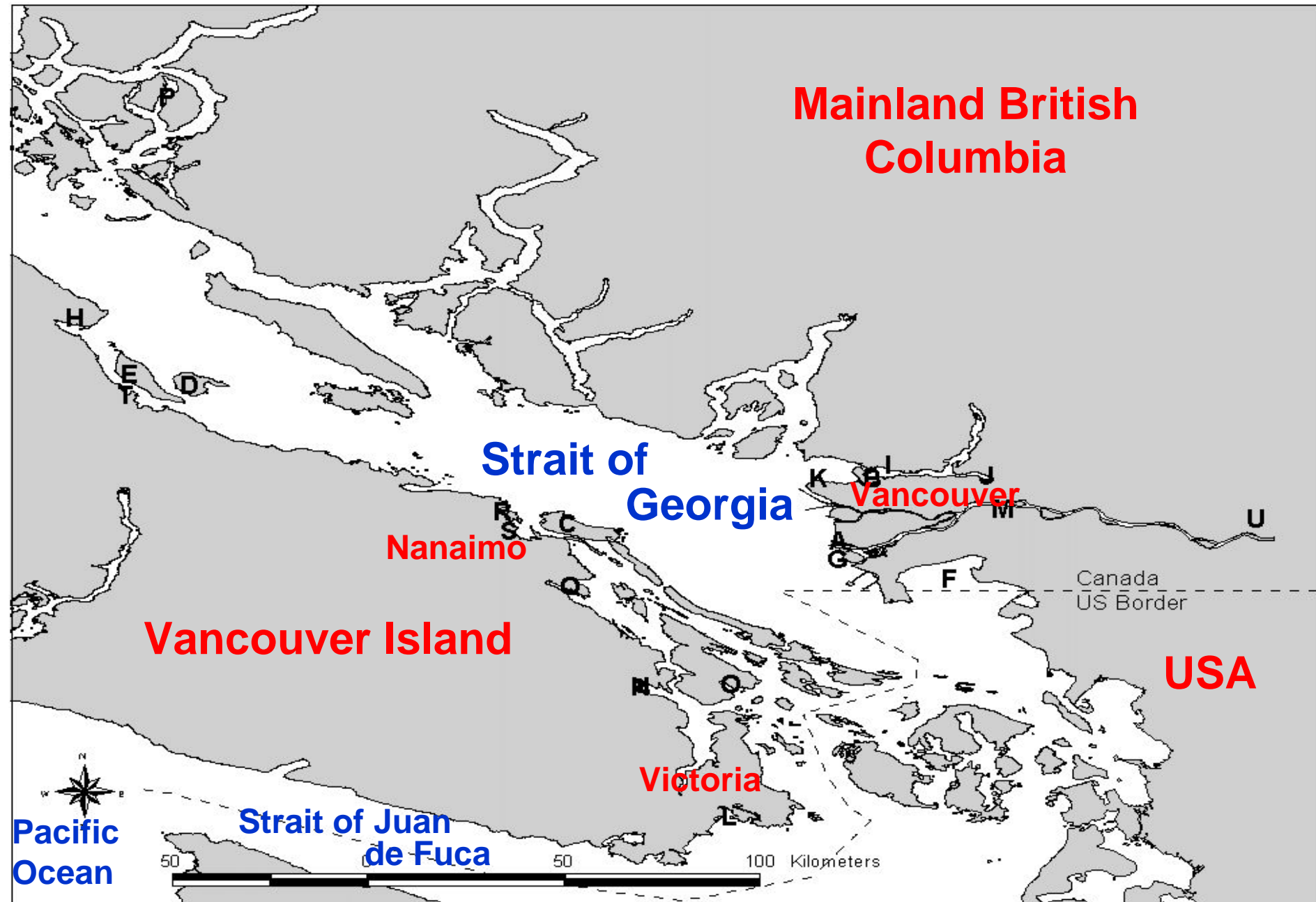


Marine and estuarine non-indigenous species (NIS) in the Strait of Georgia, British Columbia, Canada

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Letters refer to places mentioned in Levings et al. 2002



Geographic and Oceanographic features

Data

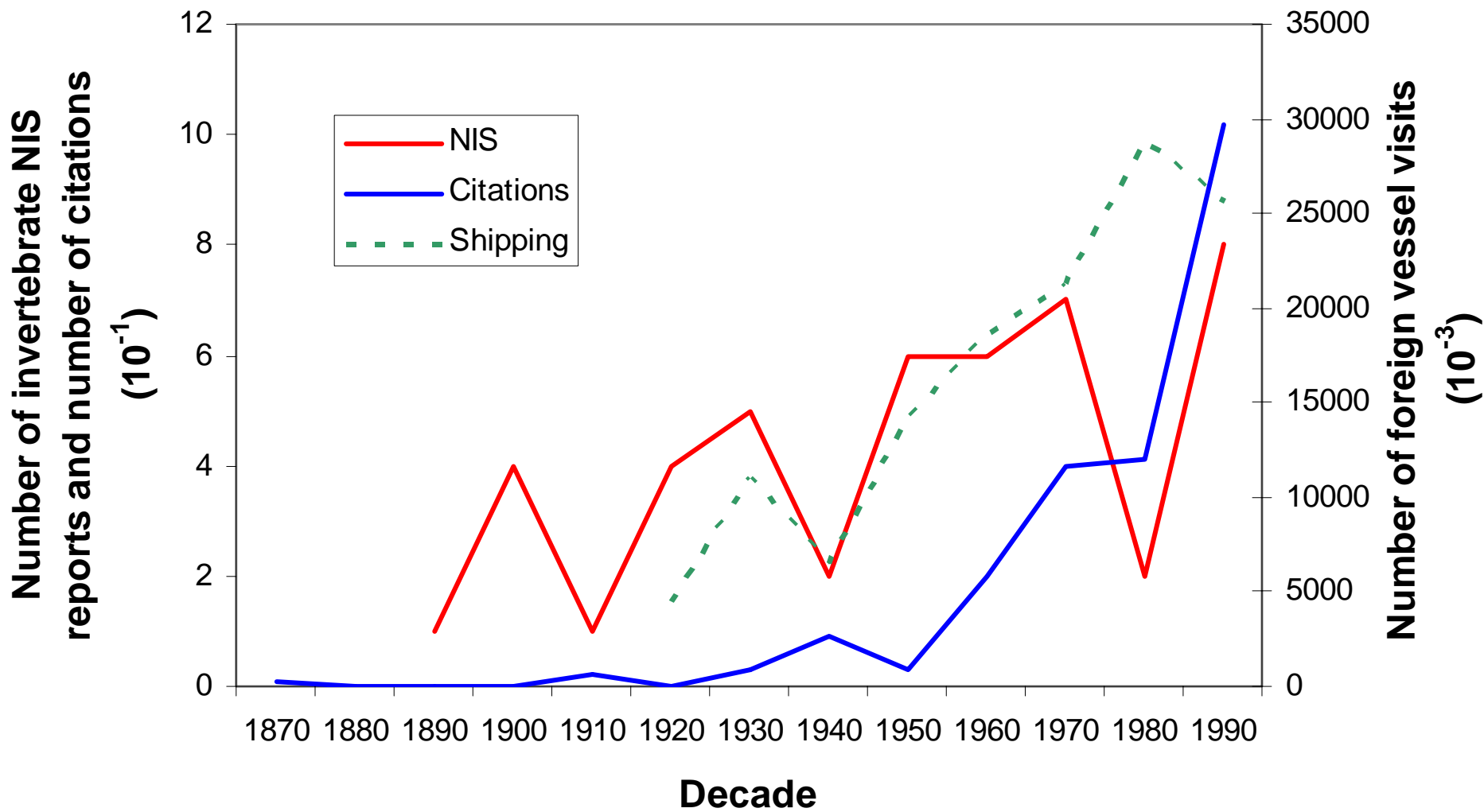
Surface area ¹	6800 km ²
Volume ¹	1050 km ³
Mean depth ¹	155 m
Yearly mean runoff ¹	5800 m ³ • s ⁻¹
Basin flushing time, summer ¹	50–75 d
Basin flushing time, winter ¹	100–200 d
Representative annual “warm water” temperature range (Ladysmith Harbor) ²	5.5–20.6° C.
Representative annual “cool water” temperature range (East Point) ²	7.1–11.6° C,
Representative annual “estuarine” surface salinity range (Sturgeon Bank) ²	0–25 ppt
Representative annual “marine” surface salinity range (Cape Mudge) ²	27.1–29.1 ppt
Shoreline length of rock/gravel beaches ²	2668 km
Shoreline length of sand/mud beaches ²	1053 km

OCEANOGRAPHIC AND GEOLOGICAL SETTING

- Lies between about 49 and 50 degrees N
- Is a high latitude temperate marine ecosystem
- The main body of the Strait is relatively warm and brackish, with the oceanographic characteristics of a stratified estuary
- Most of the freshwater is contributed by the Fraser River, which has about 100 km of tidal freshwater in its lower reaches
- There is considerable spatial variation in water properties (especially temperature and salinity), with “microhabitats” in tidal passes, embayments, and fjords
- The east side north of Vancouver and around the Gulf Islands is generally rocky, while the west side of the Strait north of Nanaimo is mostly loose substrate, with extensive intertidal areas

- The Strait is recognizable as a distinct ecosystem from other parts of the BC coast:
warm-stenothermal brackish-water ecosystem
- The number of reported non-indigenous (NIS) invertebrate species in the Strait has increased exponentially in the last half of the 20th century, a trend that also may exist for algae and vascular plants
- Some of the NIS may have been hitchhikers introduced with imported oysters decades ago and only now being detected in surveys, or the increased number of NIS may be a true increase, influenced by increased human activity in the region
- Systematic ecological surveys have been few, and identification of alien species has been spotty

- Based on the literature and authoritative personal communications, we estimate that as of 2000, the following numbers of NIS have established populations in the Strait or along its shoreline:
 - algae – 22
 - vascular plants – 22
 - invertebrates – 65
 - fish – 3
 - birds – 1 (Mute Swan)
 - mammals - 1 (Norway Rat)
- At about **87 species**, the total number of NIS algae and invertebrates reported here is relatively high when compared to other temperate high latitude marine ecosystems, where between 32-80 introduced species have typically been recorded (Hines and Ruiz, 2000).



Temporal changes in number of non-indigenous species of marine invertebrates reported from the Strait of Georgia, number of citations in Anderson et al (1999), and number of foreign vessels arriving in the Port of Vancouver each year.

- This listing was prepared after consulting the most recently published information, supplemented with personal knowledge.
 - Our current provisional listing of NIS (including cryptogenic species*) for the Strait is based mainly on [three internal reports](#) (Taylor 1999, Lindstrom 1999, Anderson et al 1999)
 - Preliminary results of a [Rapid Field Assessment Survey in February and March 1999](#) (Biologica 2000) at 33 locations in the Strait are also included.

*a species that is not demonstrably native or introduced
Carlton (1979)

Caveats

- There were some differences in the criteria specified in the three reports to decide if a species was non-indigenous or not.
- The invertebrate report (Anderson et al 1999) stipulated that to qualify as non-indigenous, the species must have been absent, as shown by ecological survey in a study area at a baseline time, and then, at a later time, reported as an established, isolated, self-propagating population. For invertebrates, then, range extensions by themselves did not thus confer NIS status.
- This criterion was not always applied to the algae and vascular plant data in the reports.

- Because of timing and seasonality problems, the **Rapid Field Assessment Survey did not effectively sample all habitats** and or allow sufficient effort for detailed identification of the flora and fauna collected.
- All **records do not necessarily indicate successful establishment of the species**, only that the species has at least once been found in the wild.
- Current programs in place include licencing of intentional introductions (based on a risk assessment approach), quarantine procedures and other mitigative actions to prevent release of NIS.

Phytoplankton

- There are no known introduced species of phytoplankton in the Strait.
- However, taxonomic experts (Dr. F.J.R. Taylor, UBC Dept of Botany, pers. comm.) have speculated some species of the dinoflagellate genus *Alexandrium* may have arrived with ballast water in Vancouver Harbour.

Macroalgae

- The brown seaweed *Sargassum muticum* (Yendo) Fensholt, introduced from Japan with oysters (see below), has been known since the 1940s.
- Two species of red algae, *Gelidium vagum* Okamura and *Lomentaria hakodatensis* Yendo, are cryptogenic.
- It is likely that at least one species of *Ceramium* in local waters is introduced, based on successful hybridization with North Atlantic *Ceramium*.
- *Antithamnionella spirographidis* is frequently found associated with docks and harbours nearly worldwide occurrence in temperate waters is introduced.

- Several other species have been identified as possible introductions, although they are really cryptogenic.
 - The red algae *Caulacanthus ustulatus* is likely a relictual endemic on this coast.
 - The red algae *Porphyra mumfordii* and the brown algae *Scytothamnus* sp. or *S. cf. fasciculatus* are known only from southern British Columbia (Barkley Sound and Strait of Georgia) and Oregon, and both have close relatives in Chile.
- Other cryptogenic species may represent examples of recent introductions. These include:
 - *Enteromorpha* and *Ulva*, *Capsosiphon fulvescens*, *Gayralia* [*Monostroma*] *oxyserpma*, *Percursaria percura*, *Ulothrix implexa*, and *U. speciosa* among the green algae;
 - *Colpomenia peregrina*, *Fucus spiralis*, *Melanosiphon intestinalis*, *Petalonia fascia*, and *Scytosiphon lomentaria* among brown algae; and
 - *Chondria dasyphila* and *Grateloupia doryphora* among red algae.

Vascular plants

- *Saline tidal habitats*: The dwarf eelgrass (*Zostera japonica*) is fairly widespread on sand and gravel beaches. Smooth cordgrass (*Spartina patens*) has been located in marsh habitat at three locations.
- *Tidal freshwater habitats* (especially the Fraser River estuary):
 - The most obvious example of an aggressive exotic in these habitats is purple loosestrife (*Lythrum salicaria*), although there is an indication that yellow flag (*Iris pseudacorus*) could be spreading.
 - Reed canarygrass (*Phalaris arundinacea*), thought by some workers to be an introduced plant, is the dominant grass on sand beaches in the upper Fraser estuary. Another invasive adventive grass, which has made major incursions into both freshwater and brackish marshes is creeping bentgrass (*Agrostis stolonifera*).
 - The lesser cattail (*Typha angustifolia*) is well-established near Point Grey and seems to be expanding its range. The thatch grass (*Phragmites australis*) has been collected in the Fraser River estuary.

Invertebrates

- Provisionally, because of incomplete reports and changes in taxonomy, we estimate 65 species of non-indigenous invertebrates have been recorded in the tidal waters of the Strait. This is a minimum estimate since the list does not include non-indigenous insects. Insect larvae are found in ballast water surveys.
- The majority are gastropod and bivalve molluscs, tunicates, and amphipod crustaceans.
- Numerous invertebrate "hitchhikers" have been introduced with intentional Atlantic and Japanese seed oysters introductions (e.g., the drill (*Urosalpinx cinerea*) and Manila clam (*Venerupis philippinarium*)).

Fishes

- Five species of non-indigenous fish have been recorded in the tidal waters of the Strait, three of them from tidal freshwater habitats of the Fraser River estuary
- *Saline tidal habitats*: As far as known, no non-indigenous species of marine or anadromous fish have yet established populations in the Strait, although feral juvenile Atlantic salmon (*Salmo salar*) have been reported in Amor de Cosmos Creek, just north of the Strait in Johnstone Strait.
 - Shad (*Alosa sapidissima*) is an Atlantic fish species that has been periodically recorded from the Fraser River estuary, but have not established in the Strait and individuals found may be infrequent migrants from NIS populations established elsewhere in the Pacific

- **Tidal freshwater habitats:** Three species of cyprinid fish, all native to either east of the Rocky Mountains or Asia, are well known from habitats in the lower Fraser River. These are *carp* (*Cyprinus carpio*), *brown bullhead* (*Ameiurus nebulosus*), and *black crappie* (*Pomoxis nigromaculatus*).
 - several trout species [*Salmo salar* (Atlantic salmon), *Salmo gairdneri* kamloops (rainbow trout), *Salmo trutta* (brown trout), *Salvelinus fontinalis* (brook trout) and *Cristivomer (Salvelinus) namaycush* (lake trout)] were introduced into the Cowichan River which flows into the Strait. Of these, *brown trout* have become established in the river, and river surveys indicate that on rare occasions (less than 5% of swim surveys), *brown trout* are found in the tidal area of the river.

Birds

The **mute swan** (*Cygnus olor*), native to Europe, has established populations in the Strait at both the Cowichan River estuary and Fulford Harbour (Saltspring Island).

Mammals

A semi-aquatic mammal, the Norway rat (*Rattus norvegicus*) is common in the intertidal zone near Vancouver harbour where populations originated from ocean going ships.

Ecosystem Effects

- Most introductions to date have been benign or have resulted in functional changes that remain undetected. The main exceptions are the extensive occurrence of Japanese oysters and manila clams in the mid 1900s, and the recent establishment of the dark mahogany, or varnish, clam (*Nuttallia obscurata*) in the 1990s, all of which now support both commercial and culture fisheries.
- There have been no observed widespread ecosystem changes such as major shifts in predatory species or changes in productivity capacity in the Strait that could be related to the arrival of NIS, but there have also been no focused research projects to date on these topics.

- However, the brown seaweed *Sargassum muticum* is the most obvious non-indigenous species of algae in the Strait and some researchers have speculated that this species may have had impacts on other algae by competing for space. Anecdotal reports suggest that in parts of the Strait in the 1940s and 1950s, *Sargassum* was so abundant that it affected fishing and nearshore boat usage. Today, it is not nearly as abundant, which suggests that local herbivores and other species are now cropping it sufficiently to maintain it in some equilibrium with other species. Alternatively, changed oceanographic conditions in the Strait may be somehow restraining this algae at this time.

- The dwarf eelgrass (*Z. japonica*) is the most widespread non-indigenous species of vascular plant in the Strait, and while this plant does foster increased local invertebrate diversity, it may be replacing mud and sand flat habitat on Roberts Bank, Fraser River estuary, with vegetated habitat, perhaps modifying the feeding habitats of shorebirds.
- Similarly, Smooth Cordgrass (*Spartina spp*) has the potential to modify intertidal habitats by increasing sedimentation on sand and mudflats, possibly to the detriment of native fauna.

Recent Introductions

- Colonial tunicate (*Didennum* spp.)
- The European green crab (*Carcinus maenas*) has been recently (1999, 2000) found in Esquimalt Harbour, near Victoria, and on the west coast of Vancouver Island, and while it may have entered the Strait, to date this NIS has not been recorded from the Strait.



Control or eradication of established NIS in the Strait

Control is effectively impossible for species with pelagic larval stages that are dispersed via ocean currents (e.g., the green crab) or vascular plants that have a copious seed production, such as purple loosestrife. While a variety of measures have been undertaken to control some NIS found in the Strait, documentation of their efficacy is typically lacking.

Canadian Aquatic Invasive Species Network (CAISN)

- Creation of the **Canadian Aquatic Invasive Species Network (CAISN)** has been proposed to the Natural Sciences and Engineering Research Council of Canada (NSERC), whose purpose will be:
 - to conduct the first set of comprehensive studies exploring the principal *vectors and pathways* that transport aquatic invasive species (AIS) to freshwater and marine ecosystems in Canada,
 - to characterize the *factors that influence establishment success* of these species, and
 - to construct *risk assessment* models that will direct future management policies.
- We suggest these are the most important components of basic and applied invasion science today.
- This Network will represent the first attempt by any country to marry the diverse expertise and interests of universities, governments, industries, and NGOs with regard to NIS, and we believe our approach will assist affected industries, lead to policy development, and advance invasion science.

- CAISN's research program will consist of 16 projects in which three common research themes are addressed in a regionally specific context using common methodology, personnel, and analyses.
- These projects will be undertaken by 26 of Canada's leading NIS experts based at both universities and federal labs.
- The CAISN will train 42 MSc and PhD students and postdoctoral fellows.
- We anticipate total expenditures associated with the CAISN to total \$5.7 million over five years, with \$3.8 million requested from NSERC.
- Our principal Network partners have committed to provide the financial support for the remaining expenditures (\$1.9 million). *In kind* contributions will exceed \$3.0 million over the five years of the Network.

Summary

- Our review of NIS in the Strait clearly shows that [this important inland sea has been invaded by many species from all major plant and animal phyla](#).
- The [southeast portion of the Strait](#), with the Port of Vancouver and estuarine characteristics because of freshwater discharge from the Fraser River, may be [particularly vulnerable to the introduction of NIS from brackish coastal waters](#) elsewhere in the world.
- The [central and northern portions of the Strait](#) are more saline and are the locations of most shellfish culture, all of which involves NIS species, and as such may be [particularly vulnerable to the introduction of disease NIS from saline coastal waters](#) elsewhere in the world.