# Biological Invasions in Alaska's Coastal Marine Ecosystems: Establishing a Baseline

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Submitted by

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## Executive Summary

Biological invasions are a significant force of change in coastal ecosystems, altering native communities, fisheries, and ecosystem function. The number and impact of non-native species have increased dramatically in recent time, causing serious concern from resource managers, scientists, and the public. Although marine invasions are known from all latitudes and global regions, relatively little is known about the magnitude of coastal invasions for high latitude systems.

We implemented a nationwide survey and analysis of marine invasions across 24 different bays and estuaries in North America. Specifically, we used standardized methods to detect non-native species in the sessile invertebrate community in high salinity (>20psu) areas of each bay region, in order to control for search effort. This was designed to test for differences in number of non-native species among bays, latitudes, and coasts on a continental scale. In addition, supplemental surveys were conducted at several of these bays to contribute to an overall understanding of species present across several additional habitats and taxonomic groups that were not included in the standardized surveys.

Our standardized surveys included six different bay regions in Alaska: Ketchikan, Sitka, Prince William Sound, Kachemak Bay, Kodiak, and Dutch Harbor. Supplemental surveys were conducted primarily at Kachemak Bay and Kodiak, and an additional low-salinity site in Cook Inlet near Anchorage.

In this report, we report our findings for these sites and compare them to six other bays surveyed along western North America, between California and Washington.

In our standardized surveys of Alaskan sites, we identified between 22 and 48 species per bay. Below, we highlight several findings from these surveys:

- Of the species identified, most were native or cryptogenic, and very few were classified as introduced.
- Nonindigenous species (NIS) were detected at only three of the six bay regions, including Ketchikan (3 species), Sitka (3 species), and Kachemak (1 species). Thus, the greatest number of NIS was present at the most southerly sites, and no introduced species were detected on panels from the two island sites, Kodiak and Dutch.
- Cryptogenic species, those of uncertain native versus non-native status, ranged from 5 to 17 species per bay, representing 14-39% (mean=26.7%) of total species richness per bay. Thus, although the total number of known NIS was relatively low (≤ 8% of total species richness per bay), the actual number of NIS may be greater, since the status of several species on our panels remains unresolved.
- Across all bays, we detected a total of 4 NIS on our panels for these major taxonomic groups. Two were tunicates, (*Botrylloides violaceus* and *Botryllus schlosseri*), one was a bryozoan (*Schizoporella japonica*), and one was a hydroid (*Pinauay crocea*). Of the bays with introduced species, *Botrylloides* occurred in all three, *Schizoporella* occurred in two, whereas *Botryllus* and *Pinauay* occurred in only one.
- One of these non-native species was a new record for Alaska, the tunicate *Botryllus*, while the hydroid *Pinauay* (= Ectopleura) had only one previous Alaska record, in 1937 (see Appendix G). The other tunicate, *Botrylloides*, was detected north of Puget Sound for the first time in our earlier surveys (Hines and Ruiz 2000).

When compared to similar surveys from California to Washington, our results show a strong latitudinal pattern of NIS occurrence for western North America and suggest that relatively few NIS are now common in Alaska's coastal waters. NIS were much more common at lower latitudes along the Pacific coast, and may serve as a source for northward spread. In fact, several of the NIS in Alaska appear to be recent arrivals that may be spreading.

A synthesis of literature-based records and survey results document the occurrence of 20 non-native species marine and estuarine habitats in Alaska, across a wide range of taxonomic groups. As with the survey data alone, this represents a low level of invasions compared to many other sites, creating a steep latitudinal cline between California and Alaska.

Based upon our surveys, we now have confidence that this latitudinal pattern of invasions is real. Previously, it was not clear whether such pattern simply reflected a limited or uneven search effort across sites, but our surveys now control for search effort and remove such potential bias.

Although this low prevalence in Alaska may reflect a low susceptibility to invasions, there is currently no evidence to support this. This pattern may instead result primarily from the historically low propagule supply to Alaska relative to other more invaded sites. This argues strongly for a precautionary and proactive management strategy to limit the transfer of organisms by ships, aquaculture, and other human-mediated mechanisms, thereby reducing the risk of invasions.

To further evaluate the risk of future invasions in Alaska, we recommend a focus in three general areas:

- Evaluate the physiological capacity of non-native organisms to colonize Alaskan waters.
- Measure the critical densities (dose-response relationship) of organism delivery for establishment, as a basis for management decisions about propagule supply and acceptable levels of risk.
- Track northward spread of NIS and colonization or Alaska waters. We have now established a baseline measure of NIS for several sites in Alaska and have been tracking northward range expansion of NIS in California, Oregon, and Washington. We recommend establishing several long-term, low-level monitoring sites in Alaska to evaluate changes through time, concurrent with changes in vector activity and management.

# INTRODUCTION

## Establishing A Baseline for Evaluating Coastal Marine Invasion

The extent and significance of nonindigenous species (NIS) invasions in coastal marine ecosystems have become increasingly evident in recent years (Carlton 1989, 1996a; Carlton and Geller 1993; Ruiz et al. 1997, Grosholz 2002). We know of at least 500 NIS that already have invaded marine and estuarine habitats of the U.S, and the tempo of invasion appears to be increasing rapidly (Cohen and Carlton 1998, Ruiz et al. 2000). NIS have caused substantial environmental and economic damage to coastal areas (Carlton 2001). In marine and estuarine environments, the impacts of biological invasions include dramatic changes to ecological community structure and ecosystem dynamics, parasite and pathogen interactions with native species, commercial fisheries stress, and detrimental alterations to physical habitat structure (Carlton 2001, Grosholz 2002, Levin et al. 2002). Although existing data underscore the increasing ecological and economic consequences of NIS invasions (OTA 1993; Ruiz et al. 1999; GAO 2002, Perrings et. al 2002), there are serious limitations in our present knowledge about coastal marine invasions (Ruiz et al. 2000). Such information gaps affect critical management decisions and hamper development of invasion biology as a predictive science (Carlton 1996b; Kareiva 1996; Vermeij 1996; Ruiz et al. 1997; Ruiz & Hewitt 2002).

The actual rates and spatial patterns of marine invasions remain largely unresolved (Ruiz et al. 2000, Ruiz & Hewitt 2002). Although past work has identified many "apparent" patterns of invasion among coastal systems (Carlton 1979; Cohen and Carlton 1995; Reise et al. 1999, Hewitt et al. 1999, Ruiz et al. 2000), these derive primarily from literature-based syntheses of published information rather than standardized, quantitative, and contemporary field surveys. Reports for each site must be viewed as only minimum estimates for the extent of invasions. Importantly, the quality and quantity of information is very uneven among sites, reflecting distinct differences in sampling methods as well as search effort (in space and time) among taxonomic groups, habitats, bays, and geographic regions (Ruiz et al. 2000). For example, an extensive and on-going sampling program of soft-sediment benthic invertebrates may exist for some sites, but it may have been decades since this biota was sampled at other sites. Even where recent faunal surveys exist, the sampling designs and level of taxonomic analyses usually differ among sites and over time. Thus, spatial and temporal patterns of invasion, both within and among sites, are confounded by sampling biases present in the available data (Ruiz et al. 2000).

Understanding patterns of NIS invasions among systems is of paramount importance to the development of effective management strategies (Ruiz and Carlton 2003). Without this foundation of basic information, we cannot assess the relative risk of invasions according to taxonomic group, species, geographic region, habitat type, or vector. Moreover, spatial patterns of invasion are key to focusing monitoring, early detection / rapid response, and vector management efforts to reduce risks of new invasions.

In 1998, the Forum on Ecological Surveys (sponsored by U.S. Fish and Wildlife Service) concluded that fundamental data for assessing such risks in coastal marine systems were lacking, and that no plan existed in the U.S. to provide these data. Today, the uneven and incomplete nature of contemporary surveys remain a critical information gap, limiting guidance and evaluation of management decisions. For example, standardized contemporary surveys of non-native species are required to accurately assess (a) the relative importance of existing vectors (i.e., transfer mechanisms) in contemporary invasions, (b) the effect of management actions, such as ballast water exchange, on the rate of invasions, (c) which species represent significant ecological risks, and (d) how these factors may vary spatially.

## Nationwide Survey: Sessile Invertebrates in High Salinity Habitats

To help address this gap in understanding NIS invasion patterns, we implemented an ambitious program of standardized field surveys of NIS established in coastal bays and estuaries of North America (including the United States and Canada). Conducted over a 5-year period, this program has been funded by several different grants. Surveys in Alaska were funded primarily by the Prince William Sound Citizens' Advisory Council (RCAC) and U.S. Fish and Wildlife Service. Surveys in the contiguous US were funded by the Department of Defense Legacy Program, National Sea Grant, and Smithsonian Institution.

To date, this nationwide survey has included 24 different estuaries among all three coasts of the North America (see Figure 1), and additional surveys are funded over the next two years in the Caribbean basin, Central America, and Hawaii. Sites surveyed to date in the continental U.S. include:

- **<u>Pacific coast:</u>** Dutch Harbor, AK; Kodiak, AK; Kachemak Bay, AK; Prince William Sound, AK; Sitka Sound, AK; Ketchikan, AK; Puget Sound, WA; Coos Bay, OR; Humboldt Bay, CA; San Francisco Bay, CA; Long Beach, CA; San Diego Bay, CA;
- **<u>Atlantic coast</u>:** Conception Bay, Newfoundland; Portsmouth Harbor, NH and Great Bay, ME; Narragansett Bay, RI; Chesapeake Bay, VA; Charleston, SC; Jacksonville, FL; Indian River Lagoon, FL; Biscayne Bay, FL;
- **<u>Gulf coast</u>:** Tampa Bay, FL; Pensacola Bay, FL; Galveston Bay, TX; Corpus Christi, TX.

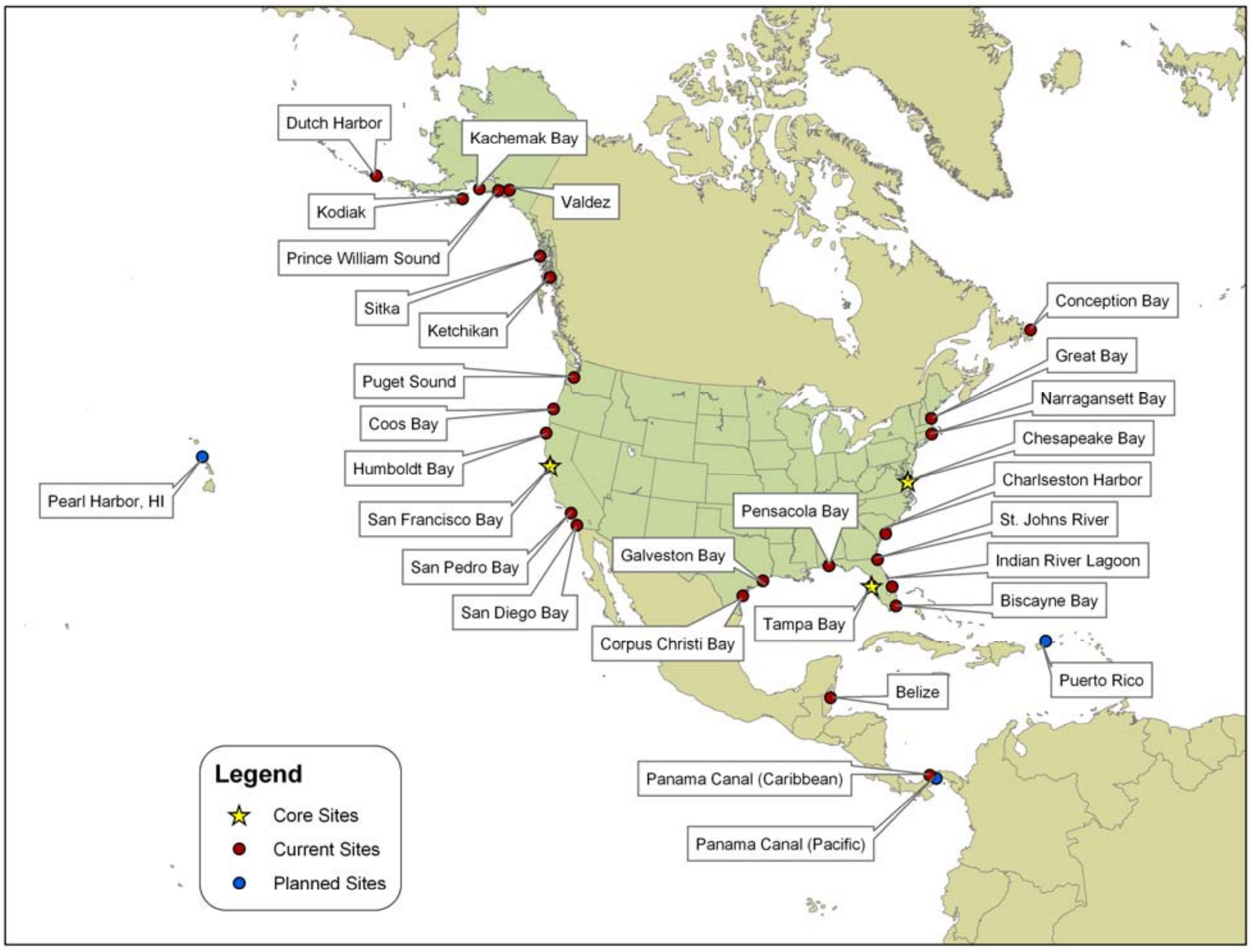


**Figure 1. Location of Bays included in Nationwide Survey of Sessile Invertebrate Communities in North America.** All sites were surveyed at least once, following identical protocols outlined in text. Core sites have been surveyed multiple times, across years and seasons.

Surveys focused on sessile invertebrate communities in the high salinity portions of each estuary. Certainly invasions occur in many different habitats (e.g., soft-sediment, marshes, holoplankton) or salinity zones. The surveys were not intended to provide comprehensive analyses of invasions. Instead, our goal was to provide standardized data that was comparable across sites and time periods, providing a baseline of information that we presently lack --- even for one habitat type.

For the surveys, we selected fouling communities in the high salinity waters of bays as a starting point for multiple reasons:

- The vast majority of marine invasions are reported to occur in bays and estuaries, mostly likely because these are foci for global commerce and associated organism transfers;
- A high proportion of the known invasions for bays and estuaries actually occur in the fouling community --- fouling organisms comprise > 180 species, of the roughly 300 non-native species of marine invertebrates known to be established in North America (e.g., Cohen & Carlton 1995; Hewitt et al. 1999; Ruiz et al. 2000).
- Relative to many habitat types, fouling communities are easily surveyed with standardized measures --- which control for subtle differences in substrate type, orientation, depth, and type of analyses (Sutherland & Karlson 1977, Sutherland 1978, Dean 1991, Hewitt 1993).
- The taxonomy and biogeography of fouling organisms is also better resolved than many other marine invertebrates.
- Importantly, many of the invasions now associated with ships could derive from transfer in ballast water or on hull surfaces (Fofonoff et al. 2003). Thus, tracking changes in invasions patterns of fouling communities over time --- as efforts to manage ballast water increase (IMO 2005) --- may provide opportunities to separate the relative contribution of ballast water versus hull fouling to invasions.
- The reason for restriction of initial surveys to high salinity results from the fact that many bays only have high salinity conditions. Thus, we wished to control for possible effects of salinity in these initial analyses.

We are just now completing analyses of species identifications from surveys across all 24 of these bays and estuaries. The resulting data are being used to examine (test for) patterns of invasion among bays, across latitudes, and among coasts. Over time, we intend to repeat surveys at several key bays to examine patterns of spread for NIS. Species occurrence records from these surveys are all geographically referenced (latitude and longitude) and any new specimens are being deposited in museum collections for future reference. Importantly, we intend to make all of these data accessible via the World Wide Web, allowing public access to our database. The database can be searched by species, taxonomic group, and geographic region. This will be a component of NISbase (see www.NISbase.org), which is being developed as a joint program with US Geological Survey and NOAA to provide NIS locality data on a national scale, including distribution maps and species-specific information (fact sheets) on the biology, ecology, taxonomy, and impacts.

### Marine NIS in Alaska

We have compiled data on NIS in Alaska and other sites from several sources, in addition to the nationwide survey of sessile invertebrates (as above). First, taxonomists participated in our surveys at several sites and independently made supplemental collections, creating species lists across a wide range of habitats and taxonomic groups. These "rapid assessments" or supplemental collections were not intended to be standardized or comprehensive but augmented our survey data, as opportunity allowed. Second, we reviewed available literature on species reported in Alaskan bays and estuaries, to synthesize records for NIS detected in other studies.

In this report, we provide a summary of results to date from the surveys and analyses of NIS in Alaskan waters. We also examine the extent of NIS in Alaska compared to those reported for other sites.

## METHODS

### A. Field Surveys: Sessile Invertebrate Communities

We conducted field surveys of sessile invertebrates in 6 different bay regions in Alaska (Figure 1), including from south to northwest: Ketchikan, Sitka Sound, Prince William Sound, Kachemak Bay, Kodiak, and Dutch Harbor. The surveys were designed to provide standardized measures to compare community composition across bays and to detect non-native species that were previously unknown for the particular bay(s). In general, we attempted to restrict the survey to waters > 20psu salinity, to control for salinity-related variation in species composition across bays.

For each bay, we deployed panels in a stratified fashion to serve as passive collectors. We divided the high salinity zone of each bay into 10 areas (blocks) of approximately equal area. Within each block, we selected structures (e.g., piers, marina docks, buoys, bridges) from which to deploy the panels. We sought to randomly select the specific structure for deployment wherever possible, but selection was sometimes constrained by access. For some bays, no structures were available in a block or all of the plates were lost, causing a reduction in the total number of blocks used in these bays (see results).

For each block, we deployed 20 panels that were suspended 1m below the water surface at mean lower low water. We assumed a loss rate of up to 50% and hoped to retrieve 10 plates per block for analysis. Panels were placed randomly on the selected structure within a block. The panels were constructed of type I gray PVC (14cm x 14cm), sanded on one side to create a rough surface, attached to a brick, and hung in a horizontal or downward position, facing the bottom. In addition to PVC panels, we also deployed wooden blocks (2 per area) that were used to assay for shipworms and other boring organisms. Thus, a total of 22 collecting units (20 PVC and 2 wood) were deployed at each block, totaling approximately 220 collecting units (10 blocks X 22 units) for most bays. [For further description of construction or deployment of each collecting unit, see Appendix A.]

We also collected physical and chemical data for each block of deployment. We measured latitude and longitude, using a handheld GPS unit upon deployment. At each block, a temperature data logger (Hobo brand, Boxcar pro3 software) was deployed at the same depth as the plates, to provide a continuous record of water temperature, recorded at 6 hour intervals. In addition, during each deployment and retrieval of plates (i.e., twice) for each block, we measured water temperature, dissolved oxygen, and salinity at the surface and depths of 1m, 2m, 5m, and 10m (where such depths were available). Secchi depth and bottom depth were also recorded at these times as well.

Deployment occurred in the late spring and early summer, to coincide with times of high larval recruitment, and plates were retrieved for analysis after 3 months. Upon retrieval of the panels, the non-target surfaces (i.e. sides and back) were scraped to remove extraneous organisms, and the target of surface of each panel was photographed. We randomly assigned a rank number (1 through 20) to each plate per block and analyzed the first ten panels for species composition. We examined each panel with a dissecting microscope, noting each morphologically distinct sessile invertebrate and collecting five specimens as vouchers of each morphotype (where available) per panel. Each morphotype voucher collection was preserved in an individual vial and labeled to specify the source bay, block, and panel.

Each voucher collection was identified to species or the lowest possible taxonomic level. In some cases, species-level identification was simply not possible, especially for recent recruits. SERC staff were trained by taxonomic experts to identify key sessile invertebrate groups (tunicates, bryozoans, hydroids, and barnacles). SERC staff identified vouchers and worked with taxonomists to confirm a subset of these identifications. Nudibranchs were identified by Jeff Goddard, and other molluscs were identified by Nora Foster. Any new species records for a particular bay received additional scrutiny and confirmation by a taxonomic expert. All voucher identifications were recorded in a database to track the identification and source of each voucher specimen and to provide the basis of analyses across bays.

Although the primary goal of these surveys was to provide standardized measures of non-native species composition for sessile invertebrates, we collected all sessile invertebrate species, identified these, and classified them as to native versus non-native status in Alaska (see Literature Review, below). In addition, the panels often included a rich assortment of mobile organisms (e.g., amphipods, isopods, polychaetes). These were collected by lightly washing plates in a dilute formalin solution, to cause mobile biota to abandon the panels, and then rinsing the resulting organisms into a jar of buffered formalin. The analysis of these mobile organisms greatly exceeds the scope of the current project, but we have retained similar collections for all 24 bays surveyed in North America in order to pursue at a later date, as time and resources allow.

Wooden blocks from each area were also retrieved after 3 months and examined for the presence of boring organisms. Temperature data loggers, deployed in association with the wooden blocks, were collected at the same time, and the temperature data was downloaded for subsequent analyses.

Each bay was surveyed once in this fashion between 2000 – 2003. Table 1 provides a summary of the sampling effort in each of the six bays for the standardized surveys. As described above, we deployed approximately 200 PVC panels plus 20 wooden blocks per bay, distributed among 9-10 different locations (blocks), with a goal of retrieving and analyzing 100 panels (≥10 per block). The specific location for each block is shown in Appendix B, and a continuous measure of water temperature as recorded by the temperature data loggers is provided in Appendix C. The total number of analyzed plates per bay ranged from 91-143. The most plates were analyzed at Kachemak Bay, at the onset of this survey program, as allowed by the number of participants. The fewest panels were analyzed at Ketchikan, as all of the panels were lost at one block. This sampling effort yielded from 1,217 to 2,311 voucher specimens per bay for species-level identification.

**B. Supplemental Collections Associated with Surveys**

For most field surveys, our team for retrieval included participants who were expert in the identification and biology of particular taxonomic groups. While these participants assisted us directly in the standardized fouling panel surveys, they also often made supplemental collections and generated species lists independently. In general, these supplemental surveys were variable in nature among sites and taxonomic groups, and they were intended to find additional non-native species (known to the respective participants) that may be missed by our surveys, due either to habitat preferences, rarity, or phenology of recruitment.

Additional supplemental collections were conducted at two sites independent of our field surveys for sessile invertebrates. In 2000 and 2001, 12-14 panels were deployed and retrieved from Port Valdez. Although we followed the general protocols outlined above, the depth of deployment was greater (5-10m) to reduce contact with the low salinity surface waters around Valdez (see Hines and Ruiz 2000 for description).

In August 2003, a supplemental survey of soft-sediment, zooplankton, and shoreline habitats was conducted for Anchorage area, at the upper end of Cook Inlet. The purpose of the survey was to search for native and introduced species in the vicinity of the disturbed habitats of the commercial wharf, small boat launching area, shoreline of the City of Anchorage extending around into Turnagain Arm. Collecting by hand on low tide, we surveyed invertebrates, vascular plants, and algae along shorelines at Anchorage Harbor, small boat launching ramp area, shore along Westchester Lagoon, Coastal Wildlife Refuge, and two sites on the shoreline of Turnagain Arm. We also collected plankton samples and benthic grab samples by small boat off the Port of Anchorage docks, small boat harbor/ launching area, and City of Anchorage. Approximately 12 plankton tows were pulled using a small net with 0.25 $m^2$ circular mouth opening and 80u mesh pulled on oblique tows from bottom to surface at slow speed (approx. 2 knots). Approximately 15 benthic grab samples were collected with a 0.1 $m^2$ Ponar grab, which achieved variable penetration of the bottom, depending on the compactness of the sediments.

Beyond the SERC staff, participants on the respective field surveys and supplemental collections are listed in Table 2. Each participant was asked to provide a species list for any organisms collected and identified during supplemental surveys. A cumulative species list from these supplemental collections is provided for each location. Each of these species is classified as native, non-native, or cryptogenic, based upon information from the taxonomic experts and literature review (see next section).

These supplemental collections serve to expand the cumulative number of organisms identified at each site, but it is important to recognize that they do not allow for comparisons among sites. For each site, the taxa examined and the researchers were different for supplemental surveys. Thus, these collections augment knowledge of local fauna and help detect NIS but do not control for potential sampling bias among sites. Instead, the standardized surveys serve for comparisons among sites and establishing a baseline for repeated sampling through time.

**Table 1. Number of Samples Collected in Standardized Panel Surveys.** For each bay and block, shown by columns are (a) number of panels deployed, (b) number of panels retrieved, (c) number of panels used for analysis, and (d) number of individual voucher lots collected, preserved, and archived for identification. Each sample lot often included multiple specimens.

| Bay | BlockName | # Plates Deployed | # Plates Retrieved | # Plates Analyzed | # Vouchers |
|---|---|---|---|---|---|
| Dutch Harbor | | | | | |
| | City Spit Dock | 22 | 22 | 10 | 126 |
| | Delta Western Fuel dock | 22 | 21 | 10 | 120 |
| | East point Dock | 22 | 21 | 10 | 123 |
| | North Pacific Fuel (Captains Bay) | 22 | 22 | 10 | 78 |
| | North Pacific Fuel dock (Dharbor) | 22 | 20 | 10 | 179 |
| | OSI main dock | 22 | 18 | 10 | 106 |
| | OSI Pot Dock (Capt Bay) | 22 | 22 | 10 | 86 |
| | Port of Dutch Harbor | 22 | 20 | 10 | 130 |
| | Unisea Dock | 22 | 20 | 10 | 162 |
| | Walashek/Small Boat Harbor | 22 | 22 | 10 | 107 |
| | Totals | 220 | 208 | 100 | 1217 |
| Kachemak Bay | | | | | |
| | Bear Cove | 22 | 14 | 14 | 168 |
| | Halibut Cove | 22 | 20 | 15 | 299 |
| | Homer Spit (Boat Harbor) | 22 | 17 | 15 | 275 |
| | Jakalof Bay | 22 | 19 | 19 | 259 |
| | Peterson Bay | 22 | 15 | 15 | 243 |
| | Port Graham Hatchery | 22 | 21 | 15 | 221 |
| | Seldovia Harbor | 22 | 18 | 15 | 261 |
| | Tutka Bay Hatchery | 23 | 15 | 15 | 214 |
| | Tutka Bay Wilderness Lodge | 22 | 20 | 20 | 371 |
| | Totals | 199 | 159 | 143 | 2311 |
| Ketchikan | | | | | |
| | Bar Harbor | 22 | 21 | 10 | 182 |
| | Casey Moran (city float) | 22 | 20 | 10 | 182 |
| | Cruise Dock | 22 | 13 | 10 | 195 |
| | Hole In the Wall Marina | 22 | 22 | 10 | 228 |
| | Homestead Skiffs | 22 | 22 | 10 | 213 |
| | Knudsen Cove Marina | 22 | 22 | 11 | 168 |
| | Promech Air | 22 | 22 | 10 | 194 |
| | Refuge Cove Marina | 22 | 22 | 10 | 182 |
| | Thomas Basin | 22 | 22 | 10 | 125 |
| | Totals | 198 | 186 | 91 | 1669 |
| Kodiak | | | | | |
| | Anton Larsen | 22 | 20 | 10 | 163 |
| | Container Dock | 22 | 21 | 10 | 251 |
| | Floating Brkwater | 22 | 19 | 11 | 331 |
| | Gibson Cove | 22 | 22 | 10 | 217 |
| | Logging Camp | 21 | 21 | 10 | 248 |
| | Ouzinkie Pier | 20 | 19 | 10 | 305 |
| | Seaplane Dock | 22 | 22 | 10 | 228 |
| | St.Paul Harbor Marina | 22 | 20 | 10 | 210 |
| | Transient Pier | 21 | 18 | 10 | 200 |
| | USCG | 22 | 22 | 7 | 126 |
| | Totals | 216 | 204 | 98 | 2279 |
| Prince William Sound | | | | | |
| | AFK Hatchery | 22 | 22 | 10 | 156 |
| | Alice Cove | 22 | 22 | 10 | 130 |
| | Cannery Creek Hatchery | 22 | 22 | 10 | 102 |
| | Chenega Bay Marina | 22 | 21 | 10 | 162 |
| | Cordova SBH- Approach 4 | 22 | 22 | 10 | 127 |
| | Cordova Small Boat Harbor Marina | 22 | 21 | 10 | 92 |
| | Fairmont Bay Oyster farm | 22 | 21 | 10 | 161 |
| | Growler Bay | 22 | 22 | 10 | 84 |
| | Main Bay Hatchery | 22 | 22 | 10 | 92 |
| | Wally Nordberg Hatchery | 22 | 21 | 10 | 117 |
| | Totals | 220 | 216 | 100 | 1223 |
| Sitka | | | | | |
| | Cedar Beach Rd. | 13 | 12 | 10 | 153 |
| | Cove Marina | 22 | 20 | 10 | 226 |
| | Crescent Harbor | 22 | 20 | 10 | 217 |
| | Galankin Island | 22 | 20 | 10 | 180 |
| | Medvejie Hatchery | 22 | 20 | 10 | 170 |
| | Samson Tug | 22 | 20 | 10 | 134 |
| | Sawmill Cove | 22 | 20 | 10 | 129 |
| | Sealing Cove | 22 | 20 | 10 | 199 |
| | Sitka Sea Farm | 22 | 19 | 10 | 261 |
| | Thomsen Harbor | 22 | 18 | 10 | 237 |
| | Totals | 211 | 189 | 100 | 1906 |

**Table 2. Survey Participants.** Taxonomists specializing in different fields of study joined us to survey for additional organisms not found on settling plates. Their taxonomic specialty and research institution (last known) is listed.

| **Kachemak (AK) 2000** | **Specialty** | **Research Institution** |
|---|---|---|
| Lea-Anne Henry | Hydrozoa | Scottish Association for Marine Science, United Kingdom |
| Jeff Cordell | Crustacea | University of Washington, WA |
| Claudia Mills | Hydromedusa | Friday Harbor Laboratory, WA |
| Jon Norenburg | Nemertea | Smithsonian Museum of Natural History, DC |
| Jerry Kudenov | Polycheata | University of Alaska Anchorage, AK |
| Judy Winston | Bryozoa | Virginia Museum of Natural History, VA |
| Nora Foster | Bivalvia | University of Alaska Museum of the North, AK |
| Sarah Cohen | Tunicata | San Francisco State University, CA |
| Chad Hewitt | West coast taxa | CSIRO research on invasive marine pests (CRIMP), Australia |
| Conrad Field | Logistical assistance | Center for Alaskan Coastal Studies, Homer, AK |
| SERC personnel | Fouling panel analysis | Smithsonian Environmental Research Center, MD |
| **Kodiak (KD) 2001** | | |
| Lea-Anne Henry | Hydrozoa | Scottish Association for Marine Science, United Kingdom |
| Nora Foster | | University of Alaska Museum of the North, AK |
| Gretchen and Charlie Lambert | Tunicata | Friday Harbor Laboratory, WA |
| SERC personnel | Fouling panel analysis | Smithsonian Environmental Research Center, MD |
| **Sitka (ST) 2001** | | |
| SERC personnel | Fouling panel analysis | Smithsonian Environmental Research Center, MD |
| **Dutch Harbor (DH) 2002** | | |
| Nora Foster | Bivalvia | University of Alaska Museum of the North, AK |
| SERC personnel | Fouling panel analysis | Smithsonian Environmental Research Center, MD |
| **Ketchikan (KT) 2003** | | |
| Gretchen and Charlie Lambert | Tunicata | Friday Harbor Laboratory, WA |
| Matt Dick | Bryozoa | Hokkaido University, Japan |
| SERC personnel | Fouling panel analysis | Smithsonian Environmental Research Center, MD |
| **Prince Willam Sound (PW) 2003** | | |
| SERC personnel | Fouling panel analysis | Smithsonian Environmental Research Center, MD |
| **Anchorage 2003** | | |
| Tuck Hines | General | Smithsonian Environmental Research Center, MD |
| Denny Lassuy | Invasive species | US Fish and Wildlife Service, AK |
| Gary Sonnevil | General | US Fish and Wildlife Service, AK |
| Linda Mccann | General | Smithsonian Environmental Research Center, MD |
| Mary McGann | Foraminifera | U.S. Geological Survey, CA |
| Jerry Kudenov | Polycheata | University of Alaska Anchorage, AK |
| Bob Piorkowski | General | Alaska Fish and Game, AK |
| Irina Lapina | Botany | The Natural Heritage Foundation, AK |
| Carmen Field | Naturalist | Kachemak Bay Research Reserve, AK |
| SERC personnel | Fouling panel analysis | Smithsonian Environmental Research Center, MD |

## C. Literature Review

We undertook a literature review to identify NIS in coastal bays and estuaries of Alaska. This included analysis of NIS previously reported along western North America and species lists from past studies in Alaska. Using this background information along with input from our taxonomic experts, we classified each species identified in our surveys as native, non-native, or cryptogenic (of uncertain native versus non-native status), following the general criteria outlined and discussed in Chapman and Carlton 1991, Carlton 1996, Ruiz et al. 2000. This information is presented below, along with a synthesis and summary information of NIS reported in Alaskan coastal waters.

# RESULTS

## A. Field Surveys: Sessile Invertebrate Communities

***Quantitative Analysis of NIS for Four Major Taxonomic Groups***

For standardized surveys of sessile invertebrates, we focused primarily on analysis of three major taxonomic groups: the bryozoans, hydroids, and tunicates. Together, these constitute the majority of sessile invertebrate species found on our settling panels. For the large mobile organisms on panels, species diversity of nudibranchs was relatively high. We have completed analyses of voucher specimens for these four taxonomic groups to compare species richness and frequency of nonindigenous species among sites.

We identified a total of 22 to 48 species per bay in these four major taxonomic groups (Figure2, Appendix D). Dutch Harbor had the lowest species richness (23 species) followed by Prince William Sound (28 species), whereas we identified ≥ 37 species from panels in the other bays. Our qualitative observations suggest that species diversity of the surrounding background (hard substrate) communities followed a similar pattern, with sites at Dutch Harbor being noticeably lower than other bays.

Of these species, most were native or cryptogenic, and very few were classified as introduced. As shown in Figure 2 and Table 3, NIS were detected at only three of the six bay regions, including Ketchikan (3 species), Sitka (3 species), and Kachemak (1 species). It is interesting to note that the greatest number of NIS were present at the most southerly sites, and no introduced species were detected on panels from the two island sites, Kodiak and Dutch.

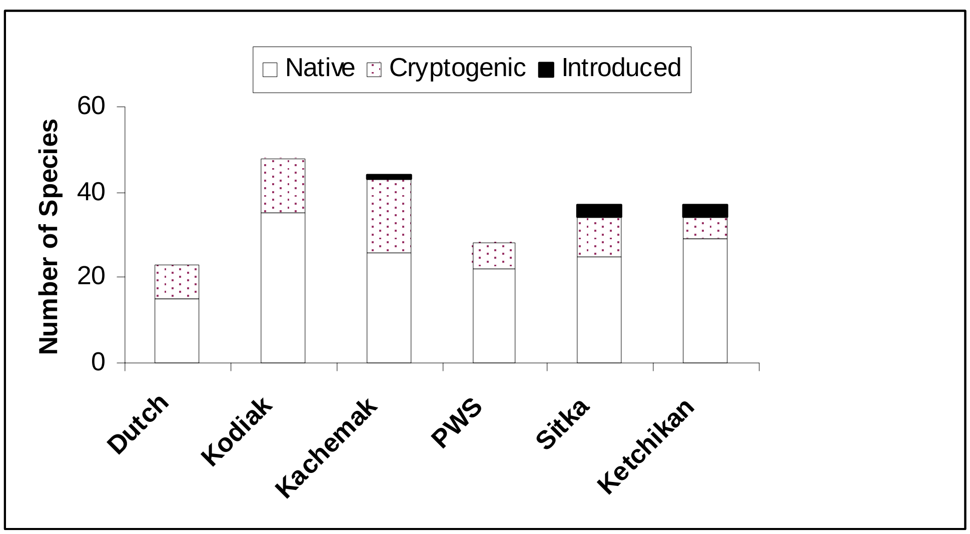


**Figure 2. Number of Native, Cryptogenic, and Introduced Species Identified in Standardized Surveys of Sessile Invertebrate Communities in Alaska.** Four taxonomic groups were included in these comparisons: Bryozoans, Hydroids, Tunicates, and Nudibranchs (see text for further description).

**Table 3. Nonindigenous Species (NIS) of Invertebrates Identified from the Standardized Surveys.** Shown are the NIS found on panels at each bay during the surveys. Other NIS have been reported from some bays (Table 4) but were not found in this survey; see text for further discussion.

| Bay | | |
|---|---|---|
| **Kachemak Bay** | | |
| | **Tunicata** | |
| | | *Botrylloides violaceus* |
| **Ketchikan** | | |
| | **Bryozoa** | |
| | | *Schizoporella japonica* |
| | **Hydrozoa** | |
| | | *Ectopleura crocea* |
| | **Tunicata** | |
| | | *Botrylloides violaceus* |
| **Sitka** | | |
| | **Bryozoa** | |
| | | *Schizoporella japonica* |
| | **Tunicata** | |
| | | *Botrylloides violaceus* |
| | | *Botryllus schlosseri* |

It is noteworthy that cryptogenic species ranged from 5 to 17 species per bay, representing 14-39% (mean=26.7%) of total species richness per bay. Thus, although the total number of known NIS was relatively low (≤ 8% of total species richness per bay), the actual number of NIS may be greater, since the native versus non-native status of several species on our panels remains unresolved.

Across all bays, we detected a total of 4 NIS on our panels for these major taxonomic groups. Two were tunicates, (*Botrylloides violaceus* and *Botryllus schlosseri*), one was a bryozoan (*Schizoporella japonica*), and one was a hydroid (*Pinauay crocea*). Of the bays with introduced species, *Botrylloides* occurred in all three, *Schizoporella* occurred in two, whereas *Botryllus* and *Pinauay* occurred in only one.

One of these non-native species was a new record for Alasak, the tunicate *Botryllus*, while the hydroid *Pinauay* (= Ectopleura) had only one previous Alaska record, in 1937 (see Appendix G). The other tunicate, *Botrylloides*, was detected north of Puget Sound for the first time in our earlier surveys (Hines and Ruiz 2000).

Although we have focused primarily on species richness per bay, the frequency of occurrence of NIS within bays is also informative (Appendix D). For Kachemak, the one non-native species (*Botrylloides*) was detected at only one block. In contrast, this same species was found at 5 blocks for Ketchikan and 7 blocks for Sitka. The non-native bryozoan *Schizoporella* also was widespread at Ketchikan (9 blocks) and Sitka (8 blocks). The non-native hydroid was detected at only one block at Ketchikan.

Our panel results indicate a strong latitudinal pattern of NIS occurrence for western North America and suggest that relatively few NIS are now common in Alaska's coastal waters. Focusing solely on tunicates, as a dominant component of NIS diversity in Alaska, there is a significant decline in the number of non-native species from south to north. Figure 3 shows the mean number non-native tunicates per block in each of twelve bays, comparing results from the Alaska surveys to identical surveys conducted in the California, Oregon, and Washington (see Introduction and Figure 1 for further background). Across all sites, species richness per block declines with increasing latitude in a linear fashion ($r^2$=0.72, $p<0.05$).

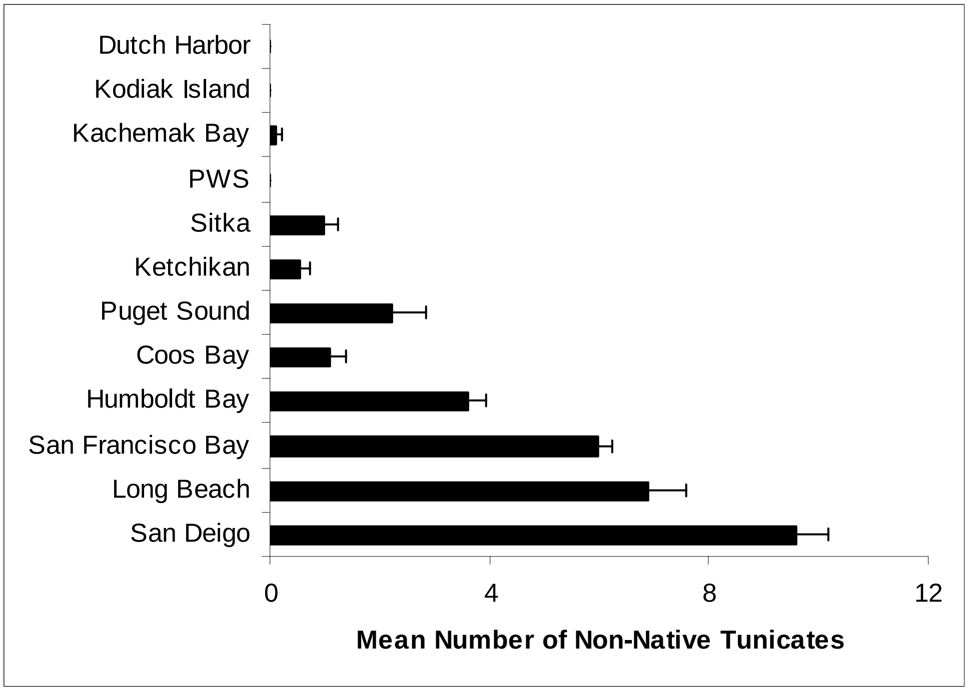


**Figure 3. Mean Number of Non-Native Tunicates Identified in Surveys of Bays in Western North America.** Shown are the mean (+se) number of non-native tunicates per block in standardized surveys of twelve estuaries, showing a northward decline.

Synthesis of existing literature suggests the occurrence of a latitudinal pattern in the number of NIS for western North America more generally, across taxonomic groups (see Literature Review). To date, it was not clear the extent to which this pattern was real or reflected differences in search effort, which has undoubtedly been much lower in Alaska compared to California, Oregon, and Washington (see Ruiz et al. 2000 for discussion). However, our panel surveys now control for search effort across latitudes and confirm that marine NIS are presently uncommon in Alaskan waters relative to other sites. We have only shown a comparison across sites for tunicates, to underscore the general pattern. The addition of other taxonomic groups for comparisons among bays and latitudes, the focus of a current projected funded by National Sea Grant, will further accentuate these differences, because NIS were even less frequent in Alaska for other groups compared to southern bays.

During this survey, we detected only one new NIS that was not previously reported to occur in Alaskan waters (see Literature Review). The survey included many sites with low search effort to date (prior to this survey), as well as a second survey of Prince William Sound (see Hines and Ruiz 2000), and it now seems clear that NIS are not common. In fact, the only NIS records from panel surveys north of Sitka are for the tunicate *Botrylloides*, detected at a single block in Kachemak Bay in this survey and previously from a single block in Prince William Sound. This may suggest that a northward expansion is now underway for this single species, perhaps with implications for many other NIS that occur to the south (see Discussion).

### *Qualitative Analysis of NIS for Other Taxonomic Groups*

Figure 4 shows the total number of species identified per bay from the panel survey, combining those for the four major taxonomic groups (above) and those for other taxonomic groups. The qualitative analyses include taxonomic groups with a few sessile species such as barnacles, mussels, and serpulid polychaetes, as well as some groups that consist of predominantly mobile species such as gastropods (other than nudibranchs). As discussed above, the main distinction between quantitative and qualitative records is that not all vouchers were examined for the latter group, such that comparisons across sites are premature. Nonetheless, the qualitative records contribute to the overall knowledge of species occurring at each site and are therefore discussed briefly here and documented in Appendices

E and F. [Note: There also exist several other taxonomic groups (e.g., amphipods, isopods, errant polychaetes) with predominantly mobile species on the panels that have not yet been examined. Although beyond the scope of our current project, it remains our long-term goal to analyze this material as well.]

Qualitative analysis of these other taxonomic groups add an additional 7-16 species per bay (mean = 11.5 species) that were detected with our panel surveys. None of these are considered to be non-native. Taken together with the species used in quantitative analyses, this increases the average species richness from our panel analyses to a current value of 47.7 species per bay. The increased species pool does not alter the overall pattern of diversity among bays, with Dutch Harbor and Prince William Sound having the lowest species richness, as this is driven by the dominance of sessile invertebrates (in the quantitative analysis) as the focus of this study.

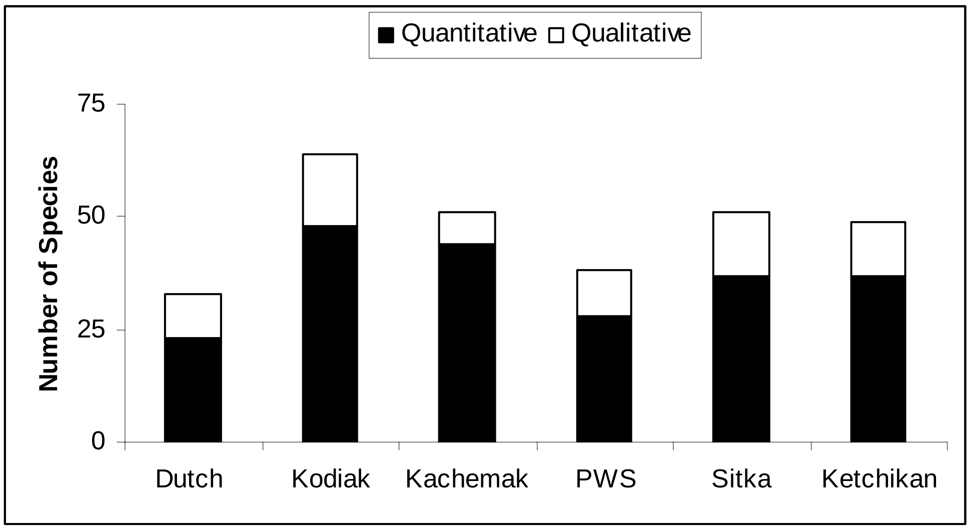


**Figure 4. Total Number of Species Identified from Panels in each Bay.** Shown are the cumulative number of species identified in quantitative and qualitative analyses of panels per bay (see text for explanation).

**B. Supplemental Collections Associated with Surveys**

***Panel Surveys in Port Valdez***

We collected and identified 31 different invertebrate species from panels placed in Port Valdez in 2000 and 2001 (Appendix E). This was a limited number of panels (n= 12-14 per year), intended to assay for the presence of any NIS that were common in the port area, and at least half of the panels were placed at the Alyeska Terminal each year. Of the 31 species, none were considered non-native, twenty-four were classified as native, and seven were cryptogenic.

***Other Supplemental Collections and Surveys***

The most extensive supplemental collections were made at Kachemak Bay and Anchorage area, including a survey of submersed and emergent plants. This resulted from the large number of people participating at these two sites (Table 2). Supplemental collections at Kodiak were more limited in taxonomic scope, whereas supplemental collections were very limited for the surveys at Sitka, Ketchikan, and Prince William Sound (but see extensive earlier such survey in Hines and Ruiz 2000).

A cumulative list of all species identified from the supplemental surveys and the standardized sessile community surveys (section A above) is presented in Appendix F. Here we summarize the key findings by bay or region for the three bay regions with more extensive supplemental surveys.

**<u>1. Kachemak Bay.</u>** A total of 363 species were identified for Kachemak Bay, combining the supplemental and standardized surveys. The distribution of these species among taxonomic groups is shown in Figure 5. The supplemental surveys greatly increased (beyond the standardized surveys) the number of species examined for coelenterates, bryozoans, molluscs, and crustaceans. Nemerteans and vascular plants, not previously included, were also examined by supplemental surveys.

Despite an increased search effort, very few NIS were detected for the invertebrates, consistent with the findings for the sessile invertebrate community alone. None of the species identified were considered to be non-native for the coelenterates, bryozoans, crustaceans, nemerteans, or a variety of other invertebrate groups (Figure 5, Appendix F). Beyond the increase in total species examined for these groups, it is noteworthy that several of these groups were poorly sampled or completely absent from the standardized surveys. Crustaceans received little previous attention, and the supplemental survey included many subgroups (such as copepods, amphiphods, decapods) that were not included in analysis of panels. As noted above, the Nemertea is a also a group (phylum) that was not previously examined.

Two non-native species were identified among 104 molluscs examined (Figure 5). This large increase in sample size was attributed mainly to increase supplemental sampling of bivalves and gastropds by Nora Foster, but also included some chitons (Appendix F). The two non-native species identified were the soft-shell clam *Mya arenaria* and the Pacific oyster *Crassostrea gigas*. Neither of these were new records for Kachemak Bay (Hines and Ruiz 2000). Of these, *C. gigas* is cultured and does not currently have established reproductive poulations within these sites.

One non-native species was identified among the tunicates, the colonial *Botrylloides violaceus*. This species was detected only on the panel survey, as discussed above.

Thus, only three of the 303 invertebrate species examined were considered NIS. Of the remaining species, twenty four were considered cryptogenic, indicating uncertainty about native versus non-native status in Alaska, and most (19) of these were in the four major taxonomic groups examined by the panel surveys.

A greater number and proportion of non-native species were identified for vascular plants (Figure 5, Appendix F). Six of the sixty plants observed by Dr. Dennis Whigham (SERC) were considered non-native, although many of these were found at the margins of marine/estuarine communities, occurring above the high tide or in surrounding wetlands.

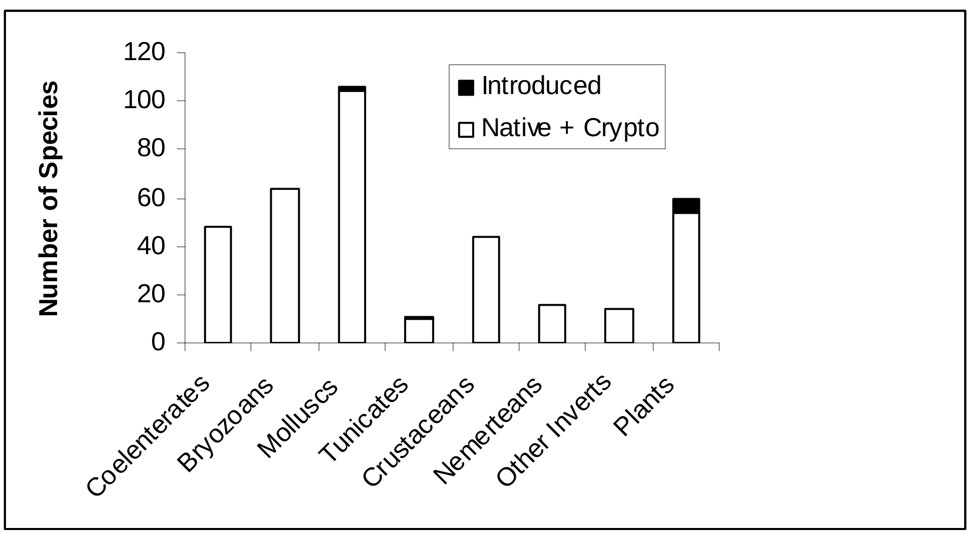


**Figure 5. Number of Native, Cryptogenic, and Introduced Species Identified per Taxonomic Group in Kachemak Bay.** This total combines standardized surveys of sessile invertebrate communities and supplemental surveys.

**2. <u>Anchorage area.</u>** Unlike the other sites, only supplemental surveys were done in Anchorage area. This was a two-day effort that was associated with panel surveys at other sites. However, no panels were deployed at the

Anchorage site, because (a) panel surveys were restricted to higher salinity (> 20 psu) waters and (b) the goal here was to examine other habitats and taxonomic groups.

A majority of the 109 species identified in this supplemental survey were foraminifera and vascular plants (Figure 6, Appendix F). Although invertebrates were also collected from the plankton and soft sediment habitats, the diversity was very low in this area.

Of the 7 invertebrate taxa identified none were classified as NIS. In addition, we observed enormous numbers of the undescribed Nereid polychaete worm, which Jerry Kudenov believed was as a "new species" and was conducting further taxononmic analysis. This worm is probably the most abundant macro-invertebrate on the intertidal soft-bottom flats and subtidal areas of the upper Inlet and Turnagain Arm.

Eighteen species of foraminfera were identified by Dr. Mary McGann (USGS, Menlo Park) from sediment samples, and none of these were considered non-native. We had been particularly interested in the possible presence of the non-native species *Trochammina hadai*, which had been described previously from Alaska (see Literature Review), but this was not detected at this site.

Twenty two species (26%) of the 84 species vascular plants identified by Irina Lapina (The Natural Heritage Foundation) were considered non-native. This is a higher proportion than observed at Kachemak Bay. It is worth noting that the Anchorage survey include many upland plants, which occur above the high tide. It is also relevant to consider the level of human visitation, which likely differs greatly to the two regions, as this increases the opportunity for species transport.

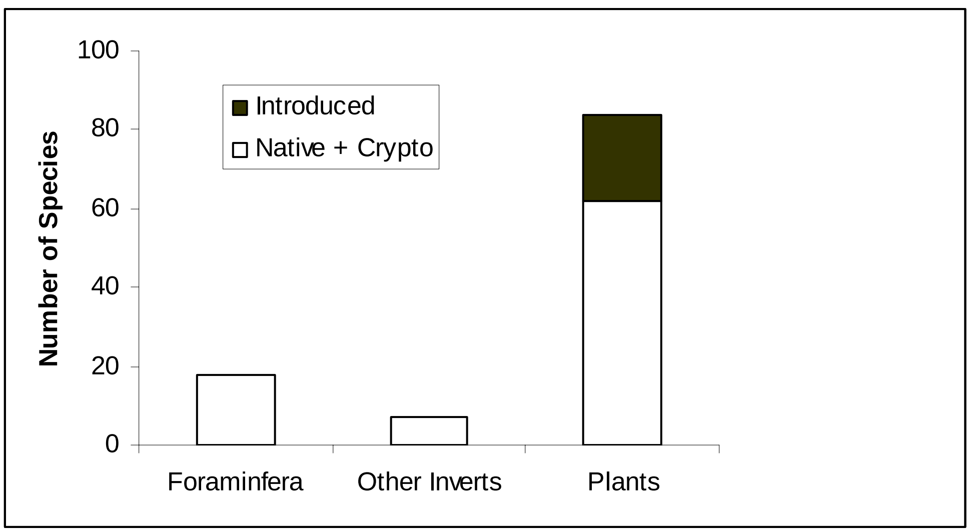


**Figure 6. Number of Native, Cryptogenic, and Introduced Species Identified per Taxonomic Group in Anchorage Area.** These data include only supplemental surveys.

**3. Kodiak.** As with Kachemak Bay, supplemental surveys by Nora Foster resulted in a large increase in the number of mollusc species, primarily bivalves and gastropods, examined for Kodiak (Figure 7, Appendix F). A total of 77 species of molluscs were identified, and the clam *Mya arenaria* was the only one considered non-native. This species has been previously reported and appears to be widespread in Alaskan waters (Hines and Ruiz 2000).

In total, 122 species were identified for this area, including those from the panel surveys. In addition, Drs. Gretchen and Charles Lambert examined tunicates at many supplemental sites, without detection of additional NIS. Thus, we conclude that non-native species are certainly not common at this site.

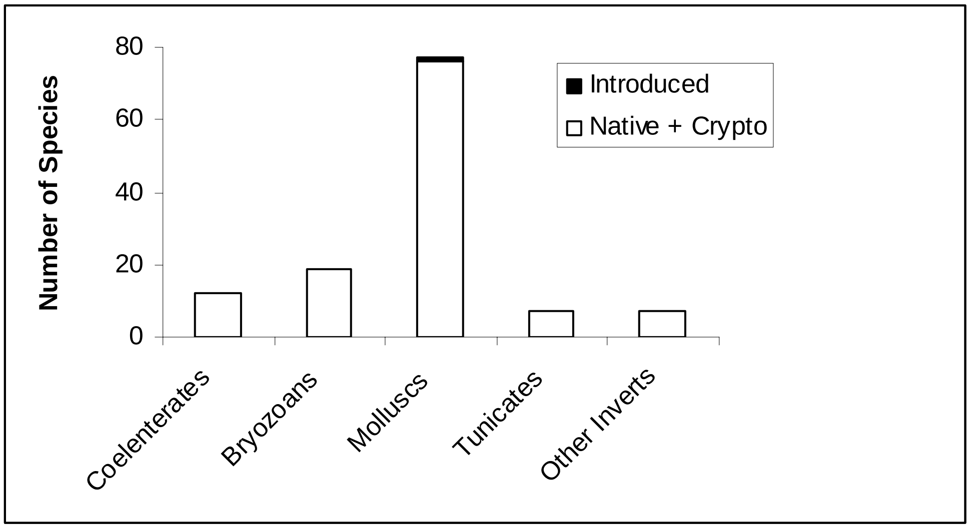


**Figure 7. Number of Native, Cryptogenic, and Introduced Species Identified per Taxonomic Group from Kodiak.** This total combines standardized surveys of sessile invertebrate communities and supplemental surveys.

### C. Literature Review

Table 4 shows a cumulative list of non-native species reported for marine and estuarine waters in each of the 6 focal bay regions as well as the Port of Valdez.

Despite the large number of non-native plants (25 species) documented in supplemental surveys, most of these are found consistently above the high tide level. Only 1 vascular plant, *Cotula coronopifoloia* (brass buttons), is considered to be an obligatory to wetlands and commonly found in estuarine habitats. Another 6 species of macroalgae are established in marine habitats for at least one of the six coastal bays in our study. However, it is noteworthy that these groups were not the focus of our surveys or another major survey effort to examine NIS, so it is possible that some non-native plants may be well established and common.

We presently know of 10 non-native marine invertebrates and 2 non-native marine fish species that have been reported in these focal regions, but it is uncertain whether 4 of these species have established self-sustaining populations (Table 4). The history and invasion status for each of these taxa, as well as some of the cryptogenic species encountered in Alaskan water is described in Appendix G.

**Table 4. Non-Native Species Reported for Each Bay Region in Alaska.** This includes a synthesis of species detected in this study and those reported in the literature (see text and Appendix G for details). In several cases (denoted by an asterisk), it is not clear whether the speicies has established a self-sustaining population. Most of the plant species occur above the high tide mark and are therefore not truly marine/estuarine species.

| | Anchorage | Dutch Harbor | Kachemak | Ketchikan | Kodiak | Prince William Sound | Sitka | Valdez |
|---|---|---|---|---|---|---|---|---|
| **Taxonomic Group** | | | | | | | | |
| ***Species*** | | | | | | | | |
| Red Algae | | | | | | | | |
| *Caulacanthus ustulatus* | | | | | | I | | |
| *Ceramium sinicola* | | | | | | I | | |
| *Chroodactylon ramosum* | | | | | | I | | |
| Brown Algae | | | | | | | | |
| *Fucus cottonii* | | | | | | I | | |
| *Macrocystis integrifolia**** | | | | | | I | | |
| *Microspongium globosum* | | | | | | I | | |
| *Sargassum muticum* | | | | I | | | | |
| Vascular Plants | | | | | | | | |
| *Bromus inermis* | I | | | | | | | |
| *Capsella bursa pastoris* | I | | | | | | | |
| *Chenopodium album* | I | | | | | | I | |
| *Cotula coronopifoloia* | | | | I | | | | |
| *Crepis tectorum* | I | | | | | I | I | I |
| *Elymus repens* | I | | | | I | I | I | I |
| *Erysimum cheiranthoides* spp. *cheiranthoides* | I | | | | | | | |
| *Leucanthemum vulgaris* | I | | | | | I | I | I |
| *Linaria vulgaris* | I | | | | | | | |
| *Linum perenne* ssp. *lewisii* | I | | | | | | | |
| *Lolium multiflorum* | I | | | | | | | |
| *Matricaria discoidea* | | | I | | | I | | |
| *Melilotus alba* | I | | | | | | | |
| *Phleum pratense* | I | | | | | I | | |
| *Plantago major* | I | | I | | | | | |
| *Poa pratensis* | | | I | | | I | | |
| *Polygonum aviculare* | I | | I | | | | | |
| *Polygonum convolvulus* | I | | | | | I | I | |
| *Stellaria media* | I | | | | | | I | |
| *Taraxacum officinale* | I | | I | | | | | |
| *Tragopogon dubius* | I | | | | | I | I | I |
| *Trifolium hybridum* | I | | | | | I | I | I |
| *Trifolium pratense* | I | | | | | | | |
| *Trifolium repens* | I | | I | | | | | |
| *Vicia cracca* | I | | | | | | | |
| Amphipoda | | | | | | | | |
| *Jassa marmorata** | | | | | | | I | |
| Bivalvia | | | | | | | | |
| *Crassostraea gigas** | | I | I | I | | I | I | I |
| *Mya arenaria* | | | I | I | I | I | I | I |
| Bryozoa | | | | | | | | |
| *Schizoporella japonica* | | | | I | | I | I | I |
| Hydrozoa | | | | | | | | |
| *Pinauay crocea** | | | | I | | | | |
| Polychaeta | | | | | | | | |
| *Heteromastus filiformis* | | | | | | I | | |
| Porifera | | | | | | | | |
| *Cliona thoosina* | | | | | | I | | |
| Protozoa | | | | | | | | |
| *Trochammina hadai* | | | | | | I | | |
| Tunicata | | | | | | | | |
| *Botrylloides violaceus* | | | I | I | | I | I | |
| *Botryllus schlosseri* | | | | | | | I | |
| Fish | | | | | | | | |
| *Alosa sapidissima*** | I | | I | I | | I | I | I |
| *Salmo salar** | | | | I | | I | I | I |

* Not known to have established populations in Alaskan waters

** Summer migrant from spwaning areas to the south.

***Native to southern Alaska, brought to Prince William Sound for fishery purposes. Unlikely to be established, but a possible vector for other organisms.

The cumulative number of non-native invertebrate species for these Alaska sites is very low relative to more southern bays and estuaries in western North America. Figure 8 shows the number of non-native marine invertebrate species that we consider to be established in each of 12 bays, as compiled in our database (NEMESIS 2005).The minimum number of NIS was 60 in the six bays examined for California to Washington, with the highest number occurring in San Francisco Bay (see also Cohen and Carlton 1995). In contrast, the number of NIS for the six Alaska sites was at least one order of magnitude lower, ranging from 0-5 species. These data across all invertebrate taxa exhibit a similar pattern, with even more extreme latitudinal differences, to that observed for the sessile invertebrate surveys alone (Figure 3).

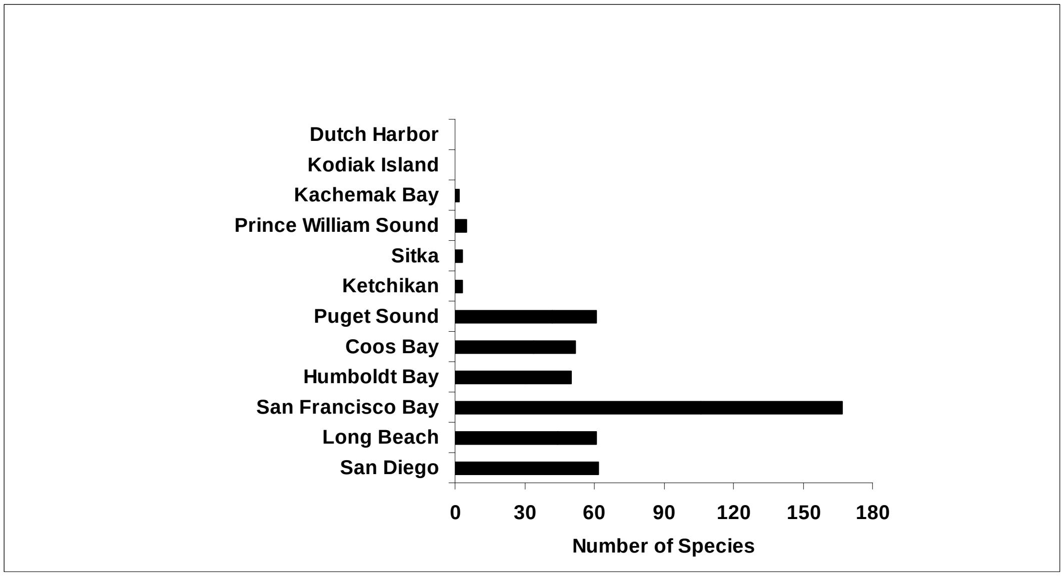


**Figure 8. Total number of Non-native Marine Invertebrate Species with Established Populations in Different Bays along Western North America.** This includes species reported in the literature and from our standardized surveys of sessile invertebrate communities at each bay.

## DISCUSSION

Overall, our results indicate that non-native species of marine invertebrates are relatively rare in coastal waters of Alaska at the present time, compared to lower latitude sites in North America and elsewhere. Although we had previously reported that such a latitudinal pattern appeared to exist (Ruiz et al. 2000), there was considerable uncertainty about whether this was real or an artifact of low sampling effort for Alaska, since there had not been many surveys for NIS along Alaskan shores (especially relative to other sites). We now have considerable confidence that this pattern is indeed real.

Our sessile community surveys control for such search effort and demonstrate striking differences in the number of NIS between Alaska and other sites from California to Washington. Figure 3 illustrates this for tunicates alone. The magnitude of this difference in increased when adding other taxonomic groups of sessile invertebrates, and this comparison is the focus of ongoing analyses for non-Alaskan sites (funded by National Sea Grant, Department of Defense Legacy Program, National Fish & Wildlife Foundation, and Smithsonian Institution). In addition, the supplemental surveys further reinforce this finding.

When considering the entire diversity of invertebrates, across all taxonomic groups and habitat types (e.g., soft-sediment benthos, plankton communities, etc), a strong difference also exists in the total number of NIS known to occur in Alaska compared to other sites, as shown in Figure 8. It seems likely that this pattern is also real, given the magnitude of the difference and the absence of many relatively large, conspicuous non-native species, such as some of the crabs and molluscs that occur in California. However, it is also important to keep in mind that many habitats and taxa have not been explicitly examined in Alaska, for these focal bays and elsewhere, and some invasions have almost certainly occurred without notice. Thus, the extent to which bias contributes to the overall magnitude of differences remains to be tested beyond the sessile invertebrate community, which was the primary focus of our analyses.

The mechanism(s) that underlie the observed latitudinal pattern and relative paucity of non-native invertebrates in Alaska is not clear. Previously, Ruiz et al. (2000) had suggested three general hypotheses that could explain this geographic pattern, alone or in combination, including (1) bias in the data, (2) differences in propagule supply, and (3) differences in susceptibility to invasion. As discussed above, we can now reject the first hypothesis, as there are real patterns when controlling for search effort. The other two hypotheses have not yet been tested and are discussed further below.

In general, invasion risk should increase with increasing propagule supply, assuming suitable conditions exist for colonization. Such a positive relationship should exist for the density/number of organisms released at any one inoculation event as well as the number of inoculation events (Ruiz and Carlton 2003).

Historically, propagule supply to Alaska has probably been low relative to other sites on the west coast of North America. Although a direct measure of supply is not available, it may be possible to use proxies to estimate general levels of supply. Ships transfer organisms in ballasted materials and on exposed outer surfaces (hulls), and number of arrivals can provide one measure of supply. Also, aquaculture activities and seafood imports also create another transfer mechanism and thus represent another measure of supply. It is useful to note that many, if not most, of the non-native species in Alaska may have arrived via shipping and live trade. Although a long-term analysis of these mechanisms has not yet been done, we surmise that both activities have been low historically, relative to many other sites in North America (which are more invaded). Thus, supply itself may contribute strongly to the overall latitudinal pattern of invasions observed to date.

The supply from these two general mechanisms has grown in the past decades, including especially the increase in oyster / mussel culture, salmon culture, commercial shipping, and cruise ships. The increase is perhaps most striking for the export of oil from Port Valdez, beginning in the 1970s, whereby oil tankers arrive at high frequency to the port, transporting organisms in ballast water and on the hulls of vessels (see Hines and Ruiz 2000 for description). Most of these tankers arrived with large quantities of ballast water from ports in Washington and California, including the highly invaded San Francisco Bay. As a result of the tanker trade, and other known transfer mechanisms, there has undoubtedly been an increase in propagule supply of non-native invertebrates to Alaska.

Despite this increase, there have been relatively few NIS found to date in Alaska. This may simply represent a time lag in detection. Once established, it can take years for a population to increase in abundance, spread, and become detected. There is considerable uncertainty about the length of time required for detection, even given extensive searching. Based upon our survey results, it is clear that NIS are not now common in Alaska, but we cannot say with any confidence that many species are not already established in limited areas or at low densities, currently below our threshold for detection.

At least one species may be undergoing a range expansion in Alaska at the present time. The colonial tunicate *Botrylloides* has been detected at 4 of the bay regions examined. Our surveys found this species in Ketchikan, Sitka, and Kachemak Bay, and an earlier survey found this organism at Tatitlek Island, Prince William Sound. At each Kachemak and Prince William Sound, the species was only detected at one location (block). Based upon the widespread geographic distribution and environmental tolerance of this species, this species appears capable of spreading and becoming abundant in Alaska. It would be very worthwhile to track the spread of this species, as a model system for Alaska invasions, given its potential impact as a dominant space occupant on hard substrate and the relative ease of detection.

Although Alaska is certainly vulnerable to invasion by NIS, given that a few have already established, its relatively susceptibility to invasion requires further evaluation. As a minimum, we can assume that non-native species will continue to be transferred coastwise to Alaska, from the combination of natural northward spread and human-mediated transfer. A critical question is how many of these taxa can become established and flourish upon arrival.

Based upon preliminary examination, it appears that many non-native species that now occur along western North America can tolerate environmental conditions in Alaska, based upon geographic distribution in other global regions. Such opportunity should improve with increasing temperatures from global warming. A more detailed examination of the European green crab, *Carcinus maenas*, suggests it can successfully complete larval development in Alaskan waters (Hines et al. 2004). With current funding from RCAC, we are now formally estimating the potential northern range for several non-native species, to test whether environmental conditions present any barrier to colonization.

Assuming that many NIS are able to tolerate Alaskan waters, will they be able to establish self-sustaining populations? This depends in part on the propagule supply and biotic interactions. Approximately half of the non-native invertebrates that have colonized San Francisco Bay have not spread outside of this bay to date, yet it appears that many are not limited by environmental tolerance. Instead, we hypothesize that transport opportunities are limited or often insufficient to allow colonization to other regions. If correct, this has direct relevance for Alaska, as efforts to limit propagule supply by ships and other human-mediated agents may greatly delay or limit possible invasions.

Perhaps the most complicated aspect of colonization is whether, and the extent to which, biotic interactions may limit population establishment and growth. There is some evidence for such biotic resistance in several other systems. However, predictive capacity is very limited in this regard at the present time (see Simberloff, as cited in Wittenberg and Cock 2001; Ruiz and Carlton 2003), due to the large number of interacting factors that can influence survivorship at local scales. Although this biotic resisteance is an interesting aspect of invasion dynamics and important to understanding as well as predicting outcomes, this is also the most complex. At the present time, there is no compelling reason to expect that Alaska has a high level of biotic resistance to invasion.

## CONCLUSIONS & RECOMMENDATIONS

We have documented the occurrence of 20 non-native species marine and estuarine habitats in Alaska, across a wide range of taxonomic groups. This represents a low level of invasions compared to many other sites, creating a steep latitudinal cline when compared to Washington, Oregon, and California. The factors driving this pattern remain unclear, but our surveys now rule out limited or uneven search effort as an explanation. Although this low prevalence in Alaska may reflect a low susceptibility to invasions, there is currently no evidence to support this. This pattern may instead result primarily from the historically low propagule supply to Alaska relative to other more invaded sites. This argues strongly for a precautionary and proactive management strategy to limit the transfer of organisms by ships, aquaculture, and other human-mediated mechanisms, thereby reducing the risk of invasions.

To further evaluate the risk of future invasions in Alaska, we recommend a focus in three general areas:

- <u>Evaluating the physiological capacity of non-native organisms to colonize Alaskan waters.</u> This should include a primary focus on those NIS already established along western North America, as a source of new colonists. The key question here is the extent to which most organisms are physiologically able to tolerate and thrive in environmental conditions of Alaska. If an organism cannot survive and reproduce in Alaskan waters, taking into account climate change, it simply cannot establish. Although biotic interactions may limit colonization success further, this is difficult to assess, especially across many taxa.
- <u>Measuring the dose-response relationship between the density of organisms delivered (i.e., propagule supply) and the likelihood of establishment.</u> There is a fundamental gap in the knowledge about dose-response relationships, and yet this is the basis for management decisions about propagule supply and acceptable levels of risk. At the present time, a dose-response relationship has not been established for any marine invertebrate population. Any such analysis for Alaska should obviously be done in containment (or in the current range of target species) and focus on species with appropriate physiological tolerance for local conditions.

- Tracking northward spread of NIS and colonization or Alaska waters. We have now established a baseline measure of NIS for several sites in Alaska and have been tracking northward range expansion of NIS in California, Oregon, and Washington. We recommend establishing several long-term, low-level monitoring sites in Alaska to evaluate changes through time, concurrent with changes in vector activity and management.

## LITERATURE CITED


Carlton JT (1979) History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific coast of North America. Ph.D. dissertation, University of California, Davis

Carlton JT (1989) Man's role in changing the face of the ocean: Biological invasions and implications for

Carlton JT (1996) Pattern, process, and prediction in marine invasion ecology. Biological Conservation 78:97-106

Carlton JT (1996) Biological invasion and cryptogenic species. Ecology 77:1653-1655

Carlton JT (2001.) Introduced species in US Coastal Waters: Environmental Impacts and Management Priorities, Pew Ocean Commissions, Arlington, Virginia, 36 pp

Carlton JT, Geller JB (1993) Ecological roulette: The global transport of nonindigenous marine organisms. Science 261:78-82

Chapman JW, Carlton JT (1991) A test of the criteria for introduced species: the global invasion by the isopod *Synidotea laevidorsalis* (Miers, 1881). Journal of Crustacean Biology 11:386-400.

Cohen AN, Carlton JT (1995) Biological Study: Non-Indigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta. US Fisheries and Wildlife and National Sea Grant College Program Report, NTIS Number PB96-166525, Springfield, Virginia, USA, 273 pp

Cohen AN, Carlton JT. (1998) Accelerating invasion rate in a highly invaded estuary. Science 279:555-558

Dean TA (1981) Structural aspects of sessile invertebrates as organizing forces in an estuarine fouling community. Journal of Marine Biology and Ecology 53:163-180

Fofonoff, PW, Ruiz GM, Steves B, Carlton JT ( 2003) In Ships or On Ships? Mechanisms of transfer and invasion for non-native species to the coasts of North America. In: *Invasive Species: Vectors and Management Strategies*, GM Ruiz and JT Carlton (editors), pp. 152-182. Island Press, Washington.

General Accounting Office G (2002) Invasive species: clearer focus and greater commitment to effectively manage the problem. Report No. GAO-03-1, General Accounting Office, U.S, Washington. 96pp

Grosholz E (2002) Ecological and evolutionary consequences of coastal invasions. Trends Ecol Evol 17:22-27

Hewitt CL (1993) Marine biological invasions: the distributional ecology and interactions between native and introduced encrusting organisms. Ph.D. Dissertation, University of Oregon

Hewitt CL (1993) Marine biological invasions: The distributional ecology and interactions between native and introduced encrusting organisms. PhD dissertation, University of Oregon

Hewitt CL, Campbell ML, Thresher RE, Martin RB (eds) (1999.) Marine Biological Invasions of Port Phillip Bay, Victoria, CRIMP Technical Report 20, CSIRO Division of Marine Research, Hobart, Australia

Hines AH & GM Ruiz. 2000. Biological invasions of cold-water coastal ecosystems: Ballast-mediated introductions in Port Valdez / Prince William Sound, Alaska. Final Report, Regional Citizens Advisory Council of Prince William Sound, 400 pp.

Hines AH, GM Ruiz, N Hitchcock, & C deRivera. 2004. Projecting range expansion of invasive European green crabs (Carcinus maenas) to Alaska: Temperature and salinity tolerance of larvae. Report submitted to Prince William Sound Regional Citizens' Advisory Council and the US Fish & Wildlife Service, 22p.

IMO 2005 GloBallast Programme Website, International Maritime Organization, http://globallast.imo.org

Kareiva P (1996) Developing a predictive ecology for noninidgenous species and ecological invasions. Ecology 77:1651-1652

Levin PS, Coyer JA, Petrik R, Good TP (2002) Community-wide effects of nonindigenous species on temperate rocky reefs. Ecology 83:3182-3193

Office of Technology Assessment OTA (1993) Harmful Non-indigenous Species in the United States. Report No. OTA-F-565, Office of Technology Assessment (US Congress), US Government Printing Office, Washington, DC

Perrings C, M. Williamson, E. B. Barbier, D. Delfino, S. Dalmazzone, J. Shogren, P. Simmons, and A. Watkinson (2002) Biological invasion risks and the public good: an economic perspective. Conservation Ecology [online] 6:1-7

Reise K, Gollasch S, Wolff WJ (1999) Introduced marine species of the North Sea coasts. Helgoländer Meeresunters 52:219-234

Ruiz GM, Hewitt CL (2002) Toward understanding patterns of coastal marine invasions: A prospectus. In: Leppakoski E, Olenin S., and Gollasch S. (ed) Invasive Aquatic Species of Europe. Kluwer Academic Publishers, Dordrect, p 529-547

Ruiz GM, Carlton JT, Grosholz ED, Hines AH (1997) Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent, and consequences. American Zoologist 37:621-632

Ruiz GM, Fofonoff P, Hines AH, Grosholz ED (1999.) Nonindigenous species as stressors in estuarine and marine communities: assessing invasion impacts and interactions. Limnol Oceanogr 44:950-972
Ruiz GM, Fofonoff PW, Carlton JT, Wonham MJ, Hines AH (2000) Invasion of coastal marine communities in North America: apparent patterns, processes, and biases. Annl Rev Ecol Syst 31:481-531
Ruiz GM, Carlton JT (2003) Invasion vectors: a conceptual framework for management. In: *Invasive Species: Vectors and Management Strategies*, GM Ruiz and JT Carlton (editors), pp. 459-504. Island Press, Washington.
Sutherland JP (1978) Functional roles of *Schizoporella* and *Styela* in the fouling community at Beaufort, North Carolina. Ecology 59: 257-264
Sutherland JP & Karlson RH (1977) Development and stability of the fouling community at Beaufort, North Carolina. Ecological Monographs 47: 425-446
Vermeij GJ (1996.) An agenda for invasion biology. Biological Conservation 78:3-9
Wittenberg, R., Cock WJM (editors) (2001) Invasive alien species: a toolkit of best prevention and management practices. CAB International, Wallingford, Oxon. 238p.

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# Appendix A

## Design and Construction of Collectors Used in Surveys: PVC Panels and Wooden Blocks

# Protocol of Settling Plate construction

## WOODS:

**Step 1**: Cut 3-1x6 boards (two Red Oak, one White Pine) into 5.5"L x2.75"W.

**Step 2**: Drill 2 holes on each wood piece according to the markings on the jig for drilling.

**Step 3**: Sandwich the Pine (soft) in between 2 Oak (hard) pieces. Secure with the eyebolts, washers and nuts. See Figure A.

- After eyebolts are inserted, turn the eyes of the bolts so they FACE each other.
- Screw in nuts TIGHTLY.

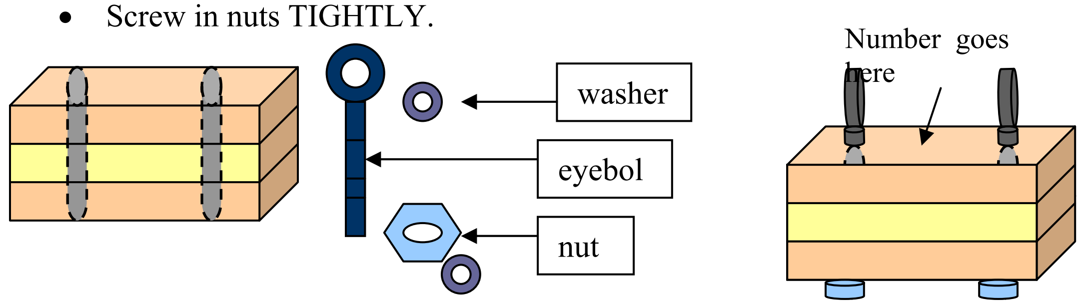



**Figure A.** Components and final view of wood sandwiches

**Step 4**: On the side without the nuts, use the wood burner to etch a unique, designated serial number in the middle of the wood. This is easier if done BEFORE the plates are bolted together. See figure A.

## PVC:

**Step 1**: Drill 2 holes on both sides of the plate according to the markings on the jig.

**Step 2**: Lightly sand (**gently** and evenly) one side of the plate with an electric sander.

**Step 3**: On the smooth, **non**-sanded side of the plate, use the burner to etch a unique,designated serial number in the middle of the plate. See Figure B.

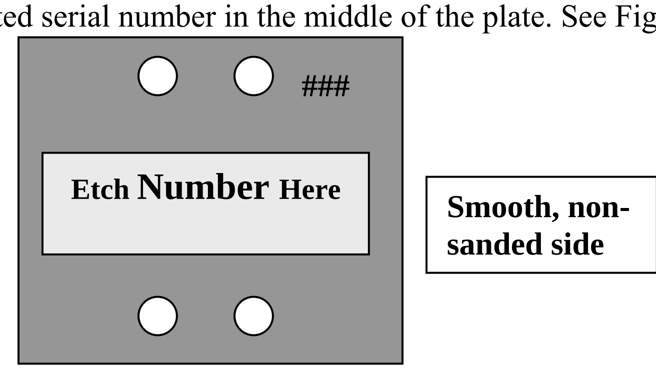



**Figure B.** The etched number should be about the size of a brick's thickness.

**Step 4**: In one *corner* of the plate, the serial number **must** be written (small) with a thick Sharpie (identifies plate number after bricks are attached). See "####" on Figure B.

## CONSTRUCTION OF PLATE UNITS:

**Step 1**: **PVC ONLY**: Lace a large (yellow in figures) cable tie from top of one hole, under (sanded) bottom of plate and up through second hole on the SAME side. Close cable tie so there is a loose loop. See Figure C.

**Step 2**: **PVC ONLY**: Repeat on other side of plate.

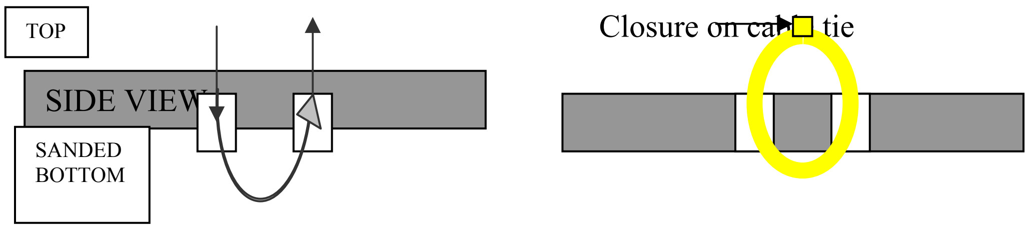



**Figure C.** Side views of PVC Plate Construction

**Step 3**: **PVC**: Place brick in middle of plate on top (etched) side so the cable tie loops are on the sides of brick.

**WOODS**: Place brick between eyebolts (on etched side).

**Step 4**: **PVC:** Lace an extra Large cable tie (red in figures) through one loop, through middle hole of brick, under loop on other side and back through same hole to the other side in order to close cable tie. See Figure D1.

**WOODS:** Lace Ex-L cable tie through one eye, the brick's middle hole, the other eye, and back through the same middle hole to close the cable tie.

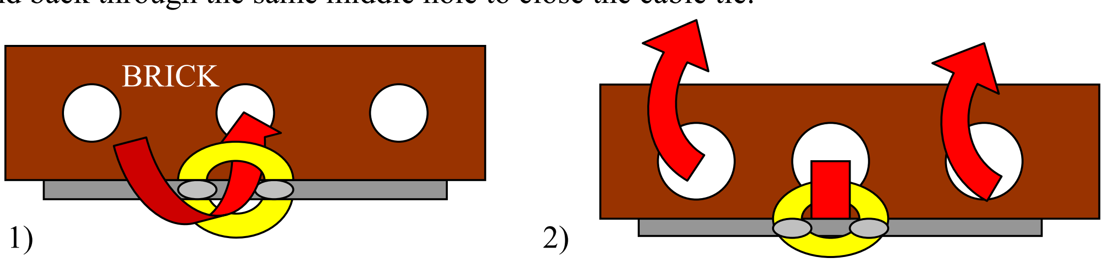



**Figure D.** Side views of brick attachment to PVC plate

**Step 5**: **BOTH:** Tighten all cable ties.

**<u>Step 6</u>**: **BOTH:** Loop an extra large cable tie through one hole on each end of the brick (1 tie per side). Do not close these cable ties tightly; line gets attached to these loops. See Figure D2.

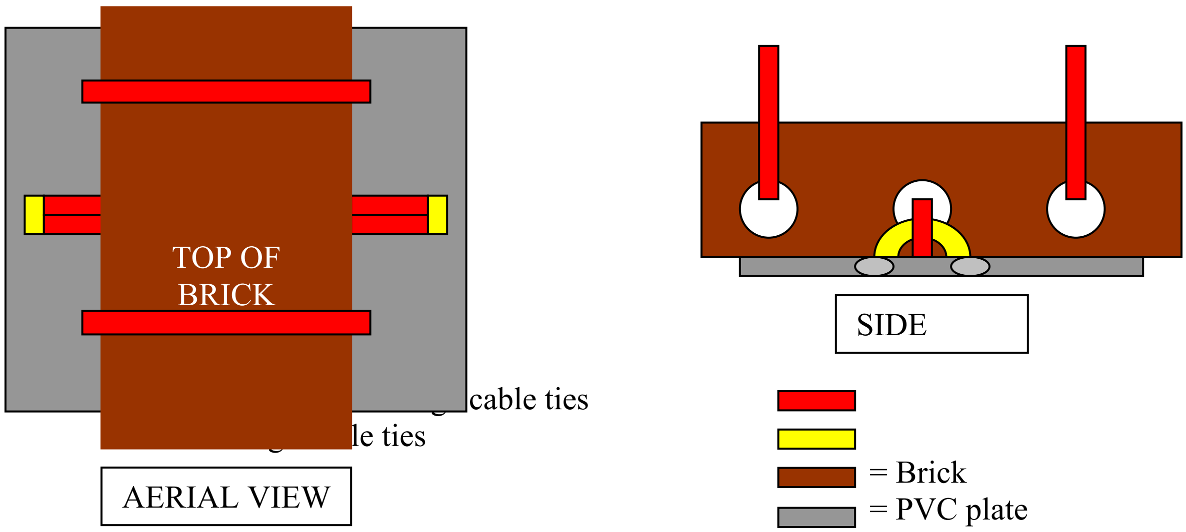
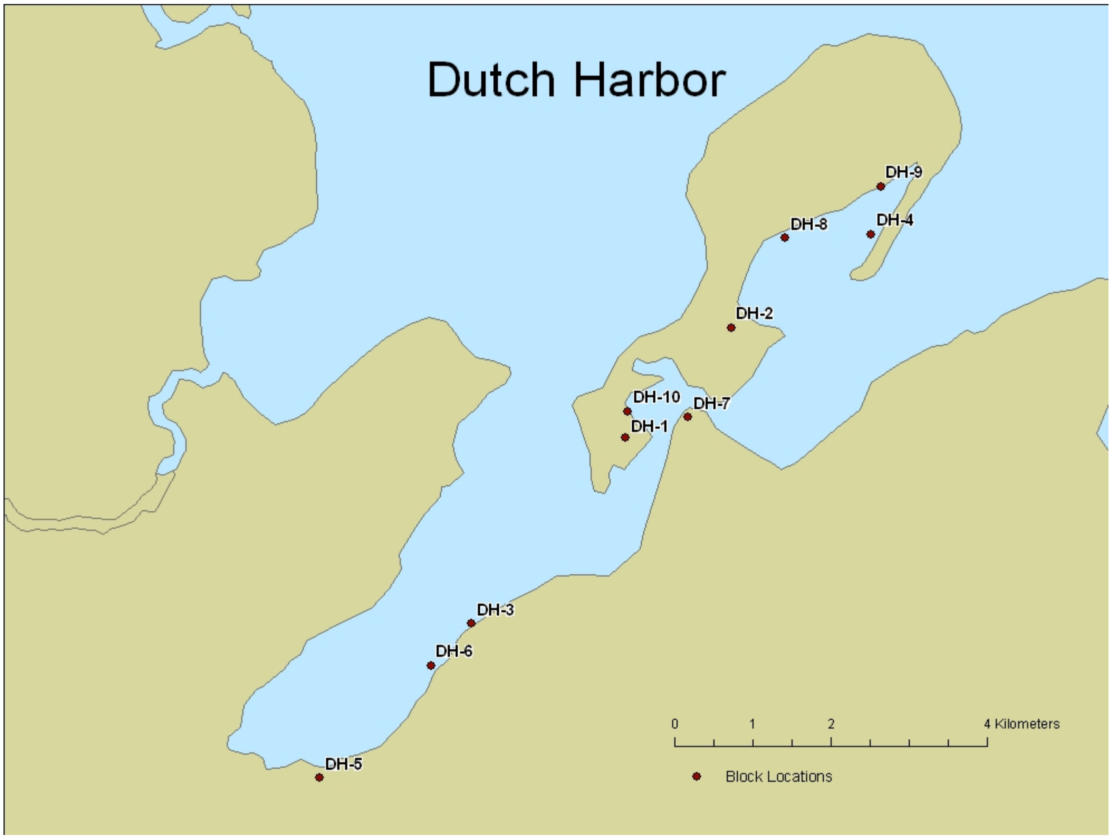


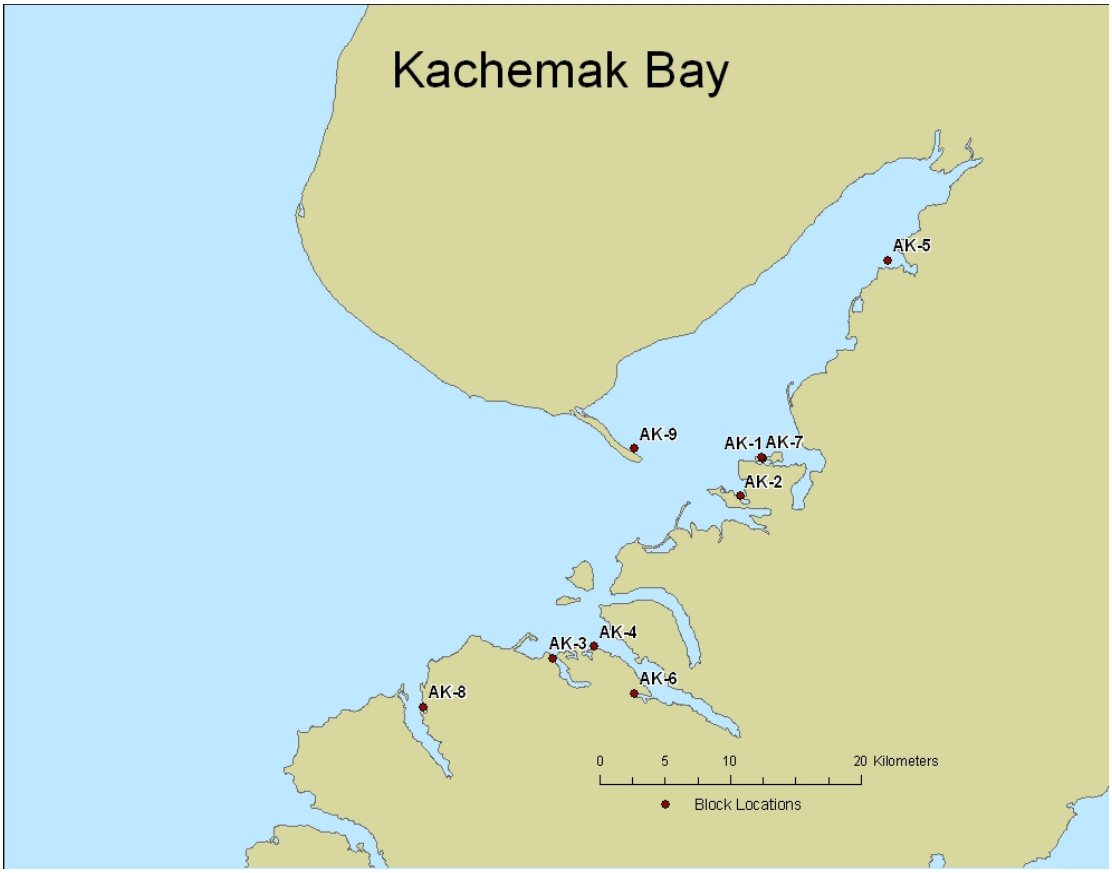

**Figure E.** Final views (pre-line attachment) of PVC unit

## Appendix B

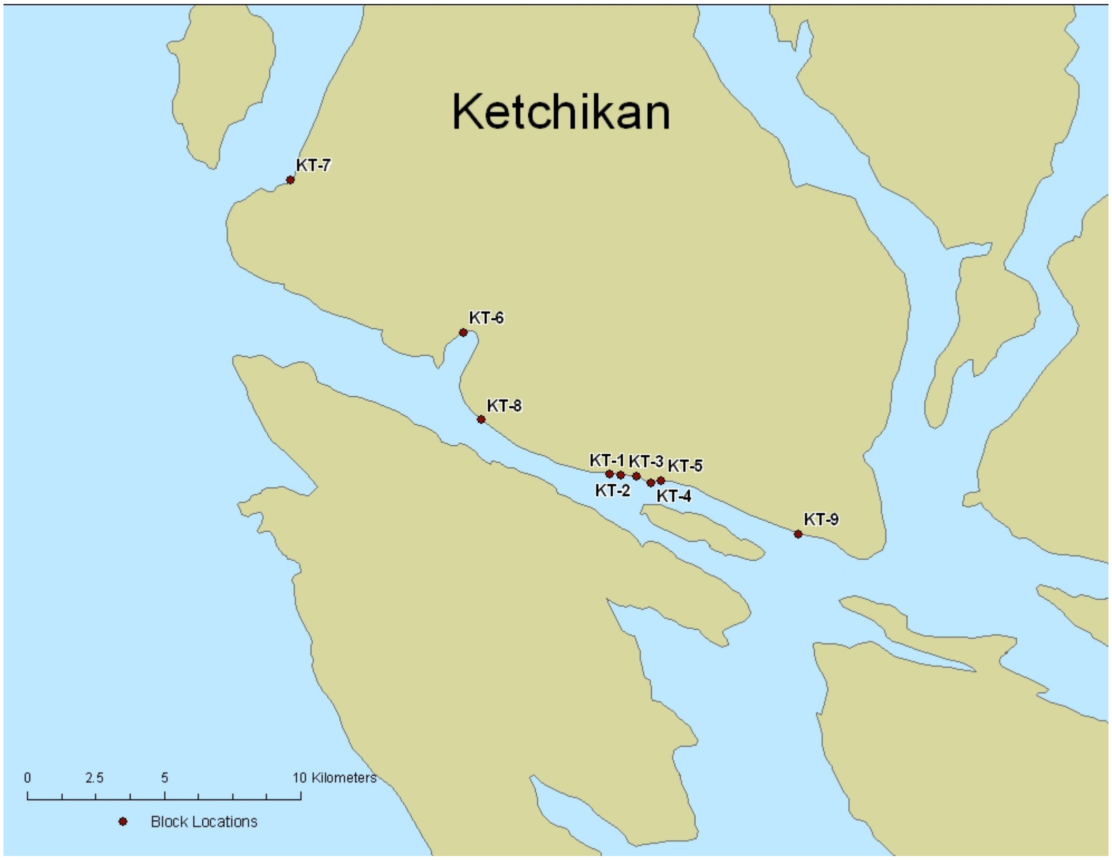
**Maps Showing the Locations of Bays,
and Areas within Bays (Blocks), Surveyed**

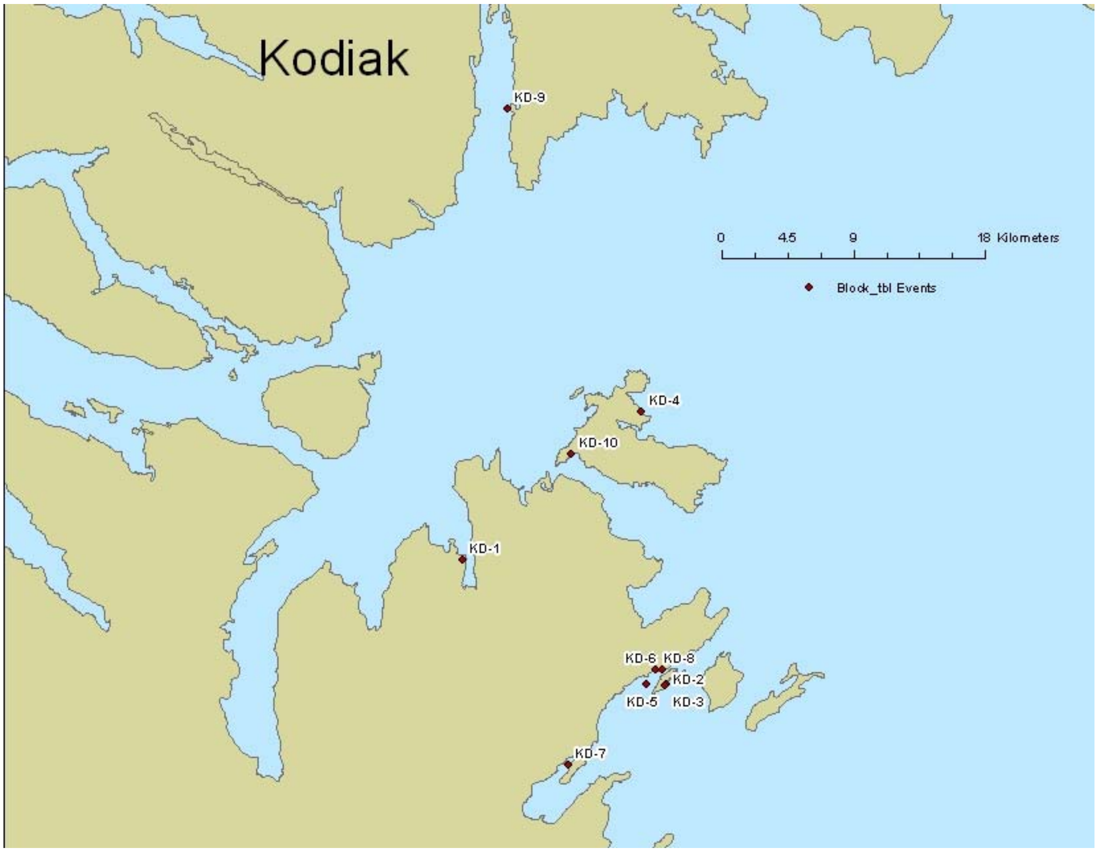

Alaska Survey Sites
Prince William Sound
Kachemak Bay
Kodiak
Sitka
Ketchikan
Dutch Harbor
0
325
650
1,300 Kilometers
Bay Locations

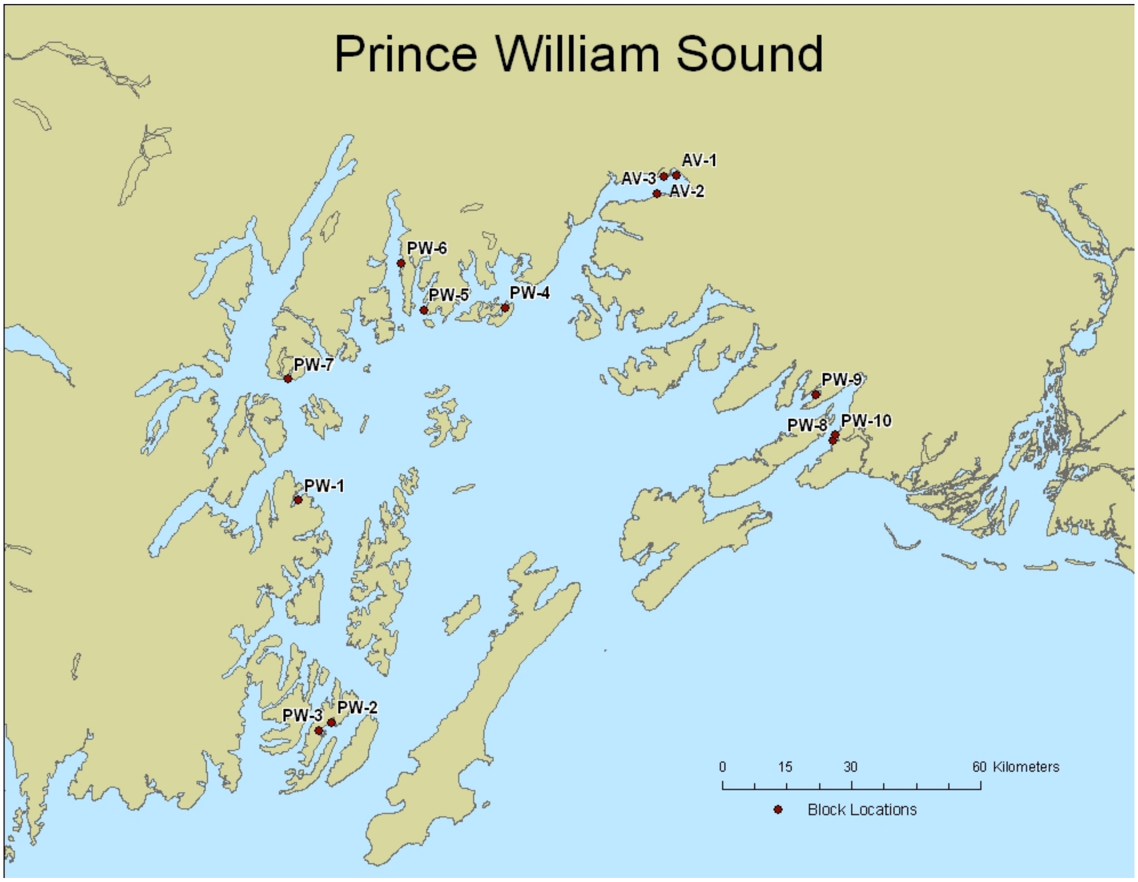

Dutch Harbor
DH-9
DH-8
DH-4
DH-2
DH-10
DH-7
DH-1
DH-3
DH-6
DH-5
0
1
2
4 Kilometers
Block Locations

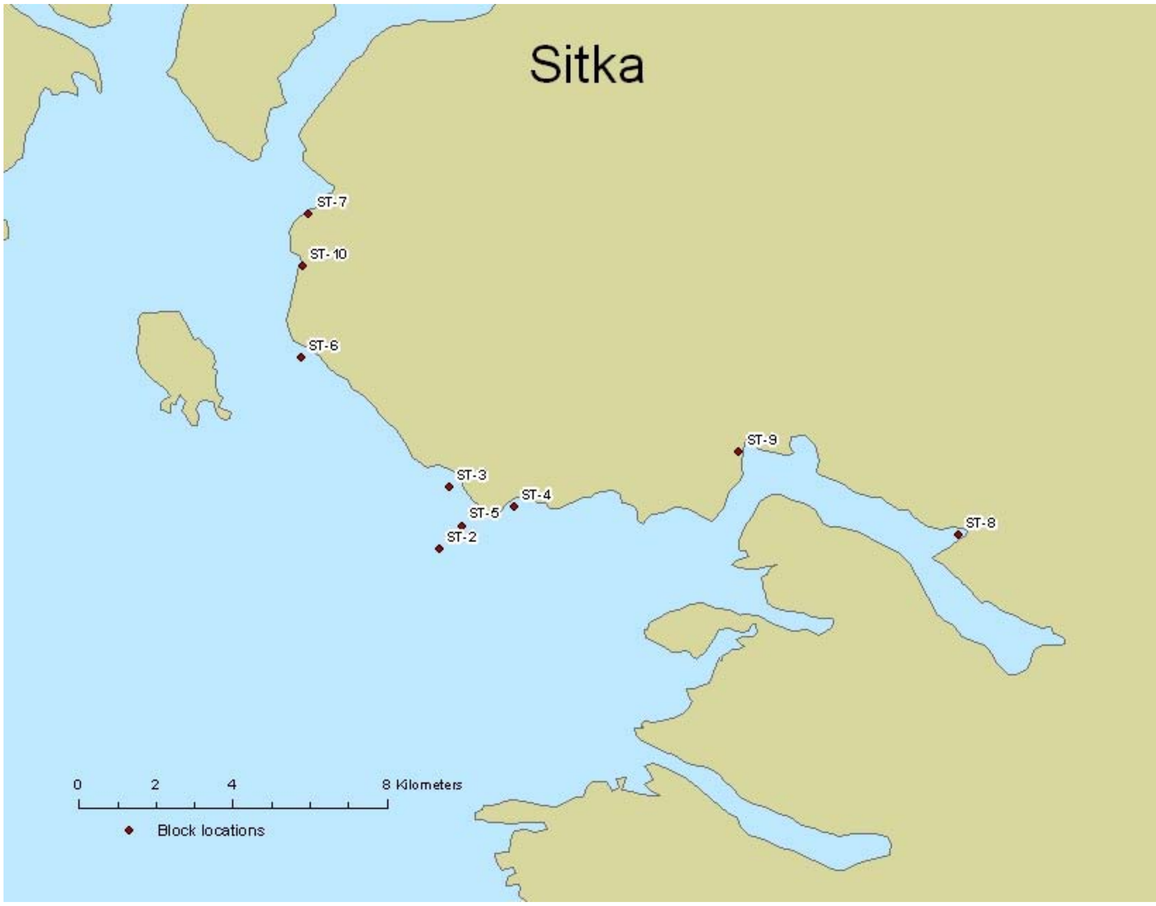


Kachemak Bay
AK-5
AK-9
AK-1
AK-7
AK-2
AK-4
AK-3
AK-6
AK-8
0
5
10
20 Kilometers
Block Locations


Ketchikan
KT-7
KT-6
KT-8
KT-1
KT-3
KT-5
KT-2
KT-4
KT-9
0
2.5
5
10 Kilometers
Block Locations


Kodiak
KD-9
0 4.5 9 18 Kilometers
Block_tbl Events
KD-4
KD-10
KD-1
KD-6
KD-8
KD-2
KD-5
KD-3
KD-7


Prince William Sound
AV-1
AV-3
AV-2
PW-6
PW-5
PW-4
PW-7
PW-9
PW-8
PW-10
PW-1
PW-3
PW-2
0
15
30
60 Kilometers
Block Locations

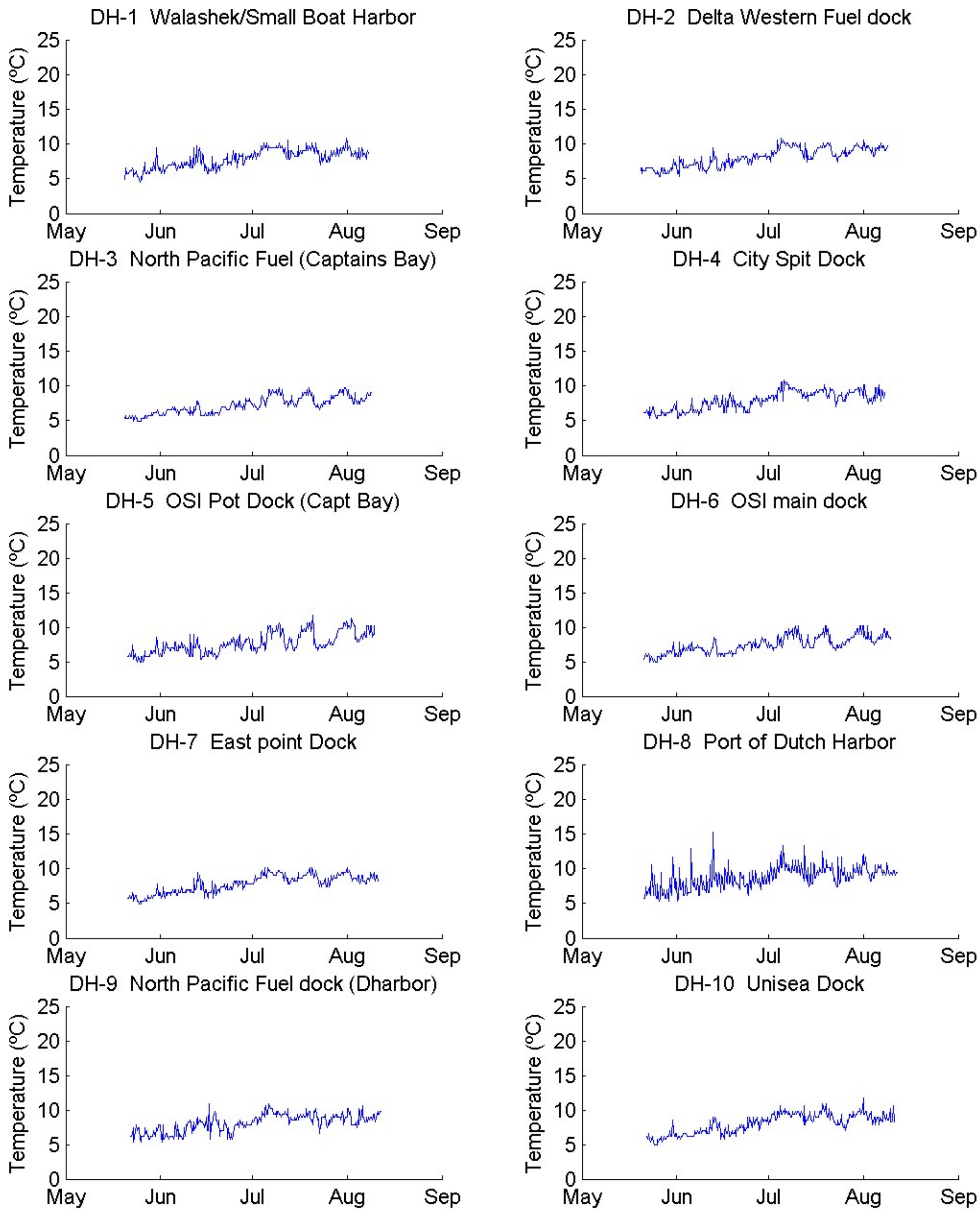

Sitka
ST-7
ST-10
ST-6
ST-3
ST-4
ST-5
ST-2
ST-9
ST-8
0
2
4
8 Kilometers
Block locations

## Appendix C.

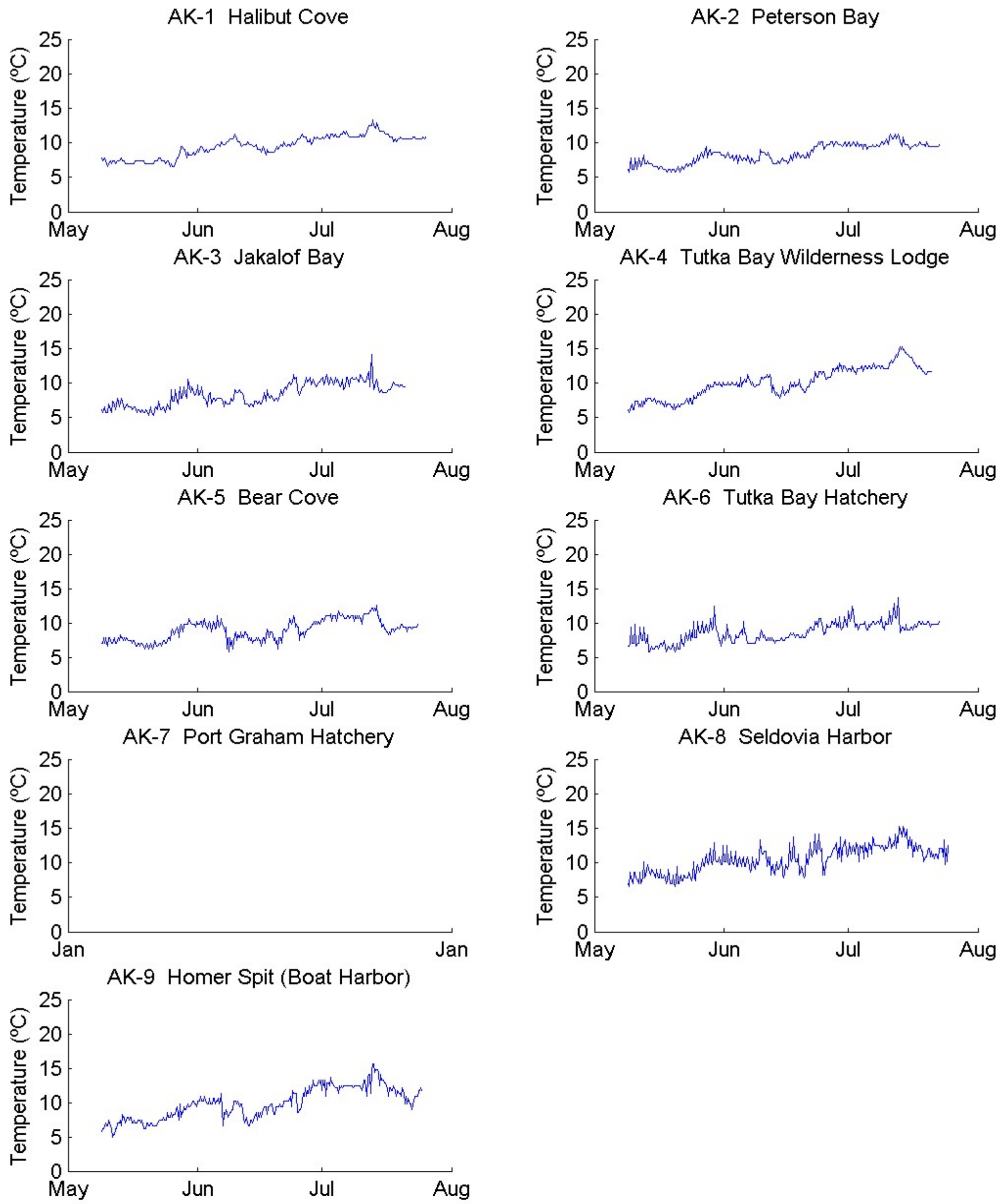
**Water Temperatures Recorded by Data Loggers for the Multiple Blocks Surveyed within each Bay.**

[Blank figures indicate data logger was not recovered.]

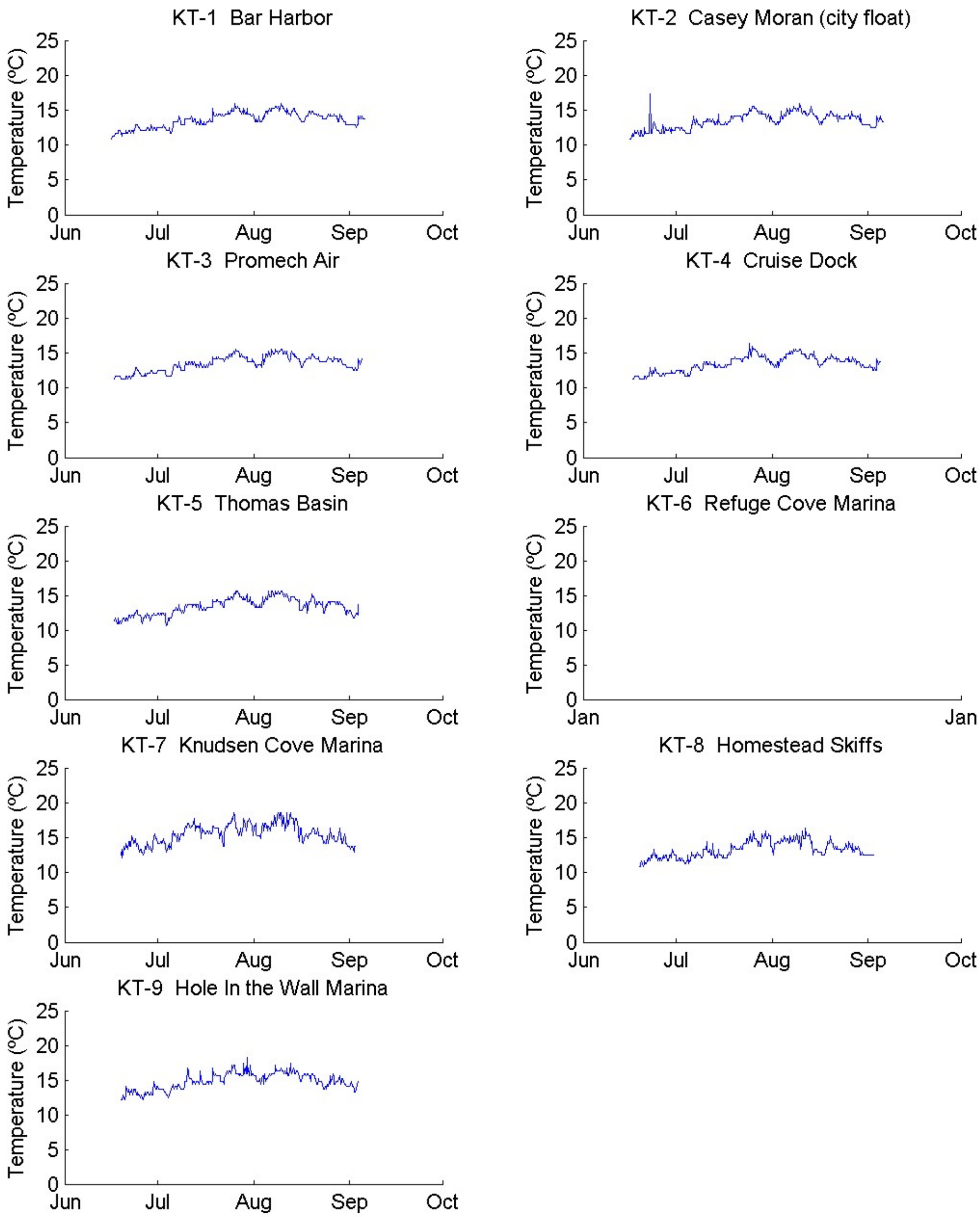
## Water Temperature by Block for Dutch Harbor



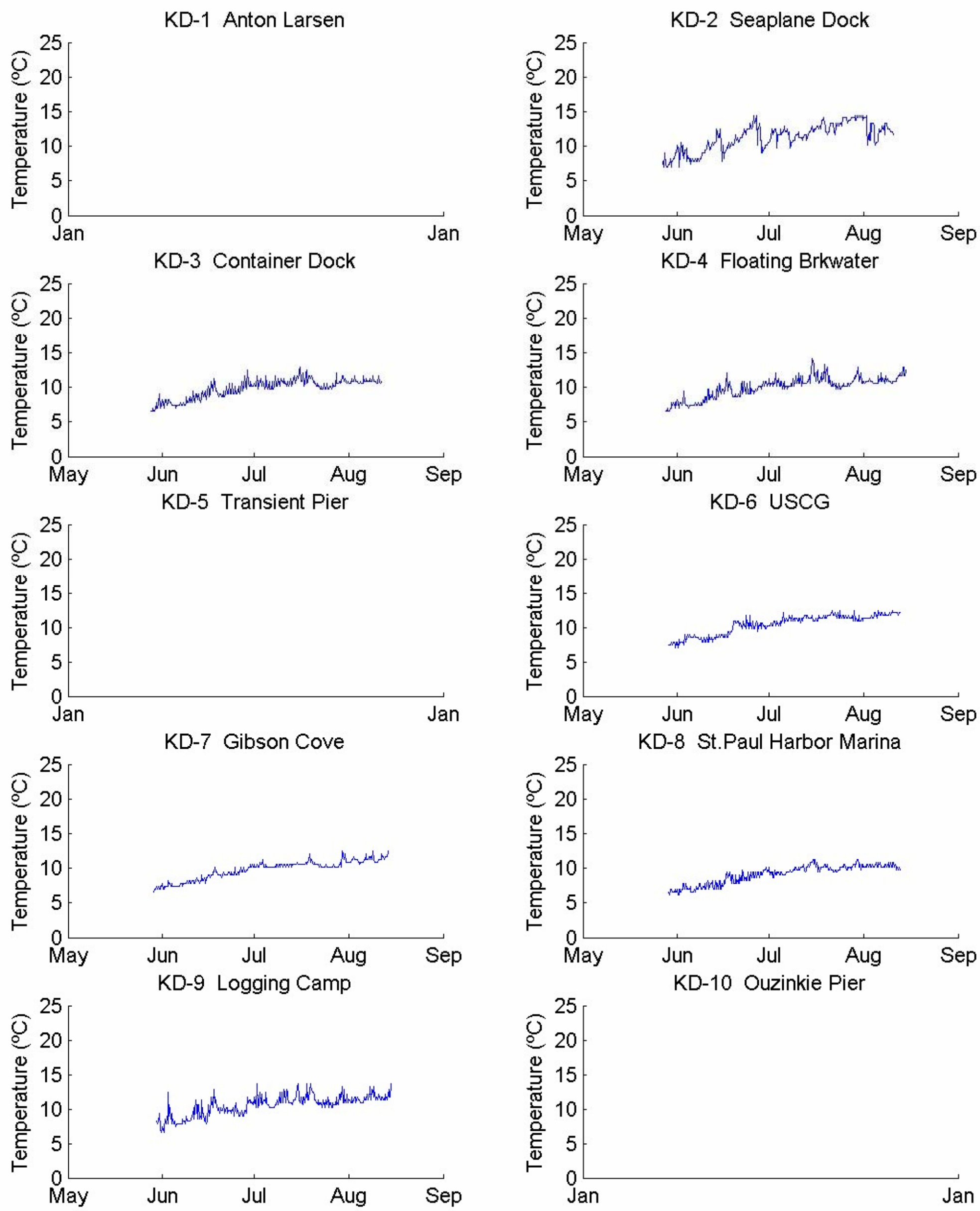
## Water Temperature by Block for Kachemak Bay



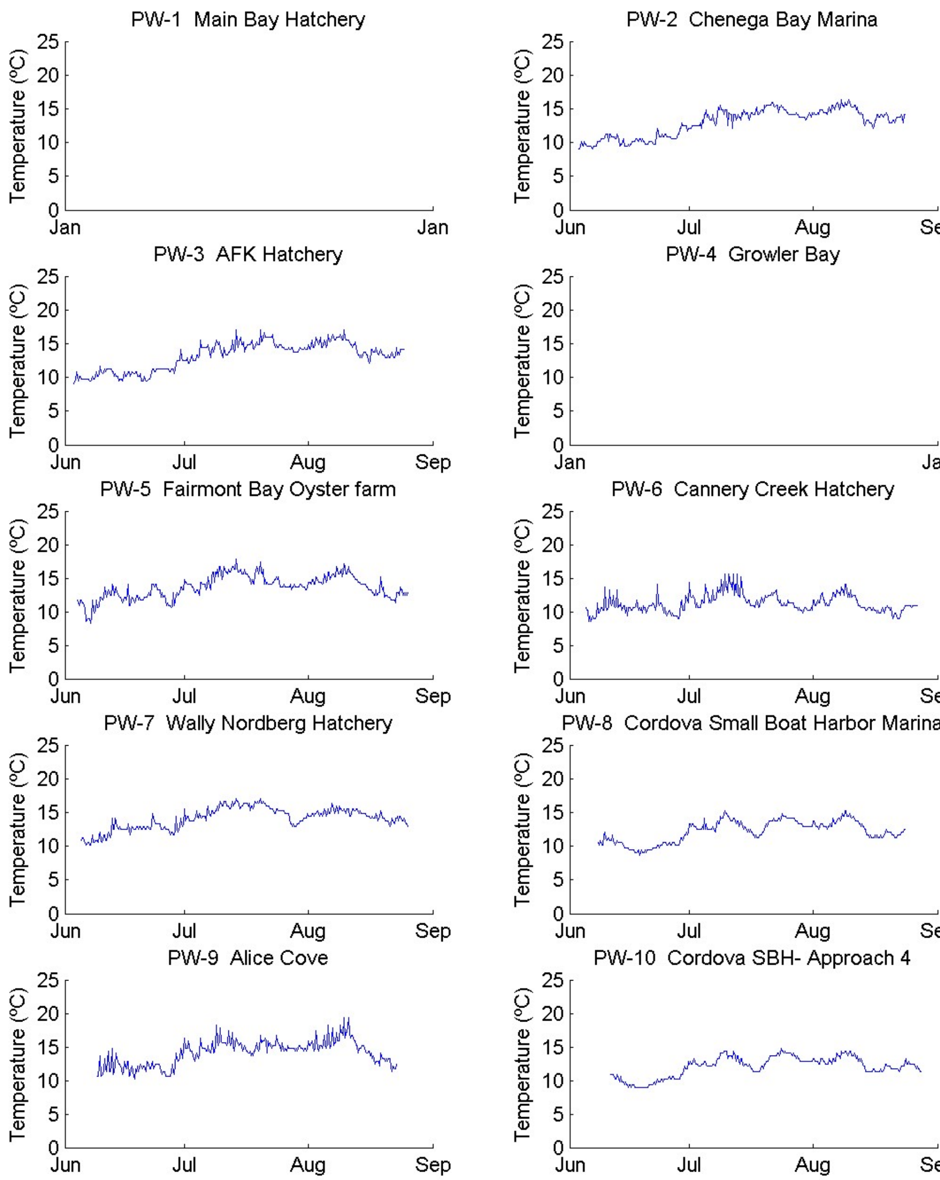
## Water Temperature by Block for Ketchikan



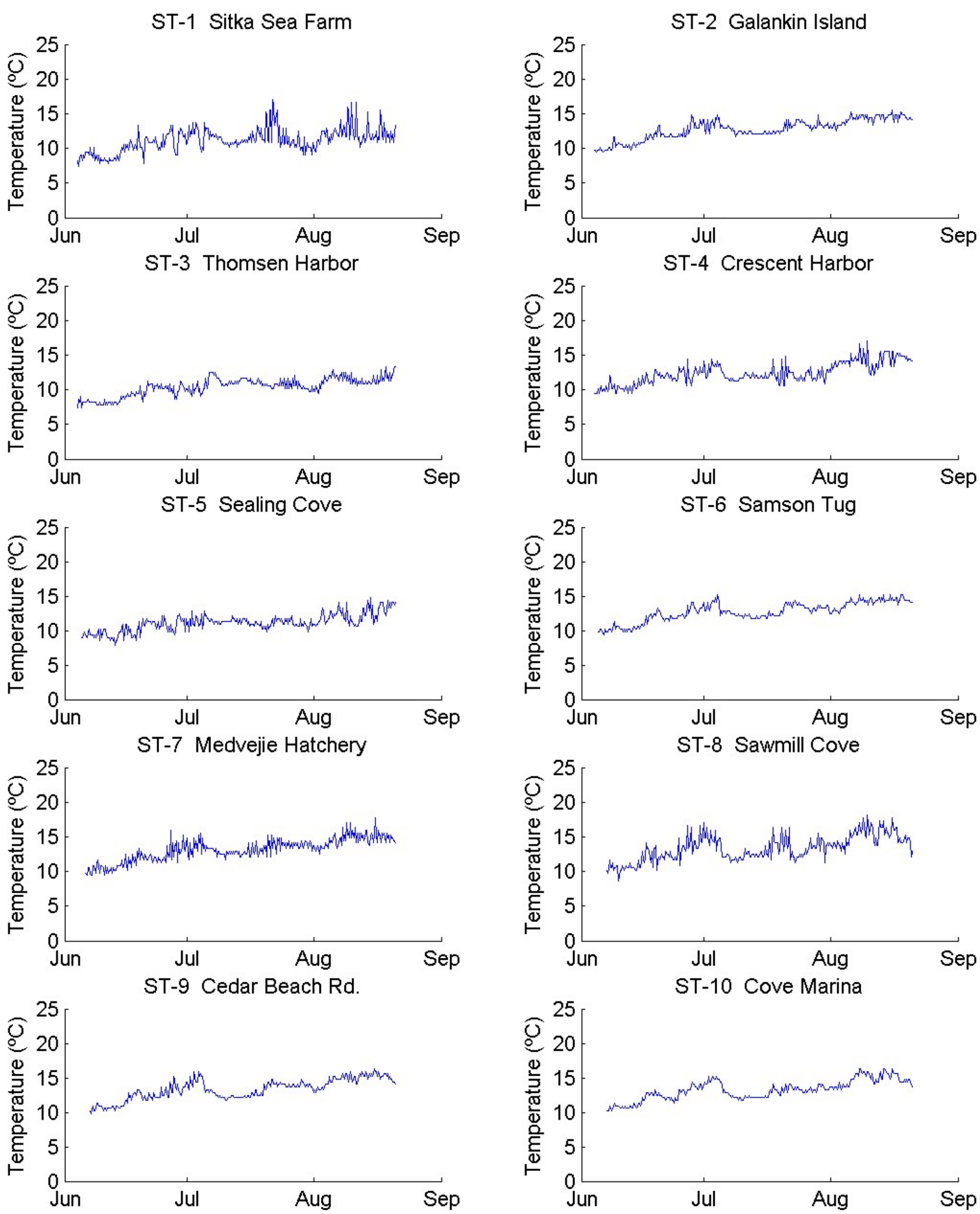
Water Temperature by Block for Kodiak



Water Temperature by Block for Prince William Sound



## Water Temperature by Block for Sitka



## Appendix D

### List of Species Identified from Standardized Surveys by Bay and Location (Blocks) at the Six Focal Bay Regions

[Shown are the number of blocks in which each species was detected per bay on panels. The species list for each site is divided between quantitative surveys and qualitative analysis. For quantitative analysis, all voucher species collected were identified to species or the lowest possible taxonomic unit. This was done for bryozoans, hydroids, tunicates, and nudibranchs. For qualitative analysis only a subset were identified to species (see text for further description). For each species, the invasion status is described as Native (N), Cryptogenic (C), Introduced (I), or Uncertain (U). Taxa with uncertain status were most often those that could not be identified to species, due to size or quality of the specimen upon colletion.]

| | | Block | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BAY | NIS STATUS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| **Dutch Harbor** | | | | | | | | | | | |
| A. Quantitative Analysis | | | | | | | | | | | |
| BRYOZOA | | | | | | | | | | | |
| Alcyonidium sp. | U | x | x | | x | | | x | | x | x |
| Alcyonidium sp. A | U | | | | x | x | x | x | x | x | x |
| Bugula pacifica | N | | | x | | | | | x | x | |
| Callopora sp. | U | | | | | | | | | | x |
| Cauloramphus sp. | U | | x | | | | | | | x | |
| Cauloramphus sp. A | U | | x | | | | | | | x | |
| Celleporella hyalina | C | x | x | x | x | x | x | x | x | x | x |
| Cribrilina corbicula | N | | | | | | | | | x | |
| Crisiella sp. A | U | | | | | | | | | | x |
| Lichenopora verrucaria | N | | | | | | | | | x | |
| Membranipora villosa | N | x | | | | | x | | | x | x |
| Tegella aquilirostris | N | | x | | x | | | x | x | x | x |
| Tegella armifera | N | | x | | x | | | | | x | |
| Tegella sp. | U | | x | | | | | | | x | x |
| Tegella sp. A | U | | | | | | | | | x | x |
| HYDROZOA | | | | | | | | | | | |
| Calycella syringa | C | | | | x | | | | | | |
| Campanulariidae | U | x | | x | | | | | x | x | |
| Clytia hemisphaerica | C | | | | x | | | | | x | |
| Clytia sp. | U | x | | | | | | | | x | |
| Cuspidella grandis | N | x | x | x | x | x | x | x | x | x | x |
| Cuspidella humilis | N | x | x | x | x | x | x | x | x | x | x |
| Cuspidella sp. | U | | x | x | | x | x | | | x | x |
| Gonothyraea clarki | C | | | | x | | x | x | x | x | x |
| Gonothyraea loveni | C | | x | | | | | | | | |
| Gonothyraea sp. | U | | | | | | | | | | x |
| Obelia dichotoma | C | x | x | x | x | x | x | x | x | x | x |
| Obelia longissima | C | x | x | x | x | x | x | x | x | x | x |
| Obelia sp. | U | x | x | | x | | | | | x | x |
| NUDIBRANCHIA | | | | | | | | | | | |
| Cuthona sp. | U | | | | | | | | x | | x |
| Dendronotus frondosus | N | x | x | | x | | | | x | | x |
| Eubranchus rupium | N | | | | x | | x | x | x | x | x |
| Flabellina trophina | N | | | | | | | x | x | x | x |
| Onchidoris bilamellata | N | x | | x | | x | x | x | x | x | |
| TUNICATA | | | | | | | | | | | |
| Ascidia callosa | N | x | x | | x | | | | x | x | x |
| Ascidia columbiana | N | | | | | | | | | x | |
| Ascidia sp. | U | | | | | | x | x | | | |
| Corella sp. | U | | | | | | | | | x | |
| Distaplia alaskensis | C | | | | | | | x | | | |
| Distaplia occidentalis | N | | x | x | x | x | | | x | | |
| Distaplia sp. | U | | x | | x | | | | x | | x |
| Molgula sp. | U | | | | | | | | x | | |

B. Qualitative Analysis

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANNELIDA | | | | | | | | | | | | |
| Serpulidae | | | | | | | | | | | | |
| | Pseudochitinopoma occidentalis | N | | | | x | | | | x | | x |
| Spirorbidae | | | | | | | | | | | | |
| | Circeis armoricana | N | | | | | | | | | x | |
| CRUSTACEA | | | | | | | | | | | | |
| Cirripedia | | | | | | | | | | | | |
| | Balanus crenatus | N | x | | | | | | | | | |
| | Semibalanus cariosus | N | x | | | x | | | | | | |
| MOLLUSCA | | | | | | | | | | | | |
| Bivalvia | | | | | | | | | | | | |
| | Hiatella arctica | N | x | x | | | | | | x | | x |
| | Mytilidae | U | | | | x | | | x | | | x |
| | Mytilus trossulus | N | | x | x | | | | x | x | x | x |
| | Turtonia minuta | N | x | | | | | | x | x | x | |
| Gastropoda | (except Nudibranchia) | | | | | | | | | | | |
| | cf. Lacuna sp. | U | | | | x | | | | | x | |
| | Lacuna vincta | N | x | | | x | x | x | x | x | x | |
| | Margarites pupillus | N | | | | | | | | | x | |
| | Trochidae cf. Margarites pupillus | U | | | | | | | | | x | |

**Kachemak Bay**

A. Quantitative Analysis

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRYOZOA | | | | | | | | | | | | |
| | Alcyonidium hirsutum | N | | | | | | x | | | | |
| | Alcyonidium irregulare | N | | | | | | | | | x | |
| | Alcyonidium nr polyoum | C | | x | | | x | x | | | | |
| | Alcyonidium sp. | U | | | | x | x | | | | | |
| | Alcyonidium sp. 2 | U | | | x | x | x | | | | | |
| | Bowerbankia aggregata | N | | | | | x | | | | | |
| | Bowerbankia sp. | U | x | | | | | | | | | |
| | Bugula pacifica | N | x | x | x | | | | | x | x | |
| | Callopora craticula var. sedovi | N | | | | | | | | | x | |
| | Celleporella hyalina | C | x | x | x | x | x | x | x | x | x | |
| | Cribrilina annulata | N | x | | | | | | | | x | |
| | Cribrilina corbicula | N | x | | | x | | | | | x | |
| | Electra crustulenta | C | x | | | | | | x | | x | |
| | Electra sp. | U | | | | | | | x | | | |
| | Lichenopora sp. | U | | | | | | | | x | | |
| | Lichenopora verrucaria | N | | | | x | | | | x | | |
| | Membranipora villosa | N | | | x | | | | | | | |
| | Parasmittina sp. | U | | | | | | | | | x | |
| | Porella acutirostris | N | | | | | | | | | x | |
| | Porella columbiana | N | | | | | | | | | x | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tegella aquilirostris | N | x | | x | | | | | | x |
| | Tubulipora sp. | U | | | | | | | | x | |
| HYDROZOA | | | | | | | | | | | |
| | Bougainvillia sp. | U | | x | | | | | | | |
| | Calycella syringa | C | x | | x | | | x | | x | |
| | Campanulina rugosa | N | | | | | | | | | x |
| | Clytia gracilis | C | | | | | | | | | x |
| | Clytia hemisphaerica | C | x | x | x | | | | x | | x |
| | Clytia kincaidi | N | x | | x | | | | | | |
| | Clytia sp. | U | | | | | | | | x | |
| | Cuspidella grandis | N | | | | x | | x | | x | |
| | Cuspidella humilis | N | x | | x | x | | x | | x | |
| | Cuspidella sp. | U | | | | | x | | | | x |
| | Gonothyraea clarki | C | x | x | x | x | x | x | x | x | x |
| | Gonothyraea loveni | C | | | x | | | x | | | x |
| | Laomedea exigua | C | | x | | | | | | | |
| | Laomedea sp. | U | x | | | | | | | | |
| | Obelia dichotoma | C | x | x | x | x | x | x | | | x |
| | Obelia geniculata | C | | | | x | | | | | |
| | Obelia longissima | C | x | x | x | x | x | | x | x | x |
| | Obelia sp. | U | x | x | x | x | x | x | | x | x |
| | Opercularella lacerata | C | | | | | | | | | x |
| | Opercularella sp. | U | | | | | x | | | | |
| | Sarsia eximia | C | | x | x | | | x | x | x | |
| | Sarsia sp. | U | | x | x | x | | x | x | | |
| | Sarsia tubulosa | C | | | x | | | | | x | |
| NUDIBRANCHIA | | | | | | | | | | | |
| | Acanthodoris pilosa | N | x | | | | x | | | | |
| | Aeolidiidae | U | | | x | x | | | | | |
| | Cuthona cf. pustulata | U | | | | | | | x | | |
| | Cuthona sp. | U | | | | x | | | | | |
| | Cuthona viridis | C | | | x | | | | | | |
| | Dendronotus frondosus | N | x | | x | | | | x | x | |
| | Dendronotus sp. | U | | | x | x | | | x | | |
| | Eubranchus olivaceus | N | x | x | x | x | x | x | x | x | x |
| | Eubranchus rupium | N | | | | x | x | | | | |
| | Onchidoris bilamellata | N | x | | x | x | x | x | | | x |
| | Onchidoris sp. | U | | x | | | | | | | |
| TUNICATA | | | | | | | | | | | |
| | Ascidia callosa | N | x | | x | | | | x | x | x |
| | Ascidia columbiana | N | x | | x | | | | | | |
| | Ascidia sp. | U | | | x | | | | | | x |
| | Botrylloides violaceus | I | x | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cnemidocarpa finmarkiensis | N | | x | | | | | | | |
| Distaplia alaskensis | C | | | | | | | | x | x |
| Distaplia occidentalis | N | | | | | | | | x | |
| Molgula retortiformis | N | | | x | | | | | x | |
| Perophora sp. | U | | | | | | | | x | |
| Styela sp. | U | | | | | | | | x | |

B. Qualitative Analysis

ANNELIDA

Serpulidae

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Crucigera zygophora | N | x | | | x | x | | | | x |
| Pseudochitinopoma occidentalis | N | x | x | x | x | x | x | x | x | x |
| Serpula sp. | U | x | | x | x | x | | | x | |

Syllidae

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Typosyllis sp. | U | x | | | | | | | | |

CRUSTACEA

Isopoda

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Munna sp. | U | x | | | | | | | | |

MOLLUSCA

Bivalvia

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cardiidae | U | | | | | | x | | | |
| Mytilidae | U | | x | | x | x | | | | x |
| Mytilus trossulus | N | x | x | x | x | x | x | x | x | x |
| Turtonia minuta | N | | | | | | | x | | |

Gastropoda (except Nudibranchia)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Lacuna sp. | U | | | | x | | | x | | |
| Lacuna vincta | N | | | x | x | x | x | x | | |
| Margarites pupillus | N | | x | x | x | | | | | |
| Rissoidae cf. Onoba carpenteri | U | | | | | | | x | | |

**Ketchikan**

A. Quantitative Analysis

BRYOZOA

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Alcyonidium cf. hirsutum | U | | | | | | x | | | |
| Alcyonidium sp. | U | | | x | | | x | | x | x |
| Bowerbankia aggregata | N | | | | | x | | | | |
| Bowerbankia sp. | U | x | x | x | x | x | x | x | x | x |
| Bugula pacifica | N | x | x | x | x | x | x | x | x | x |
| Bugula sp. | U | x | | x | | | x | x | x | x |
| Callopora craticula | N | | | x | | | x | x | x | x |
| Callopora lineata | N | | | | | | | | | x |
| Celleporella cf. reflexa | U | | | | x | | | | | |
| Celleporella hyalina | C | x | x | x | x | x | x | x | x | x |
| Celleporella sp. | U | | | x | | | | | x | |
| Cribrilina annulata | N | | x | | x | | | x | | |
| Cribrilina corbicula | N | x | | x | x | | x | x | x | x |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cryptosula zavjalovensis | N | | | | x | | | | x | |
| Dendrobeania laxa | N | | | | | | | | | x |
| Dendrobeania lichenoides | N | | | | x | | | | | |
| Hippoporina insculpta | N | | x | | x | | | | | |
| Membranipora villosa | N | x | x | x | | | | x | | x |
| Pacificincola insculpta | N | | | | x | | | | | |
| Rhamphostomella sp. | U | | | | | | | | | x |
| Schizoporella japonica | I | x | x | x | x | x | x | x | x | x |
| Tegella aquilirostris | N | x | x | x | x | x | x | x | x | x |
| Tubulipora cf. pacifica | U | | | | | | | | | x |
| Tubulipora sp. | U | x | | x | | | | | | x |
| HYDROZOA | | | | | | | | | | |
| Campanulariidae | U | | x | | x | | | | | x |
| Clytia hemisphaerica | C | | | x | | | | | | |
| Clytia kincaidi | N | | | x | | | x | | x | x |
| Clytia sp. | U | | | x | x | | x | x | x | x |
| Pinauay crocea | I | | | | x | | | | | |
| Eudendrium sp. | U | | | | | | | | x | |
| Garveia sp. | U | | | | x | | | | | |
| Gonothyraea clarki | C | | | | | x | x | | | |
| Obelia dichotoma | C | | x | x | | | x | | | |
| Obelia longissima | C | x | x | x | x | x | x | | | x |
| Obelia sp. | U | | | | | x | | | | |
| Tubularia harrimani | N | | | | x | | | | | |
| NUDIBRANCHIA | | | | | | | | | | |
| Cuthona albocrusta | N | x | | | x | x | | | | |
| Cuthona sp. | U | | | | x | | | | | x |
| Dendronotus frondosus | N | | | x | | | | | | |
| Dirona sp. | U | | | | | | x | | | |
| Flabellina trophina | N | | x | x | | | | | | |
| Hermissenda crassicornis | N | | | | | | | x | | x |
| Onchidoris bilamellata | N | x | | | | x | | | | |
| Palio dubia | N | | | | | | | | | x |
| TUNICATA | | | | | | | | | | |
| Ascidia callosa | N | | | | | | | x | | |
| Botrylloides violaceus | I | x | x | | x | | x | | x | |
| Corella inflata | N | x | x | x | x | x | x | x | x | x |
| Corella sp. | U | | x | | | | x | | | x |
| Corella willmeriana | N | | | | | | x | x | | x |
| Distaplia occidentalis | N | x | x | x | x | | | | x | x |
| Halocynthia aurantium | N | | | | x | | | | | |
| Perophora annectens | N | | | | | | x | | | |
| Phlebobranchia | U | | x | | | | | | | |
| Styela sp. | U | | | | x | | | | | |
| B. Qualitative Analysis | | | | | | | | | | |
| CRUSTACEA | | | | | | | | | | |
| Cirripedia | | | | | | | | | | |
| Balanidae | U | | | | | | | | | x |
| Balanus crenatus | N | | | | | | x | | | |
| MOLLUSCA | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bivalvia | | | | | | | | | | | | |
| | Hiatella arctica | N | x | x | x | x | x | x | x | x | x | |
| | Macoma sp. | U | | | | | | | | x | | |
| | Mytilus trossulus | N | x | x | x | x | x | x | x | x | x | |
| | Pododesmus macroschisma | N | | x | | x | x | x | | x | x | |
| | Protothaca staminea | N | x | | | | x | x | | | | |
| | Veneridae cf. Nutricola tantilla | U | | | x | | | | | | | |
| Gastropoda | (except Nudibranchia) | | | | | | | | | | | |
| | Astyris gauspata | N | | x | | | | | | | | |
| | cf. Lacuna sp. | U | | | | | | | | x | | |
| | Crepipatella dorsata | N | | x | | | | | | | | |
| | Lacuna vincta | N | | x | | x | | x | | | | |
| | Lottia ochracea | N | | | x | | | | | | | |
| | Lottia sp. | U | | | | | x | | | | | |
| | Margarites pupillus | N | | x | | | | | | x | | |
| | Odostomia sp. | U | | x | x | | x | x | | | | |
| | Onoba carpenteri | N | | | x | x | | | | x | | |
| | Pododesmus macroschisma | N | | | | | | | x | | x | |
| **Kodiak** | | | | | | | | | | | | |
| <u>A. Quantitative Analysis</u> | | | | | | | | | | | | |
| BRYOZOA | | | | | | | | | | | | |
| | Alcyonidium hirsutum | N | | | | x | | | | | | |
| | Alcyonidium mammillatum | N | | x | | | | | | x | | |
| | Alcyonidium nr polyoum | C | | x | | | | | | | | |
| | Alcyonidium sp. | U | | x | | x | | x | | x | | x |
| | Bowerbankia aggregata | N | x | | | | | | | | | |
| | Bugula pacifica | N | | x | x | x | x | | x | x | x | x |
| | Bugula sp. | U | | x | | | | | | | | |
| | Callopora craticula | N | | | | | | | | x | | x |
| | Callopora lineata | N | | | x | | | | | | | x |
| | Callopora sp. | U | | | | | | | | | | x |
| | Celleporella hyalina | C | x | x | x | x | x | x | x | x | x | x |
| | Cribrilina annulata | N | | | | x | | | x | x | x | x |
| | Cribrilina corbicula | N | | | x | x | | | | | | x |
| | Crisiella sp. A | U | | | | | | | | x | | |
| | Cylindroporella tubulosa | N | | | | | | | | x | | |
| | Filicrisia sp. A | U | | | | | | | | x | | |
| | Heteropora sp. | U | | | | | | | | | | x |
| | Lichenopora sp. | U | | | x | | | | | x | | x |
| | Lichenopora verrucaria | N | | x | x | | | | | x | | x |
| | Parasmittina sp. | U | | | | | | | | | | x |
| | Parasmittina trispinosa | N | | | | | | | | | | x |
| | Tegella aquilirostris | N | | x | x | x | | | | x | | |
| | Tegella arctica | N | | | | | | | | | | x |
| | Tegella armifera | N | | x | x | | | | | | | x |
| | Tegella cassidata | N | | x | | | | | | | | |
| | Tubulipora flabellaris | N | | | | | | | | | | x |
| | Tubulipora sp. | U | | | | | | | | | | x |
| | Tubulipora tuba | N | | | | | | | | | | x |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HYDROZOA | | | | | | | | | | | |
| Calycella syringa | C | | | | x | | | | | | x |
| Campanulina rugosa | N | | | | | | | | | | x |
| Clytia gracilis | C | | x | x | | x | x | x | | | x |
| Clytia hemisphaerica | C | x | | x | x | | | | x | x | x |
| Clytia kincaidi | N | | | x | | | x | | | | |
| Clytia sp. | U | | | | | | | x | | | x |
| Garveia annulata | N | | | | | x | | | | | |
| Gonothyraea clarki | C | | x | x | x | | | | | | x |
| Gonothyraea gracilis | C | | | | | | | | | x | x |
| Obelia dichotoma | C | | | x | | x | | x | | | |
| Obelia longissima | C | x | x | x | x | x | x | x | x | x | x |
| Obelia sp. | U | | x | | x | | x | x | | | x |
| Opercularella lacerata | C | | | x | | | | x | x | | |
| Sarsia eximia | C | | | | x | | | | | | x |
| Sarsia sp. | U | | x | | | | | | x | | x |
| NUDIBRANCHIA | | | | | | | | | | | |
| Acanthodoris pilosa | N | | x | x | x | x | x | x | x | x | x |
| Acanthodoris sp. | U | | | | x | | x | | | | |
| Adalaria jannae | N | | x | | | | | | | | |
| Aeolidia papillosa | N | | x | x | | x | | | | | |
| Cuthona concinna | N | | | | x | | | | | | |
| Dendronotus frondosus | N | | x | x | x | x | | x | x | | x |
| Dirona sp. | U | | | x | | | | | | | |
| Eubranchus rupium | N | x | x | x | | x | | | | x | x |
| Flabellina trophina | N | x | x | x | x | x | x | x | x | | x |
| Hermissenda crassicornis | N | | x | x | x | x | x | x | | x | |
| Onchidoris bilamellata | N | x | | | | | | x | x | | |
| Onchidoris muricata | N | x | | | x | | x | x | x | x | |
| Palio dubia | N | x | | x | x | | x | | | x | |
| TUNICATA | | | | | | | | | | | |
| Ascidia callosa | N | | | | x | x | | x | x | | x |
| Ascidia columbiana | N | | | | x | | | | | | |
| Ascidia sp. | U | | | | x | | | | | | |
| Didemnum albidum | C | | | | | | | | | | x |
| Didemnum carnulentum | C | | | | | | | | | | x |
| Distaplia occidentalis | N | | x | x | x | x | | x | x | | x |
| Distaplia sp. | U | | x | x | | x | | x | x | | x |
| Molgula retortiformis | N | | x | x | x | x | | | | | |
| Molgula sp. | U | | x | | x | | | | | | |
| Styela sp. | U | | x | | | | | | | | |
| Styela truncata | N | | x | x | x | | | x | x | x | |

<u>B. Qualitative Analysis</u>

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ANNELIDA | | | | | | | | | | | |
| Serpulidae | | | | | | | | | | | |
| Crucigera zygophora | N | | | | x | x | x | | x | x | x |
| Pseudochitinopoma occidentalis | N | | x | x | x | x | x | x | x | x | x |
| Serpula sp. | U | | | | x | x | | | x | x | |
| Spirorbidae | | | | | | | | | | | |
| Circeis armoricana | N | | x | x | x | | | | x | | x |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Circeis spirillum | N | | | | | | | | x | | x |
| | Paradexiospira vitrea | N | | | | | | | | | | x |
| CRUSTACEA | | | | | | | | | | | | |
| Cirripedia | | | | | | | | | | | | |
| | Balanus crenatus | N | x | | | | | | | | | |
| | Balanus sp. | U | x | | | | | | | | | |
| MOLLUSCA | | | | | | | | | | | | |
| Bivalvia | | | | | | | | | | | | |
| | Cardiidae | U | | x | | x | | | x | | | |
| | cf. Macoma sp. | U | | | | | x | | | | | |
| | Hiatella arctica | N | x | x | | | x | x | | | | |
| | Mytilidae | U | | | | | | | | | | x |
| | Mytilus trossulus | N | x | x | x | x | x | x | x | x | x | x |
| | Turtonia minuta | N | | | | x | | | x | | | x |
| Gastropoda | (except Nudibranchia) | | | | | | | | | | | |
| | Astyris gauspata | N | | | x | | | | | | x | |
| | cf. Margarites sp. | U | | | x | x | x | x | x | | x | x |
| | Crepidula sp. | U | | | | | | | | | | x |
| | Lacuna cf. vincta | N | | | x | x | x | | | | | |
| | Lacuna sp. | U | x | x | | x | x | | | | | |
| | Lacuna vincta | N | x | x | x | x | x | | x | | x | x |
| | Lottia cf. pelta | U | x | | | | | | | | | |
| | Lottia sp. | U | | | | x | | | | | x | |
| | Margarites pupillus | N | x | x | | x | | | | | | x |
| | Margarites sp. | U | | | | | | | | | x | |
| | Odostomia sp. | U | | | x | | | | | | | |
| | Onoba carpenteri | N | | | | | | x | x | | | |
| | Pododesmus macroschisma | N | | | x | x | | | | | | |
| | cf. Trochidae | N | x | x | x | | | | | | | |
| | Turtonia minuta | N | | | x | x | | | x | | | x |

**Prince William Sound**

A. Quantitative Analysis

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRYOZOA | | | | | | | | | | | | |
| HYDROZOA | | | | | | | | | | | | |
| | Campanulariidae | U | | | x | x | | | | | | |
| | Clytia hemisphaerica | C | x | | | x | | x | | | | |
| | Clytia kincaidi | N | | | x | x | | | | | | |
| | Clytia sp. | U | | | | x | | x | | | | |
| | Cuspidella humilis | N | | | | x | | | | | | |
| | Cuspidella sp. | U | | | | x | | | | | | |
| | Gonothyraea clarki | C | x | | x | x | | | | | | |
| | Obelia dichotoma | C | | x | x | x | x | x | x | x | x | |
| | Obelia longissima | C | | | x | | x | x | x | | x | |
| | Obelia sp. | U | x | x | | | | | x | x | x | x |
| NUDIBRANCHIA | | | | | | | | | | | | |
| | Eubranchus rupium | N | | | | | | x | | | | |
| | Flabellina trophina | N | | | | x | | x | | | | |
| | Hermissenda crassicornis | N | | x | x | | x | x | x | | | x |
| | Palio dubia | N | | | | | x | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TUNICATA | | | | | | | | | | | | |
| | Ascidia callosa | N | | | | | x | | | | | |
| | Corella inflata | N | | x | | | x | | x | x | | x |
| | Corella sp. | U | | | x | | x | | | | | |
| | Corella willmeriana | N | | | | | | | | x | | |
| | Distaplia alaskensis | C | | | | | | | | x | | x |
| | Distaplia occidentalis | N | | | | | | | | x | | x |
| | Distaplia sp. | U | | | | | | | | x | | |
| | Pyuridae | U | | | x | | | | | | | |

<u>B. Qualitative Analysis</u>

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CRUSTACEA | | | | | | | | | | | | |
| Cirripedia | | | | | | | | | | | | |
| | Balanus crenatus | N | x | x | x | | x | | x | | x | x |
| | Balanus glandula | N | x | x | x | x | x | x | x | | x | x |
| MOLLUSCA | | | | | | | | | | | | |
| Bivalvia | | | | | | | | | | | | |
| | cf. Protothaca staminea | N | | | x | | | | | | | |
| | Hiatella arctica | N | x | x | x | x | x | x | x | x | x | x |
| | Lacuna vincta | U | | | x | | | | x | | | |
| | Mytilus sp. | N | | | x | | | | | | | |
| | Mytilus trossulus | U | x | x | x | x | x | x | x | x | x | x |
| | Veneridae | U | | | x | | | | | | | |
| Gastropoda | (except Nudibranchia) | | | | | | | | | | | |
| | Astyris gauspata | N | | | | | x | | x | | | |
| | Crepidula sp. | U | | | | | x | | | | | |
| | Lacuna sp. | U | | | x | x | | | | | | |
| | Lacuna vincta | N | x | | x | | x | x | x | | x | |
| | Littorina scutulata | N | | | | | x | | | | | |
| | Littorina sitkana | N | | | | | | x | | | | |
| | Odostomia sp. | U | | | | | | | x | | | |
| | Onoba carpenteri | N | | | x | | x | | | | | |

**Sitka**

<u>A. Quantitative Analysis</u>

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRYOZOA | | | | | | | | | | | | |
| | Alcyonidium polyoum | C | | | | | | | x | | | |
| | Bowerbankia aggregata | N | x | | x | | | | | | | x |
| | Bowerbankia sp. | U | x | | x | | | | | | | |
| | Bowerbankia sp. B | U | | | x | | | | | | | |
| | Bugula pacifica | N | x | x | x | x | x | x | x | x | x | x |
| | Callopora craticula | N | x | | | | | x | | x | | x |
| | Celleporella hyalina | C | x | x | x | x | x | x | x | | x | x |
| | Cribrilina annulata | N | x | | | x | x | x | | x | x | x |
| | Cribrilina corbicula | N | x | x | | | | x | | | x | x |
| | Ctenostomata | U | x | | | | | | | | | |
| | Cyclostomata | U | x | x | | | | | | | | |
| | Fenestrulina delicia | C | x | | | | | | | | | |
| | Fenestruloides eopacifica | N | x | | | | | | | | | |
| | Fenestruloides sp. | U | x | | | | | | | | | |
| | Fenestruloides sp. A | U | x | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Membranipora sp. | U | | | | x | | | | | | |
| | Membranipora villosa | N | | | | x | | x | | | | x |
| | Schizoporella japonica | I | x | x | x | x | x | x | | | x | x |
| | Tegella aquilirostris | N | x | x | x | x | x | x | | x | | x |
| | Tubulipora pacifica | N | | | | | | x | | | | |
| | Tubulipora sp. | U | | | | | | x | | x | | |
| | Tubulipora sp. B | U | | | | | | x | | | | |
| | Tubulipora sp. C | U | | | | | | x | | | | |
| | Tubulipora tuba | U | x | x | | | | x | | x | | |
| HYDROZOA | | | | | | | | | | | | |
| | Clytia gracilis | C | x | | x | | | | | | x | |
| | Clytia hemisphaerica | C | x | | x | x | | x | x | | | |
| | Clytia kincaidi | N | | | x | | | | | | | |
| | Clytia sp. | U | | | | x | | | x | | | |
| | Garveia sp. | U | | | | | | | x | | | |
| | Gonothyraea clarki | C | | | x | | | | x | | | |
| | Gonothyraea sp. | U | | | x | | | | | | | |
| | Obelia dichotoma | C | | | | | | | | | | x |
| | Obelia longissima | C | | | x | | x | | x | | x | x |
| | Obelia sp. | U | | | x | | x | | | | | |
| NUDIBRANCHIA | | | | | | | | | | | | |
| | Acanthodoris pilosa | N | | | x | | x | | x | | | |
| | Acanthodoris sp. | U | | | | | | | x | | | |
| | Aeolidia papillosa | N | | | | | | | x | | | |
| | Corambe steinbergae | N | | | | | | | | | | x |
| | Cuthona sp. | U | | x | | | | | x | | x | |
| | Dendronotus frondosus | N | | | | | | | x | | | x |
| | Dirona sp. | U | x | | | x | | | | | x | |
| | Eubranchus rupium | N | x | | | | x | | | | x | |
| | Flabellina trophina | N | | | | | | | x | | | |
| | Hermissenda crassicornis | N | x | x | x | x | x | x | x | | | x |
| | Onchidoris bilamellata | N | | | x | | x | | | | | |
| | Palio dubia | N | | | x | | x | | x | | x | x |
| TUNICATA | | | | | | | | | | | | |
| | Ascidia callosa | N | | | x | | x | | | | | |
| | Ascidia columbiana | N | | | x | | | | | | | x |
| | Ascidia sp. | U | x | | | x | | | | | | |
| | Botrylloides sp. | U | | | | | x | | | | | |
| | Botrylloides violaceus | I | x | x | x | x | x | | | | x | x |
| | Botryllus schlosseri | I | | | x | x | x | | | | | |
| | Corella inflata | N | x | | x | x | x | | | x | x | x |
| | Corella sp. | U | | | | | | | | | x | |
| | Corella willmeriana | N | | | | x | | | | x | | x |
| | Didemnidae | U | x | | | | | | | | | |
| | Didemnum carnulentum | C | x | | | | | | | | | |
| | Distaplia occidentalis | N | | | x | x | | x | | | | x |
| | Distaplia sp. | U | x | x | | x | x | x | | | | x |
| | Styela sp. | U | x | | x | | x | x | | | x | |
| | Styela truncata | N | x | | x | x | x | | | | x | x |

B. Qualitative Analysis

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANNELIDA | | | | | | | | | | | | |
| Serpulidae | | | | | | | | | | | | |
| | Pseudochitinopoma occidentalis | N | x | x | | x | | x | | x | | x |
| | Salmacina tribranchiata | N | x | | | x | | | | | x | |
| | Serpula sp. | U | x | x | x | x | x | x | | | | x |
| CRUSTACEA | | | | | | | | | | | | |
| Cirripedia | | | | | | | | | | | | |
| | Balanus crenatus | N | | | x | | | | | | | x |
| | Balanus sp. | U | | | x | | | | | | | |
| MOLLUSCA | | | | | | | | | | | | |
| Bivalvia | | | | | | | | | | | | |
| | cf. Diplodonta sp. | U | | | x | | | | | | | |
| | Hiatella arctica | N | | | x | | x | | | | | x |
| | Mytilus sp. | U | | | x | | | | | | | |
| | Mytilus trossulus | N | x | x | x | x | x | x | x | x | x | x |
| | Pododesmus macroschisma | N | | | | | | | | | | x |
| | Veneridae | U | x | x | | | | | | | | |
| Gastropoda | (except Nudibranchia) | | | | | | | | | | | |
| | Astyris gauspata | N | x | x | x | | | | | | | x |
| | cf. Astyris sp. | U | | x | | | | | | | | |
| | cf. Margarites pupillus | U | x | | | | | | | | | |
| | cf. Margarites sp. | U | | | x | | | | | | | |
| | Crepidula sp. | U | x | x | x | x | x | | x | x | | x |
| | Crepipatella dorsata | N | | | | | | | | | | x |
| | Diaphana sp. | U | x | | | | | | | | | |
| | Haminoea cf. vesicula | U | | | | x | | | | | | |
| | Haminoea vesicula | N | x | | | | | | | | | |
| | Lacuna cf. vincta | U | | | | | x | | x | | | |
| | Lacuna sp. | U | x | x | | x | | x | x | x | | x |
| | Lacuna vincta | N | x | x | x | x | x | x | | x | x | x |
| | Lottia sp. | U | x | x | x | x | | | | | | |
| | Odostomia sp. | U | | x | x | | | | | | x | |
| | Onoba carpenteri | N | x | | | | | | | | | |
| | Pododesmus macroschisma | N | | x | | x | x | x | x | x | x | x |
| | Rissoidae cf. Onoba carpenteri | U | | | | x | | | | | | |
| | Tegula pulligo | N | x | | | | | | | | | |

## Appendix E

### List of Species Identified by Supplemental Survey from Port Valdez

[Shown are the species identified on panels from Port Valdez. Invasion stuats is shown as described for Appendix D.]

| BAY | | | | NIS STATUS |
|---|---|---|---|---|
| **Valdez** | | | | |
| | Qualitative Analysis Only | | | |
| | | ANNELIDA | | |
| | | Serpulidae | | |
| | | | Crucigera zygophora | N |
| | | | Pseudochitinopoma occidentalis | N |
| | | Spirorbidae | | |
| | | | Circeis armoricana | N |
| | | BRYOZOA | | |
| | | | Bugula californica | N |
| | | | Bugula cuculifera | N |
| | | | Bugula longirostrata | N |
| | | | Bugula pacifica | N |
| | | | Bugula sp. | U |
| | | | Bugulidae | U |
| | | | Callopora cf.craticula | U |
| | | | Callopora craticula | N |
| | | | Callopora sp. | U |
| | | | Celleporella hyalina | C |
| | | | Codonellina argentea | N |
| | | | Cribrilina corbicula | N |
| | | | Crisidia sp. | U |
| | | | Crisiella sp. | U |
| | | | Crisiella sp. A | U |
| | | | Cyclostomata | U |
| | | | Fenestrulina delicia | C |
| | | | Fenestruloides sp. | U |
| | | | Fenestruloides sp. A | U |
| | | | Fenestruloides/Fenestrulina sp. | U |
| | | | Lichenopora sp. | U |
| | | | Membranipora villosa | N |
| | | | Parasmittina sp. | U |
| | | | Parasmittina trispinosa | N |
| | | | Porella acutirostris | N |
| | | | Porella sp. | N |
| | | | cf. Porella sp. | U |
| | | | Rhamphostomella cellata | N |
| | | | Rhamphostomella sp. | U |
| | | | Tubulipora sp. | U |
| | | CRUSTACEA | | |
| | | Cirripedia | | |
| | | | Balanidae | U |
| | | | Balanus sp. | U |
| | | HYDROZOA | | |
| | | | Clytia gracilis | C |
| | | | Clytia hemisphaerica | C |

| | | |
|---|---|---|
| | Clytia kincaidi | N |
| | Clytia sp. | U |
| | Garveia annulata | N |
| | Garveia sp. | U |
| | Gonothyraea clarki | C |
| | Obelia dichotoma | C |
| | Obelia longissima | C |
| | Opercularella sp. | U |
| MOLLUSCA | | |
| Bivalvia | | |
| | Hiatella arctica | N |
| | Mytilidae | U |
| | Mytilus trossulus | N |
| Gastropoda | | |
| | Cuthona albocrusta | N |
| | Lacuna vincta | N |
| | Onchidoris bilamellata | N |
| | Pododesmus macroschisma | N |
| TUNICATA | | |
| | Ascidia sp. | U |
| | Corella inflata | N |

# Appendix F

## Cumulative List of Species Identified by Standardized and Supplemental Surveys at the Six Focal Bay Regions

[Shown are all species identified per bay number, combining results from Panels (P) and Supplemental (S) Surveys. For each species, the invasion status is described as Native (N), Cryptogenic (C), Introduced (I), or Uncertain (U). Taxa with uncertain status were most often those that could not be identified to species, due to size or quality of the specimen upon collection.]

| Bay Region | | | | | |
|---|---|---|---|---|---|
| | Group | Verified Genus | Verified Species | Plates(P) or Survey(S) | Invasion Status (N,I,C,U) |
| **ANCHORAGE** | | | | | |
| | Foraminifera | | | | |
| | | Alveolophragmium | columbiensis | S | N |
| | | Astrononion | gallowayi | S | N |
| | | Bolivina | decussata | S | N |
| | | Buccella | frigida | S | N |
| | | Buliminella | elegantissima | S | N |
| | | Cassidulina | minuta | S | N |
| | | Cibicides | fletcheri | S | N |
| | | Discorbis | sp. | S | U |
| | | Eggerella | advena | S | N |
| | | Elphidiella | hannai | S | N |
| | | Elphidium | excavatum clavatum | S | N |
| | | Elphidium | cf. subarticum | S | U |
| | | Fissurina | sp. | S | U |
| | | Globigerina | bulloides | S | N |
| | | Globigerina | quinqueloba | S | N |
| | | Globigerina | sp. | S | U |
| | | Haplophragmoides | sp. | S | U |
| | | Neogloboquadrina | pachyderma | S | N |
| | | Nonionella | basispinata | S | N |
| | | Trochammina | kellettae | S | N |
| | | Trochammina | macrescens | S | N |
| | | Trochammina | pacifica | S | N |
| | | Trochammina | squamiformis | S | N |
| | | Trochammina | sp. | S | U |
| | Crustacea | | | | |
| | Amphipoda | | | | |
| | | Lagunogammarus | setosus | S | N |
| | | Onisimus | litoralis | S | N |
| | Caridea | | | | |
| | | Crangon | franciscorum | S | N |
| | Copepoda | | | | |
| | | Acartia (Acartiura) | sp. | S | U |
| | | Calanus | sp. | S | U |
| | Mysids | | | | |
| | | Mysis | litoralis | S | N |
| | | Neomysis | mercedis | S | N |
| | Mollusca | | | | |
| | Bivalvia | | | | |
| | | Macoma | balthica | S | N |
| | Vascular plants | | | | |
| | | Achillea | millefolium var. borealis | S | N |
| | | Agropyron | subsecundum (Link) Hitche | S | N |

| | | | |
|---|---|---|---|
| Alnus | incana, Moench subspecies Tenuifolia (Nutt). Breitung | S | N |
| Angelica | lucida L. | S | N |
| Arabis | holboellii Hornem. | S | N |
| Arctostaphylos | uva-ursi (L.) Spreng. | S | N |
| Artemisia | arctica Less. | S | N |
| Atriplex | Gemlini C.A. Mey | S | N |
| Betula | papyrifera Marsh. | S | N |
| Bolboschoenus | maritimus | S | N |
| Bromus | inermis Leyss. | S | I |
| Calamagrostis | canadensis | S | N |
| Capsella | bursa pastoris (L.) Medic. | S | I |
| Carex | Lyngbyei Hornem. | S | N |
| Carex | ramenskii Kom | S | N |
| Carex | subspathacea Wormsk. | S | N |
| Chenopodium | album L. | S | I |
| Cicuta | mackenzieana Raup | S | N |
| Conioselinum | chinense (L.) BSP. | S | N |
| Crepis | tectorum L. | S | I |
| Elymus | repens (L.) Beauv. | S | I |
| Epilobium | angustifolium L. | S | N |
| Epilobium | palustre L. | S | N |
| Equisetum | arvense L. | S | N |
| Equisetum | fluviatile L. ampl. Ehrh. | S | N |
| Equisetum | palustre L. | S | N |
| Erysimum | Cheiranthoides L. Cheiranthoides subspecies | S | I |
| Festuca | rubra L. coll. | S | N |
| Galium | trifidum L. Columbianum subspecies (Rydb.) Hult. | S | N |
| Glaux | maritima L. | S | N |
| Hedysarum | alpinum L. | S | N |
| Hieracium | umbellatum L. | S | N |
| Hippuris | vulgaris L. | S | N |
| Hordeum | jubatum L. | S | N |
| Hordeum | murinum, Leporinum subspecies | S | N |
| Lathyrus | maritimus L. | S | N |
| Lathyrus | palustris L. | S | N |
| Lepidium | densiflorum Schrad | S | N |
| Leucanthemum | vulgaris Lam. | S | I |
| Leymus | mollis (Trin) Polger | S | N |
| Ligusticum | scoticum Hultenii subspecies (Fern) | S | N |
| Linaria | vulgaris Mill. | S | I |
| Linum | perenne L. subspecies Lewisii (Pursh) Hult | S | I |
| Lolium | multiflorum Lam. | S | I |
| Lupinus | polyphyllus Lindl. | S | N |
| Lupinus | nootkatensis Donn | S | N |
| Melilotus | alba Medkius | S | I |
| Oxytropis | campestris var. varians (Rybd.) Barneby | S | N |
| Phleum | pratense L. | S | I |
| Plantago | maritima L. | S | N |
| Plantago | major L. | S | I |
| Poa | eminens Presl | S | N |

| | | | | | |
|---|---|---|---|---|---|
| | | Polemonium | pulcherrimum Hook. | S | N |
| | | Polygonum | aviculare L. | S | I |
| | | Polygonum | convolvulus L. | S | I |
| | | Populus | trichocarpa | S | N |
| | | Potentilla | palustris (L.) Scop. | S | N |
| | | Potentilla | diversifolia Lehm. | S | N |
| | | Potentilla | Egedii Wormsk. | S | N |
| | | Potentilla | norvegica L. | S | N |
| | | Puccinellia | phryganodes (Trin) | S | N |
| | | Puccinellia | nutkaensis (Presl) | S | N |
| | | Ranunculus | cymbalaria Pursh | S | N |
| | | Ribes | hudsonianum Richards. | S | N |
| | | Ribes | triste Pall | S | N |
| | | Rhinanthus | minor L. | S | N |
| | | Rosa | acicularis Lindl. | S | N |
| | | Rubus | idaeus L. | S | N |
| | | Rumex | fenestratus Greene | S | N |
| | | Rumex | transitorius Rech. F. | S | N |
| | | Salicornia | europea L. | S | N |
| | | Spergularia | canadensis (Pers) G. Don | S | N |
| | | Stellaria | humifusa Rottb. | S | N |
| | | Stellaria | media (L.) Vill. | S | I |
| | | Taraxacum | officinale Weber | S | I |
| | | Tragopogon | dubius Scop. | S | I |
| | | Trifolium | hybridum L. | S | I |
| | | Trifolium | pratense L | S | I |
| | | Trifolium | repens L. | S | I |
| | | Triglochin | maritimun L. | S | N |
| | | Triglochin | palustris L. | S | N |
| | | Trisetum | spicatum (L.) Richter | S | N |
| | | Typha | latifolia L. | S | N |
| | | Vicia | cracca L. | S | I |
| **DUTCH HARBOR** | | | | | |
| Annelida | | | | | |
| | Serpulidae | | | | |
| | | Pseudochitinopoma | occidentalis | P | N |
| | Spirorbidae | | | | |
| | | Circeis | armoricana | P | N |
| Bryozoa | | | | | |
| | | Alcyonidium | sp. | P | U |
| | | Alcyonidium | sp. A | P | U |
| | | Bugula | pacifica | P | N |
| | | Callopora | sp. | P | U |
| | | Cauloramphus | sp. | P | U |
| | | Cauloramphus | sp. A | P | U |
| | | Celleporella | hyalina | P | C |
| | | Cribrilina | corbicula | P | N |
| | | Crisiella | sp. A | P | U |
| | | Lichenopora | verrucaria | P | N |
| | | Membranipora | villosa | P | N |

| | | | | | |
|---|---|---|---|---|---|
| | | Tegella | aquilirostris | P | N |
| | | Tegella | armifera | P | N |
| | | Tegella | sp. | P | U |
| | | Tegella | sp. A | P | U |
| Cnidaria | | | | | |
| | Hydrozoa | | | | |
| | | Calycella | syringa | P | C |
| | | Campanulariidae | | P | U |
| | | Clytia | hemisphaerica | P | C |
| | | Clytia | sp. | P | U |
| | | Cuspidella | grandis | P | N |
| | | Cuspidella | humilis | P | N |
| | | Cuspidella | sp. | P | U |
| | | Gonothyraea | clarki | P | C |
| | | Gonothyraea | loveni | P | C |
| | | Gonothyraea | sp. | P | U |
| | | Obelia | dichotoma | P | C |
| | | Obelia | longissima | P | C |
| | | Obelia | sp. | P | U |
| Crustacea | | | | | |
| | Cirripedia | | | | |
| | | Balanus | crenatus | P | N |
| | | Semibalanus | cariosus | P | N |
| Mollusca | | | | | |
| | Bivalvia | | | | |
| | | Axinosida | serricata | S | N |
| | | Clinocardium | californiense | S | N |
| | | Clinocardium | ciliatum | S | N |
| | | Clinocardium | nuttallii | S | N |
| | | Clinocardium | sp. | S | U |
| | | Crassostraea | gigas (dead only) | S | I |
| | | Crenella | decussata | S | N |
| | | Diplodonta | aleutica | S | N |
| | | Eunuclua | tenuis | S | N |
| | | Hiatella | arctica | P, S | N |
| | | Kellia | suborbicularia | S | N |
| | | Macoma | balthica | S | N |
| | | Macoma | brota | S | N |
| | | Macoma | calcarea | S | N |
| | | Macoma | carlottensis | S | N |
| | | Macoma | golikovi | S | N |
| | | Macoma | inquinata | S | N |
| | | Macoma | moesta moesta | S | N |
| | | Mactromeris | polynyma | S | N |
| | | Modiolus | modiolus | S | N |
| | | Musculus | discors | S | N |
| | | Musculus | niger | S | N |
| | | Mya | pseudoarenaria | S | N |
| | | Mya | sp. | S | U |
| | | Mya | truncata | S | N |

| | | | |
|---|---|---|---|
| Mysella | sp. | S | U |
| Mytilidae | | P | U |
| Mytilus | trossulus | P, S | N |
| Nuculana | pernula | S | N |
| Nuculana | sp. | S | U |
| Nutricola | lordi | S | N |
| Pododesmus | macroschisma | S | N |
| Protothaca | staminea | S | N |
| Rochefordia | tumida | S | N |
| Saxidomus | giganteus | S | N |
| Serripes | groenlandicus | S | N |
| Tellina | lutea | S | N |
| Thracia | myopsis | S | N |
| Thracia | sp. | S | U |
| Thyasira | flexuosa | S | N |
| Thyasiridae | | S | U |
| Tindaria | sp. | S | U |
| Turtonia | minuta | P, S | N |
| Yoldia | thraeciaformis | S | N |
| Yoldiella | sp. | S | U |
| Gastropoda (except nudibranchia) | | | |
| Acmaea | sp. | S | U |
| Astyris | rosacea | S | N |
| Balcis | alaskensis | S | N |
| Boreotrophon | sp. | S | U |
| Buccinum | baeri | S | N |
| Buccinum | plectrum | S | N |
| Cingula | aleutica | S | N |
| Cingula | sp. | S | U |
| Collisella | sp. | S | U |
| Cryptobranchia | alba | S | N |
| Cryptobranchia | sp. | S | U |
| Cryptonatica | affinis | S | N |
| Fusitriton | oregonensis | S | N |
| cf. Lacuna | sp. | P | U |
| Lacuna | vincta | P,S | N |
| Littorina | sitkana | S | N |
| Lottia | borealis? | S | U |
| Lottia | pelta | S | N |
| Margarites | beringensis | S | N |
| Margarites | pupillus | P,S | N |
| Melanella | randolphi | S | N |
| Moelleria | quadrae | S | N |
| Moelleria | sp. | S | U |
| Neptunea | pribiloffensis | S | N |
| Neptunea | ventricosa | S | N |
| Nucella | canaliculata | S | N |
| Nucella | lima | S | N |
| Odostomia | spp. | S | U |
| Oenopota | sp. | S | U |

| | | | | | |
|---|---|---|---|---|---|
| | | Retusa | sp. | S | U |
| | | Rissoidae | | S | U |
| | | Siphonaria | thirsites | S | N |
| | | Solariella | obscura | S | N |
| | | Tectura | scutum | S | N |
| | | Tectura | sybaritica | S | N |
| | | Trichotropis | insignis | S | N |
| | | Trochidae cf. Margarites | pupillus | P | U |
| | | Troponopsis | sp. | S | U |
| | | Velutina | sp. | S | U |
| | | Volutharpa | ampullacea | S | N |
| | Nudibranchia | | | | |
| | | Cuthona | sp. | P | U |
| | | Dendronotus | frondosus | P, S | N |
| | | Eubranchus | rupium | P | N |
| | | Flabellina | trophina | P | N |
| | | Onchidoris | bilamellata | P, S | N |
| | | Onchidoris | muricata | S | N |
| | Polyplacophora | | | | |
| | | Katherina | tunicata | S | N |
| | | Mopalia | ciliata | S | N |
| | | Mopalia | hindsii | S | N |
| | | Schizoplax | brandtii | S | N |
| | | Spongioradsia | aleutica | S | N |
| | | Tonicella | lineata | S | N |
| Tunicata | | | | | |
| | | Ascidia | callosa | P | N |
| | | Ascidia | columbiana | P | N |
| | | Ascidia | sp. | P | U |
| | | Corella | sp. | P | U |
| | | Distaplia | alaskensis | P | C |
| | | Distaplia | occidentalis | P | N |
| | | Distaplia | sp. | P | U |
| | | Molgula | sp. | P | U |
| **KACHEMAK BAY** | | | | | |
| Annelida | | | | | |
| | Serpulidae | | | | |
| | | Crucigera | zygophora | P | N |
| | | Pseudochitinopoma | occidentalis | P | N |
| | | Serpula | sp. | P | U |
| | Syllidae | | | | |
| | | Typosyllis | sp. | P | U |
| Bryozoa | | | | | |
| | | Alcyonidium | hirsutum | P | N |
| | | Alcyonidium | irregulare | P, S | N |
| | | Alcyonidium | nr polyoum | P, S | C |
| | | Alcyonidium | sp. | P | U |
| | | Alcyonidium | sp. 2 | P | U |
| | | Alcyonidium | sp. A (transparent, on kelp) | S | U |
| | | Alcyonidium | sp. B (bubble kenozoids) | S | U |

| | | | |
|---|---|---|---|
| Alcyonidium | sp. C (thick, orange colored) | S | U |
| Alcyonidium | sp. D (gray/tan, high intertidal) | S | U |
| Alderina | brevispina | S | N |
| Berenicea | arctica | S | N |
| Bowerbankia | aggregata | P, S | N |
| Bowerbankia | sp. | P | U |
| Bugula | pacifica | P, S | N |
| Callopora | armata | S | N |
| Callopora | decidua | S | N |
| Callopora | craticula var. sedovi | P, S | N |
| Cauloramphus | magnus | S | N |
| Cauloramphus | pseudospinifer | S | N |
| Celleporella | hyalina | P, S | C |
| Celleporella | reflexa | S | N |
| Celleporella | sp. | S | N |
| Cribrilina | annulata | P | N |
| Cribrilina | corbicula | P, S | N |
| Crisia | cf. arctica | S | U |
| Crisia | sp. | S | N |
| Cryptosula | okadai | S | N |
| Cylindroporella | tubulosa | S | N |
| Dendrobeania | exilis | S | N |
| Dendrobeania | lichenoides | S | N |
| Desmacystis | sandalia | S | N |
| Diplosolen | obelia | S | N |
| Disporella | alaskensis | S | N |
| Electra | arctica | S | N |
| Electra | crustulenta | P, S | C |
| Electra | sp. | P | U |
| Ellisina | levata | S | N |
| Escharella | peristomata | S | N |
| Fenestruloides | eopacifica | S | N |
| Flustrellidra | cervicornis | S | N |
| Flustrellidra | gigantea | S | N |
| Harmeria | scutulata | S | N |
| Heteropora | alaskensis | S | N |
| Hippoporidra | truculenta | S | N |
| Hippoporina | apertura | S | N |
| Hippoporina | vulgaris | S | N |
| Hippothoa | mawatarii | S | N |
| Lagenicella | neosocialis | S | N |
| Lichenopora | sp. | P | U |
| Lichenopora | verrucaria | P | N |
| Membranipora | membranacea | S | N |
| Membranipora | serrilamella | P | N |
| Microporella | alaskana | S | N |
| Microporella | californica | S | N |
| Microporella | neocribroides | S | N |
| Microporina | articulata | S | N |
| Myriozoella | plana | S | N |

| | | | | |
|---|---|---|---|---|
| | Parasmittina | alaskensis | S | N |
| | Parasmittina | sp. | P | U |
| | Plagioecia | ambigua | S | N |
| | Porella | alba | S | N |
| | Porella | acutirostris | P, S | N |
| | Porella | columbiana | P, S | N |
| | Porella | immersa | S | N |
| | Rhynchozoon | tumulosum | S | N |
| | Scrupocellaria | arctica | S | N |
| | Smittina | majuscula | S | N |
| | Stomachetosella | cruenta | S | N |
| | Tegella | arctica | S | N |
| | Tegella | armifera | S | N |
| | Tegella | aquilirostris | P, S | N |
| | Tegella | horrida | S | N |
| | Terminoflustra | membranaceotruncata | S | N |
| | Tricellaria | occidentalis | S | N |
| | Tubulipora | penicillata | S | N |
| | Tubulipora | tuba | S | N |
| | Tubulipora | sp. | P, S | U |
| Cnidaria | | | | |
| Anthozoa | | | | |
| | Anthopleura | elegantissima | S | N |
| | Anthopleura | xanthogrammica | S | N |
| | Metridium | senile | S | U |
| | Urticina (Tealia) | columbiana | S | N |
| | Urticina (Tealia) | crassicornis | S | N |
| Hydrozoa | | | | |
| | Abietinaria | amphora | S | N |
| | Abietinaria | annulata | S | N |
| | Abietinaria | turgida | S | N |
| | Aequorea | aequorea v. aequorea | S | N |
| | Aequorea | aequorea v. albida | S | N |
| | Agalma | elegans | S | N |
| | Aglantha | digitale | S | N |
| | Bougainvillia | principis | S | N |
| | Bougainvillia | cf. superciliaris | S | U |
| | Bougainvillia | sp. | P, S | U |
| | Calycella | syringa | P, S | C |
| | Campanulina | rugosa | P | N |
| | Clytia | gracilis | P | C |
| | Clytia | gregaria (Phialidium gregarium) | S | C |
| | Clytia | hemisphaerica | P, S | C |
| | Clytia | kincaidi | P, S | N |
| | Clytia | sp. | P | U |
| | Cuspidella | grandis | P, S | N |
| | Cuspidella | humilis | P | N |
| | Cuspidella | sp. | P | U |
| | Dipleurosoma | typicum | S | N |
| | Eperetmus | typus | S | N |

| | | | | |
|---|---|---|---|---|
| | Eutonina | indicans | S | N |
| | Garveia | annulata | S | N |
| | Gonothyraea | clarki | P, S | C |
| | Gonothyraea | loveni | P | C |
| | Laomedea | exigua | P | C |
| | Laomedea | sp. | P | U |
| | Leuckartiara | cf. foersteri | S | U |
| | Melicertum | ostocostatum | S | N |
| | Mitrocoma | cellularia | S | N |
| | Obelia | dichotoma | P, S | C |
| | Obelia | geniculata | P | C |
| | Obelia | longissima | P, S | C |
| | Obelia | sp. | P | U |
| | Opercularella | lacerata | P, S | C |
| | Opercularella | sp. | P | U |
| | Orthopyxis | caliculata | S | C |
| | Polyorchis | penicillatus | S | N |
| | Proboscidactyla | flavicirrata | S | N |
| | Sarsia | sp. B "cliffordi" with short red stomach | S | U |
| | Sarsia | eximia | P, S | C |
| | Sarsia | sp. | P | U |
| | Sarsia | tubulosa | P, S | C |
| | Sertularia | robusta | S | N |
| | Sertularella | elegans | S | N |
| | Sertularella | rugosa | S | N |
| | Staurophora | mertensii | S | N |
| | Stomotoca | atra | S | N |
| | Thuiaria | dalli | S | N |
| Scyphozoa | | | | |
| | Aurelia | labiata | S | N |
| | Aurelia | cf.limbata (tan margin) | S | U |
| | Cyanea | capillata | S | N |
| | Haliclystus | salpinx/monstrosus | S | N |
| | unidentified scyphistomae | prob Aurelia sp. | S | U |
| Crustacea | | | | |
| Amphipoda | | | | |
| | Calliopiidae | | S | U |
| | Caprella | alaskana | S | N |
| | Caprella | laeviuscula | S | N |
| | Corophium | carlottensis | S | N |
| | Dexamonica | reduncans | S | N |
| | Ischyrocerus | sp. | S | N |
| | Jassa | staudei | S | N |
| | Metacaprella | kennerlyi | S | N |
| | Paraeurystheus | dentata | S | N |
| | Stenothoidae | | S | N |
| | Thorlaksonius | sp. | S | U |
| Copepoda | | | | |
| | Acrenhydrosoma | sp. | S | U |
| | Ameira | longipes | S | C |

| | | | |
|---|---|---|---|
| Ameira | sp. | S | U |
| Amphiascopsis | cinctus | S | C |
| Amphiascus | minutus | S | N |
| Amphiascus | sp. | S | U |
| Amphiascoides | sp.1 | S | U |
| Amphiascoides | sp. | S | U |
| Amonardia | arctica | S | N |
| Amonardia | normani | S | N |
| Arthropsyllus | serratus | S | C |
| Dactylopusia | vulgaris | S | N |
| Dactylopodella | sp. | S | U |
| Danielssenia | typica | S | N |
| Danielssenia | quadriseta | S | N |
| Diarthrodes | sp.1 | S | U |
| Diarthrodes | sp.2 | S | U |
| Diosaccus | spinatus | S | C |
| Echinolaophonte | sp. | S | N |
| Ectinosoma | sp. | S | N |
| Eupelte | sp. | S | U |
| Haloschizopera | sp. | S | U |
| Halectinosoma | sp. | S | U |
| Harpacticus | compressus | S | N |
| Harpacticus | septentrionalis | S | N |
| Harpacticus | uniremis | S | N |
| Harpacticus | sp.1 (uniremis group) | S | U |
| Harpacticus | sp.2 (obscurus group) | S | U |
| Harpacticus | sp. | S | U |
| Heterolaophonte | discophora | S | N |
| Heterolaophonte | longisetigera | S | N |
| Heterolaophonte | sp. | S | U |
| Laophonte | elongata | S | N |
| Mesochra | pygmaea | S | C |
| Mesochra | sp. | S | U |
| Normanella | sp. | S | U |
| Paradactylopodia | sp. | S | U |
| Paralaophonte | macera | S | N |
| Paralaophonte | pacifica | S | N |
| Paralaophonte | perplexa | S | N |
| Paralaophonte | sp.1 | S | U |
| Paramphiascelia | sp. | S | U |
| Parastenhelia | spinosa | S | N |
| Parathalestris | californica | S | N |
| Parathalestris | sp.1 | S | U |
| Porcellidium | sp. | S | U |
| Pseudonychocamptus | koreni | S | N |
| Pseudonychocamptus | spinifer | S | N |
| Scutellidium | sp. | S | U |
| Stenhelia | peniculata | S | N |
| Stenhelia | sp. | S | U |
| Tegastes | sp.1 | S | U |

| | | | | |
|---|---|---|---|---|
| | Tegastes | sp.2 | S | U |
| | Tisbe | cf. furcata | S | U |
| | Tisbe | sp.1 | S | U |
| | Tisbe | sp. | S | U |
| | Order Cyclopoida | | S | U |
| | Order Poecilostomatoida | | S | U |
| | Order Siphonostomatoida | | S | U |
| Cumacea | | | | |
| | Cumelia | vulgaris | S | N |
| Decapoda | | | | |
| | Cancer | magister | S | N |
| | Cancer | oregonensis | S | N |
| | Heptacarpus | brevirostris | S | N |
| | Hippolytidae | | S | U |
| | Majidae | | S | U |
| | Oregenia | gracilis | S | N |
| | Scyra | acutifrons | S | N |
| | Telmessus | cheiragonus | S | N |
| Isopoda | | | | |
| | Gnorimosphaeroma | oregonense | S | N |
| | Munna | sp. | P, S | U |
| Ostracoda | | | | |
| | Podocopida | | S | U |
| Mollusca | | | | |
| Bivalvia | | | | |
| | Astarte | arctica | S | N |
| | Axinopsida | serricata | S | N |
| | Cardiidae | | P | U |
| | Chlamys | rubida | S | N |
| | Clinocardium | californiense | S | N |
| | Clinocardium | nuttallii | S | N |
| | Clinocardium | sp. | S | U |
| | Crassostraea | gigas | S | I |
| | Dipodonta | impolita | S | N |
| | Entodesma | navicula | S | N |
| | Enucula | tenuis | S | N |
| | Glycymeris | septentrionalis | S | N |
| | Hiatella | arctica | S | N |
| | Humilaria | kennerlyi | S | N |
| | Kellia | suborbicularis | S | N |
| | Liocyma | fluctuosa | S | N |
| | Macoma | balthica | S | N |
| | Macoma | brota | S | N |
| | Macoma | expansa | S | N |
| | Macoma | golikovi | S | N |
| | Macoma | inquinata | S | N |
| | Macoma | lama | S | N |
| | Macoma | nasuta | S | N |
| | Mactromeris | polynyma | S | N |
| | Modiolus | modiolus | S | N |

| | | | |
|---|---|---|---|
| Musculus | discors | S | N |
| Musculus | sp. | S | U |
| Mya | arenaria | S | I |
| Mya | pseudoarenaria | S | N |
| Mya | sp. | S | U |
| Mya | truncata | S | N |
| Mytilidae | | P | U |
| Mytilus | trossulus | P, S | N |
| Nuculana | minuta | S | N |
| Nuculana | pernula | S | N |
| Pandora | sp. | S | U |
| Pandora | wardiana | S | N |
| Patinopecten | caurinus | S | N |
| Pododesmus | macroschisma | S | N |
| Protothaca | staminea | S | N |
| Rochefortia | turnida | S | N |
| Saxidomus | gigantea | S | N |
| Serripes | groenlandicus | S | N |
| Serripes | cf. laperousii | S | U |
| Serripes | sp. | S | U |
| Tellina | lutea | S | N |
| Tellina | modesta | S | N |
| Tellina | nuculoides | S | N |
| Thracia | myopsis | S | N |
| Thracia | trapzoides | S | N |
| Tresus | nuttallii | S | N |
| Turtonia | minuta | P, S | N |
| Valisina | vernicosa | S | N |
| Gastropoda (except nudibranchia) | | | |
| Aglaja | ocelligera | S | N |
| Acmaea | mitra | S | N |
| Amphissa | columbiana | S | N |
| Balcis | columbiana | S | N |
| Balcis | sp. | S | U |
| Bittium | sp. | S | U |
| Boreocingula | martyni | S | N |
| Boreotrophon | clathratus | S | N |
| Boreotrophon | truncatus | S | N |
| Buccinum | baeri | S | N |
| Buccinum | glaciale | S | N |
| cf. Cerithiopsis | | S | U |
| Cranopsis | cucullata | S | N |
| Crepidula | nummaria | S | N |
| Curitorna | incisula | S | N |
| Cryptobranchia | alba | S | N |
| Cryptobranchia | concentrica | S | N |
| Cryptonatica | affinis | S | N |
| Fusitriton | oregonensis | S | N |
| Lacuna | sp. | P | U |
| Lacuna | vincta | P, S | N |

| | | | | |
|---|---|---|---|---|
| | Lirabuccinum | dira | S | N |
| | Littorina | scutulata | S | N |
| | Littorina | sitkana | S | N |
| | Lottia | ochracea | S | N |
| | Lottia | pelta | S | N |
| | Margarites | beringensis | S | N |
| | Margarites | pupillus | P, S | N |
| | Moellaria | costulata | S | N |
| | Nassarius | mendicus | S | N |
| | Neadmete | modesta | S | N |
| | Neptunea | lyrata | S | N |
| | Nucella | canaliculata | S | N |
| | Nucella | lamellosa | S | N |
| | Nucella | lima | S | N |
| | Oenopota | alaskensis | S | N |
| | Oenopota | sp. | S | U |
| | Olivella | beatica | S | N |
| | Propebela | arctica | S | N |
| | Puncturella | galeata | S | N |
| | Puncturella | noachina | S | N |
| | Puncturella | sp. | S | U |
| | Rissoidae cf. Onoba | carpenteri | P | U |
| | Scabrotrophon | maltzani | S | N |
| | Spiromoellaria | kachemakensis | S | N |
| | Spiromoellaria | quadrae | S | N |
| | Tectura | persona | S | N |
| | Tectura | scutum | S | N |
| | Trichotropsis | cancellata | S | N |
| | Trichotropsis | insignis | S | N |
| | Velutina | velutina | S | N |
| Nudibranchia | | | | |
| | Acanthodoris | pilosa | P | N |
| | Aeolidia | papillosa | S | N |
| | Aeolidiidae | | P | U |
| | Archidoris | montereyensis | S | N |
| | Cuthona | cf.pustulata | P | U |
| | Cuthona | sp. | P | U |
| | Cuthona | viridis | P | C |
| | Dendronotus | frondosus | P, S | N |
| | Dendronotus | sp. | P | U |
| | Doridella | steinbergi | S | N |
| | Eubranchus | olivaceus | P, S | N |
| | Eubranchus | rupium | P | N |
| | Hermissenda | crassicornis | S | N |
| | Onchidoris | bilamellata | P, S | N |
| | Onchidoris | cf.muricata | S | U |
| | Onchidoris | sp. | P | U |
| | Polyceraalio (=Palio?) | zosterae | S | N |
| | Triopha | catalinae | S | N |
| Polyplacophora | | | | |

| | | | | |
|---|---|---|---|---|
| | Katharina | truncata | S | N |
| | Leptochiton | sp. | S | U |
| | Mopalia | cilata | S | N |
| | Mopalia | lignosa | S | N |
| | Mopalia | spectabilis | S | N |
| | Tonicella | insignis | S | N |
| | Tonicella | lineata | S | N |
| | Tonicella | sp. | S | U |
| Tunicata | | | | |
| | Aplidium | californicum | S | N |
| | Ascidia | callosa | P, S | N |
| | Ascidia | columbiana | P | N |
| | Ascidia | sp. | P | U |
| | Boltenia | sp. | S | U |
| | Botrylloides | violaceus | P | I |
| | Botryllus | sp. | S | U |
| | Cnemidocarpa | finmarkiensis | P | N |
| | Corella | inflata | S | N |
| | Corella | wilmeriana | S | N |
| | Didemnum | sp. | S | U |
| | Distaplia | alaskensis | P, S | C |
| | Distaplia | occidentalis | P, S | N |
| | Halocynthia | aurantium | S | N |
| | Molgula | retortiformis | P | N |
| | Perophora | sp. | P | U |
| | Styela | sp. | P, S | U |
| | Trididemnum | sp. | S | U |
| Other invertebrates | | | | |
| Echinoderm | | | | |
| | Asterias | amurensis | S | N |
| | Cucumaria | frondosa japonica | S | N |
| | Dermasterias | imbricata | S | N |
| | Eupentacta | pseudoquesemita | S | N |
| | Evasterias | troschellii | S | N |
| | Leptasterias | hexactis | S | N |
| | Pycnopodia | helianthoides | S | N |
| | Strongylocentrotus | droebachiensis | S | N |
| Ctenophora | | | | |
| | Beroe | cucumis | S | N |
| | Bolinopsis | infundibulum | S | N |
| | Pleurobrachia | bachei | S | N |
| Nemertea | | | | |
| | Amphiporus | angulatus | S | N |
| | Amphiporus | formidabilis | S | N |
| | Amphiporus | imparispinosus | S | N |
| | Carinoma | mutabilis | S | N |
| | Carinomella | lactea | S | N |
| | Cerebratulus | latus | S | N |
| | Cerebratulus | cf.marginatus | S | U |
| | Cerebratulus | montgomeryi | S | N |

| | | | | |
|---|---|---|---|---|
| | Emplectonema | buergeri | S | N |
| | Emplectonema | gracile | S | N |
| | Lineus | torquatus | S | N |
| | Micrura | alaskensis | S | N |
| | Micrura | verrilli | S | N |
| | Myoisophagos | sanguineus | S | N |
| | Paranemertes | cf.pallida | S | U |
| | Paranemertes | peregrina | S | N |
| | Paranemertes | sp. | S | U |
| | Procephalothrix | cf.spiralis | S | U |
| | Tetrastemma | spp. | S | U |
| | Tubulanus | sexlineatus | S | N |
| | Tubulanus | cf.theeli | S | U |
| | Zygonemertes | virescens | S | N |
| Vascular Plants | | | | |
| | Achillea | millefolium var. borealis | S | N |
| | Agrostis | scabra | S | N |
| | Argentina | anserina | S | N |
| | Atriplex | gmelini | S | N |
| | Atriplex | alaskensis | S | N |
| | Caltha | palustris | S | N |
| | Carex | lynbyei | S | N |
| | Carex | cf.mackenziei | S | U |
| | Carex | raminskii | S | N |
| | Cicuta | virosa | S | N |
| | Cochlearia | officinalis | S | N |
| | Conioselinum | gmelinii | S | N |
| | Dendranthema | arcticum | S | N |
| | Deschampsia | beringensis | S | N |
| | Eleocharis | kamtecharctica | S | N |
| | Epilobium | angustifolium | S | N |
| | Equisetum | fluviatile | S | N |
| | Equisetum | palustris | S | N |
| | Festuca | altaica | S | N |
| | Festuca | rubra | S | N |
| | Festuca | sp. | S | U |
| | Glaux | maritima | S | N |
| | Hippuris | tetraphylla | S | N |
| | Hippuris | vulgaris | S | N |
| | Honckenya | peploides | S | N |
| | Hordeum | brachyantherum | S | N |
| | Juncus | alpinus | S | N |
| | Juncus | articus | S | N |
| | Juncus | bufonius | S | N |
| | Juncus | sp. | S | U |
| | Lathyrus | japonicus | S | N |
| | Leymus | mollis | S | N |
| | Ligustichum | scoticum | S | N |
| | Luzula | multiflora | S | N |
| | Matricaria | discoidea | S | I |

| | | | |
|---|---|---|---|
| Parnassia | palustris | S | N |
| Plantago | major | S | I |
| Poa | arctica | S | N |
| Poa | eminens | S | N |
| Poa | glauca | S | N |
| Poa | pratensis | S | I |
| Poa | sp. | S | U |
| Polygonum | aviculare | S | I |
| Polygonum | viviparum | S | N |
| Potamogeton | gramineus | S | N |
| Potentilla | egedii | S | N |
| Potentilla | palustris | S | N |
| Puccinellia | hultenii | S | N |
| Puccinellia | phryganodes | S | N |
| Puccinellia | nutkaensis | S | N |
| Ranunculus | cymbalaria | S | N |
| Ranunculus | gmelini | S | N |
| Rhinanthes | minor var. groenlandica | S | N |
| Rubus | arcticus | S | N |
| Rumex | arctica var fenestrata | S | N |
| Salicornia | maritima | S | N |
| Sparganium | angustifolium | S | N |
| Spergularia | canadensis | S | N |
| Stellaria | humifusa | S | N |
| Taraxacum | officinale | S | I |
| Trifolium | repens | S | I |
| Triglochin | maritimum | S | N |
| Triglochin | palustris | S | N |
| Zostera | marina | S | N |

**KETCHIKAN**

Bryozoa

| | | | |
|---|---|---|---|
| Alcyonidium | cf.hirsutum | P | U |
| Alcyonidium | sp. | P | U |
| Bowerbankia | sp. | P | U |
| Bugula | pacifica | P, S | N |
| Bugula | pugeti | S | N |
| Bugula | sp. | P | U |
| Callopora | craticula | P, S | N |
| Callopora | lineata | P | N |
| Cauloramphus | magnus | S | N |
| Cauloramphus | multiavicularia (new species) | S | N |
| Cauloramphus | tortilis (new species) | S | N |
| Celleporella | hyalina | P, S | C |
| Celleporella | nodasakae (new species) | S | N |
| Celleporella | reflexa | P, S | N |
| Celleporella | sp. | P | U |
| Cribrilina | annulata | P, S | N |
| Cribrilina | corbicula | P, S | N |
| Cryptosula | zavjalovensis | P, S | N |
| Dendrobeania | laxa | P | N |

| | | | | |
|---|---|---|---|---|
| | Dendrobeania | lichenoides | P, S | N |
| | Fenestruloides | blaggae | S | N |
| | Fenestruloides | tongassorum (new species) | S | N |
| | Hippoporina | insculpta | P | N |
| | Hincksina | longiavicularia | S | N |
| | Membranipora | villosa | P, S | N |
| | Microporella | germana | S | N |
| | Microporella | ketchikanensis (new species) | S | N |
| | Microporella | neocribroides | S | N |
| | Microporella | setiformis | S | N |
| | Pacificincola | insculpta | S | N |
| | Porella | alba | S | N |
| | Porella | acutirostris | S | N |
| | Porella | donoghueorum (new species) | S | N |
| | Puellina | caesia (new species) | S | N |
| | Rhamphostomella | sp. | P | U |
| | Rhynchozoon | tumulosum | S | N |
| | Rhynchozoon | glabrum n. sp. | S | N |
| | Schizoporella | japonica | P, S | I |
| | Schizoporella | sp. | P | I |
| | Tegella | aquilirostris | P, S | N |
| | Tegella | horrida | S | N |
| | Tubulipora | cf.pacifica | P | U |
| | Tubulipora | sp. | P | U |
| Cnidaria | | | | |
| Hydrozoa | | | | |
| | Campanulariidae | | P | U |
| | Clytia | hemisphaerica | P | C |
| | Clytia | kincaidi | P | N |
| | Clytia | sp. | P | U |
| | Pinauay | crocea | P | I |
| | Eudendrium | sp. | P | U |
| | Garveia | sp. | P | U |
| | Gonothyraea | clarki | P | C |
| | Obelia | dichotoma | P | C |
| | Obelia | longissima | P | C |
| | Obelia | sp. | P | U |
| | Tubularia | harrimani | P | N |
| Crustacea | | | | |
| Cirripedia | | | | |
| | Balanidae | | P | U |
| | Balanus | crenatus | P | N |
| Mollusca | | | | |
| Bivalvia | | | | |
| | Hiatella | arctica | P | N |
| | Macoma | sp. | P | U |
| | Mytilus | trossulus | P | N |
| | Pododesmus | macroschisma | P | N |
| | Protothaca | staminea | P | N |
| | Veneridae cf. Nutricola | tantilla | P | U |

| | | | | |
|---|---|---|---|---|
| Gastropoda (except nudibranchia) | | | | |
| | Astyris | gauspata | P | N |
| | cf. Lacuna | sp. | P | U |
| | Crepipatella | dorsata | P | N |
| | Lacuna | vincta | P | N |
| | Lottia | ochracea | P | N |
| | Lottia | sp. | P | U |
| | Margarites | pupillus | P | N |
| | Odostomia | sp. | P | U |
| | Onoba | carpenteri | P | N |
| | Pododesmus | macroschisma | P | N |
| Nudibranchia | | | | |
| | Cuthona | albocrusta | P | N |
| | Cuthona | sp. | P | U |
| | Dendronotus | frondosus | P | N |
| | Dirona | sp. | P | U |
| | Flabellina | trophina | P | N |
| | Hermissenda | crassicornis | P | N |
| | Onchidoris | bilamellata | P | N |
| | Palio | dubia | P | N |
| Tunicata | | | | |
| | Aplidium | californicum | S | N |
| | Ascidia | callosa | P | N |
| | Ascidia | columbiana | S | N |
| | Boltenia | villosa | S | N |
| | Botrylloides | violaceus | P, S | I |
| | Cnemidocarpa | finmarkiensis | S | N |
| | Corella | inflata | P, S | N |
| | Corella | sp. | P | U |
| | Corella | willmeriana | P, S | N |
| | Chelyosoma | productum | S | N |
| | Distaplia | occidentalis | P, S | N |
| | Halocynthia | aurantium | P, S | N |
| | Metandrocarpa | taylori | S | N |
| | Perophora | annectens | P | N |
| | Phlebobranchia | | P | U |
| | Styela | sp. | P | U |
| | Styela | truncata | S | U |
| **KODIAK** | | | | |
| Annelida | | | | |
| Serpulidae | | | | |
| | Crucigera | zygophora | P | N |
| | Serpula | sp. | P | U |
| | Pseudochitinopoma | occidentalis | P | N |
| | Serpula | sp. | P | U |
| Spirorbidae | | | | |
| | Circeis | armoricana | P | N |
| | Circeis | spirillum | P | N |
| | Paradexiospira | vitrea | P | N |
| Bryozoa | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | | Alcyonidium | hirsutum | P | N |
| | | Alcyonidium | mammillatum | P | N |
| | | Alcyonidium | nr polyoum | P | C |
| | | Alcyonidium | sp. | P | U |
| | | Bowerbankia | aggregata | P | N |
| | | Bugula | pacifica | P | N |
| | | Bugula | sp. | P | U |
| | | Callopora | craticula | P | N |
| | | Callopora | lineata | P | N |
| | | Callopora | sp. | P | U |
| | | Celleporella | hyalina | P | C |
| | | Cribrilina | annulata | P | N |
| | | Cribrilina | corbicula | P | N |
| | | Crisiella | sp. A | P | U |
| | | Cylindroporella | tubulosa | P | N |
| | | Filicrisia | sp. A | P | U |
| | | Heteropora | sp. | P | U |
| | | Lichenopora | sp. | P | U |
| | | Lichenopora | verrucaria | P | N |
| | | Parasmittina | sp. | P | U |
| | | Parasmittina | trispinosa | P | N |
| | | Tegella | aquilirostris | P | N |
| | | Tegella | arctica | P | N |
| | | Tegella | armifera | P | N |
| | | Tegella | cassidata | P | N |
| | | Tubulipora | flabellaris | P | N |
| | | Tubulipora | sp. | P | U |
| | | Tubulipora | tuba | P | N |
| Crustacea | | | | | |
| | Cirripedia | | | | |
| | | Balanus | crenatus | P | N |
| | | Balanus | sp. | P | U |
| Cnidaria | | | | | |
| | Hydrozoa | | | | |
| | | Calycella | syringa | P | C |
| | | Campanulina | rugosa | P | N |
| | | Clytia | gracilis | P | C |
| | | Clytia | hemisphaerica | P | C |
| | | Clytia | kincaidi | P | N |
| | | Clytia | sp. | P | U |
| | | Garveia | annulata | P | N |
| | | Gonothyraea | clarki | P | C |
| | | Gonothyraea | gracilis | P | C |
| | | Obelia | dichotoma | P | C |
| | | Obelia | longissima | P | C |
| | | Obelia | sp. | P | U |
| | | Opercularella | lacerata | P | C |
| | | Sarsia | eximia | P | C |
| | | Sarsia | sp. | P | U |
| Mollusca | | | | | |

| | | | | |
|---|---|---|---|---|
| Bivalvia | | | | |
| | Bankia | etacea | S | N |
| | Cardiidae | | P | U |
| | Clinocardium | nuttallii | S | N |
| | Entodesma | navicula | S | N |
| | Hiatella | arctica | P, S | N |
| | cf. Macoma | sp. | P | U |
| | Macoma | baltica | S | N |
| | Macoma | golikovi | S | N |
| | Macoma | inquinata | S | N |
| | Macoma | lama | S | N |
| | Mactromeris | polynyma | S | N |
| | Modiolus | modiolus | S | N |
| | Musculus | glacialis | S | N |
| | Mya | arenaria | S | I |
| | Mya | pseudoarenaria | S | N |
| | Mya | truncata | S | N |
| | Mytilidae | | P | U |
| | Mytilus | trossulus | P, S | N |
| | Pododesmus | macroschisma | S | N |
| | Protothaca | staminea | S | N |
| | Saxidomus | gigantea | S | N |
| | Siliqua | alta | S | N |
| | Tresus | capax | S | N |
| | Turtonia | minuta | P, S | N |
| | Vilasina | seminuda | S | N |
| Gastropoda (except nudibranchia) | | | | |
| | Acmaea | mitra | S | N |
| | Amphissa | columbiana | S | N |
| | Astyris | gauspata | P | N |
| | Boreotrophon | truncatus | S | N |
| | Buccinum | baeri | S | N |
| | Crepidula | dorsata | S | N |
| | Crepidula | sp. | P, S | U |
| | Cryptobranchia | alba | S | N |
| | Cryptobranchia | concentrica | S | N |
| | Fusitriton | orgonensis | S | N |
| | Lacuna | sp. | P | U |
| | Lacuna | vincta | P, S | N |
| | Littorina | scutulata | S | N |
| | Littorina | sitkana | S | N |
| | Lottia | cf.pelta | P | U |
| | Lottia | pelta | S | N |
| | Lottia | sp. | P, S | U |
| | Margarites | helicinus | S | N |
| | Margarites | pupillus | P, S | N |
| | Margarites | sp. | P | U |
| | Nucella | canaliculata | S | N |
| | Nucella | lamellosa | S | N |
| | Nucella | lima | S | N |

| | | | | | |
|---|---|---|---|---|---|
| | | Odostomia | sp. | P, S | U |
| | | Onchidella | borealis | S | N |
| | | Onoba | carpenteri | P | N |
| | | Pododesmus | macroschisma | P | N |
| | | Scabrotrophon | maltzani | S | N |
| | | Tectura | persona | S | N |
| | | Tectura | scutum | S | N |
| | | Trichotropis | cancellata | S | N |
| | | Trichotropis | insignis | S | N |
| | | cf. Trochidae | | P | U |
| | | Turtonia | minuta | P | N |
| | | Volutharpa | apullacea | S | N |
| | Nudibranchia | | | | |
| | | Acanthodoris | pilosa | P | N |
| | | Acanthodoris | sp. | P | U |
| | | Adalaria | jannae | P | N |
| | | Adalaria | proxima | S | N |
| | | Aglaja | pacifica | S | N |
| | | Aeolidia | papillosa | P | N |
| | | Archidoris | montereyensis | S | N |
| | | Cuthona | concinna | P | N |
| | | Dendronotus | frondosus | P, S | N |
| | | Dialula | sandiegensis | S | N |
| | | Dirona | albolineata | S | N |
| | | Dirona | sp. | P | U |
| | | Eubranchus | rupium | P | N |
| | | Flabellina | trophina | P | N |
| | | Hermissenda | crassicornis | P, S | N |
| | | Janolus | fuscus | S | N |
| | | Melibe | leonina | S | N |
| | | Onchidoris | bilamellata | P, S | N |
| | | Onchidoris | muricata | P | N |
| | | Palio | dubia | P | N |
| | | Polycera | zosterae | S | N |
| | Polyplacophora | | | | |
| | | Katharina | tunicata | S | N |
| | | Leptochiton | rugatus | S | N |
| | | Mopalia | ciliata | S | N |
| | | Mopalia | swanii | S | N |
| | | Schizoplax | brandtii | S | N |
| | | Tonicella | insignis | S | N |
| | | Tonicella | lineata | S | N |
| Tunicata | | | | | |
| | | Ascidia | callosa | P | N |
| | | Ascidia | columbiana | P | N |
| | | Ascidia | sp. | P | U |
| | | Didemnum | albidum | P | C |
| | | Didemnum | carnulentum | P | C |
| | | Distaplia | occidentalis | P | N |
| | | Distaplia | sp. | P | U |

| | | | | |
|---|---|---|---|---|
| | Molgula | retortiformis | P | N |
| | Molgula | sp. | P | U |
| | Styela | sp. | P | U |
| | Styela | truncata | P | N |
| **PRINCE WILLIAM SOUND** | | | | |
| Bryozoa | | | | |
| | Alcyonidium | sp. | P | U |
| | cf. Bowerbankia | sp. | P | U |
| | Bugula | cf. pacifica | P | U |
| | Bugula | pacifica | P | N |
| | Bugula | sp. | P | U |
| | Callopora | cf. craticula | P | U |
| | Callopora | craticula | P | N |
| | Callopora | sp. | P | U |
| | Callopora/Tegella | | P | U |
| | Celleporella | cf.hyalina | P | U |
| | Celleporella | hyalina | P | C |
| | Celleporella | cf.reflexa | P | U |
| | cf. Cheilostomata | | P | U |
| | Cribrilina | cf.annulata | P | U |
| | Cribrilina | annulata | P | N |
| | Cribrilina | cf.corbicula | P | U |
| | Cribrilina | corbicula | P | N |
| | cf. Crisiella | sp. | P | U |
| | Crisiella | cf.producta | P | U |
| | Crisiella | sp. | P | U |
| | Crisiidae | | P | U |
| | Electra | crustulenta | P | C |
| | Fenestrulina | delicia | P | C |
| | cf. Fenestruloides | eopacifica | P | U |
| | cf. Lichenopora | verrucaria | P | U |
| | Membranipora | cf.villosa | P | U |
| | Membranipora | villosa | P | N |
| | Tegella | aquilirostris | P | N |
| | Tegella | sp. | P | U |
| | Tubulipora | sp. | P | U |
| Cnidaria | | | | |
| Hydrozoa | | | | |
| | Campanulariidae | | P | U |
| | Clytia | hemisphaerica | P | C |
| | Clytia | kincaidi | P | N |
| | Clytia | sp. | P | U |
| | Cuspidella | humilis | P | N |
| | Cuspidella | sp. | P | U |
| | Gonothyraea | clarki | P | C |
| | Obelia | dichotoma | P | C |
| | Obelia | longissima | P | C |
| | Obelia | sp. | P | U |
| Crustacea | | | | |
| Cirripedia | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Balanus | crenatus | P | N |
| | | | Balanus | glandula | P | N |
| | Mollusca | | | | | |
| | | Bivalvia | | | | |
| | | | Hiatella | arctica | P | N |
| | | | Lacuna | vincta | P | N |
| | | | Mytilus | sp. | P | U |
| | | | Mytilus | trossulus | P | N |
| | | | cf. Protothaca | staminea | P | U |
| | | | Veneridae | | P | U |
| | | Gastropoda (except nudibranchia) | | | | |
| | | | Astyris | gauspata | P | N |
| | | | Crepidula | sp. | P | U |
| | | | Lacuna | sp. | P | U |
| | | | Lacuna | vincta | P | N |
| | | | Littorina | scutulata | P | N |
| | | | Littorina | sitkana | P | N |
| | | | Odostomia | sp. | P | U |
| | | | Onoba | carpenteri | P | N |
| | | Nudibranchia | | | | |
| | | | Eubranchus | rupium | P | N |
| | | | Flabellina | trophina | P | N |
| | | | Hermissenda | crassicornis | P | N |
| | | | Palio | dubia | P | N |
| | Tunicata | | | | | |
| | | | Ascidia | callosa | P | N |
| | | | Corella | inflata | P | N |
| | | | Corella | sp. | P | U |
| | | | Corella | willmeriana | P | N |
| | | | Distaplia | alaskensis | P | C |
| | | | Distaplia | occidentalis | P | N |
| | | | Distaplia | sp. | P | U |
| | | | Pyuridae | | P | U |
| **SITKA** | | | | | | |
| | Annelida | | | | | |
| | | Serpulidae | | | | |
| | | | Pseudochitinopoma | occidentalis | P | N |
| | | | Salmacina | tribranchiata | P | N |
| | | | Serpula | sp. | P | U |
| | Bryozoa | | | | | |
| | | | Alcyonidium | polyoum | P | C |
| | | | Bowerbankia | aggregata | P | N |
| | | | Bowerbankia | sp. | P | U |
| | | | Bowerbankia | sp. B | P | U |
| | | | Bugula | pacifica | P | N |
| | | | Callopora | craticula | P | N |
| | | | Celleporella | hyalina | P | C |
| | | | Cribrilina | annulata | P | N |
| | | | Cribrilina | corbicula | P | N |
| | | | Ctenostomata | | P | U |

| | | | | |
|---|---|---|---|---|
| | Cyclostomata | | P | U |
| | Fenestrulina | delicia | P | C |
| | Fenestruloides | eopacifica | P | N |
| | Fenestruloides | sp. | P | U |
| | Fenestruloides | sp. A | P | U |
| | Membranipora | sp. | P | U |
| | Membranipora | villosa | P | N |
| | Schizoporella | sp. | P | U |
| | Schizoporella | japonica | P | I |
| | Tegella | aquilirostris | P | N |
| | Tubulipora | sp. | P | N |
| | Tubulipora | sp. B | P | U |
| | Tubulipora | sp. C | P | U |
| | Tubulipora | pacifica | P | U |
| | Tubulipora | tuba | P | U |
| Cnidaria | | | | |
| Hydrozoa | | | | |
| | Clytia | gracilis | P | C |
| | Clytia | hemisphaerica | P | C |
| | Clytia | kincaidi | P | N |
| | Clytia | sp. | P | U |
| | Garveia | sp. | P | U |
| | Gonothyraea | clarki | P | C |
| | Gonothyraea | sp. | P | U |
| | Obelia | dichotoma | P | C |
| | Obelia | longissima | P | C |
| | Obelia | sp. | P | U |
| Crustacea | | | | |
| Cirripedia | | | | |
| | Balanus | crenatus | P | N |
| | Balanus | sp. | P | U |
| Mollusca | | | | |
| Bivalvia | | | | |
| | cf. Diplodonta | sp. | P | U |
| | Hiatella | arctica | P | N |
| | Mytilus | sp. | P | U |
| | Mytilus | trossulus | P | N |
| | Pododesmus | macroschisma | P | N |
| | Veneridae | | P | U |
| Gastropoda (except nudibranchia) | | | | |
| | Astyris | gauspata | P | N |
| | cf. Astyris | sp. | P | U |
| | cf. Margarites | pupillus | P | U |
| | cf. Margarites | sp. | P | U |
| | Crepidula | sp. | P | U |
| | Crepipatella | dorsata | P | N |
| | Diaphana | sp. | P | U |
| | Haminoea | vesicula | P | N |
| | Lacuna | sp. | P | U |
| | Lacuna | vincta | P | N |

| | | | | |
|---|---|---|---|---|
| | Lottia | sp. | P | U |
| | Odostomia | sp. | P | U |
| | Onoba | carpenteri | P | N |
| | Pododesmus | macroschisma | P | N |
| | Rissoidae cf. Onoba | carpenteri | P | U |
| | Tegula | pulligo | P | N |
| Nudibranchia | | | | |
| | Acanthodoris | pilosa | P | N |
| | Acanthodoris | sp. | P | U |
| | Aeolidia | papillosa | P | N |
| | Corambe | steinbergae | P | N |
| | Cuthona | sp. | P | U |
| | Dendronotus | frondosus | P | N |
| | Dirona | sp. | P | U |
| | Eubranchus | rupium | P | N |
| | Flabellina | trophina | P | N |
| | Hermissenda | crassicornis | P | N |
| | Onchidoris | bilamellata | P | N |
| | Palio | dubia | P | N |
| Tunicata | | | | |
| | Ascidia | callosa | P | N |
| | Ascidia | columbiana | P | N |
| | Ascidia | sp. | P | U |
| | Botrylloides | sp. | P | U |
| | Botrylloides | violaceus | P | I |
| | Botryllus | schlosseri | P | I |
| | Corella | inflata | P | N |
| | Corella | sp. | P | U |
| | Corella | willmeriana | P | N |
| | Didemnidae | | P | U |
| | Didemnum | carnulentum | P | C |
| | Distaplia | occidentalis | P | U |
| | Distaplia | sp. | P | U |
| | Styela | sp. | P | U |
| | Styela | truncata | P | N |
| **VALDEZ** | | | | |
| Annelida | | | | |
| Serpulidae | | | | |
| | Crucigera | zygophora | P | N |
| | Pseudochitinopoma | occidentalis | P | N |
| Spirorbidae | | | | |
| | Circeis | armoricana | P | N |
| Bryozoa | | | | |
| | Bugula | californica | P | N |
| | Bugula | cuculifera | P | N |
| | Bugula | longirostrata | P | N |
| | Bugula | pacifica | P | N |
| | Bugula | sp. | P | U |
| | Bugulidae | | P | U |
| | Callopora | craticula | P | N |

| | | | | | |
|---|---|---|---|---|---|
| | | Callopora | sp. | P | U |
| | | Celleporella | hyalina | P | C |
| | | Codonellina | argentea | P | N |
| | | Cribrilina | corbicula | P | N |
| | | Crisidia | sp. | P | U |
| | | Crisiella | sp. | P | U |
| | | Crisiella | sp. A | P | U |
| | | Cyclostomata | | P | U |
| | | Fenestrulina | delicia | P | C |
| | | Fenestruloides | sp. | P | U |
| | | Fenestruloides | sp. A | P | U |
| | | Fenestruloides/Fenestrulina | sp. | P | U |
| | | Lichenopora | sp. | P | U |
| | | Membranipora | serrilamella | P | N |
| | | Membranipora | villosa | P | N |
| | | Parasmittina | sp. | P | U |
| | | Parasmittina | trispinosa | P | N |
| | | Porella | acutirostris | P | N |
| | | Porella | aperta | P | N |
| | | Porella | sp. | P | U |
| | | Rhamphostomella | cellata | P | N |
| | | Rhamphostomella | cf.spinigera or cf. townsendi | P | U |
| | | Rhamphostomella | sp. | P | U |
| | | Tubulipora | sp. | P | U |
| Cnidaria | | | | | |
| | Hydrozoa | | | | |
| | | Clytia | gracilis | P | C |
| | | Clytia | hemisphaerica | P | C |
| | | Clytia | kincaidi | P | N |
| | | Clytia | sp. | P | U |
| | | Garveia | annulata | P | N |
| | | Garveia | sp. | P | U |
| | | Gonothyraea | clarki | P | C |
| | | Obelia | dichotoma | P | C |
| | | Obelia | longissima | P | C |
| | | Opercularella | sp. | P | U |
| Crustacea | | | | | |
| | Cirripedia | | | | |
| | | Balanus | sp. | P | U |
| Mollusca | | | | | |
| | Bivalvia | | | | |
| | | Hiatella | arctica | P | N |
| | | Mytilidae | | P | U |
| | | Mytilus | trossulus | P | N |
| | Gastropoda (except nudibranchia) | | | | |
| | | Lacuna | vincta | P | N |
| | | Pododesmus | macroschisma | P | N |
| | Nudibranchia | | | | |
| | | Cuthona | albocrusta | P | N |
| | | Onchidoris | bilamellata | P | N |

| | | | | |
|---|---|---|---|---|
| Tunicata | | | | |
| | Ascidia | sp. | P | U |
| | Corella | inflata | P | N |

# Appendix G

## Description of Non-native Marine and Estuarine Species Reported in Alaska

## DEFINITE INTRODUCTIONS; ESTABLISHED POPULATIONS

### Kingdom Plantae, Phylum Rhodophycota

***Caulacanthus ustulatus*** (Kutzing 1843)
Synonyms: *Fucus acicularis* Turner 1843; *Caulacanthus compressus* Harvey 1849 *Caulacanthus horridulis* Weber-van Bosse 1921; *Caulacanthus rigidus* A. B. Cribb; *Caulacanthus spinellus* J.D. Hooker & Harvey
Common name: red alga
Invasion Status: Introduced
Population Status: Established

The red alga *Caulacanthus ustulatus* is "a rather inconspicuous small red alga", which has short, erect branches, up to 3 cm high, growing forming cylindrical stolons, forming loose irregular mats, usually in rocky intertidal zones, but also in tropical mangrove swamps (Zuccarello et al. 2002). *Caulacanthus ustulatus* was described from Cadiz, Spain, but has a cosmopolitan range in the Eastern Atlantic (France-South Africa) and the Indo-West Pacific (South Africa-Japan, and east to Australia, New Zealand, and Hawaii. A molecular analysis indicates that this species contains two major lineages, an Indo-West Pacific lineage and an Atlantic lineage (Zuccarello et al. 2002). The Pacific lineage is a recent invader in the Eastern Pacific (Baja California Mexico, before 1961; British Columbia 1974; San Pedro California 1999; Prince William Sound AK 1989-1996) and in the Northeast Atlantic (Brittany, France 1988) (Gabrielson and Scagel 1989; Lindstrom et al. 1999; Rueness and Rueness 2000; Whiteside and Murray 2004). Populations from Brittany and the San Juan Islands (Puget Sound) were grouped with the Pacific lineage in the plastid and mitochondrial DNA analysis (Zuccarello et al. 2002).

In Alaskan waters, *C. ustulatus* was collected in only Hogg Bay, during an algal survey of many locations in Prince William Sound, between 1989 and 1996. This record marks a northern range extension for this alga, previously known from southern British Columbia (Lindstrom et al. 1999). Transport of whole plants in ship fouling, or with oysters, aquaculture equipment or fragments in ballast water, are all possible vectors for the introduction of this alga.

REFERENCES
Gabrielson, Paul W.; Scagel, Robert F. 1989. The marine algae of British Columbia, northern Washington, and southeast Alaska: divison Rhdophyta (red algae), class Rhodophyceae, order Gigartinales, family Caulacanthaceae and Plocamiaceae. Canadian Journal of Botany 67: 1221-1234.
Lindstrom, S. C.; Houghton, J. P; Lees, D. C.1999. Intertidal macroalgal community structure in southwestern Prince William Sound, Alaska. Botanica Marina 42: 265-280.
Rueness, Jan; Rueness, Eli K. 2000. *Caulacanthus ustulatus (*Gigartales, Rhodophyta) from Brittany, France is an introduction from the Pacific Ocean. Cryptogamie-Algologie 21(4): 355-363.
Whiteside, K. E.; Murray, S. N. 2004. Spatial and temporal patterns of abundance in southern California populations of *Caulacanthus ustulatus* (Rhodophyta). 40(8):14.
Zuccarello, Giuseppe; West, John; Rueness, Jan. 2002. Phylogeography of the cosmopolitan red alga *Caulacanthus ustulatus* (Caulacanthaceae, Gigartinales). Phycological Research 50: 163-172.

***Ceramium sinicola*** Setchell & Gardner 1924
Synonyms:
Common name: red alga
Invasion Status: Introduced
Population Status: Established
*Ceramium sinicola* is a small branched alga, about 0.3-4 cm high, which grows as an obligate epiphyte on the green alga *Codium fragile*. This alga was previously known from Southern California and Mexico (Dawson 1950; Cho et al. 2003), but has also been reported from the Philippines (Guiry et al. 2005). In 1998, it was collected from *C. fragile* near Green Island, in Prince William Sound (Hines and Ruiz 2000; Prince William Sound Regional Advisory Council 2005a). The identity of the host plant is unclear- it could have been a native form of *C. fragile*, but it had some resemblance to the invasive *C. f.* ssp. *tomentosoides* (Hansen, in Hines and Ruiz 2000; Prince William Sound Regional Advisory Council 2005b), which is, at present, on the Pacific Coast of North America, known only from San Francisco Bay (Cohen and Carlton 1995). *Ceramium sinicola* was probably transported into Alaskan waters on *Codium fragile,* growing on hull fouling (Hansen, in Hines and Ruiz 2000).

REFERENCES
Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.
Cho, Tae Oh; Fredericq, Suzanne; Murray; Steve N.; Boo, Sung Min. 2003. New insights in the taxonomy of the *Ceramium sinicola* species complex: the resurrection of *Ceramium interruptum* (Ceramiaceae, Rhodophyta). Journal of Phycology 39: 775-788.
Dawson, E.Y. 1950. A review of *Ceramium* along the Pacific coast of North America with special reference to its Mexican representatives. Farlowia 4: 113-138.
Guiry, M. D.; Rindi, F.; Guiry, G.M., 2005. AlgaeBase version 4.0. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 08 November 2005.
Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.
Prince William Sound Regional Advisory Council 2005a. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 11: North East Pacific Red Algae Rhodophyta *Ceramium sinicola.* *http://www.pwsrcac.org/docs/d0016600.pdf*
Prince William Sound Regional Advisory Council. 2005b. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 5: Dead Man's Fingers: Chlorophyta *Codium fragile* ssp. *tomentosoides.* http://www.pwsrcac.org/docs/d0015700.pdf

***Chroodactylon ornatum*** (C. Agardh 1824) Basson 1979
Synonyms: *Conferva ornata* C. Agardh 1824; *Hormospora ramosa* Thwaites 1848; *Chroodactylon ramosum* (Thwaites) Hansgirg 1885; *Asterocytis ramosa* (Thwaites); *Asterocytis ornata* (C. Agardh) G. Hamel 1924 Gobi ex F. Schmitz 1896
Common name: red alga
Invasion Status: Introduced
Population Status: Established

*Chroodactylon ornatum* (the current name according to Guiry et al. 2005) is a small red alga, forming tiny, branched filaments up to 1-10 mm long, grayish-green in color, typically growing on other algae and on seagrasses (e.g. *Zostera*) (Taylor 1957; Sheath and Morison 1982; Prince William Sound Regional Advisory Council 2005c). This alga is remarkable for its ability to grow in both fresh and marine waters, in habitats ranging from streams and lakes (Sheath and Morison 1982) to fully marine waters, and over a wide range of latitudes, from Scandinavia and Alaska to the tropics. Culture and genetic studies would be useful to determine if this name has been applied to a species complex (Guiry et al. 2005). *Chroodactylon ornatum* is cosmopolitan in distribution but is a recent invader in the Great Lakes (1st record Lake Erie, 1964- Sheath and Morison 1982) and has only recently been discovered in Alaskan waters (Hines and Ruiz 2000; Prince William Sound Regional Advisory Council 2005c).

*Chroodactylon ornatum* a microscopic, primitive, epiphytic red alga was found growing on oyster floats at Tatilek (Prince William Sound) by Gayle Hansen. This species is previously known from southern California, but has not been found in the well-studied waters of British Columbia and Washington. It may have been introduced with oysters or in hull fouling (Hansen, in Hines and Ruiz 2000; Prince William Sound Regional Advisory Council 2005c).

REFERENCES
Guiry, M. D.; Rindi, F.; Guiry, G.M., 2005. AlgaeBase version 4.0. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 08 November 2005.
Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.
Prince William Sound Regional Advisory Council. 2005c. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 16: North West Pacific Red Alga: Rhodophyta *Chroodactylon ramosum* http://www.pwsrcac.org/docs/d0016700.pdf

Sheath, Robert G.; Morison, Mary O. 1982. Epiphytes on *Cladophora glomerata* in the Great Lakes and St. Lawrence seaway with particular reference to the red alga *Chroodactylon ramosum* (=*Asterocytis smargdina*.). Journal of Phycology 18: 385-391.
Taylor, William Randolph. 1957. Marine Algae of the Northeastern Coast of North America. University of Michigan Press. Ann Arbor.

**Kingdom Plantae, Phylum Phaeophycophyta**

***Fucus cottonii*** Wynne & Magne 1991
Synonyms: *Fucus muscoides* (A.D. Cotton) Feldmann & Magne 1964; *Fucus vesiculosus* var. *muscoides* Cotton 1912.
Common name: rockweed
Invasion Status: Introduced
Population Status: Established

*Fucus cottonii* is a brown alga belonging to a genus which contains many species of brown algae (rockweeds) commonly found in the mid-intertidal of rocky shores. However, *F. cottonii* is a dwarfed form (1-5 cm high) which grows in dense, loose-lying mats in saltmarshes and mudflats in the mid- and upper intertidal (Hines and Ruiz 2000). The status of *F. cottonii* as a separate species has been questioned- it has been considered an ecotype or growth form of *F. vesiculosus* or related species (Fletcher 1987). *F. cottonii*-like forms from saltmarshes in Maine were hybrids between *F. spiralis* and *F. vesiculosus* (Wallace et al. 2004). However, other sources treat it as a distinct species, which we will do provisionally, until molecular studies are made on northeast Pacific plants (Hines and Ruiz 2000; Guiry et al. 2005).

The historic range of *Fucus cottonii* (=*muscoides*) is along European coasts from northern Spain to Scandinavia (South and Tittley 1986). It was first found on the Pacific Coast of North America by Gayle Hansen in 1981 on Vancouver Island, British Columbia. In Alaska, she found it to be common in high marshes, along Prince William Sound in 1998 (Hines and Ruiz 2000). It may have been introduced very early, in dry ballast, or in hull fouling.

Fletcher, R.L. 1987. Seaweeds of the British Isles. Vol. 3. Fucophyceae (Phaeophyceae). Part 1. British Museum (Natural History). London.
Guiry, M. D.; Rindi, F.; Guiry, G.M., 2005. AlgaeBase version 4.0. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 08 November 2005.
Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.
South, G. Robin; Tittley, Ian. 1986. A checklist and distributional index of the benthic marine algae of the North Atlantic Ocean. Huntsman Marine Laboratory and British Museum (Natural History). St. Andrews, New Brunswick, and London.
Wallace, Aaron L.; Klein, Anita, S.; Mathieson, Arthur C. Determining the affinities of salt marsh fucoids using microsatellite markers: Evidence of hybridization and introgression between two species of *Fucus* (Phaeophyta) in a Maine estuary. Journal of Phycology 40(6):1013-1027.

***Microspongium globosum***
Synonyms: *Ascocyclus globosus* Reinke 1889; *Myrionema globosum* Foslie 1894; *Phycocelis globosus* De Toni 1895; *Myrionema polycladum* Sauvageau 1897; *Myrionema subglobosum* Kylin 1907
Common name: brown alga
Invasion Status: Introduced
Population Status: Established

*Microspongium globosum* is a tiny epiphytic brown alga which forms hemispherical or globular cushions of filaments, 0.5-1 mm in diameter, on other species of algae (Taylor 1957). In Alaska, *M. globosum* was found growing on the cryptogenic brown alga *Delamarea attenuata* (Hines and Ruiz 2000). This alga was described from the Baltic, and is known from the North Atlantic from Britain and Rhode Island to Greenland (Taylor 1957; South and Tittley 1986) and Japan (Guiry et al. 2000).

*Microspongium globosum* was collected in Alaskan waters before 1977 (Lindstrom 1977), but was not previously collected from waters of the Pacific Coast of North America .In the Prince William Sound area, it was collected by Gayle Hansen at Tatilek, in 1998, growing on the alga *D. attenuata*, attached to oyster floats (Hines and Ruiz 2000). It may have been introduced to Alaskan waters in hull fouling of ships, on oysters, or on aquaculture equipment.

REFERENCES


Guiry, M. D.; Rindi, F.; Guiry, G.M., 2005. AlgaeBase version 4.0. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 08 November 2005.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Lindstrom, S.C. 1977. An annotated bibliography of the benthic marine algae of Alaska. Alaska Department. of Fish and Game. Juneau.

Prince William Sound Regional Advisory Council. 2005c. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 16: North West Pacific Red Alga: Rhodophyta *Chroodactylon ramosum* http://www.pwsrcac.org/docs/d0016700.pdf

South, G. Robin; Tittley, Ian. 1986. A checklist and distributional index of the benthic marine algae of the North Atlantic Ocean. Huntsman Marine Laboratory and British Museum (Natural History). St. Andrews, New Brunswick, and London.

Taylor, William Randolph. 1957. Marine Algae of the Northeastern Coast of North America. University of Michigan Press. Ann Arbor.


***Sargassum muticum*** Yendo 1907
Synonyms: *Sargassum kjellmanianum* forma *muticum* Yendo 1907
Common name: Japanese Wireweed
Invasion Status: Introduced
Population Status: Established

*Sargassum muticum* is a large, brown seaweed, occasionally reaching up to 2 m in length, with a well-developed holdfast and a short stalk, which breaks up into alternating branches bearing leaf-like fronds and spherical bladders, serving as floats. It grows on hard substrates, including rocks, docks, logs, and oysters, preferably in sheltered waters, from the lower intertidal to depths up to 2 m. *Sargassum muticum* is native to the Pacific coast of Asia in southern and central Japan, Korea, and the northern coast of China (Scagel 1956). It has been introduced to the Pacific Coast of North America, from Ensenada, Mexico to southeast Alaska (Scagel 1956; Norton 1981a; Scagel et al. 1989), and to the coasts of Europe, from southern Norway and the outer Baltic to the western Mediterranean (Rueness 1999).

*Sargassum muticum* was first collected on the Pacific Coast along Strait of Georgia, British Columbia, in 1941, and soon appeared in oyster-growing areas to the south (Coos Bay, Oregon-1947; Willapa Bay, Washington-1953; Puget Sound-1957; Humboldt Bay, California 1965 (Scagel 1956; Norton 1981). By 1976, this seaweed had reached San Diego (Norton 1981a), and by 1977, it had been recorded from southeast Alaska, in Davidson Inlet, in the vicinity of Ketchikan (Scagel et al. 1989). We do not know the present distribution of *S. muticum* in Alaskan waters, but it was not identified in extensive surveys of Prince William Sound (Hines and Ruiz 2000). *Sargassum muticum* probably reached North America with transplants of Pacific Oysters (*Crassostrea gigas*), but their spread into Alaskan waters could have also involved drifting of germlings or adult plants (Norton 1981b), hull fouling, or fouled aquaculture gear. In Puget Sound, his invasive seaweed is known to inhibit native algae including kelps (*Macrocystis pyrifera; Laminaria bongardiana*), through shading, and to have negative effects on Green Sea Urchins (*Strongylocentrotus droebachiensis*), by reducing their preferred foods (Ambrose and Nelson 1982; Britton-Simmons 2004).

REFERENCES


Ambrose, R. F.; Nelson, Bobette V. 1982. Inhibition of Giant Kelp recruitment by an introduced brown alga. Botanica Marina 25: 265-267.

Britton-Simmons, Kevin H. 2004. Direct and indirect effects of the introduced alga *Sargassum muticum* on benthic, subtidal communities of Washington State, USA. Marine Ecology Progress Series 277: 61-78.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Norton, Trevor A. 1981a. *Sargassum muticum* on the Pacific coast of North America. Proceedings of the International Seaweed Symposium 8:449-456.

Norton, Trevor A. 1981b. The varied dispersal mechanisms of an invasive seaweed, *Sargassum muticum*. Phycologia 20 (2):110-11.

Rueness, Jan 1999. *Sargassum muticum* and other introduced Japanese macroalgae: biological pollution of European coasts. Marine Polution Bulletin 20 (4): 173-176.

Scagel, R.F. 1956. Introduction of a Japanese alga, *Sargassum muticum*, into the Northeast Pacific. Fisheries Research Papers, Washington Department of Fisheries 1(4): 49-58.

Scagel, R.F., Gabrielson, P.W., Garbary, D.J., Golden, L., Hawkes, M.W., Lindstrom, S.C., Oliveira, J.C., Widdowson, T.B. 1989. A synopsis of the benthic marine algae of British Columbia, southeast Alaska, Washington, and Oregon. University of British Columbia. Vancouver.

**Phylum Magnoliophyta, Class Magnoliopsida, Family Asteraceae**

***Cotula coronopifolia*** Linnaeus 1753
Common Name: Brass-Buttons
Synonyms:
Invasion Status: Introduced
Population Status: Established

*Cotula coronopifolia* (Brass-Buttons) is a small (usually less than 50 cm tall), annual flowering plant, branching from the base, with lance-like leaves, ranging from deeply toothed to smooth-edged. The flower-heads are globular, ray-less (resembling a daisy, with petals removed), composed of many tightly packed florets, and are bright yellow. This plant inhabits freshwater and brackish marshes and mudflats (Hultén 1968; Hickman 1993). *Cotula coronopifolia* is native to South Africa, but has been introduced to western North America (southern California-southeast Alaska), eastern North America (Atlantic Canada), Australia, New Zealand and Europe (Hultén 1968; Van den Toorn 1980; Partridge and Wilson 1987; Cohen and Carlton 1995; Roland and Zinck 1998).

*Cotula coronopifolia* was reported on the Pacific Coast from San Francisco Bay as early as 1878. It was probably introduced in the dry ballast of sailing ships (Cohen and Carlton 1995). It was probably been spread up and down the coast in dry ballast of coastal ships, by seeds transported by migrating birds (Cohen and Carlton 1995) and by the sale and use of this plant as an ornamental in water-gardens (many websites). Hultén (1968) reported it as occurring in the vicinity of Ketchikan and Prince of Wales Island. Brass- Buttons is currently found in Gambier Bay on Admiralty Island, Duncan Canal and Petersburg Lake on Kupreanof Island, and commonly from Prince of Wales Island, southward. This plant is considered a potentially damaging invasive species in Alaskan wetlands (Huette et al. 2005).

REFERENCES

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.

Hickman, J. C. 1993. The Jepson Manual of higher plants of California. University of California Press. Berkeley. (Online version- http://ucjeps.berkeley.edu/interchange/I_treat_indexes.html).

Huette, Tom; Bella, Elizabeth; Snyder, Jamie; Shepard, Michel. 2004. Invasive plants and exotic weeds of southeast Alaska. U.S. Department of Agriculture, Forest Service. Juneau. http://www.fs.fed.us/r10/spf/fhp/se_inv_plnt_guide.pdf

Hultén, E. 1968. Flora of Alaska and neighboring territories: a manual of the vascular plants. Stanford University Press. Stanford, California.

Partridge, T. R.; Wilson, J. B. 1987. Germination in relation to salinity in some plants of salt marshes in Otago, New Zealand. New Zealand Journal of Botany 25: 255-261.

Roland and Zinck 1998

Van Der Toorn, J. 1980. Ecology of *Cotula coronopifolia* and *Ranunculus sceleratus* L. Geographic distribution habitat and field observations. Acta-Botanica-Neerlandica. 1980; 29(5-6): 385-396.

**Kingdom Protista, Phylum Foraminifera**

***Trochammina hadai*** Uchio 1962
Synonyms:
Common name: foraminiferan, foram
Invasion Status: Introduced
Population Status: Established

The foraminiferan *Trochammina hadai* is a single-celled protozoan, with a calcareous/organic shell about 0.4 mm in diameter, consisting of several globular chambers (McGann and Sloan 1996). The shells of foraminifera are lined with pores, through which threads of cytoplasm can stream out to capture prey, to gather material for the shell, or to help the organism move (Margulis and Schwartz 1988).

Adults of *T. hadai* live in estuarine sediments, and tolerate a considerable range of temperature and salinity (McGann et al. 2000). *Trochammina hadai*, like most other forams, has a complex life cycle, in which diploid adults produce large quantities of haploid gametes, which grow into haploid adults, which then reproduce sexually to produce a new generation of diploid adults (Kitazato and Matsushita 1996).

*Trochammina hadai* was previously known as a common species in Japanese estuarine sediments. It was first collected in North America, in sediment cores from Puget Sound in 1971. Its population growth and spread has been best studied in San Francisco Bay, where it was first collected in 1983, and by the 1990s, became a major component of the benthic micofauna (McGann and Sloan 1996; Cohen and Carlton 1995). Subsequently, the foram was found in harbor sediments from San Diego Bay to Prince William Sound (McGann et al. 2000).

*Trochammina hadai* was first collected in Alaskan waters in 1989-1992, in samples taken after the oil spill in Prince William Sound (McGann et al. 2000; Prince William Sound Regional Advisory Council 2005d). McGann et al. (2003) found 15 species of forams in ballast tanks of 12 ships arriving in West Coast ports.
*Trochammina hadai* was probably introduced into North American and Alaskan waters with sediment in ballast water.

REFERENCES

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.
Kitazato, Hiroshi; Matsushita, Satoshi 1996. Laboratory observations of sexual and asexual reproduction of *Trochammina hadai* Uchio. Transactions and Proceedings of the Paleontological Society of Japan, New Series (0)182:454-466.
Margulis, Lynn; Schwartz, Karlene 1988. Five Kingdoms: An illustrated guide to the phyla of life on Earth. Freeman. New York.
McGann, Mary; Sloan, Doris 1996. Recent introduction of the foraminifer Trochammina hadai Uchio into San Francisco Bay, California, USA. Marine Micropaleontology 28: 1-3.
McGann, Mary; Sloan, Doris; Cohen, Andrew N. 2000. Invasion by a Japanese marine microorganism in Western North America. Hydrobiologia 421: 25-30.
McGann, Mary; Johengen, Thomas H.; Reid, David F.; Ruiz, Gregory F.; Hines, Anson H. 2003. Ballast Sediment: A likely mechanism for nonindigenous foraminiferal introductions. Geological Society of America, 2003 Annual Meeting Abstracts 35 (6): 503.
Prince William Sound Regional Advisory Council. 2005d. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 13:Foraminiferan: *Trochammina hadai* http://www.pwsrcac.org/docs/d0016200.pdf

**Phylum Porifera, Class Demospongiae**

***Cliona thoosina*** Topsent 1888
Common Name: boring sponge
Synonyms:
Invasion Status: Introduced
Population Status: Established

Sponges of the genus *Cliona* are yellow, and bore tunnels within mollusk shells, surfacing in pockmarks at the end of the tunnels, and sometimes overgrowing and encrusting the shells. Different species vary somewhat in their color and growth habits, but are distinguished largely by the shape of spicules (Hartman 1958). This group of sponges appears to have been poorly studied on the Pacific Coast of North America. While native species of *Cliona* are present, at least one, and possibly several, species of *Cliona* have been introduced with introductions of Eastern Oysters (*Crassostrea virginica*) from the Atlantic Coast, and possibly later with Pacific Oysters (*C. gigas*) from Japan. In San Francisco, in 1893, shells of Eastern Oysters were found to be riddled with *Cliona* sp., and similar infestations were found in other West Coast oyster-growing areas including Yaquina Bay, Oregon (1931), Puget Sound (1932), and British Columbia (by 1969) (Carlton 1979; Cohen and Carlton 1995).

In 1998, *Cliona* spp. infestations were found in the shells of field-cultured Pacific Oysters in Prince William Sound and Kachemak Bay (Hines and Ruiz 2000; Prince William Sound Regional Advisory Council. 2005e.). The sponges were identified by Klaus Ruetzler as *C. thoosina*, a species whose type locality is unknown (most likely Atlantic France). This species has been synonymized with species in the Mediterranean (Rosell and Uriz 2002), Chile and Japan by various authors, but its origin and present world distribution are unknown (Ruetzler, personal communication). *Cliona* infestations are harmful to oysters and clams, by eroding and sometimes dissolving the shells, increasing the vulnerability of the shellfish to predators. They also reduce the appeal of the mollusks to human consumers (Prince William Sound Regional Advisory Council. 2005e).

REFERENCES
Carlton, James T. 1979. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific Coast of North America. Ph.D. dissertation, University of California. Davis.
Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.
Hartman, Willard D. 1958. Natural history of the marine sponges of southern New England. Peabody Museum of Natural History Bulletin 12: 1-50.
Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.
Prince William Sound Regional Advisory Council. 2005e. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 7: Boring Sponge: *Cliona thoosina* http://www.pwsrcac.org/docs/d0015500.pdf
Rosell, Dolor; Uriz, Maria. 2002. Excavating and endolithic sponge species (Porifera) from the Mediterranean: Species descriptions and identification key. Organisms Diversity and Evolution 2: 55-85.

**Phylum Annelida, Class Polychaeta, Family Capitellidae**

***Heteromastus filiformis*** Claparede 1846
Common Name: capitellid polychaete
Invasion Status: Introduced
Population Status: Established

*Heteromastus filiformis* is an earthworm-like polychaete, with a long, slender composed of up to 140 or more cylindrical segments. These segments become more compressed around the worm's front end, while the posterior segments are more elongated. The parapodia, which in many polychaetes are paddle-like, are reduced to short stubs in the capitellids. Twelve anterior segments bear short bristles, which are short and stout on segments 2-6, and longer and hook-like on segments 7-12. The worm is reddish-brown in color. *Heteromastus filiformis* is a deposit-feeder, burrowing in sediments from the lower intertidal zone to shallow coastal waters (Nelson-Smith et al. 1990). This worm has a planktonic larva which spends a few days in the plankton.

*Heteromastus filiformis* is native to the North Atlantic from Spain and Puerto Rico to Greenland (Hartman 1969; Nelson-Smith et al. 1990; U.S. National Museum of Natural History 2002). This worm has been reported from many locations around the world, including the Red Sea, Northwest Pacific (Korea-Siberia), Brazil, South Africa, and New Zealand (Hartman 1969). It is likely that some of these records may represent native sibling species, while others represent introductions. In coastal waters of the Northeast Pacific, *H. filiformis* appears to be an introduced species. It was first collected in San Francisco Bay in 1936 and is now known from the Channel Islands, California (Carlton 1979), to Valdez, Alaska (Hines and Ruiz 2000).

The first record of *H. filiformis* in Alaskan waters was from Valdez in 1971-1972, before the start of tanker traffic . This worm was probably introduced to Alaska in ballast water, hull fouling, or with oysters. A collection off the Pribiloff Islands in 1976 at 135 m depth (U.S. National Museum of Natural History 2002) may represent a native sibling species.

REFERENCES

Carlton, James T. 1979. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific Coast of North America. Ph.D. dissertation, University of California. Davis.

Hartman, Olga. 1969. Atlas of the sedentariate polychaetous annelids from California. Allan Hancock Foundation. Los Angeles.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Nelson-Smith, A.; Knight-Jones, P.; Knight-Jones, E.W.1990. Annelida. In Hayward, P. J., and Ryland, J. S. The marine fauna of the British Isles and northwest Europe. V.1. pp. 201-306.

Prince William Sound Regional Advisory Council. 2005f. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 10: Capitellid Worm: *Heteromastus filiformis* http://www.pwsrcac.org/docs/d0016500.pdf

U.S. National Museum of Natural History 2002. Invertebrate zoology collections database. http://goode.si.edu/webnew/pages/nmnh/iz/Query.php

**Phylum Mollusca, Class Bivalvia**

***Mya arenaria*** (Linnaeus 1758)

Synonyms:

Common Names: Softshell Clam; Longneck Clam; Gaper

Invasion Status: Introduced

Population Status: Established

*Mya arenaria* is a bivalve mollusk with a large, chalky-white, ovate-elongate shell, ranging in adults from 6 to 13 cm long. The hinge of the shell forms a blunt angle (umbo), with a large projecting spoon-shaped tooth (chondropohore) in one valve, and a socket in the other. The animal has a long projecting siphon (the exhalant and inhalant siphons are fused), up to three times as long as the shell. The foot is small and muscular. When the shell is closed, there are openings at the posterior end for the foot and anterior end at the siphon. This bivalve burrows in sandy-muddy sediments, up to 40 cm deep, in the middle intertidal to shallow sublittoral zones, from marine salinities to as low as 5 ppt (Gosner 1978; Prince William Sound Regional Advisory Council 2005g). This bivalve has larvae which spend 2-3 weeks in the plankton, permitting wide natural dispersal, as well as ballast water transport (Strasser 1999).

*Mya arenaria* is believed to have originated in the Pacific, and spread through the Arctic to its current native range on the Atlantic coast of North America, from the Gulf of St. Lawrence to Georgia, (Gosner 1978), later becoming extinct in the Arctic and Eastern Pacific, in Pleistocene times. It is believed to have been introduced to European waters in Viking times, and now ranges from the White and Barents Seas in Russia to Portugal, the Mediterranean and Black Seas in Europe (Strasser 1999). On the Pacific Coast of North America, it was first collected in San Francisco Bay in 1874, where it was introduced with transplanted Eastern Oysters (*Crassostrea virginica*). This clam soon became a popular food item and was successfully planted as far south as Elkhorn Slough, California, and as far north as Kachemak Bay, Alaska (Carlton 1979; Hines and Ruiz 2000; Hines and Ruiz 2001).

The history of *M. arenaria* in Alaskan waters is complicated by confusion with several similar northern species, *M. japonica, Mya priapus*, *Mya pseudoarenaria*, *Mya truncata* (Carlton 1979). *Mya arenaria* was introduced to Puget Sound and southern British Columbia by the 1880s-1890s, but the first reliable records from southeastern Alaska are from the 1960s. By 1974, *M. arenaria* was well established in Prince William Sound (Carlton 1979). It now ranges as far north as Kodiak and the Yukon-Kuskokwim delta (Hines and Ruiz 2001). *Mya arenaria* could have been spread into Alaskan waters by deliberate transplants, accidentally with oysters, or by larvae in ballast water.

REFERENCES

Carlton, James T. 1979. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific Coast of North America. Ph.D. dissertation, University of California. Davis.

Gosner, Kenneth L. 1978. A field guide to the Atlantic seashore. Houghton-Mifflin. Boston.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Hines, Anson H.; Ruiz, Gregory M. 2001. Marine invasive species and biodiversity of South Central Alaska. Regional Citizens Advisory Council of Prince William Sound. Valdez.

Prince William Sound Regional Advisory Council. 2005g. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 4: Softshell Clam: *Mya arenaria* http://www.pwsrcac.org/docs/d0016300.pdf

Strasser, Matthias. 1999. *Mya arenaria* - an ancient invader of the North Sea coast. Helgoländer Meeresuntersuchungen 52: 309-324.

## Phylum Ectoprocta (Bryozoa), Class Gymnolaemata

***Schizoporella japonica*** (Ortmann 1890) Dick et al. 2004 in press
Synonyms: *Schizoporella unicornis* var. *japonica* Ortmann 1890
*Schizoporella unicornis* Okada 1929, Osburn 1952, Powell 1970, and many other authors. Not *S. unicornis* (Johnston 1844)
Common Name- encrusting bryozoan
Invasion Status: Introduced
Population Status: Established

*Schizoporella japonica* is an encrusting bryozoan which grows in spreading colonies consisting of roughly rectangular zooids, with calcareous walls and frontal shield, arranged in rows, with prominent furrows between rows. Zooids feed by extending a ring of tentacles called the lophophore, through an orifice in the wall of the frontal shield. Zooids are 0.5-0.9 mm long and 0.3-0.5 mm wide. Colonies range in color from white to orange, dull red, or brown. The initial founding zooid (ancestrula) is oval in shape, with a glassy frontal shield and 8 spines around the orifice. The colonies form sheets, up to 200 mm long and 20 mm wide, on rocks, docks, floats, boat hulls, and hard surfaces. Colonies range in color from white to orange, red, or brown (Powell 1970; Dick et al. in press). *Schizoporella* spp. have lecithotrophic larvae, which are likely to spend only short periods in the plankton (Cohen and Carlton 1995), so that ballast-water transport of larvae is unlikely.

The taxonomy of the genus *Schizoporella* is difficult and contentious. Until recently, the name *S. unicornis,* originally applied to a bryozoan from Britain, and *S. errata*, used for a Mediterranean form, were widely applied to similar bryozoans around the world, including invasive populations in Australia, New Zealand, and Hawai'i (Carlton 1979; Cohen and Carlton 1995;Gordon and Matawari 1992; Coles et al. 1999; Keough and Ross 1999). Dick et al. (in press) have re-examined *Schizoporella* sp. from Ketchikan and both sides of the Pacific, and have raised Ortmann's "*S. u.* var. *japonica*" to the status of a distinct species, noting differences between this form and British *S. unicornis*, and similarities between the Japanese type specimen and Alaskan *Schizoporella*. This bryozoan may have been collected in Puget Sound as early as 1927 (Carlton 1979). In 1966-1969, extensive localized growths of *S. japonica* were observed near oyster-growing areas in the Strait of Georgia, British Columbia (Powell 1970). *Schizoporella japonica* has been collected on SERC settling plates from San Francisco Bay to Prince William Sound

(Hines and Ruiz 2000; Dick et al., in press). Additional species of native and introduced *Schizoporella* may occur on other parts of the Pacific coast, particularly California, but their taxonomy remains unresolved.

*Schizoporella japonica* was first collected in Alaskan waters in 1998 in Valdez and Tatilek, Prince William Sound, and in 2001-2003 was also found in Ketchikan and Sitka. Its history in British Columbia is strongly suggestive of transport with the Pacific Oyster, *Crassostrea gigas*, but movement in hull fouling and with aquaculture gear is also possible.

REFERENCES

Carlton, James T. 1979. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific Coast of North America. Ph.D. dissertation, University of California. Davis.

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.

Coles, S. L.; DeFelice, R. C.; Eldredge, L. G.; Carlton, J. T. 1999. Historical and recent introductions of non-indigenous marine species into Pearl Harbor, Oahu, Hawaiian Islands. Marine Biology 135 (1): 147-158.

Dick, M. H., Grischenko A.V., Mawatari S. F. *In press*. Intertidal Bryozoa (Cheilostomata) of Ketchikan, Alaska. Journal of Natural History.

Gordon, Dennis P.; Mawatari, S.F. 1992. Atlas of marine-fouling bryozoa of New Zealand ports and harbors. Miscellaneous Publications of the New Zealand Oceanographic Institute 107:1-52.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Keough, M. J.; Ross, J. 1999. Introduced fouling species in Port Phillip Bay. In: Hewitt, C. L.; Campbell; M.;Thresher, R.; Martin, Richard B. (Eds.). Marine Biological Invasions of Port Phillip Bay, Victoria. Technical Report # 20. Center For Research on Introduced Marine Pests, CSIRO Marine Research. Hobart, Tasmania. Pp. 193-225.

Powell, N.A. 1970. *Schizoporella unicornis* - an alien bryozoan introduced into the Strait of Georgia. Journal of the Fisheries Research Board of Canada 27: 1847-1853.

**Phylum Chordata, Subphylum Tunicata, Class Ascidiacea**

***Botrylloides violaceus*** Oka 1927
Synonyms: *Botryllus aurantius* Oka 1927; *Botrylloides violaceum* Kott 1985; *Botrylloides diegensis* Fay and Vallee 1979 and other authors (misidentifications)
Common Name: colonial tunicate; Violet Tunicate
Invasion Status: Introduced
Population Status: Established

*Botrylloides violaceus* is a colonial tunicate, formed of many zooids arranged in ladder-like chains, covered by a transparent or whitish test. The colonies form sheets, up to 200 mm long and 20 mm wide, on rocks, docks, floats, boat hulls, and hard surfaces. The color of the colonies is often reddish-purple in life, but varies to pale-yellow or white, yellowish orange, dark red, or black. Larvae are brooded in the tests of the colony (Nishikawa 1991). The swimming tadpole-like larvae spend only 4-10 hours in the plankton, so that long-range dispersal of this tunicate depends on colonies attached to floating objects, including boats and ships.

*Botrylloides violaceus* was described from Japan in 1927. It is found in Northwest Pacific from Japan to southern China (Kott 1985). It is now widely introduced, to the Northeast Pacific, the Northwest Atlantic, and parts of the Northeast Atlantic. Recognition of its invasion in North American waters was delayed, owing to confusion with a native West Coast tunicate, *B. diegensis* (Lambert and Lambert 1998). *Botrylloides violaceus* was collected as early as 1966 on the West Coast of North America, in Santa Barbara, California (Gretchen Lambert, personal communication). Currently, it is found in many large and small West Coast harbors, from Ensenada, Mexico to Kachemak Bay, Alaska (Lambert and Lambert 2003; Hines and Ruiz 2000). On the East Coast, *B. violaceus* was probably present before 1980 in Long Island Sound, and now ranges from Chesapeake Bay (Ruiz et al. 2000) to Prince Edward Island, Canada (Locke et al. 2005). In European waters, *B. violaceus* has invaded the Lagoon of Venice, Italy (Zaniolo et al. 1998), and estuaries in the Netherlands (Gittenberger 2005).

In Alaskan waters, *Botrylloides violaceus* was first found in 1998, at Tatilek in Prince William Sound (Hines and Ruiz 2000; Lambert and Sanamyan 2001). In this study, we found it in harbors at Ketchikan, Sitka, and in Kachemak Bay. Hull fouling of ships, or transport with oysters and/or aquaculture gear are possible vectors for the transport of this tunicate into Alaskan waters.

REFERENCES

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.

Gittenberger, Adriaan. 2005. Recent population expansions of non-native ascidians in the Netherlands. International Invasive Sea Squirt Conference Abstracts. Woods Hole Oceanographic Institution, April 21-22. Woods Hole, Massachusetts.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Kott, Patricia. 1985. The Australian Ascidiacea Part 1, Phlebobranchia and Stolidobranchia. Memoirs of the Queensland Museum 23: 1-440.

Lambert, C. C.; Lambert, G. 1998. Non-indigenous ascidians in southern California harbors and marinas. Marine Biology 130: 675-688.

Lambert, C. C.; Lambert, G. 2003. Persistence and differential distribution of nonindigenous ascidians in harbors of the Southern California Bight. Marine Ecology Progress Series 259: 145-161.

Lambert, G.; Sanamyan, K. 2001. *Distaplia alaskensis* sp. nov. (Ascidiacea, Aplousobranchia) and other new ascidian records from South-central Alaska, with a redescription of *Ascidia columbiana* (Huntsman, 1912). Canadian Journal of Zoology 79: 1766-1781.

Locke, Andrea; Hanson, J. M.; Thompson, J.; Ellis, K. M. 2005. Did green crabs facilitate the clubbed tunicate (Styela clava) invasion of Prince Edward Island. . International Invasive Sea Squirt Conference Abstracts. Woods Hole Oceanographic Institution, April 21-22. Woods Hole, Massachusetts.

Nishikawa, T. 1991. The ascidians of the Japan Sea. II. Publications of the Seto Marine Biological Laboratory 35: 25-170.

Ruiz, G.M.; Fofonoff, P. W.; Carlton, J. T.; Wonham, M. J.; Hines, A. H. 2000. Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases. Annual Review of Ecology and Systematics 31: 481-531.

Zaniolo, G.; Brunetti, R.; Burighel, P. 1998. Brood pouch differentiation in *Botrylloides violaceus*, a viviparous ascidian (Tunicata). Invertebrate Reproduction and Development 33(1): 11-23.

***Botryllus schlosseri*** (Pallas 1766) Savigny 1816
Synonyms: *Alcyonium schlosseri* Pallas 1766; *Botryllus gouldii* Verrill 1871
Common Name: Golden Star Tunicate
Invasion Status: Introduced
Population Status: Established

*Botryllus schlosseri* is a colonial tunicate, formed of many zooids arranged in star-like clusters of 5-20 zooids, forming spreading colonies 25-150 mm wide, on man-made and natural hard surfaces, including rocks, docks, floats and boat hulls. Color is highly variable within and among colonies, including yellow, deep purple, red, brown and black, but the star-like arrangement of the zooids is distinctive (Van Name 1945; Nishikawa 1991; Lambert and Lambert 1998). The tadpole larvae spend less than 24 hours in the plankton, and most settle within 1 hour (Brunetti and Geghi 1982) so that long-range dispersal of this tunicate depends on floating objects, including boats and ships.

*Botryllus schlosseri* was described from Mediterranean waters in 1766. It is often regarded as native to European waters (Rinkevich et al. 1992; Stoner et al. 2002; Gretchen Lambert, personal communication), but Carlton (2003) suggests that this species could have been introduced from elsewhere centuries before its description. It is now widespread in temperate harbors around the world. On the East Coast of North America, it was collected in 1838 (Couthouy 1838) near Boston, and has recently extended its range northward to Prince Edward Island (Locke et al. 2005). This tunicate is known historically from the Gulf Coast (Van Name 1945; U.S. National Museum of Natural History 2002), but was not found south of Chesapeake Bay in our recent fouling plate survey (Ruiz et al., unpublished data). On the West Coast, *Botryllus schlosseri* was first reported from San Francisco Bay in 1947 (Cohen and Carlton 1995), and its known West Coast Range extends from Ensenada, Mexico (Lambert and Lambert 2003) to Sitka, Alaska.

In Alaskan waters, *Botryllus schlosseri* was first found in 2001, at several locations in Sitka Sound (this study). Prior to our collections, the northernmost records for this species were from Puget Sound (Cohen et al. 1998). This species was probably transported into Alaskan waters with hull fouling, with oysters, or with aquaculture gear.

REFERENCES

Brunetti, Riccardo; Geghi, Luigi. 1982. Larval ecology of *Botryllus schlosseri* (Ascidiacea). A preliminary investigation. Naturalista Siciliano 6: 126-129.

Carlton, James T. 2003. Community assembly and historical biogeography in the North Atlantic Ocean: the potential role of human-mediated dispersal vectors. Hydrobiologia 503: 1-8.

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.

Cohen, A. N. and 17 authors. 1998. Puget Wound expedition: a rapid assessment survey of non-indigenous species in the shallow waters of Puget Sound. Washington State Department of Natural Resources. Olympia.

Couthouy, Joseph P. 1838. Descriptions of new species of Mollusca and shells, and remarks on several polypi found in Massachusetts Bay. Boston Journal of Natural History 2: 53-111.

Lambert, C. C.; Lambert, G. 1998. Non-indigenous ascidians in southern California harbors and marinas. Marine Biology 130: 675-688.

Lambert, C. C.; Lambert, G. 2003. Persistence and differential distribution of nonindigenous ascidians in harbors of the Southern California Bight. Marine Ecology Progress Series 259: 145-161.

Lambert, G.; Sanamyan, K. 2001. *Distaplia alaskensis* sp. nov. (Ascidiacea, Aplousobranchia) and other new ascidian records from South-central Alaska, with a redescription of *Ascidia columbiana* (Huntsman, 1912). Canadian Journal of Zoology 79: 1766-1781.

Locke, Andrea; Hanson, J. M.; Thompson, J.; Ellis, K. M. 2005. Did green crabs facilitate the clubbed tunicate (*Styela clava*) invasion of Prince Edward Island. . International Invasive Sea Squirt Conference Abstracts. Woods Hole Oceanographic Institution, April 21-22. Woods Hole, Massachusetts.

Nishikawa, T. 1991. The ascidians of the Japan Sea. II. Publications of the Seto Marine Biological Laboratory 35: 25-170.

Rinkevich, Baruch; Shapira, Michal; Weissman, Irving; Saito, Yasunori. 1992. Allogeneic responses between three remote populations of the cosmopolitan ascidian *Botryllus schlosseri*. Zoological Science 9: 989-994.

Ruiz, G.M.; Fofonoff, P. W.; Carlton, J. T.; Wonham, M. J.; Hines, A. H. 2000. Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases. Annual Review of Ecology and Systematics 31: 481-531.

Stoner, Douglas S.; Ben-Shlomo, Rachel; Rinkevich, Baruch; Wiessman, Irving. 2002. Genetic variability of *Botryllus schlosseri* invasions to the east and west coasts of the USA. Marine Ecology Progress Series 243: 93-100.

U.S. National Museum of Natural History 2002. Invertebrate zoology collections database. http://goode.si.edu/webnew/pages/nmnh/iz/Query.php

Van Name, Willard G. 1945. The North and South American ascidians. Bulletin of the American Museum of Natural History 84:1-462.

**Phylum Chordata, SubphylumVertebrata, Class Osteichthyes**

***Alosa sapidissima*** (Wilson in Rees, 1811)

Synonyms: *Clupea sapidissima* Wilson in Rees 1811; *Clupea indigena* Mitchill 1814; *Alosa praestabilis* DeKay 1842

Common Name: American Shad

Invasion Status: Introduced

Population Status: Established, marine migrant, breeding in freshwaters south of Alaska

The American Shad is a large (to 75 cm total length) fish of the herring family (Clupeidae), distinguished from the Pacific Herring (*Clupea pallasi*) by the presence of keeled scales on the belly, and by a row of dark spots on each side (Eschmeyer et al. 1983). It is anadromous, migrating several to hundreds of km up rivers to spawn, developing in freshwater, and then as a juvenile and adult, ranging over long distances in the ocean in search of food, mostly planktonic crustaceans (shrimp, mysids, euphausiids) (Hart 1973). American Shad are native to the Atlantic Coast of North America from Labrador , to the St. Johns River, Florida (Page and Burr 1991). They were introduced to the San Francisco Bay watershed in 1871, and rapidly spread northward along the Pacific Coast, spawning at least as far north as the Columbia River (Chapman 1942; Cohen and Carlton 1995), while feeding adults have been caught as far south as Baja California Mexico, and as far north as Cook Inlet and the Kamchatka Peninsula (Center for Aquatic Resource Studies 2005).

*Alosa sapidissima* was first reported from Alaskan waters in 1891 from the Stikine River, near Wrangell Island (Chapman 1942). A specimen from Port Moller, Alaskan Peninsula, on the Bering Sea, is at the University of Alaska museum (Nora Foster, personal communication). Frequent catches occur in southeast Alaskan waters during strong El Niňo years (J. Karinen, personal communication). Numbers of American Shad have been increasing in waters of Washington State, and studies were being considered to examine the possibility of competition with Pacific Herring (Raymond M. Buckley, personal communication).

REFERENCES

Chapman, Wilbert M. 1942. Alien fishes in the waters of the Pacific Northwest. California Fish and Game 28: 9-15.
Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.
Eschmeyer, William N.; Herald, Earl S.; Hamman, Howard. 1983. A field guide to Pacific coast fishes. Houghton Mifflin. Boston.
Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada. Ottawa.
Page, Lawrence M.; Burr, Brooks M. 1991. Freshwater Fishes. Houghton Mifflin. Boston.

***Esox lucius*** (Linnaeus, 1758)
Synonyms:
Common Name: Northern Pike
Invasion Status: Introduced (Pacific drainages); Native (Arctic and Bering Sea drainages)
Population Status: Established

*Esox lucius* (Northern Pike) is a large (up to 133 cm total length) freshwater predatory fish. It is the only member of its family in Alaskan waters. The Northern Pike has a circumpolar native range, from Europe to Siberia, and from Labrador to Alaska (Page and Burr 1991; Morrow 1980). It has been introduced, with varying success, to many locations outside its native range, including Atlantic drainages from Maine to North Carolina, many Midwestern locations at the southern edge of its range, and a few Pacific watershed locations, including Clarks Fork River, Idaho, and Lake Davis, in the Sacramento basin, California (Center for Aquatic Resource Studies 2005). Although the pike is a freshwater fish, we include it here because it is known to enter brackish water, including the Baltic Sea (Scott and Crossman 1973), and because, as a predator on salmonid fishes, it has the potential to effect marine ecosystems and fisheries in Alaska.

In Alaska, Northern Pike is native to rivers and lakes of the Arctic Ocean Basin, and also those entering the Bering Sea, but in the 1970s it was introduced illegally to tributaries of the Susitna River, in the vicinity of Anchorage, and to various lakes and streams on the Kenai Peninsula (Morrow 1980). Northern Pike introductions are a serious concern, because these fish are major predators, feeding primarily on other fishes, including trout and salmon, and have the potential to effect fisheries and threatened/endangered fish populations. (Morrow 1980). An attempt to eradicate an illegally established population in Lake Davis, California, was unsuccessful, costly, and unpopular, since it affected water supplies, recreation, and the local tourist economy (Lee 2002).

REFERENCES

Center for Aquatic Resource Studies, Biological Resource Division, U.S. Geological Survey 2005. Nonindigenous Aquatic Species Database. Gainesville, FL. http://nas.er.usgs.gov
Lee, Dennis P. 2002. Northern pike control at Lake Davis, California. In: Cailteux, Richard; and 6 editors (Eds.). Rotenone in fisheries: are the rewards worth the risks? American Fisheries Society. Bethesda, Maryland.
Morrow, James E. 1980. The Freshwater Fishes of Alaska. Alaska Northwest Publishing Company. Anchorage.
Page, Lawrence M.; Burr, Brooks M. 1991. Freshwater Fishes. Houghton Mifflin. Boston.
Scott, W. B.; Crossman, E. J. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada. Ottawa.

## DEFINITE INTRODUCTIONS; ESTABLISHMENT UNCERTAIN

### Kingdom Plantae, Phylum Phaeophycophyta

***Macrocystis integrifolia*** Bory de Saint-Vincent 1826
Synonyms:
Common Name: Giant Kelp
Invasion Status: Native in Southeast Alaska, Introduced in Prince William Sound; Kachemak Bay
Population Status: Failed (where introduced)

*Macrocystis integrifolia* (Giant Kelp) is a huge brown alga, with a tough stalk growing from a holdfast, and huge serrated blade-like fronds, with inflated air-bladders at the bases, branching out from the stalk. The overall length of a single plant can exceed 20 m, and the plant can grow in waters as deep as 6 m. However, in southeastern Alaska, the Giant Kelp rarely exceeds 3 m in length, because of the low water temperatures (Prince William Sound Regional Advisory Council 2005h). *Macrocystis integrifolia* ranges from Southeast Alaska to southern California, and also occurs in Chile (Guiry et al. 2005).

Giant Kelp is native to Alaskan waters, at least as far north as Sitka, and drifting plants, carried by currents, have been reported as far north as Kodiak (Scagel et al. 1989CHECK). However, since 1979, blades of *M. integrifolia* have been flown from southeast Alaska and placed in impoundment nets with spawning Pacific Herring (*Clupea pallasi*). The blades of kelp, with attached herring roe, are a delicacy in Japan. Kelp blades which appear clean to the eye are selected for the "roe-on-kelp" fishery, but microscopic algae and invertebrates could be transported northward by this industry. Many blades and fronds of kelp were found floating and washed up in Prince William Sound, apparently escaping from the nets, but none were found to be attached (Hansen, in Hines and Ruiz 2000). Establishment of Giant Kelp in Prince William Sound, perhaps aided by climate change, could have profound effects on local marine communities. The transport and spread of attached benthic invertebrates, on the alga, is possibly a more immediate concern (Hines and Ruiz 2000; Prince William Sound Regional Advisory Council 2005h).

REFERENCES
Guiry, M. D.; Rindi, F.; Guiry, G.M., 2005. AlgaeBase version 4.0. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 08 November 2005.
Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.
Prince William Sound Regional Advisory Council. 2005h. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 8: Giant Sea Kelp: *Macrocystis integrifolia* http://www.pwsrcac.org/docs/d0016100.pdf

### Phylum Cnidaria, Class Hydrozoa

***Garveia franciscana*** (Torrey 1902) Vervoort 1964
Synonyms: *Bimeria franciscana* Torrey 1902; *Bimeria tunicata* Fraser 1943; *Perigonimus megas* Kinne 1956
Common Name: Rope Grass Hydroid
Invasion Status: Introduced
Population Status: Unknown

The hydroid *Garveia franciscana* forms bushy, branching colonies, up to 30 cm tall, with flowerlike hydranths sprouting from the branches, sometimes, with additional secondary hydranths budding from the bases of primary hydranths. The hydranths are not enclosed by a covering (theca). This hydroid does not produce medusae, but it does sexually produce planula larvae which spend only a short period in the plankton (Vervoort 1964). This hydroid grows on a wide variety of natural and man-made surfaces, including wharves, logs, boat hulls, oysters and oyster-racks, rocks and jetties, and powerplant water systems (Calder 1971; Cory 1967).

The native region of *Garveia franciscana* is unknown, although the Indo-Pacific has been suggested as a region of origin (Carlton 1979; Cohen and Carlton 1995). This hydroid has a wide distribution, mostly in tropical to warm-temperate regions, and most often in brackish waters, though it has been introduced to the southern North Sea and Baltic (Vervoort 1964). On the coast of North America, it ranges from Brazil to Delaware Bay (Calder 1971; Calder and Mayal 1998), with recent records from New Hampshire and Rhode Island (Pederson et al. 2005; Ruiz et al., unpublished data). If this species is found to be conspecific with *G. cerulea* Clarke 1883, then its Atlantic coast range extends to New Brunswick (Fraser 1944), but the relationships of these two species are unresolved, at present (Calder 1971; Calder, personal communication). On the Pacific Coast of North America, this species has until recently, only been reported from San Francisco Bay, where it was first described (Carlton 1979; Cohen and Carlton 1995).

In 1997, this hydroid was identified from fouling plates from Homer, Alaska on Kachemak Bay, by Leanne Henry (Hines and Ruiz 2000). Since this species is characteristic of temperate-to-tropical brackish waters (Vervoort 1964), further collections will be needed to confirm the establishment of this species in Alaska. Hull fouling is a likely vector for this species in Alaskan waters.

REFERENCES

Calder, Dale R. 1971. Hydroids and hydromedusae of southern Chesapeake Bay. Virginia Institute of Marine Science, Special Papers in Marine Science 1: 1-125.

Calder, D.R.; Mayal, E.M. 1998. Dry season distribution of hydroids in a small tropical estuary, Pernambuco, Brazil. Zoologische Verhandelingen 323: 69-78.

Carlton, James T. 1979. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific Coast of North America. Ph.D. dissertation, University of California. Davis.

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.

Cory, Robert L. (1967) Epifauna of the Patuxent River estuary. Chesapeake Science 8: 71-89.

Fraser, C. McLean (1944) Hydroids of the Atlantic Coast of North America University of Toronto Press, Toronto 1-441.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Pederson, Judith and 15 authors. 2005. Marine invaders in the Northeast. MIT Sea Grant College Program. Cambridge, Massachusetts. http://www.mass.gov/envir/massbays/pdf/ras2003.pdf

Vervoort, W. (1964) Note on the distribution of *Garveia franciscana* (Torrey 1902) and *Cordylophora caspia* (Pallas, 1771) in the Netherlands. Zoologische Mededelingen 39: 125-146.

***Pinauay crocea*** (Agassiz 1862) Marques and Migotto 2001
Synonyms: *Paraphyra microcephala* Agassiz 1865; *Tubularia elegans* Clark 1876; *Tubularia crocea* Agassiz 1862; *Ectopleura crocea* Petersen 1990
Common Name: Pinkmouth Hydroid
Invasion Status: Introduced
Population Status: Unknown

*Pinauay crocea* is a hydroid whose colonies grow on hard surfaces, including rocks, pilings, buoys, and boat hulls, in tangled masses up to 100-120 mm in height, with up to several hundred unbranched stems, each with one flower-like hydranth, with two whorls of 20-24 tentacles (Fraser 1937; Calder 1971; Watson 1999). The hydroids are athecate (lacking a chitnous covering). Unlike many hydroids, *P. crocea* does not bud off medusae. It does sexually produce tentacled, sea-anemone-like actinula larvae which drift in the plankton. Actinula larvae of another tubularian hydroid begin to attach to hard surfaces within 24 hours of release (Yamashita et al. 2004). Thus, transport on floating objects or on boat hulls are the likeliest means of long-distance dispersal.

*Pinauay crocea* was described from the Atlantic Coast of North America, where it ranges from the Caribbean Sea to Nova Scotia (Calder 1971). It is now apparently found through much of the world in temperate waters, in both the Northern and Southern Hemispheres, although some of these records could be due to cryptic species (Watson 1998).

It was first reported on the Pacific Coast by Agassiz in 1865, from San Francisco Bay. By 1876, it was found in San Diego Bay (Carton 1979), and was reported to range as far north as the Gulf of Alaska (Fraser 1937, no specific location given). However, while Fraser had reported collections in Puget Sound and British Columbia in 1911-1937, Claudia Mills (in Cohen et al. 1998) commented that there had been no recent documented collections in Washington waters. The northernmost recent published reports which we could find were from Coos Bay, Oregon (Ruiz et al. 2000).

In 2003, we collected one specimen of a hydroid identified as *P. crocea*, from our plates in Ketchikan. We are unsure whether this hydroid has an established population in Alaskan waters. The likeliest vectors for its transport include hull fouling, oysters, and aquaculture equipment.

REFERENCES


Calder, Dale R. 1971. Hydroids and hydromedusae of southern Chesapeake Bay. Virginia Institute of Marine Science, Special Papers in Marine Science 1: 1-125.

Carlton, James T. 1979. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific Coast of North America. Ph.D. dissertation, University of California. Davis.

Cohen, A. N. and 17 authors. 1998. Puget Wound expedition: a rapid assessment survey of non-indigenous species in the shallow waters of Puget Sound. Washington State Department of Natural Resources. Olympia.

Fraser, C. McLean. 1937. Hydroids of the Pacific Coast of Canada and the United States. University of Toronto Press. Toronto

Marques, Antonio C.; Migotto, Alvaro E. 2001. Cladistic analysis and new classification of the family Tubulariidae (Hydrozoa, Anthomedusae). Papies Avulsos de Zoologia (São Paulo) 41(25): 465-488.

Watson, J. E. 1999. Review of hydroids introduced to Victorian waters. In: Hewitt, C. L.; Campbell; M.;Thresher, R.; Martin, Richard B. (Eds.). Marine Biological Invasions of Port Phillip Bay, Victoria. Technical Report # 20. Center For Research on Introduced Marine Pests, CSIRO Marine Research. Hobart, Tasmania. Pp. 88-107.

Yamashita, Keiji; Kawaii, Satoru; Nakai, Mitsuyo; Fusetani, Nobuhiro. 2003. Larval behavioral, morphological changes, and nematocyte dynamics of *Tubularia mesembryanthemum* Allman 1871. Biological Bulletin 204: 256-269.


**Phylum Annelida, Class Polychaeta, Family Lumbrineridae**

***Lumbrineris heteropoda*** (Marenzellar 1879) Treadwell 1936
Synonyms: *Lumbriconeris heteropoda* Marenzellar 1879; *Lumbrineris heteropoda* Treadwell 1936; *Kuwaita heteropoda* Carrera-Parra & Orensanz 2002
Common Name: lumbrinereid polychaete worm
Invasion Status: Introduced
Population Status: Unknown

Polychaetes of the family Lumbrineridae have an elongated, cylindrical, body body, tapering slightly at the "head" and more at the "tail" end. The head end lacks appendages, and the parapodia ("paddle-feet") are reduced to short, single branches, giving the worm an earthworm-like appearance. These are carnivorous worms, burrowingin soft mud, and their habits and long, threadlike bodies makes it difficult to obtain whole specimens (Pettibone 1963). *Lumbrineris heteropoda* has a wide reported range in the Indo-Pacific region, from the Red Sea to Japan, Korea, and Russia, although some of these records may represent cryptic species (Carrera-Parra and Orensanz 2002). Lumbrinerid polychaetes have 2 modes of development, either direct development in jelly-like egg-masses, or short lived larvae (e.g., ~5 days in the plankton for *Lumbrineris impatiens,* France (Bhaud et al. 1987).

Two specimens of *L. heteropoda,* one from Resurrection Bay, and one from Glacier Bay, are known from Alaskan waters. These occurrences are thought to represent introductions of this species (Nora Foster, personal communication; Hines and Ruiz 2000). Transport in ballast water or sediment is the likeliest mode of introduction. Establishment of this species should be considered uncertain until more specimens are found.

REFERENCES

Bhaud, M; Cazaux, C 1987. Description and identification of polychaete larvae, their implications in current biological problems. Oceanis. 1987; 13(6): 595-753
Carrera-Parra, Luis F.; Orensanz, Jose M. 2002. Revision of *Kuwaita* Mohammad, 1973 (Annelida, Polychaeta, Lumbrineridae). Zoosystema 24 (2): 273-281.
Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.
Pettibone, Marian H. 1963. Marine polychaete worms of the New England region. 1. Aphroditidae through Trochochaetidae. Bulletin of the United States National Museum 227 (Part 1): 1-356.

**Phylum Mollusca, Class Bivalvia**
***Crassostrea gigas*** (Thunberg, 1793)
Synonyms: *Ostrea gigas* Thunberg, 1793
Common Names: Pacific Oyster; Japanese Oyster
Invasion Status: Introduced
Population Status: Unknown

*Crassostrea gigas* (Pacific Oyster) is a bivalve mollusk with large white-to gray (occasionally with brownish or purplish patches) roughly oval shells, with the two valves differing in shape, and vary variable depending on substrate and crowding. The upper (right) valve is flattened with a low round umbo (the hump above the hinge), while the lower valve is rounder and with a more pronounced umbo. The valves range from smooth to fluted. The shells usually reach 8-30 cm in length and occasionally 400 mm. Pacific Oysters attach to hard surfaces such as rocks, logs, shells, or other oysters, in the lower intertidal or shallow sublittoral, and once firmly attached, remain fixed for life (Quayle 1969; Zenetos et al. 2003; Prince William Sound Regional Advisory Council 2005i). Larvae spend 11-30 days in the plankton before settlement (His 1989).

*Crassostrea gigas* is native to the Northwest Pacific, from Sakhalin, Russia to Hong Kong. Within that range, a variety of races or strains are known, varying in size and shape (Quayle 1969; Carriker and Gaffney 1996). Some of these forms may actually be cryptic species. The most widely transplanted form, and the one grown in Pacific waters of North America is the 'Miaygi strain' (Quayle 1969). *Crassostrea gigas* is the most widely cultured oyster in the world, now cultured and/or established in the wild, in European waters from Germany to Spain and the Black Sea, South Africa, Australia, New Zealand, southern South America, and the coast of North America, from Mexico to Alaska (Carlton 1979; Nell and Holliday 1988; Cranfield et al. 1998; Orensanz et al. 2002; Zenetos et al. 2003). In North American waters, the Pacific oyster spawns erratically and cultured spat are stocked to maintain most fisheries (Carlton 1979), but occasional to regular spawning and settlement are reported in estuaries from Humboldt Bay to southern British Columbia (Boyd et al. 2002; Cohen et al. 1998; Quayle 1969).

Pacific Oysters were introduced to Puget Sound in 1902, and first planted in British Columbia waters in 1912. In 1939, oyster culture was first started in Alaskan waters in Ketchikan (Carlton 1979). It is now reared from Ketchikan north to Prince William Sound and Kachemak Bays. Alaskan waters are too cold for successful reproduction of *C. gigas*, which requires waters of at least 16 C for spawning (Quayle 1969; His 1989; Prince William Sound Regional Advisory Council 2005i)

REFERENCES
Boyd, Milton J.; Mulligan, Tim J; Shaughnessy, Frank J. 2002. Non-indigenous marine species of Humboldt Bay, California. California Department of Fish and Game. Sacramento.
Carlton, James T. 1979. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific Coast of North America. Ph.D. dissertation, University of California. Davis.
Carriker, Melbourne R.; Gaffney, Patrick M. 1996. A catalogue of selected species of living oysters (Ostreacea) of the world. In: Kennedy, Victor S., Newell, Roger I. E., Eble, A. (Eds.). The Eastern Oyster *Crassostrea virginica*. Maryland Sea Grant. College Park, Maryland. Pp. 1-8.
Cranfield, H.J.; Gordon, D.P.; Willan, R.C.; Marshall, B.A; Battershill, C.N.; Francis, M.P.; Nelson, W.A.; Glasby, C.J.; Read, G.B. 1998. Adventive marine species in New Zealand. The National Institute of Water and Atmospheric Research. New Zealand.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

His, E.; Robert, R.; Dinet, A. 1989. Combined effects of temperature and salinity on fed and starved larvae of the Mediterranean mussel *Mytilus galloprovincialis* and the Japanese oyster. *Crassostrea gigas*. Marine Biology 100: 455-463.

Nell, John A.; Holliday, John E. 1988. Effects of salinity on the growth and survival of Sydney Rock oyster (*Saccostrea commercialis*) and Pacific oyster (*Crassostrea gigas*) larvae and spat. Aquaculture 68: 39-44.

Quayle, D. B. 1969. Pacific oyster culture in British Columbia. Canadian Fisheries Research Board Bulletin 169: 1-192.

Prince William Sound Regional Advisory Council. 2005i. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 3: Pacific (Japanese) Oyster: *Crassostrea gigas* http://www.pwsrcac.org/docs/d0015900.pdf

Zenetos, Argyro; Gofas, Serge; Russo, Giovanni; Templado, Jose. 2003. CIESM atlas of exotic species in the Mediterranean: Molluscs. Monaco.

**Phylum Arthropoda, Subphylum Crustacea, Class Malacostraca, Order Amphipoda**
***Jassa marmorata*** Holmes 1903
Synonyms: *Jassa falcata* Chevreux and Page 1925 (in part)
Common Names: tube-building amphipod
Invasion Status: Introduced
Population Status: Unknown

Gammarid amphipods of the genus *Jassa* are shrimp-like crustaceans, characterized by a pair of relatively long, bristly second antennae, used in feeding, and a large, claw-like 2nd gnathopod (appendage on the 2nd body segment). In males this appendage is larger than in females, and bears a claw-like terminal segment, and a prominent “thumb” on the swollen penultimate segment. In this genus, there are two types of males, smaller “minors”, and “majors”, which can be twice as large as “minors”and females, and have a greatly enlarged gnathopod and “thumb” “Major” males reach about 10 mm long. (Holmes 1905; Conlan 1989; Prince William Sound Regional Advisory Council. 2005j). These amphipods build tubes of detritus and bits of algae, attached to hard surfaces, including rocks, docks, ship hulls, and vegetation. Adults extend their appendages to filter the water for edible particles (Ulrich et al.1995).

Until recently, specimens of *Jassa* from all over the world were routinely identified as *Jassa falcata*, a species which now appears to be confined to European waters. The most cosmopolitan species of the genus *is J. marmorata*, described by Holmes from New England, and considered by Cohen and Carlton (1995) and Chapman (2000) as a probable Northwest Atlantic native. *Jassa marmorata* is now known from both sides of the North and South Atlantic, and the North and South Pacific, primarily from harbors used by shipping (Conlan 1989). Its earliest known record from the Pacific Coast of North America is from Estero de San Antonio, Calfornia (north of San Francisco Bay) in 1941 (Cohen and Carlton 1995). Its present documented range extends from Baja California, Mexico to Point Slocum, Alaska, near Sitka (Conlan 1989).

Conlan (1989) lists one sample of *J. marmorata* from Point Slocum, Alaska. However, identification of this species in Alaskan waters is complicated by the presence of a very similar native species, *J. stauderi*. Consequently, specimens in Prince William Sound surveys were identified as *Jassa* sp. by John Chapman (Hines and Ruiz 2000). *Jassa marmorata* could have been introduced to Alaska in ballast water or fouling. The occurrence of established populations in Alaskan waters requires confirmation.

REFERENCES

Chapman John W. 2000. Climate effects on the geography of nonindigenous peracaridan crustacean introductions in estuaries. In: Pederson, Judith (Ed.). Marine Bioinvasions: Proceeding of a conference, January 24-27, 1999. MIT Sea Grant College Program. Cambridge, Massachusetts. Pp. 66-80.

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.

Conlan, Kathleen E. 1989. Revision of the crustacean amphipod genus *Jassa* (Corophioidea: Ischyroceridae). Canadian Journal of Zoology 68: 2031-2075.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.
Holmes, S. J. 1905. The Amphipoda of southern New England. Bulletin of the Bureau of Fisheries 24: 457-541.
Prince William Sound Regional Advisory Council. 2005j. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 14: Tube Dwelling Amphipod: *Jassa marmorata* http://www.pwsrcac.org/docs/d0016400.pdf

Ulrich, I.; Anger, K.; Schottler, U. 1995. Tube-buildng in two epifaunal amphipod species, *Corophium insidiosum* and *Jassa falcata* Helgoländer Meeresuntersuchungen. 49: 393-398.

**Phylum Echinodermata, Class Stelleroidea, Subclass Ophiuroidea**

***Ophiothrix koreana*** Duncan 1879
Synonyms:
Common Names: brittle-star
Invasion Status: Introduced
Population Status: Unknown

Brittle-stars are small echinoderms, resembling starfish, but their long, very flexible arms are clearly set off from the pentagonal central disk, and lack the ambulacral grooves found on the undersides of starfish. Different species vary greatly in their nutrition, from canivory to filter-feeding and scavenging. Many species are brooders, with direct development, but in many others, fertilization and development occur in the plankton. For six species, the planktonic period ranged from 14 to 40 days (Barnes 1987).

*Ophiothrix koreana* is native to Northwest Pacific, including Korea and the Sea of Japan. A single specimen from Juneau constitutes the only record of this species from the coast of North America (Hines and Ruiz 2000). This species could have been introduced as larvae in ballast water, or as adults in hull fouling.

REFERENCES

Barnes, Robert D. 1987. Invertebrate zoology. 5th edition. Saunders. Philadelphia.
Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

**Phylum Chordata, SubphylumVertebrata, Class Osteichthyes**

*Salmo salar* Linnaeus, 1758
Synonyms:
Common Name: Atlantic Salmon
Invasion Status: Introduced
Population Status: Unknown

*Salmo salar* (Atlantic Salmon) resembles Pacific salmons and trouts (*Oncorhynchus* spp.) in overall appearance, but has several distinguishing features: (1) It has black spots on the back, as do most Pacific species, but also has black spots on the gill-covers, lacking in the Pacific natives.(2) Black spots are absent in the tail in *S. salar,* but present in most Pacific species. (3) The rear edge of the upper jaw reaches only to the midpoint of the eye (except in large males, where it projects further back), whereas, in Pacific species, the jaw ends well behind the eye. (4) The anal fin of Atlantic Salmon has 8-11 rays, while Pacific species have 11-13 rays. The Atlantic Salmon reaches a larger maximum size (140 cm) than most of the Pacific species, with the exception of the Chinook Salmon (*O. tshawytscha*) (Scott and Crossman 1973; Page and Burr 1991). The life history of *Salmo salar* resembles that of the native Pacific salmons, with spawning in freshwater, a juvenile period in estuaries, adult life at sea, and upstream spawning migrations of tens to hundreds of km). However, unlike Pacific salmons, Atlantic salmon can survive the spawning migration and spawn again (Scott and Crossman 1973).

*Salmo salar* (Atlantic Salmon) are native to both sides of the Atlantic, from the Ungava Peninsula to the Housatonic River (Connecticut) and from the Barents Sea and inflowing rivers to Portugal, and over the intervening Atlantic Ocean. Native, landlocked populations also occur in some lakes (Scott and Crossman 1973). Deliberate introductions of Atlantic Salmon have been made in many parts of the world, including Australia, New Zealand, South America, and the sub-Antarctic Island of Kerguelen. These have been largely unsuccessful, except for a few small land-locked populations (Lever 1996). On the Pacific Coast of North America attempts were made to introduce Atlantic Salmon at locations from California to British Columbia from 1874 to 1933 (Carl and Giguet 1972; Cohen and Carlton 1995). The development of extensive net-pen aquaculture of *S. salar*, beginning in 1971 in Puget Sound, and in 1985, in British Columbia, has resulted in the escape of many thousands of fish (Wing et al. 1992). .

In 1990, the first capture of Atlantic Salmon was reported from Alaskan waters, off Cape Cross, southeast Alaska (Wing et al. 1992). Since then, hundreds of specimens have been caught in Alaskan waters, including at least two records in fresh water (Valdez-Cordova County, Copper River, 2000; Ketchikan area, Situk River, 2000) (Center for Aquatic Resource Studies 2005). One specimen was caught in the Bering Sea in 1997 (Brodeur and Busby 1998). Many of the specimens caught in Alaskan waters are in poor condition, but spawning and production of juvenile fish has been observed in British Columbia waters (Volpe et al. 2000). Established populations of the Atlantic Salmon are not yet documented from the Pacific, but the possibility is considered a threat to native salmon stocks.

REFERENCES

Brodeur, Richard D.; Busby, Morgan S. 1998. Occurrence of an Atlantic Salmon *Salmo salar* in the Bering Sea. Alaska Fisheries Research Bulletin 5 (1):64-66.

Carl, G. Clifford, Guiguet, C. J. 1972. Alien animals in British Columbia. British Columbia Provincial Museum: Department of Recreation and Conservation: Handbook 14: 1-102.

Center for Aquatic Resource Studies, Biological Resource Division, U.S. Geological Survey. 2005. Nonindigenous Aquatic Species Database. Gainesville, Florida. http://nas.er.usgs.gov

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring Maryland.

Lever, Christopher. 1996. Naturalized fishes of the world. Academic Press. London.

Page, Lawrence M.; Burr, Brooks M. 1991. Freshwater Fishes. Houghton Mifflin. Boston.

Scott, W. B.; Crossman, E. J. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada. Ottawa.

Volpe, John P.; Taylor, Eric B.; Rimmer, David W.; Glickman, Barry. 2000. Evidence of natural reproduction of aquaculture-escaped Atlantic salmon in a coastal British Columbia river. Conservation Biology 14 (3): 899-903.

## SELECTED CRYPTOGENIC SPECIES

### Kingdom Plantae, Phylum Phaeophycophyta

***Delamarea attenuata*** (Kjellman 1883) Rosenvinge 1893
Synonyms: *Scytosiphon attenuatus* Kjellman 1883
*Delamarea paradoxa* Hariot 1889
*Physematoplea attenuata* (Kjellman) Kjellman 1890
Common name: brown alga
Invasion Status: Cryptogenic
Population Status: Established

*Delamarea attenuata* is a coarse, string-like brown alga, 5-8 cm tall, growing from a disc-like base, usually in groups (Taylor 1957). This alga was found by Gayle Hansen, growing on floats at Tatilek, in Prince William Sound (Hanson, in Hines and Ruiz 2000). *Delamarea attenuata* has a high-latitude distribution, in the Atlantic from Germany and Massachusetts to Greenland, and in the Pacific, in Alaska, Japan (Hokkaido), and the Commander Islands, Russia (Guiry et al. 2005). The Pacific records are somewhat recent, including the first record for Japan was published in 1980 (Kawai and Kurogi 1980). Alaska (Lindstrom 1977, cited by Guiry et al), and the Commander Islands records (Selivanova and Zhigadlova 1997).

*Delamarea attenuata* was considered cryptogenic in Alaska by Gayle Hanson (Hines and Ruiz 2000). Its relatively recent discovery in the Pacific, its small number of reported occurrences (Hines and Ruiz 2000) and the fact that it was overgrown by the introduced epiphyte *Microspongium globosum* (Hanson, in Hines and Ruiz 2000) suggest that it may have been introduced. Alternatively, this alga could have a natural, circumpolar distribution, and may have just been overlooked.

REFERENCES

Guiry, M. D.; Rindi, F.; Guiry, G.M., 2005. AlgaeBase version 4.0. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 08 November 2005.
Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.
Kawai, H.; Kurogi, M. 1980. Morphology of a brown alga *Delamarea-attenuata:* New-record (Dictyosiphonales) for Japan. Japanese-Journal-of-Phycology. 1980; 28(4): 225-231.
Lindstrom, S. C. 1977. An annotated bibliography of the benthic marine algae of Alaska. Alaska Department of Fish and Game. Juneau.
Selivanova, O.N.; Zhigadlova, G.G. 1997. Marine algae of the Commander Islands. Preliminary remarks on the revision of the flora. II. Phaeophyta. *Botanica Marina* 40: 9-13.
Taylor, William Randolph. 1957. Marine Algae of the Northeastern Coast of North America. University of Michigan Press. Ann Arbor.


### Kingdom Plantae, Phylum Chlorophycota

***Codium fragile*** (Suringar 1867) Hariot 1889
Synonyms: *Acanthocodium fragile* Suringar 1867
Common name: Dead Man's Fingers
Invasion Status: Cryptogenic
Population Status: Established

*Codium fragile* is a complex, wide-ranging species (probably a species complex), composed of at least 7 named subspecies and probably many undescribed species (Goff et al. 1992; Guiry et al. 2005). It is a dark-green coarsely bushy seaweed, growing from a coarse holdfast, with thick, ropelike fronds with Y-shaped branches. Dead Man's Fingers grows on a wide range of hard surfaces, including rocks, shells, logs, docks, and other algae (Prince William

Sound Regional Advisory Council 2005k). Different forms of this species are native to the Indian Ocean, the northwest Pacific (Philippines-China-Japan-Russia), the southwest Pacific (Australia-New Zealand), Antarctica, the southeast Pacific (Chile) and the northeast Pacific (California-southeast Alaska) (Guiry et al. 2005).

At least 3 invasive subspecies of *C. fragile* are known, of which the most widely invasive form is *C. fragile* ssp. *tomentosoides,* native to the Northwest Pacific, and now introduced to the northeast Atlantic (Iceland-southern Norway-Spain-Tunisia), northwest Atlantic (Prince Edward Island-North Carolina), southwest Pacific (Australia-New Zealand), southeastern Pacific (Chile), and northeastern Pacific (San Francisco Bay) (South and Tittley 1986; Goff et al. 1992; Bird et al. 1993; Cohen and Carlton 1995; Guiry et al. 2005). However, in several cases, because of the presence of very similar native forms, molecular methods have been needed to confirm the presence of the introduced form (Goff et al. 1992; González and Santalices 2004). *C. f.* ssp. *tomentosoides* gametes spend little time in the plankton, so that the likeliest modes of transport are by fouling, with shellfish, and by the use of seaweed as bait-packing material (Carlton and Scanlon 1985).

In Alaskan waters, native forms of *C. fragile* have long been known to occur as far north as Sitka (Scagel et al. 1989). In surveys in 1997, Gayle Hanson found at least two forms of *C. fragile* growing on Green Island, Prince William Sound, a northward range extension for the species. Both types showed some resemblance to *C. f.* ssp. *tomentosoides*, but appeared to fall within the morphological range of native forms (Hanson, in Hines and Ruiz 2000). Molecular analysis would be useful in determining the identity of the Green Island population. So far, on the Pacific Coast of North America, the occurrence of *C. f.* ssp. *tomentosoides* has only been confirmed from San Francisco Bay (Goff et al. 1992; Cohen and Carlton 1995).

REFERENCES

Bird, C. J., Dadswell, M. J., Grund, D. W. 1993. First record of the potential nuisance alga *Codium fragile* ssp. *tomentosoides* (Chlorophyta, Caulerpales) in Atlantic Canada. Proceedings of the Nova Scotian Institute of Science 40: 11-17.

Carlton, J.T.; Scanlon, J.A.1985. Progression and dispersal of an introduced alga: *Codium fragile* ssp. *tomentosoides* (Chlorophyta) on the Atlantic Coast of North America.

Cohen, Andrew N.; Carlton, James T. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant). Washington DC, Silver Spring, Maryland.

Goff, Lynda J.; Liddle, Larry; Silva, Paul C.; Voytek, Mary; Coleman, Annette. 1992. Tracing species invasion in *Codium,* a siphonous green alga, using molecular tools. American Journal of Botany 79 (11): 1279-1285.

González, Alejandra; Santalices, Bernabė. 2004. A dichotomous species of *Codium* (Bryopsidales, Chlorophyta) is colonizing northern Chile. Revista Chilena de Historia Natural 77: 293-304.

Guiry, M. D.; Rindi, F.; Guiry, G.M., 2005. AlgaeBase version 4.0. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 08 November 2005.

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Prince William Sound Regional Advisory Council. 2005k. Nonindigenous Aquatic Species of Concern for Alaska Fact Sheet 5: Dead Man's Fingers: *Codium fragile* http://www.pwsrcac.org/docs/d0015700.pdf

Scagel, R.F., Gabrielson, P.W., Garbary, D.J., Golden, L., Hawkes, M.W., Lindstrom, S.C., Oliveira, J.C., Widdowson, T.B. 1989. A synopsis of the benthic marine algae of British Columbia, southeast Alaska, Washington, and Oregon. University of British Columbia. Vancouver.

South, G. Robin; Tittley, Ian. 1986. A checklist and distributional index of the benthic marine algae of the North Atlantic Ocean. Huntsman Marine Laboratory and British Museum (Natural History). St. Andrews, New Brunswick, and London.


**Phylum Ectoprocta (Bryozoa), Class Gymnolaemata**

***Fenestrulina delicia*** Winston, Hayward & Craig 2000
Synonyms:
Common Name- encrusting bryozoan
Invasion Status: Cryptogenic
Population Status: Established

*Fenestrulina delicia,* an encrusting bryozoan, forms dense, shining white circular patches on shells and algae, ~50 mm in diameter. The zooids are rounded-hexagonal to oval, 0.53-.78 mm long and 0.38-0.45 mm wide, with lateral walls sloping inward, leaving gaps between some zooids. The orifice, though which the animal extends its lophophore (ring of feeding tentacles) is semicircular, with 1-4 spines on the margins. Zooids may develop a prominent brood chamber (ovicell) which is hemispherical, and develops radiating ridges The initial founding zooid (ancestrula) is oval in shape, with a membranous frontal wall, and soon becomes surrounded by a hexagonal arrangement of zooids (Winston et al. 2000; Dick et al., in press). *Fenestrulina delicia* was first observed and studied by Craig, in Maine, starting in 1994, and then formally described by Winston et al. (2000).

In 2001, *F. delicia* was found on SERC fouling plates at Sitka and Valdez. The recent discovery of this species in two widely separated locations raises the possibility of it being introduced to either Alaska or Maine, or to both regions from an unknown native range. Another possibility is that this is a circumpolar species that has gone undetected, owing to its similarity to several similar species of *Fenestrulina* (Dick et al., in press.).

REFERENCES

Dick, M. H., Grischenko A.V., Mawatari S. F. *In press*. Intertidal Bryozoa (Cheilostomata) of Ketchikan, Alaska. Journal of Natural History.

Winston, Judith E.; Hayward, Peter J.; Craig, Sean F. 2000. Marine bryozoans of the northeast coast of the United States: new and problem species. In: Herrera Cubilla, Amalia; Jackson, Jeremy B.C. (Eds.) Proceedings of the 11th International Bryozoology Association Conference. Smithsonian Tropical Research Institute, Balboa, Panama. Pp. 412-420.

**Phylum Chordata, Subphylum Tunicata, Class Ascidiacea**

***Distaplia alaskensis*** Lambert & Sanamyan 2001
Synonyms:
Common Name: colonial tunicate
Invasion Status: cryptogenic
Population Status: Established

*Distaplia alaskensis* is a colonial tunicate, which forms large conical lobes, connected at their base by a stolon (stalk), arising from a tuft of short stolons. Each lobe contains several dumbbell-shaped zooids (up to 4.5 mm long), divided from their neighbors by furrows. Lobes are covered by a translucent test. Lobes are up to 30 mm in length, and the whole colony may be 50 mm long, and is tan-colored. Zooids have brood pouches containing large, tadpole-like larvae (Lambert and Sanamyan 2001).

So far, *Distaplia alaskensis* is known only from docks, marinas, ropes and fouling plates in Prince William Sound, Kachemak Bay, and Dutch Harbor, and has not yet been collected in natural habitats (Lambert, in Hines and Ruiz 2000; Lambert and Sanamyan 2001; Ruiz et al., unpublished data. This tunicate could be a formerly rare Alaskan native, which now thrives in man-made habitats. It is also possible that it could have been overlooked by previous taxonomists, and considered just a variety of the widespread *D. occidentalis* (Lambert and Sanamyan 2001). Alternatively, it could be an unrecognized introduction (Hines and Ruiz 2000).

REFERENCES

Hines, Anson H.; Ruiz, Gregory M. 2000. Biological invasions at cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez/Prince William Sound (Final Report). Regional Citizens Advisory Council of Prince William Sound. Valdez.

Lambert, G.; Sanamyan, K. 2000. *Distaplia alaskensis* sp. nov. (Ascidiacea, Aplousobranchia) and other new ascidian records from South-central Alaska, with a redescription of *Ascidia columbiana* (Huntsman, 1912). Canadian Journal of Zoology 79: 1766-1781.