipoda	Hyperiidae	*Hyperoche*	*medusarum*		Cooney 1987	P	II III IV V VI			x			Austin 1985
Crustacea: Amphipoda	Hyperiidae	*Hyperoche*	unidentified		Cooney 1987	P							
Crustacea: Amphipoda	Hyperiidae	*Parathemisto*	*gracilipes*	*Thermisto*	Cooney 1987	P	II III	x		x			Austin 1985
Crustacea: Amphipoda	Hyperiidae	*Parathemisto*	*libellula*	*Thermisto*	Cooney 1987	P	II III IV V		x				Austin 1985
Crustacea: Amphipoda	Hyperiidae	*Parathemisto*	*pacifica*	*Thermisto*	Cooney 1987	P	II III IV	x					Austin 1985
Crustacea: Amphipoda	Isaeidae	*Photis*	unidentified		EVOS	ST/Inf							
Crustacea: Amphipoda	Ischyroceridae	*Ischyrocerus*	unidentified		EVOS	I/ST/Inf							
Crustacea: Amphipoda	Ischyroceridae	*Jassa*	sp./*J. marmorata*		Chapman 2000	I/Inf	II					possible	Austin 1985
Crustacea: Amphipoda	Ischyroceridae	*Jassa*	*staudei?*		Chapman 2000	I/Inf	II III IV					C	Chapman 2000
Crustacea: Amphipoda	Ischyroceridae	*Protomedeia*	unidentified		Feder and Matheke 1980	I/ST/Inf							
Crustacea: Amphipoda	Lanceolidae	*Lanceola*	*pacifica*		Cooney 1987	P	II III	x		x			Gur'yanova 1951, 1962
Crustacea: Amphipoda	Lycaeidae	*Tryphana*	*malmii*		Cooney 1987	P	II III IV V						Austin 1985
Crustacea: Amphipoda	Lysianassidae	*Andaniexis*	*subabyssis*		Cooney 1987	P	II III IV	x					Gur'yanova 1951, 1962
Crustacea: Amphipoda	Lysianassidae	*Anonyx*	unidentified		Feder and Matheke 1980	I/ST/Inf							
Crustacea: Amphipoda	Lysianassidae	*Crybelocephalus*	unidentified		Feder and Matheke 1980	P	x	x	x	x			
Crustacea: Amphipoda	Lysianassidae	*Cyphocaris*	*anonyx*	*C. micronyx*	Cooney 1987	P	II III IV V VI VII VIII			x			Austin 1985

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	**FAMILY**	**GENUS**	**SPECIES**	**OTHER NAMES**	**SPECIMEN or SOURCE**	**HABITAT**	**NEP**	**NWP**	**AR**	**NWA**	**ORIGIN**	**NIS STATUS**	**REFERENCE to DISTRIBUTION**
Crustacea: Amphipoda	Lysianassidae	*Cyphocaris*	*challengeri*		Cooney and Coyle 1988	S/P	x	x	x	x			Austin 1985
Crustacea: Amphipoda	Lysianassidae	*Hippomedon*	*kurilicus*	*H. abyssi*	UAM	ST	II III IV	x					Gur'yanova 1951, 1962
Crustacea: Amphipoda	Lysianassidae	*Koroga*	*megalops*		Cooney 1987	P	II III	x	x	x			Austin 1985
Crustacea: Amphipoda	Lysianassidae	*Lepidepecerium*	unidentified		EVOS	ST							
Crustacea: Amphipoda	Lysianassidae	*Onismius*	unidentified		EVOS	ST							
Crustacea: Amphipoda	Lysianassidae	*Orchomene*	*obtusa*		Cooney: SEA	ST	II III IV V VI VII						Gur'yanova 1951, 1962
Crustacea: Amphipoda	Lysianassidae	*Orchomene*	*pacifica*		EVOS	ST	II III IV	x					Austin 1985
Crustacea: Amphipoda	Lysianassidae	*Orchomene*	unidentified		EVOS	ST							
Crustacea: Amphipoda	Lysianassidae	*Paracallisoma*	*alberti*		Cooney 1987	P	II III	x					Gur'yanova 1951, 1962
Crustacea: Amphipoda	Melitidae	*Maera*	*loveni*	*M.danae*	Feder and Matheke 1980	ST/Inf	II	x		x			Austin 1985
Crustacea: Amphipoda	Melitidae	*Melita*	*dentata*		EVOS	ST	II III IV	x					Austin 1985
Crustacea: Amphipoda	Melphidippidae	unidentified	unidentified		Cooney: SEA	ST	II III			x	NE Pac	NR?	Austin 1985
Crustacea: Amphipoda	Oedicerotidae	*Aceroides*	*latipes*		Feder and Matheke 1980	I/ST/Inf	II III IV		x				Austin 1985
Crustacea: Amphipoda	Oedicerotidae	*Bathymedon*	unidentified		EVOS	ST/Inf							
Crustacea: Amphipoda	Oedicerotidae	*Monoculodes*	*diamesus*		Feder and Matheke 1980	I/ST/Inf	II III IV						Gur'yanova 1951, 1962
Crustacea: Amphipoda	Oedicerotidae	*Synchelidium*	*rectipalmatum*		EVOS	ST/Inf	II III IV						Austin 1985
Crustacea: Amphipoda	Oedicerotidae	*Westwoodillia*	*rectangulata?*	*W. caecula*	Cooney 1987	P	II	x					Gur'yanova 1951, 1962
Crustacea: Amphipoda	Oxycephalidae	*Streesia*	unidentified		Cooney 1987	P							
Crustacea: Amphipoda	Paraphronimidae	*Paraphronima*	*crassipes*		Cooney 1987	P	II III IV V VI VII			x			Austin 1985
Crustacea: Amphipoda	Pardaliscidae	*Nicippe*	*tumida*		Feder and Matheke 1980	I/ST/Inf	II III IV	x					Austin 1985
Crustacea: Amphipoda	Phoxocephalidae	*Harpiniopsis*	*sanpedroensis*	*Harpinia*	Feder and Matheke 1980	I/ST/Inf	II III IV						Austin 1985
Crustacea: Amphipoda	Phoxocephalidae	*Paraphoxus*	*homilis*		EVOS	ST/Inf	II III IV						Austin 1985
Crustacea: Amphipoda	Phoxocephalidae	*Paraphoxus*	*similis*		EVOS	ST/Inf	II III IV						Austin 1985
Crustacea: Amphipoda	Phronimidae	*Phronima*	*sedentaria*		Cooney 1987	P	II III IV V VI			x			Austin 1985

Table 10.5 continued.

HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Amphipoda	Phrosinidae	*Primno*	*macropa*	*P. abyssalis*	Cooney 1987	P	II III IV V VI	x		x			Austin 1985
Crustacea: Amphipoda	Pleustidae	*Pleustes*	*cataphractus*		EVOS	I/Inf	x	x		x			Austin 1985
Crustacea: Amphipoda	Pontogeneiidae	*Megamorea*	*subiener*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Pontogeneiidae	*Paramoera*	*bousfieldi*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Pontogeneiidae	*Paramoera*	*columbiana*		Feder and Bryson-Schwafel 1988	I/Inf	II III IV						Austin 1985
Crustacea: Amphipoda	Pontogeneiidae	*Paramoera*	*mohri*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Pontogeneiidae	*Pontogeneia*	*ivanovae*	*P. ivanovi*	Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Pontogeneiidae	*Pontogeneia*	*rostrata*		Chapman 2000	I/Inf	II III IV					C	Chapman 2000
Crustacea: Amphipoda	Pontoporeiidae	*Pontoporeia*	*femorata*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Amphipoda	Proscinidae	*Proscina*	*birsteini*		Cooney 1987	P	II	x					Gur'yanova 1951, 1962
Crustacea: Amphipoda	Scinidae	*Scina*	*borealis*		UAM	I/ST/Inf	II III IV V VI	x		x			Austin 1985
Crustacea: Amphipoda	Scinidae	*Scina*	*rattayi*		Cooney 1987	P	II III IV			x			Austin 1985
Crustacea: Amphipoda	Scinidae	*Scina*	unidentified		Cooney: SEA	P							
Crustacea: Amphipoda	Scinidae	*Scina*	*stebbingi*		Cooney 1987	P	II	x					Gur'yanova 1951, 1962
Crustacea: Amphipoda	Stenothoidae	*Metopa*	unidentified		Feder and Matheke 1980	I/ST/Inf							
Crustacea: Amphipoda	Stenothoidae	*Metopelloides*	*erythrophthalmus*		EVOS		II III IV						Austin 1985
Crustacea: Amphipoda	Synopiidae	*Syrrhoe*	*crenulata*		Feder and Matheke 1980	I/ST/Inf	II	x		x			Austin 1985
Crustacea: Amphipoda	Synopiidae	*Tiron*	*biocellata*		EVOS		II III IV						Austin 1985
Crustacea: Amphipoda	Talitridae	*Talitrus*	unidentified		Feder and Bryson-Schwafel 1988	I/Inf							
Crustacea: Amphipoda	Urothoidae	*Urothoe*	*denticulata*		Feder and Matheke 1980	I/ST/Inf	II III IV						Gur'yanova 1951, 1962
Crustacea: Amphipoda	Vibiliidae	*Viblia*	*australis*		Cooney 1987	P	II III IV			x			Austin 1985
Crustacea: Cladocera	Podonidae	*Evadne*	*nordmanni*		Cooney 1987	P	II III IV V VI	x	x	x			Austin 1985
Crustacea: Cladocera	Podonidae	*Evadne*	unidentified		Cooney 1987	P							

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Cladocera	Podonidae	*Evadne*	*tergistina*	*Pseudevadne*	Cooney 1987	P	II III IV V VI						Austin 1985
Crustacea: Cladocera	Podonidae	*Podon*	*leuckarti*		Cooney 1987	P	II III IV	x		x			Austin 1985
Crustacea: Cladocera	Podonidae	*Podon*	*polyphmoies*		Cooney 1987	P	II III IV V VI	x	x	x			Austin 1985
Crustacea: Cladocera	Podonidae	*Podon*	unidentified		Cooney 1987	P							
Crustacea: Copepoda: Calanoida	Acartiidae	*Acartia*	*cf. A. clausi*		Cordell 2000	P	II III IV						Cordell 2000
Crustacea: Copepoda: Calanoida	Acartiidae	*Acartia*	*longiremis*		Cooney and Coyle 1988	P	II	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Acartiidae	*Acartia*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Acartiidae	*Acartia*	*tumida*		Cooney and Coyle 1988	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Aetideus*	*divergens*	*A. armatus*	Cooney 1987	P	II III IV V VI						Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Aetideus*	*pacificus*		Cooney 1987	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Aetideus*	unidentified		Cooney 1987	P							
Crustacea: Copepoda: Calanoida	Aetideidae	*Bradyidius*	*saanichi*		Cooney 1987	P	II III IV						Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Chiridiella*	unidentified		Cooney and Coyle 1988	P							
Crustacea: Copepoda: Calanoida	Aetideidae	*Chiridius*	*gracilis*		Cooney 1987	P	II III	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Chiridius*	*poppei*		Cooney 1987	P	II	x					Brodsky 1950
Crustacea: Copepoda: Calanoida	Aetideidae	*Chiridius*	unidentified		Cooney and Coyle 1988	P							
Crustacea: Copepoda: Calanoida	Aetideidae	*Gaetanus*	*intermedius*	*Gaidius*	Cooney 1987	P	II III IV						Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Gaidius*	*tenuispinus*	*G. minutus*	Cooney 1987	P	II III IV						Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Gaidius*	*variabilis*		Cooney 1987	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Pseudochirella*	*sarsi*	Euchaetidae: *Euchaeta*	Cooney 1987	P	II III IV						Austin 1985
Crustacea: Copepoda: Calanoida	Aetideidae	*Pseudochirella*	unidentified		Cooney 1987	P							
Crustacea: Copepoda: Calanoida	Aetideidae	unidentified	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Augaptilidae	*Haloptilus*	*pseudooxycephalus*		Cooney 1987	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Augaptilidae	*Pachyptilis*	*pacificus*		Cooney 1987	P	II III	x					Austin 1985
Crustacea: Copepoda: Calanoida	Calanidae	*Calanus*	*glacialis*	*E. marshallae*	Cooney 1987	P	II III IV	x					Austin 1985

Table 10.5 continued.

HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Copepoda: Calanoida	Calanidae	*Calanus*	*marshallae*	*C. glacialis*	Cooney and Coyle 1988	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Calanidae	*Calanus*	*pacificus*		Cooney 1987	P	II III IV						Austin 1985
Crustacea: Copepoda: Calanoida	Calanidae	*Neocalanus*	*cristatus*		Cooney 1987	P	II III IV V	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Calanidae	*Neocalanus*	*flemingeri*		Cooney: SEA	P	II III IV						Miller 1988
Crustacea: Copepoda: Calanoida	Calanidae	*Neocalanus*	*plumchrus*		Cooney and Coyle 1988	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Calanidae	*Neocalanus*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Candaciidae	*Candacia*	*bipinnata*		Cooney: SEA	P	II III IV V	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Candaciidae	*Candacia*	*columbiae*		Cooney and Coyle 1988	P	II III IV	x					Cooney 1987
Crustacea: Copepoda: Calanoida	Centropagidae	*Centropages*	*abdominalis*		Cooney and Coyle 1988	P	II III IV	x					Cordell 2000
Crustacea: Copepoda: Calanoida	Clausocalanidae	*Clausocalanus*	*arcuicornis*		Cooney 1987	P	II III IV						Austin 1985
Crustacea: Copepoda: Calanoida	Clausocalanidae	*Clausocalanus*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Clausocalanidae	*Mesocalanus*	*tenuicornis*		Cooney 1987	P	II	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Clausocalanidae	*Microcalanus*	unidentified		Cooney 1987	P							
Crustacea: Copepoda: Calanoida	Clausocalanidae	*Pseudocalanus*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Corycaeidae	*Corycaeus*	*anglicus*		Cooney 1987	P	II III IV V			x			Austin 1985
Crustacea: Copepoda: Calanoida	Corycaeidae	*Corycaeus*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Ectinosomatidae	*Microsetella*	*rosea*		Cooney 1987	P	II III VI V VI	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Ectinosomatidae	*Microsetella*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Eucalanidae	*Eucalanus*	*bungii*		Cooney and Coyle 1988	P	II III IV						Austin 1985
Crustacea: Copepoda: Calanoida	Euchaetidae	*Euchaete*	*elongata*		Cooney and Coyle 1988	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Heterhabdidae	*Heterorhabdus*	*compactus*		Cooney 1987	P	II	x		x			Brodsky 1950
Crustacea: Copepoda: Calanoida	Heterhabdidae	*Heterorhabdus*	*robustoides*		Cooney 1987	P	II III	x					Gardner and Szabo 1982
Crustacea: Copepoda: Calanoida	Heterhabdidae	*Heterorhabdus*	*tanneri*		Cooney 1987	P	II III IV	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Heterhabdidae	*Heterostylites*	*longicornis*		Cooney: SEA	P	III VI V VI			x			Austin 1985
Crustacea: Copepoda: Calanoida	Heterhabdidae	*Heterostylites*	*major*		Cooney 1987	P	II III IV			x			Austin 1985
Crustacea: Copepoda: Calanoida	Lucicutiidae	*Lucicutia*	*flavicornis*		Cooney 1987	P	II III IV V VI			x			Austin 1985

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Copepoda: Calanoida	Lucicutiidae	*Lucicutia*	*ovalis*		Cooney 1987	P	II III IV			x			Austin 1985
Crustacea: Copepoda: Calanoida	Lucicutiidae	*Lucicutia*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Metridiidae	*Metridia*	*curticauda*		Cooney and Coyle 1988	P	II III IV			x			Austin 1985
Crustacea: Copepoda: Calanoida	Metridiidae	*Metridia*	*okhotensis*	*M. longa*	Cooney and Coyle 1988	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Metridiidae	*Metridia*	*pacifica*		Cooney and Coyle 1988	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Metridiidae	*Metridia*	*princeps*		Cooney and Coyle 1988	P	II III IV V VI		x	x			Austin 1985
Crustacea: Copepoda: Calanoida	Metridiidae	*Metridia*	unidentified		Cooney and Coyle 1988	P							
Crustacea: Copepoda: Calanoida	Metridiidae	*Pleuromamma*	*robusta*		Cooney 1987	P	II III IV			x			Austin 1985
Crustacea: Copepoda: Calanoida	Metridiidae	*Pleuromamma*	*scutullata*		Cooney 1987	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Monstrillidae	*Cymbasoma*	*rigidum*		Cooney 1987	P	II III			x			Austin 1985
Crustacea: Copepoda: Calanoida	Monstrillidae	*Monstrilla*	*canadensis*		Cooney 1987	P	II III IV			x			Gardner and Szabo 1982
Crustacea: Copepoda: Calanoida	Monstrillidae	*Monstrilla*	*helgolandica*		Cooney 1987	P	II III IV			x			Gardner and Szabo 1982
Crustacea: Copepoda: Calanoida	Monstrillidae	*Monstrilla*	*longiremus*		Cooney 1987	P	II III IV						Gardner and Szabo 1982
Crustacea: Copepoda: Calanoida	Monstrillidae	*Monstrilla*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Calanoida	Monstrillidae	*Monstrilla*	*wandlii*		Cooney 1987	P	II III IV			x			Gardner and Szabo 1982
Crustacea: Copepoda: Calanoida	Paracalanidae	*Paracalanus*	*parvus*		Cooney 1987	P	II III IV V VI	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Paracalanidae	*Paracalanus*	unidentified		Cordell 2000	P							
Crustacea: Copepoda: Calanoida	Phaennidae	*Gaetanus*	unidentified		Cooney and Coyle 1988	P							
Crustacea: Copepoda: Calanoida	Pontellidae	*Epilabidocera*	*longipedata*	*E. amphitrites*	Cooney 1987	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Pseudocalanidae	*Pseudocalanus*	unidentified		Cordell 2000	P							
Crustacea: Copepoda: Calanoida	Scolecitrichidae	*Lophothrix*	*frontalis*		Cooney 1987	P	II III IV V VI			x			Austin 1985
Crustacea: Copepoda: Calanoida	Scolecitrichidae	*Racovitzanus*	*antarcticus*		Cooney 1987	P	III IV	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Scolecitrichidae	*Scaphocalanus*	*brevicornis*		Cooney 1987	P	II III IV	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Scolecitrichidae	*Scaphocalanus*	*magnus*		Cooney 1987	P	II III IV	x		x			Austin 1985

Table 10.5 continued.

HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Copepoda: Calanoida	Scolecitrichidae	*Scolecithricella*	*minor*		Cooney 1987	P	II	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Scolecitrichidae	*Scolecithricella*	*ovata*	*S. subdentata*	Cooney: SEA	P	II III IV V VI						Austin 1985
Crustacea: Copepoda: Calanoida	Spinocalanidae	*Spinocalanus*	*brevicaudatus*		Cooney 1987	P	II III	x		x			Austin 1985
Crustacea: Copepoda: Calanoida	Temoridae	*Eurytemora*	*americana*		Cooney 1987	P	II III	x					Austin 1985
Crustacea: Copepoda: Calanoida	Temoridae	*Eurytemora*	*herdmani*	*E. pacifica*	Cordell 2000	P	II III IV	x					Austin 1985
Crustacea: Copepoda: Calanoida	Temoridae	*Eurytemora*	unidentified		Cooney 1987	P							
Crustacea: Copepoda: Calanoida	Tharydidae	*Undinella*	unidentified		Cooney 1987	P							
Crustacea: Copepoda: Calanoida	Tortanidae	*Tortanus*	*discaudata*		Cooney and Coyle 1988	P	II	x		x			Austin 1985
Crustacea: Copepoda: Calanoida		*Amallothryx*	*inornata*			P							
Crustacea: Copepoda: Cyclopoida	Cyclopidae	*Euryte*	unidentified		Cordell 2000	P							
Crustacea: Copepoda: Cyclopoida	Cyclopidae	*Halicyclops*	unidentified		Cordell 2000	P							
Crustacea: Copepoda: Cyclopoida	Cyclopinidae	*Cyclopina*	unidentified		Cooney 1987	P							
Crustacea: Copepoda: Cyclopoida	Cyclopinidae	unidentified	unidentified		Cordell 2000	P							
Crustacea: Copepoda: Cyclopoida	Oithonidae	*Oithona*	*similis*		Cordell 2000	P	x	x	x	x			Cordell 2000
Crustacea: Copepoda: Cyclopoida	Oithonidae	*Oithona*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Cyclopoida	Oithonidae	*Oithona*	*spinirostris*		Cordell 2000	P	x	x	x	x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Ameiridae	*Ameira*	*longipes*		Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Ameiridae	*Ameira*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Ameiridae	*Ameira*	sp. 2		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Ameiridae	unidentified	sp. 1		Cordell 2000	I/Inf							

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Copepoda: Harpacticoida	Ancorabilidae	*Arthropsyllus*	*serratus*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Canthocamptidae	*Mesochra*	*pygmaea*		Feder and Bryson-Schwafel 1988	I/Inf	II	x	x	x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Canthocamptidae	*Mesochra*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Canthocamptidae	unidentified	incertae sedis		Cordell 2000		II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Cletodidae	*Acrenhydrosoma*	unidentified		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Cletodidae	*Leimia*	*vaga*		Cordell 2000	I/Inf	II	x		x		possible	Cordell 2000
Crustacea: Copepoda: Harpacticoida	Cletodidae	*Nannopus*	*palustris*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II	x		x			Austin 1985
Crustacea: Copepoda: Harpacticoida	Cletodidae	*Rhizothrix*	unidentified		Feder and Bryson-Schwafel 1988	I/ST/Inf							
Crustacea: Copepoda: Harpacticoida	Danielsseniidae	*Danielsennia*	*typica*		Feder and Bryson-Schwafel 1988	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Amonardia*	*normani*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Amonardia*	*perturbata*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Amphiascoides*	cf. *D. debilis*		Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Amphiascoides*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Amphiascopis*	*cinctus*		Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Amphiascus*	*minutus*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Amphiascus*	sp. 1		Cordell 2000	I/Inf							

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	**FAMILY**	**GENUS**	**SPECIES**	**OTHER NAMES**	**SPECIMEN or SOURCE**	**HABITAT**	**NEP**	**NWP**	**AR**	**NWA**	**ORIGIN**	**NIS STATUS**	**REFERENCE to DISTRIBUTION**
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Diosaccus*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Diosaccus*	*spinatus*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Robertsonia*	unidentified		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Stenhelia*	*peniculata*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Diosaccidae	*Stenhelia*	unidentified		Feder and Bryson-Schwafel 1988	I/ST/Inf							
Crustacea: Copepoda: Harpacticoida	Ectinosomatidae	*Ectinosoma*	unidentified		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Ectinosomatidae	*Halectinosoma*	*finmarchium*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II	x		x			Austin 1985
Crustacea: Copepoda: Harpacticoida	Ectinosomatidae	*Halectinosoma*	*gothiceps*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II	x		x			Austin 1985
Crustacea: Copepoda: Harpacticoida	Ectinosomatidae	*Halectinosoma*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Ectinosomatidae	*Halectinosoma*	sp. 2		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Ectinosomatidae	*Halectinosoma*	sp. 3		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Ectinosomatidae	*Microarthridion*	*norvegica*		Cordell 2000	I/Inf	x	x	x	x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Harpacticidae	*Harpacticus*	*compressus*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Harpacticidae	*Harpacticus*	*septentrionalis*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Harpacticidae	*Harpacticus*	sp.- *obscurus* group 1		Cordell 2000	I/Inf	II III IV						Cordell 2000

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Copepoda: Harpacticoida	Harpacticidae	*Harpacticus*	sp.- *obscurus* group 2		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Harpacticidae	*Harpacticus*	sp.- *uniremis* group 1		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Harpacticidae	*Harpacticus*	*superflexus*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III						Cooney 1987
Crustacea: Copepoda: Harpacticoida	Harpacticidae	*Harpacticus*	*uniremis*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Harpacticidae	*Zaus*	unidentified		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Echinolaophonte*	unidentified		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Heterolaophonte*	*discophora*		Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Heterolaophonte*	*longisetigera*		Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Heterolaophonte*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Heterolaophonte*	*variabilis*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Laophonte*	*applanata?*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Laophonte*	*elongata?*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Laophonte*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Paralaophonte*	cf. *L. congenera*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Paralaophonte*	*hyperborea*		Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Paralaophonte*	*pacifica*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Paralaophonte*	*perplexa*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV		x				Cordell 2000

Table 10.5 continued.

HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Paralaophonte*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Laophontidae	*Pseudonychocamptus*	*spinifer*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Longipediidae	*Longipedia*	unidentified		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Parastenheliidae	*Parastenhelia*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Parastenheliidae	*Parastenhelia*	sp. 2		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Tachidiidae	*Microarthridion*	*littorale*		Feder and Bryson-Schwafel 1988	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Tegastidae	*Tegestes*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Tegastidae	*Tegestes*	sp. 2		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Dactylopausia*	*cf. D. glacialis*	*Dactylopodia*	Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Dactylopausia*	*glacialis*	*Dactylopodia*	Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Dactylopausia*	*paratisboides*	*Dactylopodia*	Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Dactylopausia*	sp. 1	*Dactylopodia*	Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Dactylopausia*	*vulgaris*	*Dactylopodia*	Cordell 2000	I/Inf	II	x		x			Cordell 2000
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Diarthrodes*	sp. 2		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Idomene*	unidentified		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Paradactylopodia*	*latipes*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV						Austin 1985

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Paradactylopodia*	*latipes*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV						Austin 1985
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Paradactylopodia*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Parathalestris*	sp. 1		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Parathalestris*	sp. 2		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Thalestridae	*Parathalestris*	sp. 3		Cordell 2000	I/Inf							
Crustacea: Copepoda: Harpacticoida	Tisbidae	*Scutellidium*	*arthuri*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Tisbidae	*Tisbe*	cf. *T. furcata*		Cordell 2000	I/Inf	II III IV						Cordell 2000
Crustacea: Copepoda: Harpacticoida	Tisbidae	*Tisbe*	*gracilis*		Cooney 1987	I/Inf							Cooney 1987
Crustacea: Copepoda: Harpacticoida	Tisbidae	*Tisbe*	*inflata ?*		Feder and Bryson-Schwafel 1988	I/ST/Inf	II III IV						Austin 1985
Crustacea: Copepoda: Harpacticoida	Tisbidae	*Tisbe*	unidentified		Cordell 2000	I/Inf							
Crustacea: Copepoda: Poecilostomatoida	Oncaeidae	*Lubbockia*	*wilsonae*		Cooney 1987	P	II III			x			Austin 1985
Crustacea: Copepoda: Poecilostomatoida	Oncaeidae	*Oncaea*	*borealis*	Copepoda: Cyclopoida	Cooney 1987	P	II III IV V VI			x			Austin 1985
Crustacea: Copepoda: Poecilostomatoida	Oncaeidae	*Oncaea*	*conifera*		Cooney 1987	P	II III IV	x	x	x			Austin 1985
Crustacea: Copepoda: Poecilostomatoida	Oncaeidae	*Oncaea*	*prolata*	*O. notopus*	Cooney 1987	P	II III IV						Austin 1985
Crustacea: Copepoda: Poecilostomatoida	Oncaeidae	*Oncaea*	unidentified		Cooney: SEA	P							
Crustacea: Copepoda: Poecilostomatoida	Oncaeidae	*Pseudolubbokia*	*dilatata*		Cooney 1987	P	II III IV			x			Austin 1985
Crustacea: Copepoda: Poecilostomatoida		unidentified	unidentified	Copepoda: Cyclopoida	Cordell 2000								
Crustacea: Cumacea	Bodoptriidae	*Vaunthompsonia*	*pacifica*		EVOS	ST	II III IV V VI						Austin 1985

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Cumacea	Diastylidae	*Brachydiastylis*	unidentified		Feder and Matheke 1980	I/ST/Inf							
Crustacea: Cumacea	Diastylidae	*Diastylis*	*alaskensis*		EVOS	ST	II III IV	x					Austin 1985
Crustacea: Cumacea	Diastylidae	*Diastylis*	*bidentata*		EVOS	ST	II III IV	x					Austin 1985
Crustacea: Cumacea	Diastylidae	*Diastylis*	*koreana*		EVOS	ST	II III IV	x					Austin 1985
Crustacea: Cumacea	Diastylidae	*Diastylis*	*paraspinulosa*		Hoberg 1986	ST	II III IV V VI						Austin 1985
Crustacea: Cumacea	Diastylidae	*Diastylopsis*	*dawsoni*		Hoberg 1986	ST	II III IV V VI						Austin 1985
Crustacea: Cumacea	Diastylidae	*Leptostylis*	unidentified		EVOS	ST	II III IV	x	x				Austin 1985
Crustacea: Cumacea	Lampropidae	*Lamprops*	*beringi?*		Chapman 2000	I/Inf	II III IV						Chapman 2000
Crustacea: Cumacea	Lampropidae	*Lamprops*	*quadriplicata*		EVOS	ST	II	x		x			Chapman 2000
Crustacea: Cumacea	Lampropidae	*Lamprops*	*sarsi*		EVOS	ST	II III IV	x					Austin 1985
Crustacea: Cumacea	Leuconiidae	*Eudorella*	*emarginata*		Feder and Jewett 1988	ST/Inf	II	x		x			Austin 1985
Crustacea: Cumacea	Leuconiidae	*Eudorellopsis*	*biplicata*		EVOS	ST/Inf	II	x		x			Austin 1985
Crustacea: Cumacea	Leuconiidae	*Eudorellopsis*	*deformis*		EVOS	ST/Inf	II III IV						Austin 1985
Crustacea: Cumacea	Leuconiidae	*Eudorellopsis*	*dezhavini*		EVOS	ST/Inf	II III IV	x					Austin 1985
Crustacea: Cumacea	Leuconiidae	*Eudorellopsis*	*integra*		Feder and Matheke 1980	ST/Inf	II	x		x			Austin 1985
Crustacea: Cumacea	Leuconiidae	*Leptocuma*	unidentified		Feder and Bryson-Schwafel 1988	I/ST							
Crustacea: Cumacea	Leuconiidae	*Leucon*	*nasica*		Feder and Matheke 1980	ST/Inf	II	x	x	x			Austin 1985
Crustacea: Cumacea	Leuconiidae	*Leucon*	*nasica orientalis*		UAM	ST	II	x	x	x			Austin 1985
Crustacea: Cumacea	Nannastacidae	*Campylaspis*	*rubicunda*		UAM		II	x	x	x			Schultz 1969
Crustacea: Cumacea	Nannastacidae	*Cumella*	*vulgaris*		Feder and Bryson-Schwafel 1988	I/ST/Epi	II III IV					C	Chapman 2000
Crustacea: Decapoda	Atelecyclidae	*Telmessus*	*cheiragonus*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Callianassidae	*Callinassa*	unidentified		Hart 1968	I/ST							
Crustacea: Decapoda	Cancridae	*Cancer*	*branneri*		Hart 1968	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Cancridae	*Cancer*	*gracilis*		Hart 1968	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Cancridae	*Cancer*	*magister*		Hart 1968	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Cancridae	*Cancer*	*oregonensis*		Hart 1968	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Cancridae	*Cancer*	*productus*		Hart 1968	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Crangonidae	*Argis*	*alaskensis*		UAM	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Crangonidae	*Argis*	*lar*		EVOS	ST/Epi	II III IV	x					Butler 1980

Table 10.5 continued.

HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Decapoda	Crangonidae	*Argis*	*dentata*		Squires and Figueira 1974	I/ST	II III IV	x					Butler 1980
Crustacea: Decapoda	Crangonidae	*Argis*	*levior*		Squires and Figueira 1974	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Crangonidae	*Crangon*	*alaskensis*		Cooney 1987	ST/Epi	II III IV V VI						Austin 1985
Crustacea: Decapoda	Crangonidae	*Crangon*	*communis*		Squires and Figueira 1974	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Crangonidae	*Crangon*	*dalli*		Squires and Figueira 1974	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Crangonidae	*Crangon*	*franciscorum*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Crangonidae	*Crangon*	*nigricauda*		Squires and Figueira 1974	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Crangonidae	*Lissocrangon*	*stylirostris*	*Crangon*	Squires and Figueira 1974	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Crangonidae	*Mesocrangon*	*minuitella*		EVOS	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Crangonidae	*Neocrangon*	*alaskensis*	*Crangon*	Squires and Figueira 1974	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Crangonidae	*Paracrangon*	*echinata*		Squires and Figueira 1974	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Crangonidae	*Rhynchocramgon*	*alata*		EVOS	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Crangonidae	*Sclerocrangon*	*boreas*		Squires and Figueira 1974	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Galatheidae	*Munida*	*quadrispina*		UAM	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Grapsidae	*Hemigrapsus*	*nudus*		Hart 1968	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Grapsidae	*Hemigrapsus*	*oregonensis*		Feder and Bryson-Schwafel 1988	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Hippolytidae	*Eualus*	*fabricii*		Squires and Figueira 1974	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Hippolytidae	*Eualus*	*macropthalmalmus*		UAM	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Eualus*	*suckleyi*		UAM	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Hippolytidae	*Eualus*	*avinus*		UAM	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Eualus*	*gaimardii*		Squires and Figueira 1974	ST/Epi	II III IV	x					Austin 1985

Table 10.5 continued.

HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
							BIOREGION						
Crustacea: Decapoda	Hippolytidae	*Eualus*	*pusiolus*		Squires and Figueira 1974	ST/Epi	II	x		x			Butler 1980
Crustacea: Decapoda	Hippolytidae	*Eualus*	*townsendi*		Squires and Figueira 1974	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*decorus*		Squires and Figueira 1974	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*brevirostris*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*camtschaticus*		Squires and Figueira 1974	I/ST	II III IV	x					Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*carinatus*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*paludicola*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*pictus*		Squires and Figueira 1974	I/ST	II III IV						Austin 1985
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*sitchensis*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*stimpsoni*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*stylus*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Heptacarpus*	*tridens*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Hippolyte*	*clarki*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Lebbeus*	*groenlandicus*		Squires and Figueira 1974	I/ST	II III IV	x					Butler 1980
Crustacea: Decapoda	Hippolytidae	*Spirontocaris*	*arcuata*		UAM	I/ST	II III IV		x				Butler 1980
Crustacea: Decapoda	Hippolytidae	*Spirontocaris*	*lamellicornis*		UAM	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Hippolytidae	*Spirontocaris*	*ochotensis*		Squires and Figueira 1974	I/ST	II III IV	x					Butler 1980
Crustacea: Decapoda	Hippolytidae	*Spirontocaris*	*phippsi*		Squires and Figueira 1974	I/ST	II	x		x			Austin 1985
Crustacea: Decapoda	Lithodidae	*Acantholithodes*	*hispidus*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Cryptolithodes*	*sitchensis*		Hart 1968	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Cryptolithodes*	*typicus*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Hapalogaster*	*cavicauda*		Austin 1985	I/ST/Epi	II III IV						Austin 1985
Crustacea: Decapoda	Lithodidae	*Hapalogaster*	*grebnitskii*		Hart 1968	I/ST	II III IV	x					Hart 1968
Crustacea: Decapoda	Lithodidae	*Hapalogaster*	*mertensii*		Hart 1968	I/ST/Epi	II III IV						Hart 1968

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Decapoda	Lithodidae	*Lithodes*	*aequispina*		UAM	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Lithodes*	*couesi*		UAM	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Lopholithodes*	*foraminatus*		UAM	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Oedignathus*	*inermis*		Hart 1968	I/ST/Epi	II III IV	x					Hart 1968
Crustacea: Decapoda	Lithodidae	*Paralithodes*	*camtschatica*		UAM	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Phyllolithodes*	*papillosus*		UAM	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Placetron*	*wosnessenskii*		UAM	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Lithodidae	*Rhinolithodes*	*wosnessenskii*		UAM	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Majidae	*Chionecetes*	*bairdi*		Feder and Jewett 1988	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Majidae	*Chorilia*	*longipes*		Hart 1968	ST/Epi	II III IV	x					Hart 1968
Crustacea: Decapoda	Majidae	*Hyas*	*lyratus*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Majidae	*Oregonia*	*gracilis*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Majidae	*Pugettia*	*gracilis*		Hart 1968	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Majidae	*Pugettia*	*producta*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Majidae	*Pugettia*	*richii*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Majidae	*Scyra*	*acutifrons*		Hines et al. 2000	I/ST	II III IV	x					Hart 1968
Crustacea: Decapoda	Oplophoridae	*Hymenadora*	*frontalis*		Cooney 1987	P	II III IV V VI	x					Austin 1985
Crustacea: Decapoda	Paguridae	*Discorsopagurus*	*schmitti*		UAM	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Elassochirus*	*cavimanus*		UAM	ST/Epi	II III IV	x					Hart 1968
Crustacea: Decapoda	Paguridae	*Elassochirus*	*gilli*		UAM	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Elassochirus*	*tenimanius*		UAM	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Labidochirus*	*splendescens*		UAM	I/ST	II III IV	x	x				Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*aleuticus*		UAM	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*beringanus*		UAM	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*capillatus*		UAM	I/ST	II III IV						Hart 1968

Table 10.5 continued.

HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Decapoda	Paguridae	*Pagurus*	*cornutus*		UAM	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*granosimanus*		UAM	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*hirsutiusculus hirsutiusculus*		Feder and Bryson-Schwafel 1988	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*kennerleyi*		UAM	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*samuelis*		UAM	I/ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*caurinus*		Hart 1968	I/ST	II III IV V						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*confragosus*		Feder et al. 1979	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Paguridae	*Pagurus*	*ochotensis*		Feder and Bryson-Schwafel 1988	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Pandalidae	*Pandalopsis*	*dispar*		Feder and Jewett 1988	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Pandalidae	*Pandalus*	*danae*		Squires and Figueira 1974	I/ST	II III IV						Butler 1980
Crustacea: Decapoda	Pandalidae	*Pandalus*	*jordani*		UAM	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Pandalidae	*Pandalus*	unidentified		Cooney: SEA	ST/Epi							
Crustacea: Decapoda	Pandalidae	*Pandalus*	*borealis*		Feder and Jewett 1988	ST/Epi	II	x		x			Butler 1980
Crustacea: Decapoda	Pandalidae	*Pandalus*	*goniurus*		Squires and Figueira 1974	ST/Epi	II III IV	x					Butler 1980
Crustacea: Decapoda	Pandalidae	*Pandalus*	*hypsinotus*		Squires and Figueira 1974	I/ST	II III IV	x					Butler 1980
Crustacea: Decapoda	Pandalidae	*Pandalus*	*montagui tridens*		Squires and Figueira 1974	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Pandalidae	*Pandalus*	*platyceros*		Squires and Figueira 1974	I/ST	II III IV	x					Butler 1980
Crustacea: Decapoda	Pandalidae	*Pandalus*	*stenolepis*		Squires and Figueira 1974	ST/Epi	II III IV						Butler 1980
Crustacea: Decapoda	Pasiphaeidae	*Pasiphaea*	*pacifica*		UAM	P	II III IV	x					Butler 1980
Crustacea: Decapoda	Pinnotheridae	*Pinnixa*	*littoralis*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Pinnotheridae	*Pinnixa*	*occidentalis*		Hart 1968	ST/Epi	II III IV						Hart 1968
Crustacea: Decapoda	Pinnotheridae	*Pinnixa*	*schmitti*		Feder and Matheke 1980	ST/Epi	II III IV						Hart 1968

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Decapoda	Porcellanidae	*Petrolisthes*	*eriomerus*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Decapoda	Sergestidae	*Sergestes*	*similis*	*Eusergestes*	Cooney 1987	P	II III IV V VI	x					Austin 1985
Crustacea: Decapoda	Upogebiidae	*Upogebia*	*pugettensis*		Squires and Figueira 1974	I/Inf	II III IV						Hart 1968
Crustacea: Decapoda	Xanthidae	*Lophopanopeus*	*bellus bellus*		Hart 1968	I/ST	II III IV						Hart 1968
Crustacea: Euphausiacea	Euphausiidae	*Euphausia*	*pacifica*		Cooney 1987	P	II III IV V VI	x					Austin 1985
Crustacea: Euphausiacea	Euphausiidae	*Stylocherion*	unidentified		Cooney 1987	P							
Crustacea: Euphausiacea	Euphausiidae	*Tessarabranchion*	*oculata*		Cooney 1987	P	II III IV V	x					Austin 1985
Crustacea: Euphausiacea	Euphausiidae	*Thysanoessa*	*inermis*		Cooney 1987	P	II III IV V VI	x					Austin 1985
Crustacea: Euphausiacea	Euphausiidae	*Thysanoessa*	*longipes*		Cooney 1987	P	III IV	x					Austin 1985
Crustacea: Euphausiacea	Euphausiidae	*Thysanoessa*	*spinifera*		Cooney 1987	P	II III IV V VI						Austin 1985
Crustacea: Euphausiacea	Euphausiidae	*Thysanoessa*	*inspinata*		Cooney 1987	P	II III IV	x					Austin 1985
Crustacea: Euphausiacea	Euphausiidae	*Thysanoessa*	*raschii*		Cooney and Coyle 1988	P	II	x		x			Austin 1985
Crustacea: Isopoda	Aegidae	*Rocinela*	*angustana*		UAM	ST	II III IV						Schultz 1969
Crustacea: Isopoda	Dajidae	*Holophryxus*	*alascensis*		UAM	ST	II III IV						Austin 1985
Crustacea: Isopoda	Gnathiidae	*Gnathia*	*tridens*		EVOS	ST	II III IV				California	NR	Schultz 1969
Crustacea: Isopoda	Gnathiidae	*Gnathia*	unidentified		Feder and Matheke 1980	ST/Inf							Schultz 1969
Crustacea: Isopoda	Idoteidae	*Idotea*	*fewkesi*		EVOS	I/ST	II III IV V VI						Schultz 1969
Crustacea: Isopoda	Idoteidae	*Idotea*	*obscura*		Chapman 2000	I/Epi	II III IV						Chapman 2000
Crustacea: Isopoda	Idoteidae	*Pentidotea*	*wosnessenskii*	*Idotea*	Feder and Bryson-Schwafel 1988	I/Epi	II III IV						Schultz 1969
Crustacea: Isopoda	Idoteidae	*Synidotea*	*ritteri*		UAM	ST/Epi	II III IV V				California	NR	Schultz 1969
Crustacea: Isopoda	Janiridae	*Janiropsis*	*kincaldi*	*J. pugettensis*	Chapman 2000	I	II III IV						Chapman 2000
Crustacea: Isopoda	Ligiidae	*Ligia*	*pallasii*		Chapman 2000	I/Epi	II III IV						Chapman 2000
Crustacea: Isopoda	Limnoriidae	*Limnoria*	*lignorum*		EVOS	I/ST	II III IV						Schultz 1969
Crustacea: Isopoda	Munnidae	*Munna*	cf. *M. chromocephala*		UAM	ST	II III IV				Washington	NR	Schultz 1969
Crustacea: Isopoda	Munnidae	*Munna*	*ubiquita*		EVOS	ST	II III IV				Washington	NR	Schultz 1969
Crustacea: Isopoda	Munnidae	*Pleurogonium*	unidentified			I/Epi							Schultz 1969
Crustacea: Isopoda	Sphaeromatidae	*Dynamenella*	*sheari*		UAM	I/Epi	II III IV						Austin 1985
Crustacea: Isopoda	Sphaeromatidae	*Exosphaeroma*	*amplicauda*		UAM	I/Epi	II III IV						Schultz 1969
Crustacea: Isopoda	Sphaeromatidae	*Exosphaeroma*	unidentified		UAM	I/Epi							Schultz 1969
Crustacea: Isopoda	Sphaeromatidae	*Gnorimosphaeroma*	*lutea*	*G. insulare*	Chapman 2000	I/Epi	II III IV						Chapman 2000

Table 10.5 continued.

							BIOREGION						
HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Isopoda	Sphaeromatidae	*Gnorimosphaeroma*	*oregonensis*		Feder and Bryson-Schwafel 1988	I/ST	II III IV						Schultz 1969
Crustacea: Leptostraca	Nebaliidae	*Nebalia*	unidentified		EVOS	P							
Crustacea: Mysidacea	Lophogastridae	*Gnatahophausia*	*gigas*		Cooney 1987	P	II III IV V VI VII VIII IX	x		x			Austin 1985
Crustacea: Mysidacea	Mysidae	*Acanthomysis*	*nephropthalma*		Cooney 1987	P	II III IV V VI						Austin 1985
Crustacea: Mysidacea	Mysidae	*Acanthomysis*	*pseudomacraspis*		Cooney 1987	P	II III IV	x					Austin 1985
Crustacea: Mysidacea	Mysidae	*Holmsiella*	*anomala*		Cooney 1987	P	II III IV V VI	x					Austin 1985
Crustacea: Mysidacea	Mysidae	*Meterythrops*	*robusta*		Cooney 1987	P	II III IV			x			Austin 1985
Crustacea: Mysidacea	Mysidae	*Mysis*	*littoralis*		Chapman 2000	P	II	x	x	x			Chapman 2000
Crustacea: Mysidacea	Mysidae	*Mysis*	*oculata*	*M. littoralis*	Cooney 1987	P	II III IV		x	x			Austin 1985
Crustacea: Mysidacea	Mysidae	*Neomysis*	*kadiakensis*		Cooney 1987	P	II III IV						Austin 1985
Crustacea: Mysidacea	Mysidae	*Neomysis*	*rayi*		Cooney 1987	P	II III IV V	x					Austin 1985
Crustacea: Mysidacea	Mysidae	*Pseudomma*	*truncatus*		Cooney 1987	P	II III IV V VI						Austin 1985
Crustacea: Ostracoda	Halocyprididae	*Conchoecia*	*alata minor*	*Alacia*	Cooney and Coyle 1988	ST/P	II III				British Columbia	NR	Austin 1985
Crustacea: Ostracoda	Halocyprididae	*Conchoecia*	*elegans*	*Paraconchoecia*	UAM	ST/P	II III				British Columbia	NR	Austin 1985
Crustacea: Ostracoda	Halocyprididae	*Conchoecia*	unidentified		Cooney and Coyle 1988	ST/P							
Crustacea: Ostracoda	Parodoxostomatinae	unidentified	unidentified		UAM	ST/P							
Crustacea: Ostracoda	Philomedidae	*Philomedes*	*dentata*		UAM	ST/Inf	II III				British Columbia	NR	Austin 1985
Crustacea: Ostracoda	Philomedidae	*Scleroconcha*	*trituberculata*		UAM	ST/Inf	II III				British Columbia	NR	Austin 1985
Crustacea: Ostracoda	Podocopidae	unidentified	unidentified		UAM								
Crustacea: Tanaidacea	Paratanaidae	*Leptochelia*	*savignyi*		Chapman 2000	I/Epi	II	x		x		C	Chapman 2000
Crustacea: Thoracica	Balanamorpha	*Balanus*	*crenatus*		Feder and Bryson-Schwafel 1988	I/ST	II III IV	x					Austin 1985
Crustacea: Thoracica	Balanamorpha	*Balanus*	*glandula*		Feder and Bryson-Schwafel 1988	I/Epi	II III IV						Austin 1985
Crustacea: Thoracica	Balanamorpha	*Chirona*	*evermani*		Feder and Matheke 1980	ST/Inf	II III IV						Austin 1985

Table 10.5 continued.

HIGHER TAXON	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Crustacea: Thoracica	Balanamorpha	*Semibalanus*	*balanoides*	*Balanus*	Feder and Bryson-Schwafel 1988	I/Epi	II III IV						Austin 1985
Crustacea: Thoracica	Balanamorpha	*Semibalanus*	*cariosus*	*Balanus*	Feder and Bryson-Schwafel 1988	I/Epi	II III IV	x					Austin 1985
Crustacea: Thoracica	Chthamalidae	*Chthamalus*	*dalli*		EVOS	I/Epi	II III IV	x					Austin 1985
Crustacea: Thoracica	Scalpellidae	*Scaphellum*	*pacificum*		Feder and Matheke 1980	ST/Epi	II III IV	x					Austin 1985
Pycnogonida	Ammotheidae	*Achelia*	*alaskensis*		Child 1995	ST/Epi	II III IV	x					Child 1995
Pycnogonida	Ammotheidae	*Achelia*	*borealis*		UAM	ST/Epi	II III IV	x	x				Child 1995
Pycnogonida	Ammotheidae	*Achelia*	*chaelata*		UAM	ST/Epi	II III IV				Washington	NR	Austin 1985
Pycnogonida	Ammotheidae	*Achelia*	*gracilipes*	*Ammothea*	UAM	ST/Epi	II III IV				British Columbia	NR	Austin 1985
Pycnogonida	Ammotheidae	*Achelia*	*latifrons*		Child 1995	ST/Epi	II III IV	x					Child 1995
Pycnogonida	Ammotheidae	*Achelia*	*megova*		Child 1995	ST/Epi	II III IV						Child 1995
Pycnogonida	Ammotheidae	*Achelia*	*pribilofensis*	*Ammothea*	UAM	ST/Epi	II III IV				Bering Sea	nr	Child 1995
Pycnogonida	Phoxochilidiidae	*Phoxichilidium*	*femoratum*		UAM	ST/Epi	II	x		x			Austin 1985
Pycnogonida	Phoxochilidiidae	*Phoxichilidium*	*quadrodentatum*		UAM	ST/Epi	II III IV						Austin 1985
Pycnogonida	Tanystylidae	*Tanystylum*	*anthostomasti*		UAM	ST/Epi	II III IV	x					Austin 1985

Echinodermata

Ninety-nine echinoderm species, representing all five classes are listed (Table 10.6). Principal sources for taxonomic and distributional information are D'yakonov (1954) (ophiuroids), Lambert (1981, 1997) (Asteroidea and Holothuroidea). No range extensions or possibly undescribed species were noted for Prince William Sound.

Table 10.6. Echinodermata.

CLASS	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	REFERENCE to DISTRIBUTION
Asteroidea	Asteriidae	*Evasterias*	*troschelii*		Feder and Bryson-Schwafel 1988	I/ST/Epi	II III IV				Lambert 1981
Asteroidea	Asteriidae	*Leptasterias*	*hexactis*		UAM	I/ST/Epi	II III IV				Lambert 1981
Asteroidea	Asteriidae	*Orthasterias*	*koehleri*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Asteriidae	*Pisaster*	*ochraceus*		UAM	I/ST/Epi	II III IV				Lambert 1981
Asteroidea	Asteriidae	*Pycnopodia*	*helianthoides*		Feder and Bryson-Schwafel 1988	I/ST/Epi	II III IV				Lambert 1981
Asteroidea	Asteriidae	*Rathbunaster*	*californianus*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Asteropseidae	*Dermasterias*	*imbricata*	Poraniidae	UAM	I/ST/Epi	II III IV				Lambert 1981
Asteroidea	Astropectinidae	*Dipsacaster*	*borealis*		UAM	ST	II III IV				Austin 1985
Asteroidea	Astropectinidae	*Leptychaster*	*anomalus*		Feder and Matheke 1980	ST	II III IV				Lambert 1981
Asteroidea	Astropectinidae	*Leptychaster*	*arcticus*		UAM	ST	II III IV	x	x	x	Lambert 1981
Asteroidea	Astropectinidae	*Leptychaster*	*pacificus*		Lambert 1981	ST	II III IV				Lambert 1981
Asteroidea	Benthopectinidae	*Luidiaster*	*dawsoni*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Benthopectinidae	*Nearchaster*	*aciculosus*		UAM	ST	II III IV				Austin 1985
Asteroidea	Echinasteridae	*Henricia*	*aspera*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Echinasteridae	*Henricia*	*asthenactis*		Lambert 1981	ST	II III IV				Lambert 1981
Asteroidea	Echinasteridae	*Henricia*	*leviuscula*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Echinasteridae	*Henricia*	*longispina*		Lambert 1981	ST	II III IV	x			Lambert 1981
Asteroidea	Echinasteridae	*Henricia*	*sanguinolenta*		UAM	ST	II III	x	x		Lambert 1981
Asteroidea	Echinasteridae	*Poraniopsis*	*inflata*		UAM	ST	II III IV	x			Lambert 1981
Asteroidea	Goniasteridae	*Ceramaster*	*arcticus*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Goniasteridae	*Ceramaster*	*patagonicus*		Lambert 1981	ST	II III IV V VI VII VIII IX				Lambert 1981
Asteroidea	Goniasteridae	*Gephyreaster*	*swifti*	Radiasterridae	Feder and Jewett 1987	ST	II III IV				Lambert 1981
Asteroidea	Goniasteridae	*Hippasteria*	*spinosa*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Goniasteridae	*Mediaster*	*aequalis*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Goniasteridae	*Pseudarchaster*	*parelii*		UAM	ST	II	x		x	Lambert 1981
Asteroidea	Goniopectinidae	*Ctenodiscus*	*crispatus*	Ctenodiscidae	UAM	ST	I II III IV V VI VII IX	x	x	x	Lambert 1981
Asteroidea	Luidiidae	*Luidia*	*foliolata*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Pedicellasteridae	*Pedicellaster*	*magister*	Heliasteridae	UAM	ST	II III IV	x			Austin 1985
Asteroidea	Pterasteridae	*Diplopteraster*	*multipes*		UAM	ST	II III IV V	x	x	x	Lambert 1981
Asteroidea	Pterasteridae	*Pteraster*	*militaris*		UAM	ST	II III IV	x			Lambert 1981
Asteroidea	Pterasteridae	*Pteraster*	*tesselatus*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Solasteridae	*Crossaster*	*papposus*		UAM	ST	II III IV	x	x	x	Lambert 1981
Asteroidea	Solasteridae	*Lophaster*	*furcilliger*		UAM	ST	II III IV				Lambert 1981
Asteroidea	Solasteridae	*Solaster*	*dawsoni*		UAM	ST	II III IV	x			Lambert 1981
Asteroidea	Solasteridae	*Solaster*	*endeca*		UAM	ST	II III IV V		x	x	Lambert 1981
Asteroidea	Solasteridae	*Solaster*	*paxillatus*		UAM	ST	II III IV	x			Lambert 1981
Asteroidea	Solasteridae	*Solaster*	*stimpsoni*		Lambert 1981	ST	II III IV	x			Lambert 1981
Criniodea	Antedonidae	*Florometra*	*serratissima*		Austin 1985	ST	II III IV V				Austin 1985
Criniodea	Antedonidae	*Florometra*	*asperrima*	*Helimetra gracilis*	UAM	ST	II III IV V	x			Austin 1985
Criniodea	Antedonidae	*Psathyrometra*	*fragilis*		Austin 1985	ST	II III IV V	x			Austin 1985
Criniodea	Antedonidae	*Retiometra*	*alascana*		Austin 1985	ST	II III IV				Austin 1985
Echinoidea	Echinarachniidae	*Echinarachnius*	*parma*		Foster and Hines 2000	ST	II III IV	x			Pavloskii 1955
Echinoidea	Schizasteridae	*Brisaster*	*townsendi*		Feder and Matheke 1980	ST	II III IV	x			Pavloskii 1955
Echinoidea	Strongylocentrotidae	*Allocentrotus*	*fragilis*		Feder and Jewett 1987	ST	II III IV				Austin 1985
Echinoidea	Strongylocentrotidae	*Strongylocentrotus*	*droebachiensis*		Feder and Bryson-Schwafel 1988	I/ST/Epi	II	x		x	Austin 1985
Echinoidea	Strongylocentrotidae	*Strongylocentrotus*	*franciscanus*		Rosenthal 1977	ST/Epi	II III IV V				Austin 1985
Holothuroidea	Cucumariidae	*Cucumaria*	*frondosa japonica*		Lambert 1997	ST	II III IV				Lambert 1997
Holothuroidea	Cucumariidae	*Cucumaria*	*miniata*		Lambert 1997	ST	II III IV				Lambert 1997
Holothuroidea	Cucumariidae	*Cucumaria*	*vegae*		Lambert 1997	ST	II III IV	x			Lambert 1997
Holothuroidea	Cucumariidae	*Ekmania*	*diomedeae*		Lambert 1997	ST	II III IV	x			Lambert 1997
Holothuroidea	Cucumariidae	*Pentamera*	*calcigera*		UAM	ST	II	x		x	Austin 1985
Holothuroidea	Cucumariidae	*Thyonidium*	*kurilensis*		Lambert 1997	ST	II III IV	x			Lambert 1997
Holothuroidea	Molpadiidae	*Molpadia*	*intermedia*		UAM	ST	II III IV				Lambert 1997
Holothuroidea	Phyllophoridae	*Pentamera*	*populifera*		Lambert 1997	ST	II III IV				Lambert 1997
Holothuroidea	Phyllophoridae	*Thyone*	cf. *T. benti*		UAM	ST	II III IV				Lambert 1997
Holothuroidea	Psolidae	*Psolus*	*chitonoides*		Lambert 1997	ST	II III IV				Lambert 1997
Holothuroidea	Psolidae	*Psolus*	*squamatus*		Lambert 1997	ST	II	x		x	Lambert 1997
Holothuroidea	Sclerodactylidae	*Eupentacta*	*pseudoquinquesemita*		Lambert 1997	ST	II III IV				Lambert 1997
Holothuroidea	Stichopodidae	*Parastichopus*	*californicus*		Lambert 1997	ST	II III IV				Lambert 1997
Holothuroidea	Synallactidae	*Pseudostichopus*	*mollis*		Lambert 1997	ST	x	x	x	x	Lambert 1997
Holothuroidea	Synallactidae	*Synallactes*	*challengeri*		Lambert 1997	ST	x	x	x	x	Lambert 1997
Holothuroidea	Synaptidae	*Leptosynapta*	*clarki*		UAM	ST	II III IV	x			Austin 1985
Ophiuroidea	Amphiuridae	*Amphipolis*	*squamata*		Feder and Jewett 1987	ST	x	x	x	x	Austin 1985
Ophiuroidea	Amphiuridae	*Diamphiodia*	*craterodmeta*	*Amphiodia*	Feder and Matheke 1980	ST	II III IV	x			D'Yakanov 1954
Ophiuroidea	Amphiuridae	*Unioplis*	*macraspis*	*Amphioplus*	Feder and Matheke 1980	ST	II III IV	x			Austin 1985
Ophiuroidea	Ophiactidae	*Ophiopholis*	*aculeatata*	*O. caryi*	Rosenthal 1977	ST	II II IV			x	Austin 1985
Ophiuroidea	Ophiuridae	*Ophiura*	*sarsi*		Feder and Matheke 1980	ST	II	x	x	x	Austin 1985
Ophiuroidea	Ophiuridae	*Ophiura*	*quadrispina*		Feder and Matheke 1980	ST	II III IV				D'Yakanov 1954

Bryozoa

Bryozoa are abundant in Alaskan waters and prevalent in the fouling community. The data set consists of 74 species (Table 10.7), which is probably an underestimate. Nineteen identifications are confident only to the generic level. Sources for distribution data include Dick and Ross (1988), Hines and Ruiz (2000), Kluge (1962), as well as cataloged specimens in the UAM collection. J. Winston (2000) contributed the identifications and distributional information for 22 species. *Schizoporella unicornis* is regarded as a nonindigenous species, native to the northwestern Pacific. Ten species are possible new records for Alaska, range extensions form either the Arctic or Pacific region.

Table 10.7. Bryozoa.

ORDER	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	BIOREGION NWP	BIOREGION AR	BIOREGION NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Cheilostomata: Anasca	Beaniidae	*Beania*	*mirabilis*		UAM	ST	II III IV V VI VII VIII IX	x		x	British Columbia	nr?	Austin 1985
Cheilostomata: Anasca	Bugulidae	*Bugula*	*californica*		Hines and Ruiz 2000	I	II III IV						Austin 1985
Cheilostomata: Anasca	Bugulidae	*Bugula*	*pacifica*		Hines and Ruiz 2000	I	II III IV						Austin 1985
Cheilostomata: Anasca	Bugulidae	*Bugula*	unidentified		Hines and Ruiz 2000	I							
Cheilostomata: Anasca	Bugulidae	*Dendrobeania*	*curvirostrata*		Hines and Ruiz 2000	I	II III IV V VI				British Columbia	NR?	Austin 1985
Cheilostomata: Anasca	Bugulidae	*Dendrobeania*	*lichenoides*		UAM	I	II III IV						Dick and Ross 1988
Cheilostomata: Anasca	Bugulidae	*Dendrobeania*	*murrayana*		UAM	ST	II	x	x	x			Kluge 1962
Cheilostomata: Anasca	Calloporidae	*Calloporella*	*craticula*	*Callopora*	Hines and Ruiz 2000	I/ST	II	x	x	x			Kluge 1962
Cheilostomata: Anasca	Calloporidae	*Calloporella*	*lineata*	*Callopora*	UAM	I/ST	II	x	x	x		C	Kluge 1962
Cheilostomata: Anasca	Calloporidae	*Calloporella*	*"lineata"*		Hines and Ruiz 2000	I/ST	II	x		x			Austin 1985
Cheilostomata: Anasca	Calloporidae	*Tegella*	*aquilirostris*		Hines and Ruiz 2000	I/ST	II III IV	x					Austin 1985
Cheilostomata: Anasca	Calloporidae	*Tegella*	*armifera*		Hines and Ruiz 2000	I/ST	II III IV	x					Austin 1985
Cheilostomata: Anasca	Calloporidae	*Tegella*	*robertsonae*		UAM	ST	II III IV V VI	x					Osburn 1950
Cheilostomata: Anasca	Cryptosulidae	*Cryptosula*	*okadai*		Hines and Ruiz 2000	I	II III IV	x					Dick and Ross 1988
Cheilostomata: Anasca	Cryptosulidae	*Harmeria*	*scutulata*	Hippothoidae	UAM	I/ST	II	x	x	x	Arctic	nr?	Dick and Ross 1988
Cheilostomata: Anasca	Electridae	*Cauloramphus*	*pseudospinifer*		Hines and Ruiz 2000	I	II III IV	x					Dick and Ross 1988
Cheilostomata: Anasca	Electridae	*Electra*	unidentified		UAM	I							
Cheilostomata: Anasca	Flustridae	*Terminoflustra*	*membranaceotruncata*		UAM	I/ST	II	x	x	x			Dick and Ross 1988
Cheilostomata: Anasca	Hincksinidae	*Cauloramphus*	*"variegata"*	*C. spiniferum*	UAM	I/ST	II III IV V	x		x			Austin 1985
Cheilostomata: Anasca	Membraniporidae	*Conopeum*	sp. *(chesapeakensis?)*		Hines and Ruiz 2000	I/ST	II III IV V	x	x	x			Austin 1985
Cheilostomata: Anasca	Membraniporidae	*Membranipora*	*membranipora*		Hines and Ruiz 2000	I/ST	II III	x	x	x			Kluge 1962
Cheilostomata: Anasca	Membraniporidae	*Membranipora*	*serrilamella*		UAM	I/ST	x	x	x	x	N Pacific	nr?	Austin 1985
Cheilostomata: Anasca	Microporidae	*Micropora*	unidentified		UAM	I/ST							
Cheilostomata: Anasca	Microporinidae	*Microporina*	*articulata*		UAM	I	II	x	x	x			Dick and Ross 1988
Cheilostomata: Anasca	Scrupariidae	*Brettia*	unidentified	Bicellariidae/*Corynoprella*	UAM	I/ST							
Cheilostomata: Anasca	Scrupocellariidae	*Scrupocellaria*	unidentified		UAM	I/ST							
Cheilostomata: Anasca	Scrupocellariidae	*Tricellaria*	*gracilis*		UAM	I/ST	II	x	x	x			Kluge 1962
Cheilostomata: Anasca	Scrupocellariidae	*Tricellaria*	*occidentalis*		UAM	ST	II III IV V VI				British Columbia	nr?	Austin 1985
Cheilostomata: Anasca	Scrupocellariidae	*Tricellaria*	*ternata*		UAM	I	II	x	x	x			Dick and Ross 1988
Cheilostomata: Ascophora	Cribrilinidae	*Cribrilina*	*annulata*		UAM	I/ST	II	x	x	x			Kluge 1962
Cheilostomata: Ascophora	Cribrilinidae	*Cribrilina*	*corbicula*		Hines and Ruiz 2000	I	II III IV					C	Austin 1985
Cheilostomata: Ascophora	Cribrilinidae	*Cribrilina*	unidentified		Hines and Ruiz 2000	I/ST							
Cheilostomata: Ascophora	Hippoporinidae	*Lepralia*	unidentified	*Hippothoa*	UAM	I/ST							
Cheilostomata: Ascophora	Hippothoidae	*Cellepora*	*craticula*	*Costazia*	Hines and Ruiz 2000	I/ST	x					C	Kluge 1962

Table 10.7 continued.

ORDER	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Cheilostomata: Ascophora	Hippothoidae	*Celleporella*	*hyalina*	*Hippothoa*	UAM	I/ST	x	x	x	x		C	Dick and Ross 1988
Cheilostomata: Ascophora	Hippothoidae	*Hippothoa*	unidentified		UAM	I							
Cheilostomata: Ascophora	Microporellidae	*Fenestruloides*	*eopacifica?*		Hines and Ruiz 2000	I	II III IV V VI				California	NR?	Soule et al. 1996
Cheilostomata: Ascophora	Microporellidae	*Microporella*	*germana*		Hines and Ruiz 2000	I	II III IV						Dick and Ross 1988
Cheilostomata: Ascophora	Mucronellidae	*Cystisella*	*bicornia*		Osburn 1952	ST	II III IV		x				Osburn 1952
Cheilostomata: Ascophora	Mucronellidae	*Cystisella*	*saccata*		Osburn 1952	ST	II III		x		Arctic	nr?	Osburn 1952
Cheilostomata: Ascophora	Mucronellidae	*Parasmittina*	*trispinosa*	Smittinidae	Hines and Ruiz 2000	I	x	x	x	x		C	Dick and Ross 1988
Cheilostomata: Ascophora	Mucronellidae	*Porella*	*acutirostris*	Smittinidae	UAM	I/ST	II III IV V VI	x	x	x			Dick and Ross 1988
Cheilostomata: Ascophora	Mucronellidae	*Porella*	*acutirostris*	*P. major* Smittinidae	Hines and Ruiz 2000	ST	II III IV V VI	x	x	x			Osburn 1952
Cheilostomata: Ascophora	Mucronellidae	*Rhamphostomella*	*bilaminata*	Rhamphostom ellidae	UAM	I/ST		x	x				Kluge 1962
Cheilostomata: Ascophora	Mucronellidae	*Rhamphostomella*	*gigantea*	Rhamphostom ellidae	Hines and Ruiz 2000	ST			x	x	Arctic	nr?	Osburn 1952
Cheilostomata: Ascophora	Mucronellidae	*Rhamphostomella*	*hincksi*	Rhamphostom ellidae	Hines and Ruiz 2000	ST	II	x	x				Kluge 1962
Cheilostomata: Ascophora	Mucronellidae	*Smittina*	unidentified	Smittinidae	UAM	I/ST							
Cheilostomata: Ascophora	Reteporidae	*Phidolopora*	*pacifica*	*P. labiata*	Hines and Ruiz 2000	I	II III IV						Austin 1985
Cheilostomata: Ascophora	Schizoporellidae	*Hippodiplosia*	unidentified		UAM	I/ST	II	x	x	x			Kluge 1962
Cheilostomata: Ascophora	Schizoporellidae	*Hippoporina*	*vulgaris*		Hines and Ruiz 2000	I/ST	II						
Cheilostomata: Ascophora	Schizoporellidae	*Schizomavella*	*porifera*		Hines and Ruiz 2000	I/ST	II	x	x	x	Arctic	nr?	Osburn 1952
Cheilostomata: Ascophora	Schizoporellidae	*Schizoporella*	*"unicornis"*		Hines and Ruiz 2000	I	x	x	x	x	NW Pacific	Definate	Hines and Ruiz 2000
Cheilostomata: Ascophora	Umbonulidae	*Umbonula*	unidentified		UAM	I/ST							
Ctenostomata	Alcyonidiidae	*Alcyonidium*	*hirsutum*		Hines and Ruiz 2000	I/ST	II	x	x	x	NE Atlantic	NR	Kluge 1962
Ctenostomata	Alcyonidiidae	*Alcyonidium*	*polynoum*	*A. mytili*	Hines and Ruiz 2000	I/ST	II III IV V	x	x	x		C	Austin 1985
Ctenostomata	Alcyonidiidae	*Alcyonidium*	unidentified		Hines and Ruiz 2000	I/ST							
Cyclostomata	Crisiidae	*Crisia*	*occidentalis*		UAM	I/ST	III IV V VI VII VIII IX	x		x	Washington	NR	Austin 1985
Cyclostomata	Crisiidae	*Crisia*	*serrulata*		Hines and Ruiz 2000	I	II III IV						Austin 1985
Cyclostomata	Crisiidae	*Filicrisia*	*fanciscana*		Hines and Ruiz 2000	I	II III IV	x					Austin 1985
Cyclostomata	Crisiidae	*Filicrisia*	*geniculata*		UAM	I/ST	II	x		x			Kluge 1962
Cyclostomata	Crisiidae	*Filicrisia*	*smitti*		Hines and Ruiz 2000	ST	II III	x	x	x			Kluge 1962
Cyclostomata	Diaperoeciidae	*Diaperoecia*	unidentified		UAM	ST							
Cyclostomata	Diastoporidae	*Disporella*	unidentified		UAM	I/ST							
Cyclostomata	Heteroporidae	*Heteropora*	*magna*		UAM	ST	II III IV				British Columbia	nr?	Austin 1985
Cyclostomata	Heteroporidae	*Heteropora*	*pacifica*		UAM	ST	II III IV						Austin 1985
Cyclostomata	Heteroporidae	*Heteropora*	unidentified		UAM	I/ST							
Cyclostomata	Lichenoporidae	*Lichenopora*	unidentified		UAM	I/ST							
Cyclostomata	Oncousoeciidae	*Oncousiecia*	unidentified		UAM	I/ST							
Cyclostomata	Oncousoeciidae	*Stomatopora*	*granulata*		UAM	I/ST	II III IV		x				Kluge 1962
Cyclostomata	Tubuliporidae	*Idmonea*	unidentified	Idmoneidae	UAM	I/ST							
Cyclostomata	Tubuliporidae	*Platonea*	unidentified		UAM	I/ST							
Cyclostomata	Tubuliporidae	*Tubulipora*	*flabellaris*		UAM	I/ST	II III IV		x				Kluge 1962
Cyclostomata	Tubuliporidae	*Tubulipora*	sp. *(tuba?)*		Hines and Ruiz 2000	I/ST	II III IV						
Cyclostomata	Tubuliporidae	*Tubulipora*	*tuba*	*T. occidentalis, T. fasciculifera*	Hines and Ruiz 2000	I/ST	II III IV V				British Columbia	NR?	Austin 1985

Miscellaneous Invertebrates

Ninety-five taxa, representing twelve different phyla make up this data set (Table 10.8). Nemerteans, chaetognaths, brachiopods, and urochordates , and are fairly well-known or have received the attention of the project's taxonomists. (Lambert 2000; Mills 2000). However, it is clear that sponges, flatworms, and nematodes are undercounted. The nonindigenous sponge, *Cliona thosina* was recorded by the fouling community survey (Hines and Ruiz 200).

Phylum	taxa reported in this study
Porifera	4
Platyhelminthes	none identified to species
Nemertea	54
Sipunculida	3
Priapulida	1
Echiuridae	1

Phoronidae none identified to species
Brachiopoda 3
Chaetognatha 5
Tardigrada 1
Urochordata 28
Gnathostomulida, Gastrotrichida, Kinorhyncha have not been documented.

Table 10.8. Miscellaneous invertebrates.

PHYLUM/ CLASS	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	Bioregion NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Brachiopoda: Articulata	Cancellothyrididae	*Terebratulina*	*unguicula*		UAM	I/ST/Epi	II III IV						Austin 1985
Brachiopoda: Articulata	Hemithyridae	*Hemithiris*	*psittacea*		UAM	ST	II III IV	x	x				Austin 1985
Brachiopoda: Articulata	Laqueidae	*Terebratalia*	*transversa*		UAM	ST	II III IV				SE Alaska	nr	Austin 1985
Brachiopoda: Articulata	Laqueidae	*Laqueus*	*californianus*		UAM	ST	II III IV	x					Austin 1985
Chaetagnatha	Eukrohniidae	*Eukrohnia*	*fowleri*		Cooney 1987	P	II III IV	x	x	x			Austin 1985
Chaetagnatha	Eukrohniidae	*Eukrohnia*	*bathypelagica*		Cooney 1987	P	II III IV			x			Austin 1985
Chaetagnatha	Eukrohniidae	*Eukrohnia*	*hamata*		Cooney and Coyle 1988	P	x	x	x	x			Smith and Johnson 1996
Chaetagnatha	Sagittidae	*Sagitta*	*elegans*		Cooney and Coyle 1988	P	II III IV						Smith and Johnson 1996
Chaetagnatha	Sagittidae	*Sagitta*	*scrippsae*		Cooney 1987	P	II III IV V VI VII VIII	x					Austin 1985
Echiurida	Echiuridae	*Echiuris*	*echiuris alaskensis*		Feder and Bryson-Schwafel 1988	I	II III IV	x					Austin 1985
Nematoda		unidentified	unidentified		Feder and Matheke 1980	Inf							
Nemertea	Amphiporidae	*Amphiporus*	*angulatus*		Coe 1910	I	II III IV V VI			x			Coe 1904
Nemertea	Amphiporidae	*Amphiporus*	*bimaculatus*		Coe 1910	I	II III IV V VI VII VIII						Coe 1904
Nemertea	Amphiporidae	*Amphiporus*	*exilis*	*A. formidabilis*	Coe 1910	I	II III IV V VI						Coe 1904
Nemertea	Amphiporidae	*Amphiporus*	*gelatinosus*		Austin 1985	I	II III			x			Austin 1985
Nemertea	Amphiporidae	*Amphiporus*	*imparispinosus*		Austin 1985	I	II III IV V VI VII VIII						Austin 1985
Nemertea	Amphiporidae	*Amphiporus*	*lactifloreus*			I	I						
Nemertea	Amphiporidae	*Amphiporus*	*leuciodes*		Coe 1910	I	III						Coe 1904
Nemertea	Amphiporidae	*Amphiporus*	*nebulosus*		Coe 1910	I	II III						Coe 1904
Nemertea	Amphiporidae	*Amphiporus*	*tigrinus*		Coe 1910	I	III IV						Coe 1904
Nemertea	Amphiporidae	*Zygonemertes*	*albida*		Coe 1910	I	III IV V VI						Coe 1904
Nemertea	Amphiporidae	*Zygonemertes*	*thalassina*		Coe 1910	I	II III						Coe 1904
Nemertea	Amphiporidae	*Zygonemertes*	*virescens*		Austin 1985	I	I II III IV V VI VII VIII IX			x			Austin 1985
Nemertea	Carinomidae	*Carinoma*	*griffini*	*C. mutabilis*	Coe 1910	I	III IV V VI VII VIII						Coe 1904
Nemertea	Carinomidae	*Carinomella*	*lactea*	Tubulanidae	Austin 1985	I	I II III IV V VI						Austin 1985
Nemertea	Cephalothricidae	*Cephalothrix*	*linearis*	*Procephalothrix spiralis*	Coe 1910	I	II III IV V VI						Coe 1904
Nemertea	Cerebratulidae	*Cerebratulus*	*albifrons*		Coe 1910	I	III IV V VI						Coe 1904
Nemertea	Cerebratulidae	*Cerebratulus*	*herculeus*		Coe 1910	I	III IV V VI						Coe 1904
Nemertea	Cerebratulidae	*Cerebratulus*	*longiceps*		Coe 1910	I	II III IV V						Coe 1904
Nemertea	Cerebratulidae	*Cerebratulus*	*marginatus*		Coe 1910	I	III						Coe 1904
Nemertea	Cerebratulidae	*Cerebratulus*	*montgomeryi*		Coe 1910	I	II III IV V						Coe 1904
Nemertea	Cerebratulidae	*Cerebratulus*	*occidentalis*		Coe 1910	I	II III						Coe 1904
Nemertea	Cerebratulidae	*Cerebratulus*	unidentified		Feder and Matheke 1980	ST							
Nemertea	Emplectonematidae	*Emplectonema*	*buergeri*		Coe 1910	I	III						Coe 1904
Nemertea	Emplectonematidae	*Emplectonema*	*gracile*		Coe 1910	I	II III IV V						Coe 1904
Nemertea	Emplectonematidae	*Paranemertes*	*carnea*		Coe 1910	I	II III IV						Coe 1904
Nemertea	Emplectonematidae	*Paranemertes*	*pallida*		Coe 1910	I	II III						Coe 1904
Nemertea	Emplectonematidae	*Paranemertes*	*peregrina*		Feder and Bryson-Schwafel 1988	I	II III IV	x					Austin 1985
Nemertea	Lineidae	*Lineus*	*torquatus*		Coe 1910	I	II III IV V VI						Coe 1904
Nemertea	Lineidae	*Micrura*	*alaskensis*		Coe 1910	I	III IV V VI VII VIII						Coe 1904
Nemertea	Lineidae	*Micrura*	*verrilli*		Coe 1910	I	II III IV V VI						Coe 1904
Nemertea	Lineidae	*Myoisophagus*	*sanguineus*	*Lineus socialis/vegetus*	Austin 1985	I	II III IV V VI	x		x			Austin 1985
Nemertea	Tetrastemmatidae	*Tetrastemma*	*aberrans*		Coe 1910	I	II III						Coe 1904
Nemertea	Tetrastemmatidae	*Tetrastemma*	*bicolor*		Coe 1910	I	II III						Coe 1904
Nemertea	Tetrastemmatidae	*Tetrastemma*	*caecum*	*Amphinemertes*	Coe 1910	I/ST	II III						Coe 1904
Nemertea	Tetrastemmatidae	*Tetrastemma*	*candidum*		Austin 1985	I	II III IV V VI VII VIII	x		x			Austin 1985
Nemertea	Tetrastemmatidae	*Tetrastemma*	*nigrifrons*		Austin 1985	I	I II III IV V VI VII VIII IX						Austin 1985
Nemertea	Tubulanidae	*Carinella*	*albocinctus*	*Tubulanus*	Austin 1985	ST	II III IV V VI						Austin 1985
Nemertea	Tubulanidae	*Carinella*	*annulatus*	*Tubulanus*	Austin 1985	I	II III			x			Austin 1985
Nemertea	Tubulanidae	*Carinella*	*capistrata*	*Tubulanus capistratus?*	Coe 1910	I	II						Coe 1904
Nemertea	Tubulanidae	*Carinella*	*cingulatus*	*Tubulanus*	Austin 1985	I	II III IV V VI						Austin 1985
Nemertea	Tubulanidae	*Carinella*	*dinema*	*Tubulanus sexlineatus*	Coe 1910	I	II III						Coe 1904
Nemertea	Tubulanidae	*Carinella*	*frenatus*	*Tubulanus*	Austin 1985	I	II III IV V VI						Austin 1985
Nemertea	Tubulanidae	*Carinella*	*nothus*	*Tubulanus*	Austin 1985	I	II III			x			Austin 1985
Nemertea	Tubulanidae	*Carinella*	*speciosa*	*Tubulanus polymorphus*	Coe 1910	I	II III						Coe 1904
Nemertea	Valenciniidae	*Taeniosoma*	*princeps*	*Baseodiscus*	Coe 1910	I	II III IV						Coe 1904
Phoronida		unidentified	unidentified		Feder and Matheke 1980	ST							

Table 10.8 continued.

PHYLUM/ CLASS	FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	Bioregion NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Platyhelminthes		unidentified	unidentified		Feder and Bryson-Schwafel 1988	Inf							
Porifera	Myxillidae	*Myxilla*	*incrustans*		UAM	ST	II III IV	x					Austin 1985
Porifera	Subertidae	*Suberites*	*ficus*		Scheel, Foster, and Hough, 1997	I/ST/Epi	II III IV						Austin 1985
Porifera	Spirastrellidae	*Cliona*	*thosina*		Hines et al. 2000	boring	II				unkown	definate	
Porifera	Spirastrellidae	*Cliona*	*celata*		Rosenthal 1977	Epi	II III IV V						Austin 1985
Priapulida	Priapulidae	*Priapulus*	*caudatus*		Feder and Matheke 1980	ST	II	x	x	x			Austin 1985
Sipunculida	Golfingiidae	*Golfingia*	*margaritacea*		Feder and Matheke 1980	I/ST/Inf	II	x		x			Austin 1985
Sipunculida	Golfingiidae	*Golfingia*	*vulgaris*		Feder and Matheke 1980	ST	II	x		x			Austin 1985
Sipunculida	Golfingiidae	*Phascolion*	*strombi*		Feder and Matheke 1980	ST	x	x	x	x			Austin 1985
Sipunculida	Phascolosomatidae	*Phascolosoma*	*agassizii*		Fisher 1952	I/ST/Inf	II III IV V VI VIII IX						Austin 1985
Tardigrada	Hypsibiidae	*Hypsibius*	*appelloefi*		Feder and Bryson-Schwafel 1988	ST	x	x	x	x			Schuster and Grigarick 1965
Urochordata: Ascidiacea	Ascidiidae	*Ascidia*	*adhaerens*		Lambert 2000	I	II	x		x			Lambert 2000
Urochordata: Ascidiacea	Ascidiidae	*Ascidia*	*columbiana*	*A. callosa*	Lambert 2000	I	II III IV	x					Lambert 2000
Urochordata: Ascidiacea	Ascidiidae	*Ascidia*	unidentified		Lambert 2000	I/ST/Epi							
Urochordata: Ascidiacea	Clavelinidae	*Distaplia*	*alaskensis*		Lambert 2000	ST/Epi							
Urochordata: Ascidiacea	Clavelinidae	*Distaplia*	sp. undescribed		Lambert 2000	ST/Epi						possible	Lambert 2000
Urochordata: Ascidiacea	Corellidae	*Chelysoma*	*columbiana*		Austin 1985	ST/Epi	II III IV						Austin 1985
Urochordata: Ascidiacea	Corellidae	*Chelysoma*	*productum*		Lambert 2000	ST/Epi	II III IV V VI						Austin 1985
Urochordata: Ascidiacea	Corellidae	*Corella*	*inflata*		Lambert 2000	I	II III IV						Austin 1985
Urochordata: Ascidiacea	Corellidae	*Corella*	unidentified		Lambert 2000	I							
Urochordata: Ascidiacea	Corellidae	*Corella*	*willmeriana*		Lambert 2000	I	II III IV						Austin 1985
Urochordata: Ascidiacea	Molgulidae	*Molgula*	*retortiformis*		Lambert 2000	I	II	x		x			Austin 1985
Urochordata: Ascidiacea	Polyclinidae	*Ritterella*	unidentified		Lambert 2000	I							
Urochordata: Ascidiacea	Pyruridae	*Boltenia*	*echinata*		EVOS	ST/Epi	II III IV	x					Austin 1985
Urochordata: Ascidiacea	Pyruridae	*Boltenia*	*ovifera*		UAM	ST/Epi	II III IV	x					Pavloskii 1955
Urochordata: Ascidiacea	Pyruridae	*Halocynthia*	*igoboja*		UAM	ST/Epi	II III IV	x					Austin 1985
Urochordata: Ascidiacea	Pyruridae	*Halocynthia*	*auranticum*	*Tethyum*	Scheel, Foster, and Hough, 1997	ST/Epi	II III IV	x					Austin 1985
Urochordata: Ascidiacea	Pyruridae	*Pyura*	*haustor*		Lambert 2000	ST/Epi	II III IV V VI						Austin 1985
Urochordata: Ascidiacea	Styelidae	*Botrylloides*	*violaceus*		Lambert 2000	ST/Epi		x			Japan	definate	
Urochordata: Ascidiacea	Styelidae	*Cnemidocarpa*	*finmarkiensis*	*Stylea*	Rosenthal 1977	ST/Epi	II III IV V	x		x			Austin 1985
Urochordata: Ascidiacea	Styelidae	*Metandrocarpa*	*taylori*		Rosenthal 1977	ST/Epi	II III IV V						Austin 1985
Urochordata: Ascidiacea	Styelidae	*Styela*	*truncata*		Lambert 2000	I	II III IV						Austin 1985
Urochordata: Ascidiacea	Clavelinidae	*Distaplia*	*occidentalis*		Lambert 2000	ST/Epi	III IV V VI				British Columbia	NR	Austin 1985
Urochordata: Larvacea	Fritillariidae	*Fritillaria*	*borealis*		Cooney 1987	P	II III IV V VI	x	x	x			Austin 1985
Urochordata: Larvacea	Fritillariidae	*Fritillaria*	unidentified		Cooney: SEA	P							
Urochordata: Larvacea	Oikopleuridae	*Oikopleura*	*labradorensis*		Cooney 1987	P	II III IV V	x	x	x			Wrobel and Mills 1998
Urochordata: Larvacea	Oikopleuridae	*Oikopleura*	unidentified		Cooney and Coyle 1988	P							
Urochordata: Larvacea	Oikopleuridae	*Oikopleura*	*vanhoeffeni*		Cooney 1987	P	II III	x	x	x			Wrobel and Mills 1998
Urochordata	Oikopleuridae	*Oikopleura*	*dioica*		Cooney 1987	P	II III IV V						Wrobel and Mills 1998
Urochordata	Salpida	*Salpa*	*fusiformis*		Cooney 1987	P	II III IV V VI VII VIII IX	x		x			Wrobel and Mills 1998
Urochordata	Salpida	*Salpa*	*maxima*		Cooney 1987	P	II III IV V VI VII VIII IX	x		x			Wrobel and Mills 1998

<u>Fishes</u>

The 175 species we list represent 33 families (Table 10.9). The fish data set uses records for fish specimens catalogued in the University of Alaska Museum, as well as published and manuscript sources. (Baxter unpublished manuscript, Hart 1973). Name changes derive from and Humann (1996). Two species, the American shad, *Alosa sapidissima*, and the Atlantic Salmon, *Samo salar* are nonindigenous.

Mecklenberg, (letter of 10/30/00) recognizes an undescribed cottid, possibly a *Malacocottus*. It has been identified incorrectly as *Thecopterus aleuticus*.

The following habitat descriptors used in the data sets are based on usage in Eschmeyer et al (1983)and Eschmeyer (1990) and Hart (1973).

ANA	anadromous	BW	brackish	D	dermesal
E	eelgrass	Epip	epipelagic	Est	estuaries
FW	freshwater	I	intertidal	KB	kelp bed
NS	nearshore	Off	offshore	Pel	pelagic
PB	pebble bottom	RI	rocky intertidal		
RST	rocky subtidal	SAB	sand bottom		
SB	softbottom	ST	subtidal		
SW	saltwater				

Table 10.9. Fishes.

						BIOREGION						
FAMILY	**GENUS**	**SPECIES**	**OTHER NAMES**	**SPECIMEN or SOURCE**	**HABITAT**	**NEP**	**NWP**	**AR**	**NWA**	**ORIGIN**	**NIS STATUS**	**REFERENCE to DISTRIBUTION**
Acipenseridae	*Acipenser*	*medirostris*		Hart 1973	BW, SW, NS	IV	x	x				Hart 1973
Acipenseridae	*Acipenser*	*transmontanus*		Hart 1973	ANA	IV						Hart 1973
Agonidae	*Anoplagonus*	*inermis*		UAM	D	IV	x					Hart 1973
Agonidae	*Aspidophoroides*	*bartoni*		UAM	SB, SA	IV	x					Baxter 1987ms
Agonidae	*Aspidophoroides*	*olrikii*		UAM	SB, SA	IV		x				Baxter 1987ms
Agonidae	*Bathyagonus*	*infraspinata*	*Asterotheca*	UAM	D, SB	IV						Hart 1973
Agonidae	*Bathyagonus*	*nigripinnis*		UAM	D, SB	IV	x	x				Hart 1973
Agonidae	*Bathyagonus*	*pentacanthus*	*Asterotheca*	Hart 1973	D, SB	IV						Hart 1973
Agonidae	*Bathyagonus*	*alascanus*	*Asterotheca alascana*	Hart 1973	RST, D	II III IV						Hart 1973
Agonidae	*Bothragonus*	*swani*		Hart 1973	I, ST	IV						Hart 1973
Agonidae	*Hypsagonus*	*quadricornis*		Hart 1973	D, SB	IV	x	x				Hart 1973
Agonidae	*Occella*	*verrucosa*		Hart 1973	D, SB	IV						Hart 1973
Agonidae	*Odontopyxis*	*trispinosa*		UAM	D, SB	IV				SE Alaska	nr	Hart 1973
Agonidae	*Podothecus*	*acipenserinus*	*Agonus*	Hart 1973	D	IV	x					Hart 1973
Ammodytidae	*Ammodytes*	*hexapterus*		UAM	I, ST, NS, P	IV	x	x				Hart 1973
Anarhichadidae	*Anarrhichthys*	*ocellatus*		Hart 1973	RST, D	IV	x					Hart 1973
Anoplopomatidae	*Anoplopoma*	*fimbria*		Feder et al. 1979	ST, D	IV	x	x				Hart 1973
Aulorhynchidae	*Aulorhynchus*	*flavidus*		UAM	1, ST, SAB, KB, E	II III IV						Hart 1973
Bathylagidae	*Leuroglossus*	*callorhinus*	*L. schmidti*	UAM	P	IV	x					Hart 1973
Bathymasteridae	*Bathylagus*	*milleri*		Hart 1973	P	IV	x					Hart 1973
Bathymasteridae	*Bathylagus*	*ochotensis*		Hart 1973	P	IV	x	x				Hart 1973
Bathymasteridae	*Bathymaster*	*caeruleofasciatus*		Rogers et al. 1986	RST	II III IV						Eschmeyer et al. 1983
Bathymasteridae	*Bathymaster*	*leurolepis*		Rogers et al. 1986	I/ST	II III IV	x					Eschmeyer et al. 1983
Bathymasteridae	*Bathymaster*	*signatus*		UAM	D, SB	IV	x	x				Hart 1973
Bathymasteridae	*Ronquilus*	*jordani*		Hart 1973	RST, D	IV						Hart 1973
Bothidae	*Citharichthys*	*sordidus*		Hart 1973	D, SAB	IV						Hart 1973
Carcharhinidae	*Prionace*	*glauca*		UAM	Epip	x	x	x	x			Hart 1973
Clupeidae	*Alosa*	*sapidissima*		UAM	ANA	III IV			x	Atlantic	definate	Hart 1973
Clupeidae	*Clupea*	*pallasii*		UAM	P, Est	II	x	x				Hart 1973
Cottidae	*Artedius*	*fenestralis*		Hart 1973	I, ST	IV						Hart 1973
Cottidae	*Artedius*	*harringtoni*		Hart 1973	I, RST	IV						Hart 1973
Cottidae	*Artedius*	*lateralis*		UAM	I, ST	IV						Hart 1973
Cottidae	*Blepsias*	*bilobus*		UAM	I, ST	IV	x	x				Hart 1973
Cottidae	*Blepsias*	*cirrhosus*		Hart 1973	I, ST	IV	x					Hart 1973
Cottidae	*Clinocottus*	*acuticeps*		UAM	RI, ST, SAB, E, KB	II III IV						Hart 1973
Cottidae	*Clinocottus*	*embryum*		UAM	RI	IV						Hart 1973
Cottidae	*Clinocottus*	*globiceps*		Hart 1973	RI	IV						Hart 1973
Cottidae	*Dasycottus*	*setiger*		UAM	SB	IV	x					Hart 1973
Cottidae	*Enophrys*	*bison*		Hart 1973	RST, SB	IV						Hart 1973
Cottidae	*Gymnocanthus*	*galeatus*		UAM	SB, NS	IV						Hart 1973
Cottidae	*Hemilepidotus*	*hemilepidotus*		UAM	I, RST, NS	IV	x					Hart 1973
Cottidae	*Hemilepidotus*	*jordani*		UAM	ST	IV	x					Hart 1973
Cottidae	*Hemilepidotus*	*spinosus*		Hart 1973	I, ST	IV				SE Alaska	nr	Hart 1973
Cottidae	*Icelinus*	*borealis*		UAM	SB	IV						Hart 1973
Cottidae	*Icelus*	*spiniger*		Hart 1973	SB	IV	x	x				Hart 1973
Cottidae	*Leptocottus*	*armatus*		UAM	I, ST	IV						Hart 1973
Cottidae	*Malacocottus*	*kincaidi*		UAM	SB	IV	x					Hart 1973
Cottidae	*Malacocottus*	*zonurus*		UAM	SB	IV	x					Hart 1973
Cottidae	*Myoxocephalus*	*polyacanthocephalus*		Hart 1973	I, NS, SB, SAB	IV	x					Hart 1973
Cottidae	*Myoxocephalus*	*scorpius?*	*M. groenlandicus?*	Rogers et al. 1986	ST	II III IV	x	x				Baxter 1987ms

Table 10.9 continued.

FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Cottidae	*Myoxocephalus*	*verrucosus?*		UAM	ST	IV	x					Baxter 1987ms
Cottidae	*Nautichthys*	*oculofasciatus*		Hart 1973	RST	IV	x	x				Hart 1973
Cottidae	*Oligocottus*	*maculosus*		Hart 1973	I, RST	IV	x	x				Hart 1973
Cottidae	*Oligocottus*	*rimensis*		UAM	I, RST	IV						Hart 1973
Cottidae	*Psychrolutes*	*paradoxus*		Hart 1973	NS, RST, SB	IV	x	x				Hart 1973
Cottidae	*Psychrolutes*	*sigalutes*	*Gilbertidia*	Hart 1973	RST, NS, SB	IV						Hart 1973
Cottidae	*Radulinus*	*asprellus*		UAM	NS	IV						Hart 1973
Cottidae	*Rhamphocottus*	*richardsoni*		UAM	I, RST, SAB	IV						Hart 1973
Cottidae	*Malacocottus*	sp.	*Thecopterus aleuticus*	UAM	RST	II				Bering Sea	nr	Baxter 1987ms
Cottidae	*Triglops*	*macellus*		Hart 1973	D	IV						Hart 1973
Cottidae	*Triglops*	*pingelii*		UAM	D	II	x	x	x			Hart 1973
Cryptacanthodidae	*Delolepis*	*giganteus*		Hart 1973	SB	IV						Hart 1973
Cryptacanthodidae	*Lyconectes*	*aleutensis*		UAM	ST, NS, SAB	IV						Hart 1973
Cyclopteridae	*Aptocyclus*	*ventricosus*		Hart 1973	I, ST	IV	x	x				Hart 1973
Cyclopteridae	*Careproctus*	*colletti*		UAM	SB, SA	II	x					Hart 1973
Cyclopteridae	*Careproctus*	*gilberti*		Hart 1973	SB, SA	IV						Hart 1973
Cyclopteridae	*Careproctus*	*melanurus*		UAM	ST, SB, SAB	IV						Hart 1973
Cyclopteridae	*Eumicrotremus*	*orbis*		UAM	I, RST	IV	x					Hart 1973
Cyclopteridae	*Liparis*	*callyodon*		Hart 1973	I	IV						Hart 1973
Cyclopteridae	*Liparis*	*cyclopus*		Hart 1973	NS	IV						Hart 1973
Cyclopteridae	*Liparis*	*dennyi*		UAM	SB, SA	IV						Hart 1973
Cyclopteridae	*Liparis*	*florae*		UAM	I	IV						Hart 1973
Cyclopteridae	*Liparis*	*pulchellus*		Hart 1973	SB	IV	x					Hart 1973
Cyclopteridae	*Liparis*	*rutteri*		Hart 1973	I, ST	IV						Hart 1973
Cyclopteridae	*Nectoliparis*	*pelagicus*		UAM	P	IV	x					Hart 1973
Cyclopteridae	*Paraliparis*	*deani*		UAM	D	IV	x	x		SE Alaska	nr	Hart 1973
Gadidae	*Eleginus*	*gracilis*		UAM	P, D	IV	x					Hart 1973
Gadidae	*Gadus*	*macrocephalus*		UAM	P, D	IV	x	x				Hart 1973
Gadidae	*Merluccius*	*productus*		Hart 1973	P, D	IV	x					Hart 1973
Gadidae	*Microgadus*	*proximus*		UAM	D	IV						Hart 1973
Gadidae	*Theragra*	*chalcogramma*		UAM	Off, D	IV	x	x				Hart 1973
Gasterosteidae	*Gasterosteus*	*aculeatus*		Hart 1973	FW/SW, NS	II	x					Hart 1973
Hexagrammidae	*Hexagrammos*	*decagrammus*		Hart 1973	RST, KB, SAB	IV						Hart 1973
Hexagrammidae	*Hexagrammos*	*lagocephalus*		Hart 1973	RST	IV	x					Hart 1973
Hexagrammidae	*Hexagrammos*	*octogrammus*		UAM	RST	IV	x	x				Hart 1973
Hexagrammidae	*Hexagrammos*	*stelleri*		UAM	RST, NS, E	IV	x	x				Hart 1973
Hexagrammidae	*Ophiodon*	*elongatus*		Hart 1973	NS, RST, SB, SAB	II III IV						Hart 1973
Lamnidae	*Cetorhinus*	*maximus*		Hart 1973	Epip, P, NS	x	x	x	x			Hart 1973
Lamnidae	*Lamna*	*ditropus*		Hart 1973	Off, Epip, NS	IV	x	x				Hart 1973
Osmeridae	*Hypomesus*	*pretiosus pretiosus*		Hart 1973	NS	IV	x					Hart 1973
Osmeridae	*Mallotus*	*villosus*		Hart 1973	Oceanic	II	x	x	x			Hart 1973
Osmeridae	*Spirinchus*	*thaleichthys*		Hart 1973	ANA	IV						Hart 1973
Osmeridae	*Thaleichthys*	*pacificus*		UAM	ANA	IV	x					Hart 1973
Petromyzontidae	*Lampetra*	*japonica*		Rogers et al. 1986	ANA	IV						Baxter 1987ms
Petromyzontidae	*Lampetra*	*tridentata*		Hart 1973	ANA	IV	x	x				Hart 1973
Pholidae	*Apodichthys*	*flavidus*		Hart 1973	I/RT	IV						Hart 1973
Pholidae	*Pholis*	*gilli*		UAM	I/RT	IV						Hart 1973
Pholidae	*Pholis*	*laeta*		UAM	I, ST	IV						Hart 1973
Pleuronectidae	*Atheresthes*	*stomias*		UAM	SB, Off	IV						Hart 1973
Pleuronectidae	*Eopsetta*	*jordani*		Hart 1973	SAB	IV						Hart 1973
Pleuronectidae	*Glyptocephalus*	*zachirus*		UAM	SB, SAB	IV						Hart 1973
Pleuronectidae	*Hippoglossoides*	*elassodon*		UAM	SB	IV	x	x				Hart 1973
Pleuronectidae	*Hippoglossus*	*stenolepis*		Rogers et al. 1986	ST, NS	II III IV	x					Eschmeyer et al. 1983
Pleuronectidae	*Iopsetta*	*ischyra*		Hart 1973	NS, Off	IV						Hart 1973
Pleuronectidae	*Limanda*	*aspera*		UAM	NS	IV	x	x				Hart 1973
Pleuronectidae	*Limanda*	*proboscidea*		UAM	SB	IV						Hart 1973
Pleuronectidae	*Microstomus*	*pacificus*		UAM	SB	IV						Hart 1973
Pleuronectidae	*Platichthys*	*stellatus*		UAM	NS, Est	IV	x	x				Hart 1973
Pleuronectidae	*Pleuronectes*	*bilineata*	*Lepidosetta*	UAM	NS, Off, PB	IV	x	x				Hart 1973
Pleuronectidae	*Pleuronectes*	*vetulus*	*Parophrys*	UAM	I, ST	IV						Hart 1973
Pleuronectidae	*Pleuronichthys*	*decurrens*		Feder et al. 1979	SB	IV						Hart 1973
Pleuronectidae	*Psettichthys*	*melanostictus*		Hart 1973	NS	IV						Hart 1973
Pleuronectidae	*Reinhardtius*	*hippoglossoides*		Hart 1973	SAB, PB?	II	x	x	x			Hart 1973
Rajidae	*Bathyraja*	*kincaidi*	*Raja*	UAM	D	IV						Hart 1973
Rajidae	*Bathyraja*	*aleutica*		Wilimovsky 1958	D	II III	x					Wilimovsky 1958
Rajidae	*Bathyraja*	*interrupta*		Escheyer et al. 1983		II III IV						Escheyer et al. 1983
Rajidae	*Raja*	*binoculata*		Escheyer et al. 1983	D	II III IV						Escheyer et al. 1983
Rajidae	*Raja*	*parmifera*		Escheyer et al. 1983	D	II III	x					Escheyer et al. 1983
Rajidae	*Raja*	*rhina*	*Bathyraja*	Feder et al. 1979	D	IV						Hart 1973
Rajidae	*Bathyraja*	*stellulata*	*Raja*	Hart 1973	D	IV						Hart 1973
Salmonidae	*Oncorhynchus*	*clarki*	*Salmo clarki*	Hart 1973	ANA, FW	IV						Hart 1973
Salmonidae	*Oncorhynchus*	*gorbuscha*		UAM	ANA	IV	x					Hart 1973
Salmonidae	*Oncorhynchus*	*keta*		Hart 1973	ANA	IV	x	x				Hart 1973

Table 10.9 continued.

FAMILY	GENUS	SPECIES	OTHER NAMES	SPECIMEN or SOURCE	HABITAT	BIOREGION NEP	NWP	AR	NWA	ORIGIN	NIS STATUS	REFERENCE to DISTRIBUTION
Salmonidae	*Oncorhynchus*	*kisutch*		Hart 1973	ANA	IV	x					Hart 1973
Salmonidae	*Oncorhynchus*	*mykiss*	*Salmo gardnerii*	Hart 1973	ANA	IV	x					Hart 1973
Salmonidae	*Oncorhynchus*	*nerka*		Hart 1973	ANA	IV	x	x				Hart 1973
Salmonidae	*Oncorhynchus*	*tshawytscha*		Hart 1973	ANA	IV	x	x				Hart 1973
Salmonidae	*Salmo*	*salar*		Hart 1973	ANA	III IV			x	British Columbia	definate	Hines et al. 2000
Salmonidae	*Salvelinus*	*malma*		Hart 1973	ANA	IV	x	x				Hart 1973
Scombridae	*Sarda*	*chiliensis*		Hart 1973	NS	IV	x					Hart 1973
Scorpaenidae	*Sebastes*	*aleutianus*		UAM	D	IV						Hart 1973
Scorpaenidae	*Sebastes*	*alutus*		UAM	Off	IV	x					Hart 1973
Scorpaenidae	*Sebastes*	*auriculatus*		Rogers et al. 1986	ST, NS	II III IV				SE Alaska	nr	Eschmeyer et al. 1983
Scorpaenidae	*Sebastes*	*borealis*		UAM	SB	IV	x					Hart 1973
Scorpaenidae	*Sebastes*	*brevispinis*		Hart 1973	D?	IV						Hart 1973
Scorpaenidae	*Sebastes*	*caurinus*		Hart 1973	RST, SAB, NS	IV						Hart 1973
Scorpaenidae	*Sebastes*	*ciliatus*		Hart 1973	D, NS	IV	x					Hart 1973
Scorpaenidae	*Sebastes*	*crameri*		Hart 1973	SB	IV						Hart 1973
Scorpaenidae	*Sebastes*	*diploproa*		Hart 1973	Off, SB	IV						Hart 1973
Scorpaenidae	*Sebastes*	*elongatus*		Hart 1973	RST, SB	IV						Hart 1973
Scorpaenidae	*Sebastes*	*emphaeus*		Rogers et al. 1986	ST, NS	IV						Baxter 1987ms
Scorpaenidae	*Sebastes*	*flavidus*		Hart 1973	P	IV						Hart 1973
Scorpaenidae	*Sebastes*	*maliger*		Hart 1973	RST, NS	IV						Hart 1973
Scorpaenidae	*Sebastes*	*melanops*		Hart 1973	D, NS, RR	IV						Hart 1973
Scorpaenidae	*Sebastes*	*mystinus*		Hart 1973	D, RR, KB	IV						Hart 1973
Scorpaenidae	*Sebastes*	*nebulosus*		Rogers et al. 1986	NS, RST, RR	IV				SE Alaska	nr	Baxter 1987ms
Scorpaenidae	*Sebastes*	*nigrocinctus*		Rogers et al. 1986	RST	IV				SE Alaska	nr	Baxter 1987ms
Scorpaenidae	*Sebastes*	*paucispinis*		Hart 1973	D, RR	IV						Hart 1973
Scorpaenidae	*Sebastes*	*proriger*		Hart 1973	D	IV						Hart 1973
Scorpaenidae	*Sebastes*	*ruberrimus*		Feder et al. 1979	RR	IV						Hart 1973
Scorpaenidae	*Sebastes*	*variegatus*		UAM	D	IV						Hart 1973
Scorpaenidae	*Sebsatsolobus*	*alascanus*		Hart 1973	SB	IV	x					Hart 1973
Scorpaenidae	*Sebsatsolobus*	*altivelis*		Hart 1973	Off, SB	IV						Hart 1973
Scytalinidae	*Scytalina*	*cerdale*		Hart 1973	I, NS SAB, PB	IV						Hart 1973
Sphyraenidae	*Sphyraena*	*argentea*		Hart 1973	NS	IV						Hart 1973
Squalidae	*Somniosus*	*pacificus*		Hart 1973	I, P, D	IV	x	x				Hart 1973
Squalidae	*Squalus*	*acanthias*		Hart 1973	P, D	II	x		x			Hart 1973
Stichaeidae	*Anoplarchus*	*insignis*		Hart 1973	RST	IV						Hart 1973
Stichaeidae	*Anoplarchus*	*purpurescens*		UAM	I, RST	IV						Hart 1973
Stichaeidae	*Chirolophis*	*decoratus*		Hart 1973	RST, KB	IV						Hart 1973
Stichaeidae	*Chirolophis*	*nugator*		Rogers et al. 1986	RST	II III IV						Eschmeyer et al. 1983
Stichaeidae	*Lumpenella*	*longirostris*		UAM	Off	IV						Hart 1973
Stichaeidae	*Lumpenus*	*maculatus*		UAM	SAB	IV		x				Hart 1973
Stichaeidae	*Lumpenus*	*sagitta*		UAM	Off, NS	IV	x					Hart 1973
Stichaeidae	*Phytichthys*	*chirus*		Hart 1973	I, RST	IV						Hart 1973
Stichaeidae	*Poroclinus*	*rothrocki*		Hart 1973	SB, SA	IV						Hart 1973
Stichaeidae	*Stichaeus*	*punctatus*		UAM	RST, SAB	II	x	x	x			Hart 1973
Stichaeidae	*Xiphister*	*mucosus*		UAM	I, RST	IV						Hart 1973
Trichodontidae	*Trichodon*	*trichodon*		UAM	NS, SB SAB	IV	x	x				Hart 1973
Zaproridae	*Zaprora*	*silenus*		Hart 1973	D	IV	x	x				Hart 1973
Zoarcidae	*Bothrocara*	*molle*		UAM	SB, SA	IV	x					Hart 1973
Zoarcidae	*Lycodapus*	*mandibularis*		UAM	P	IV						Hart 1973
Zoarcidae	*Lycodes*	*brevipes*		UAM	SB, SAB	IV	x	x				Hart 1973
Zoarcidae	*Lycodes*	*diapterus*		UAM	SB	IV	x	x				Hart 1973
Zoarcidae	*Lycodes*	*palearis*		UAM	SB- SAB	IV	x					Hart 1973
Zoarcidae	*Lycodopsis*	*pacifica*		Feder et al. 1979	P	IV						Hart 1973
Stichaeidae	*Xiphister*	*atropurpureus*		Hart 1973	I, RST	IV						Hart 1973

Birds

The rich bird fauna of Prince William Sound, the northern Gulf of Alaska coast and Copper River Delta has been described in detail by Isleb and Kessel (1973, 1989). From their checklist, we have selected 114 species with habitats designated " beaches and tidal flats, rocky shores, and reefs, inshore waters, and offshore waters" (Table 10.10).

The American Ornithologists' Union's (1983) Check-list of North American Birds, was used to update common and scientific names. Usage of terms that define status: migrant, visitor, breeder and resident is derived from Isleb and Kessel (1973).

Nsh	nearshore	m	migrant
Pel	pelagic	v	visitor
Int	intertidal	r	rare
		b	breeder

Table 10.10. Birds.

FAMILY	GENUS	SPECIES	COMMON NAME	OTHER NAMES	SOURCE	HABITAT	STATUS
Gaviidae	*Gavia*	*immer*	Common Loon		Isleib and Kessel 1973	nsh	r
Gaviidae	*Gavia*	*adamsii*	Yellow-billed Loon		Isleib and Kessel 1973	nsh	r
Gaviidae	*Gavia*	*arctica*	Arctic Loon		Isleib and Kessel 1973	nsh	r
Gaviidae	*Gavia*	*stellata*	Red-throated Loon		Isleib and Kessel 1973	nsh	r
Podicipedidae	*Podiceps*	*grisegena*	Red-necked Grebe		Isleib and Kessel 1973	nsh	r
Podicipedidae	*Podiceps*	*auritis*	Horned Grebe		Isleib and Kessel 1973	nsh	r
Porcellariidae	*Fulmarus*	*glacialis*	Fulmar		Isleib and Kessel 1973	pel	v
Porcellariidae	*Puffinus*	*creatopus*	Pink-footed Shearwater		Isleib and Kessel 1973	pel	v
Porcellariidae	*Puffinus*	*carneipes*	Pale-footed Shearwater		Isleib and Kessel 1973	pel	v
Porcellariidae	*Puffinus*	*griseus*	Sooty Shearwater		Isleib and Kessel 1973	pel	v
Porcellariidae	*Puffinus*	*tenuirostris*	Slender-billed Shearwater		Isleib and Kessel 1973	pel	v
Porcellariidae	*Oceandroma*	*furcata*	Fork-tailed Storm Petrel		Isleib and Kessel 1973	pel	r
Phalacrocoracidae	*Phalacrocorax*	*auritius*	Double-crested Cormorant		Isleib and Kessel 1973	nsh/int	r
Phalacrocoracidae	*Phalacrocorax*	*penicillatus*	Brandt's Cormorant		Isleib and Kessel 1973	nsh/int	b
Phalacrocoracidae	*Phalacrocorax*	*peligicus*	Pelagic Cormorant		Isleib and Kessel 1973	nsh/int	r
Phalacrocoracidae	*Phalacrocorax*	*urile*	Red-faced Cormorant		Isleib and Kessel 1973	nsh/int	r
Ardeidae	*Ardea*	*herodias*	Great blue Heron		Isleib and Kessel 1973	int	r
Anatidae	*Cygnus*	*columbianus*	Whistling Swan	*Olor*	Isleib and Kessel 1973	int	m
Anatidae	*Cygnus*	*buccinator*	Trumpeter Swam	*Olor*	Isleib and Kessel 1973	int	r
Anatidae	*Branta*	*canadensis*	Canada Goose		Isleib and Kessel 1973	int	r
Anatidae	*Branta*	*bernicula*	Brant	*B. nigricans*	Isleib and Kessel 1973	int	m
Anatidae	*Chen*	*canagica*	Emperor Goose	*Philacate*	Isleib and Kessel 1973	int	m
Anatidae	*Anser*	*albifrons*	Greater White-fronted Goose		Isleib and Kessel 1973	int	m
Anatidae	*Chen*	*caerulescens*	Snow Goose	*C. hyperborea*	Isleib and Kessel 1973	int	m
Anatidae	*Anas*	*platyrhynchos*	Mallard		Isleib and Kessel 1973	int	r
Anatidae	*Anas*	*strepera*	Gadwall		Isleib and Kessel 1973	int	r
Anatidae	*Anas*	*acuta*	Northern Pintail		Isleib and Kessel 1973	int	r
Anatidae	*Anas*	*crecca*	Green-winged Teal	*A. carolinensis*	Isleib and Kessel 1973	int	r
Anatidae	*Anas*	*discors*	Blue-winged Teal		Isleib and Kessel 1973	int	m
Anatidae	*Anas*	*penelope*	Europeam Widgeon	*Mareca*	Isleib and Kessel 1973	int	m
Anatidae	*Anas*	*americana*	American Widgeon	*Mareca*	Isleib and Kessel 1973	int	r
Anatidae	*Anas*	*clypeata*	Northern Shoveler	*Spatula*	Isleib and Kessel 1973	int	m/b
Anatidae	*Aythya*	*valisineria*	Canvasback		Isleib and Kessel 1973	int	m/b
Anatidae	*Aythya*	*marila*	Greater Scaup		Isleib and Kessel 1973	int	r
Anatidae	*Bucephala*	*clangula*	Common Goldeneye		Isleib and Kessel 1973	int/nsh	r
Anatidae	*Bucephala*	*islandica*	Barrow's Goldeneye		Isleib and Kessel 1973	int/nsh	r
Anatidae	*Bucephala*	*albeola*	Bufflehead		Isleib and Kessel 1973	int/nsh	r
Anatidae	*Clangula*	*hymenalis*	Oldsquaw		Isleib and Kessel 1973	int/nsh	r
Anatidae	*Histrionicus*	*histrionicus*	Harlequin Duck		Isleib and Kessel 1973	int/nsh	r
Anatidae	*Polysticta*	*stelleri*	Steller's Eider		Isleib and Kessel 1973	int/nsh	v
Anatidae	*Somateria*	*mollissima*	Common Eider		Isleib and Kessel 1973	int/nsh	v
Anatidae	*Somateria*	*spectabilis*	King Eider		Isleib and Kessel 1973	int/nsh	v
Anatidae	*Melanitta*	*fusca*	White-winged Scoter	*M. deglandi*	Isleib and Kessel 1973	int/nsh	r
Anatidae	*Melanitta*	*perspicillata*	Surf Scoter		Isleib and Kessel 1973	int/nsh	r
Anatidae	*Melanitta*	*nigra*	Black Scoter	*Oidema*	Isleib and Kessel 1973	int/nsh	r
Anatidae	*Lophodytes*	*cucullatus*	Hooded Merganser		Isleib and Kessel 1973	int/nsh	r
Anatidae	*Mergus*	*merganser*	Common Merganser		Isleib and Kessel 1973	int/nsh	
Anatidae	*Mergus*	*serrator*	Red-breated Merganser		Isleib and Kessel 1973	int/nsh	r
Accipitridae	*Haliaeetus*	*leucocephalus*	Bald Eagle		Isleib and Kessel 1973	int	r
Accipitridae	*Circus*	*cyaneus*	Marsh Hawk		Isleib and Kessel 1973	int	r
Accipitridae	*Pandion*	*haliaetus*	Osprey	*P. rusticolus*	Isleib and Kessel 1973	int	r
Accipitridae	*Falco*	*peregrinus*	Peregrine Falcon		Isleib and Kessel 1973	int	r
Accipitridae	*Falco*	*columbarius*	Merlin		Isleib and Kessel 1973	int	r
Gruidae	*Grus*	*canadensis*	Sandhill Crane		Isleib and Kessel 1973	int	r
Hematopodidae	*Haematopus*	*bachmani*	Black Oystercatcher		Isleib and Kessel 1973	int	r
Caradriidae	*Charadrius*	*semipalmatus*	Semipalmated Plover		Isleib and Kessel 1973	int	m/b
Caradriidae	*Charadrius*	*vociferus*	Killldeer		Isleib and Kessel 1973	int	v
Caradriidae	*Pluvialis*	*dominica*	American Golder Plover		Isleib and Kessel 1973	int	m/b
Caradriidae	*Pluvialis*	*squatarola*	Black-bellied Plover	*Squatarola*	Isleib and Kessel 1973	int	m
Caradriidae	*Aphriza*	*virgata*	Surfbird		Isleib and Kessel 1973	int	r
Caradriidae	*Arinaria*	*interpres*	Ruddy Turnstone		Isleib and Kessel 1973	int	m

Table 10.10 continued.

FAMILY	GENUS	SPECIES	COMMON NAME	OTHER NAMES	SOURCE	HABITAT	STATUS
Caradriidae	*Arinaria*	*melanocephala*	Black Turnstone		Isleib and Kessel 1973	int	r
Caradriidae	*Galligano*	*galligano*	Common Snipe	*Capella*	Isleib and Kessel 1973	int	r
Caradriidae	*Numenius*	*phaeopus*	Whimbrel		Isleib and Kessel 1973	int	m
Caradriidae	*Actitus*	*macularia*	Spotted Sandpiper		Isleib and Kessel 1973	int	m
Caradriidae	*Trigna*	*solitaria*	Solitary Sandpiper		Isleib and Kessel 1973	int	m
Caradriidae	*Heteroscelus*	*incanus*	Wandering Tattler		Isleib and Kessel 1973	int	m
Caradriidae	*Tringa*	*melanoleuca*	Greater Yellowlegs	*Tatonus*	Isleib and Kessel 1973	int	m
Caradriidae	*Tringa*	*flavipes*	Lesser Yellowlegs	*Tatonus*	Isleib and Kessel 1973	int	m
Caradriidae	*Calidris*	*canutus*	Red Knot		Isleib and Kessel 1973	int	m
Caradriidae	*Calidris*	*ptilocnemis*	Rock Sandpiper	*Erolia*	Isleib and Kessel 1973	int	m
Caradriidae	*Calidris*	*acuminata*	Sharp-tailed Sandpiper	*Erolia*	Isleib and Kessel 1973	int	m
Caradriidae	*Calidris*	*melanotos*	Pectoral Sandpiper	*Erolia*	Isleib and Kessel 1973	int	m
Caradriidae	*Calidris*	*baridii*	Baird's Sandpiper	*Erolia*	Isleib and Kessel 1973	int	m
Caradriidae	*Calidris*	*minutilla*	Least Sandpiper	*Erolia*	Isleib and Kessel 1973	int	m/b
Caradriidae	*Calidris*	*alpina*	Dunlin	*Erolia*	Isleib and Kessel 1973	int	r
Caradriidae	*Limnodromus*	*griseus*	Short-billed Dowitcher		Isleib and Kessel 1973	int	m/b
Caradriidae	*Limnodromus*	*scolopaceus*	Long-billed Dowitcher		Isleib and Kessel 1973	int	m
Caradriidae	*Calidris*	*pusilla*	Semipaliated Sandpiper	*Ereunetes*	Isleib and Kessel 1973	int	m
Caradriidae	*Calidris*	*mauri*	Western Sandpiper	*Ereunetes*	Isleib and Kessel 1973	int	m
Caradriidae	*Limosa*	*lapponica*	Bar-tailed Godwit		Isleib and Kessel 1973	int	m
Caradriidae	*Limosa*	*haemastica*	Hudsonian Godwit		Isleib and Kessel 1973	int	
Caradriidae	*Calidris*	*alba*	Sanderling	*Crocethia*	Isleib and Kessel 1973	int	m
Caradriidae	*Phalaropus*	*fulicarius*	Red Phalarope		Isleib and Kessel 1973	int/nsh/pel	m
Caradriidae	*Lobipes*	*lobatus*	Northern Phalarope		Isleib and Kessel 1973	int/nsh/pel	m/b
Stercorariidae	*Stercorarius*	*pomarinus*	Pomarine Jaeger		Isleib and Kessel 1973	pel	m
Stercorariidae	*Stercorarius*	*parasiticus*	Parasitic Jaeger		Isleib and Kessel 1973	pel	m/b
Stercorariidae	*Stercorarius*	*longicaudus*	Long-tailed Jaeger		Isleib and Kessel 1973	pel	m
Stercorariidae	*Catharacta*	*skua*	Greater Skua		Isleib and Kessel 1973	pel	v
Laridae	*Larus*	*hyperboreus*	Glaucus Gull		Isleib and Kessel 1973	int/nsh/pel	r
Laridae	*Larus*	*glaucesens*	Glaucous-winged Gull		Isleib and Kessel 1973	int/nsh/pel	r
Laridae	*Larus*	*argentatus*	Herring Gull		Isleib and Kessel 1973	int/nsh/pel	r
Laridae	*Larus*	*canus*	Mew Gull		Isleib and Kessel 1973	int/nsh/pel	r
Laridae	*Larus*	*philadelphia*	Bonaparte's Gulls		Isleib and Kessel 1973	int/nsh/pel	m/b
Laridae	*Rissa*	*tridactyla*	Black-legged Kittywake		Isleib and Kessel 1973	int/nsh/pel	r
Laridae	*Xema*	*sabini*	Sabine's Gull		Isleib and Kessel 1973	int/nsh/pel	m
Laridae	*Sterna*	*paradisaea*	Arctic Tern		Isleib and Kessel 1973	int/nsh/pel	m/b
Laridae	*Sterna*	*aleutica*	Aleutian Tern		Isleib and Kessel 1973	int/nsh/pel	b
Alcidae	*Uria*	*aalge*	Common Murre		Isleib and Kessel 1973	nsh/pel	r
Alcidae	*Uria*	*lomvia*	Thick-billed Murre		Isleib and Kessel 1973	nsh/pel	r
Alcidae	*Cepphus*	*columba*	Pigeon Guillemont		Isleib and Kessel 1973	nsh/pel	r
Alcidae	*Brachyramphus*	*marmoratus*	Marbled Murrelet		Isleib and Kessel 1973	nsh/pel	r
Alcidae	*Brachyramphus*	*brevirostis*	Kitlitz's Murrelet		Isleib and Kessel 1973	nsh/pel	r
Alcidae	*Synthliboramphus*	*antiquum*	Ancient Murrelet		Isleib and Kessel 1973	nsh/pel	r
Alcidae	*Aethia*	*psittacula*	Parakeet Auklet	*Synthlibora mphus*	Isleib and Kessel 1973	nsh/pel	b
Alcidae	*Aethia*	*cristatella*	Crested Auklet		Isleib and Kessel 1973	nsh/pel	v
Alcidae	*Cerorhica*	*monocrata*	Rhinoceros Auklet		Isleib and Kessel 1973	nsh	v/b
Alcidae	*Fratercula*	*corniculata*	Horned Puffin		Isleib and Kessel 1973	nsh/pel	r
Alcidae	*Lunda*	*cirrhata*	Tufted Puffin		Isleib and Kessel 1973	nsh/pel	r
Alcedinidae	*Megaceryle*	*alcyon*	Belted Kingfisher		Isleib and Kessel 1973	int	r
Corvidae	*Cyanocitta*	*stelleri*	Steller's Jay		Isleib and Kessel 1973	int	r
Corvidae	*Corvus*	*corax*	Common Raven		Isleib and Kessel 1973	int	r
Corvidae	*Corvus*	*caurinus*	Northwestern Crow		Isleib and Kessel 1973	int	r

Mammals

Eleven marine mammal species are well known from Prince William Sound. We also include the river otter, and black and brown bear because of their use of marine resources (salmon, intertidal animals) (Table 10.11). Wynne (1992) and UAM mammal collection records were used as a source for species names. Distribution, community, and status are inferred from range maps in Wynne (1992).

Table 10.11. Mammals.

FAMILY	GENUS	SPECIES	COMMON NAME	SPECIMEN or SOURE	HABITAT	STATUS	BIOREGION NEP	NWP	AR	NWA	Source
Balaenopteridae	*Balaenoptera*	*acutorostrata*	Minke Whale	Wynne 1992	nsh/pel	m	x	x	x	x	Wynne 1992
Balaenopteridae	*Balaenoptera*	*physalus*	Fin Whale	Wynne 1992	nsh/pel	m	x	x	x	x	Wynne 1992
Balaenopteridae	*Megaptera*	*novaeangliae*	Humpback Whale	Wynne 1992	nsh	m	x	x	x	x	Wynne 1992
Delphinidae	*Orcinus*	*orca*	Killer Whale	Wynne 1992	nsh/pel	r/m	x	x	x	x	Wynne 1992
Eschrichtiidae	*Eschrichtius*	*robustus*	Grey Whale	Wynne 1992	pel	m	II III IV				Wynne 1992
Mustelidae	*Enhydra*	*lutris*	Sea Otter	Wynne 1992	int/nsh	r	II III IV	x			Hall 1981
Mustelidae	*Lontra*	*canadensis*	River Otter	UAM Mammals	int	r	x	x	x	x	Hall 1981
Otariidae	*Callorhinus*	*ursinus*	Northern Fur Seal	UAM Mammals	pel	m	II III IV	x			Hall 1981
Otariidae	*Eumetopias*	*jubatus*	Steller's Sea Lion	UAM Mammals	nsh	r	II III IV	x			Hall 1981
Phocidae	*Phoca*	*vitulina*	Harbor Seal	UAM Mammals	nsh	r	II III IV				Hall 1981
Phoecoenidae	*Phocoena*	*phocoena*	Harbor Porpoise	Wynne 1992	nsh	m/r	II	x		x	Wynne 1992
Phoecoenidae	*Phocoenoides*	*dalli*	Dall's Porpoise	Wynne 1992	nsh/pel	m/r	II III IV	x			Wynne 1992
Ursidae	*Ursus*	*americanus*	Black Bear	UAM Mammals	int	r	II III				Hall 1981
Ursidae	*Ursus*	*arctos*	Brown Bear	UAM Mammals	int	r	II III				Hall 1981

10E. Discussion

The data sets contain entries for 1878 taxa, of which all but 180 are species-level identifications. Thirty-nine species are recognized as possibly undescribed. Eighty-nine species had not previously been reported in Prince William Sound, and represent distributional range extension. (Table 10.12.) These species were probably overlooked in previous environmental surveys, because of their small size, cryptic appearance, similarity to more well-known species, or lack of taxonomic experts to work with them. Eighteen species are likely to represent nonindigenous species. At least 97 species are uncertain in origin (cryptogenic). Over 70% of the animals (1343) are invertebrates. Arthropods 24.3%, mollusks 16.8%, and polychaete annelids 12.4% make up the largest number of total species. (Table 10.13. Figure 10.4).

	Plants	Cnidaria/ Ctenophora	Nemertea	Polychaeta	Mollusca	Arthropoda	Echinodermata	Bryozoa	Urochordata	Other invertebrates	Fishes	Birds	Mammals	TOTALS
probable NIS	5			1		2			1					9
definate NIS	1	1			2			1	1	1	2			9
range extension within Alaska		4			9	1		8		1	8			31
range extension to Alaska	17	2		19	7	10		2	1					58
cryptogenic	68			7	1			6						82
potential new or undescribed species	1			6	2				1		1			11
not identified to species	10	27	1	7	1	109		19	5	3				182
total spcies-level taxa	231	102	45	233	315	455	68	74	30	23	178	113	14	1881

Table 10.12. Summary of Prince William Sound marine biota by NIS status and identification confidence.

		Plants	Cnidaria/ Ctenophor	Mollusca	Polychaeta	Arthropoda	Echinodermata	Bryozoa	Other invertebrates	Fishes	Birds	Mammals
numer of species		231	102	315	233	455	66	74	98	178	113	14
percent of total fauna			6.2%	19.1%	14.2%	27.7%	4.0%	4.5%	6.0%	10.6%	6.9%	0.9%
percent of total biota		12.3%	5.4%	16.8%	12.4%	24.3%	3.5%	3.9%	5.2%	9.3%	6.0%	0.7%
total invertebrates	1343											
total vertebrates	302											
total plants	233											
total biota considered	1876											

Table 10.13. Summary of the plants and animals considered.

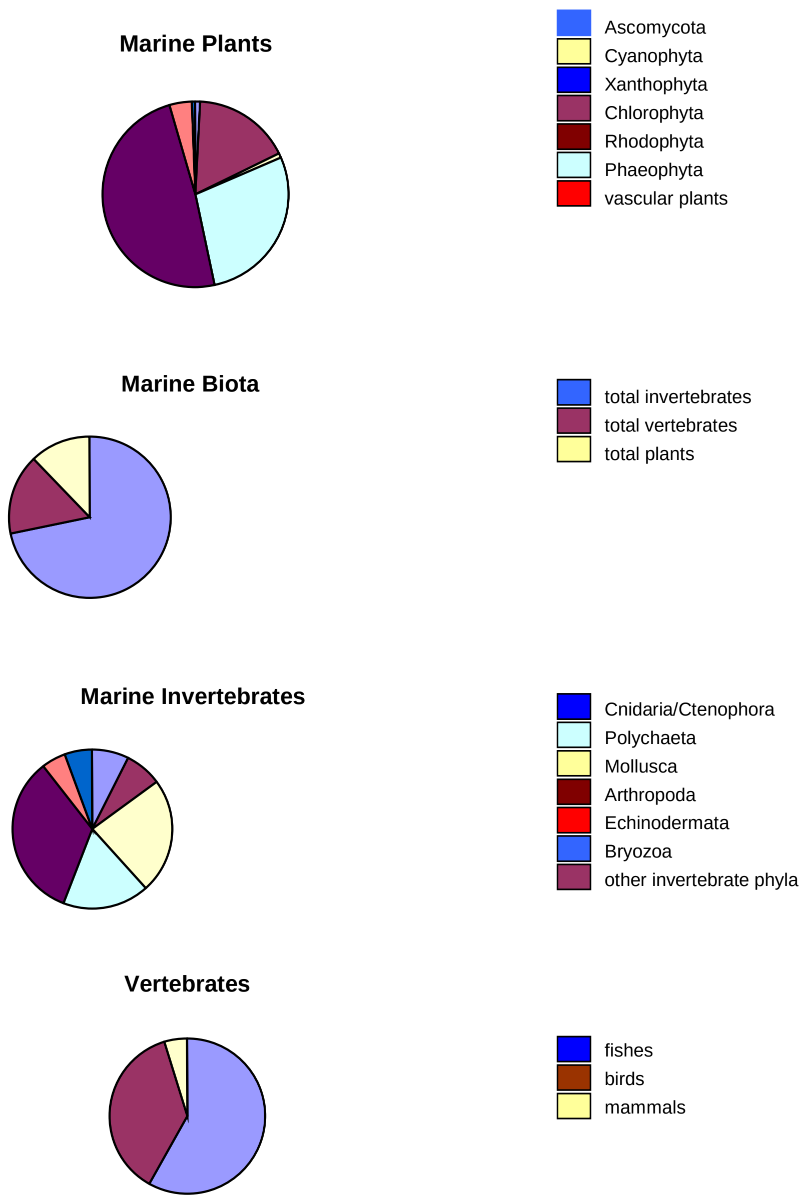

Figure 10.4. Species composition of Prince William Sound marine biota by major taxon.

The marine biota of Prince William Sound is a mix of species with ranges that overlap several biogeographic provinces. Forty-nine percent of the biota for which reliable data are available are northeast Pacific species, not found north or west of Bering Strait. Over one third of the species (43.4 %) have geographic ranges that extend into the northwestern Pacific. Fewer species have distributions that overlap the north Atlantic 19.6.5% and/or Arctic 16.9%. The biogeographic affinities vary greatly among the phyla.

We caution users of these data sets that in spite of our best efforts the information is only as good as our sources. We were unable to obtain data, or found few reliable records, for five major groups of animals: sponges, Anthozoa, Nematoda, Oligochaeta , Hirudinea, Ostracoda and insects. Two factors account for this, lack of taxonomic experts, and the need for specialized collection and preservation techniques. Further, even among several well-known taxonomic groups, we found few sources of authentic information and so we have had to rely on unpublished reports and manuscripts. We hope that using these data sets will not perpetuate erroneous records. In critical situations, users are advised to rely on museum records and consultation with other experts.

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