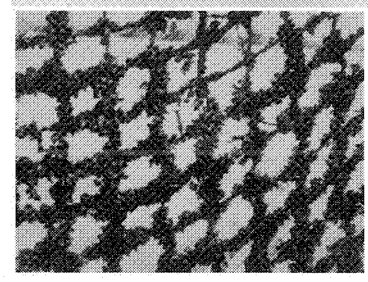
FUNDY ISSUES

ALIEN INVASIONS

Introduced Species in the Bay of Fundy and Environs.

Exotic Explosion

The swift spread of the imported European Zebra Mussel, *Dreissena bugensis*, through the Great Lakes in the 1980's, and its dramatic ecological and economic effects, focused media and public attention on this seemingly innocuous mollusk and the growing problem of invasive species. An earlier invasion of the Great Lakes in the 1960's by Sea Lampreys, *Petromyzon marinus,* navigating the newly opened St. Lawrence Seaway, and their devastating effects on freshwater fish populations had almost faded from remembrance. However, the Zebra Mussel story once again jogged the collective memory of Canadians about the great mayhem that such "foreign" invaders can wreak on lakes, rivers and coastal waters. Its teeming presence and filter feeding habit resulted in lakes largely devoid of the water-borne food particles that sustain native species, municipal and industrial water inlet pipes clogged by tightly clinging mollusks, and wharf pilings and other aquatic structures blanketed by the striped opportunists. However, the Zebra Mussel is only a very prominent tip of an unimaginably large iceberg of a problem posed worldwide by advancing legions of animal, plant and microbial invaders of freshwater and marine systems. The problem is so ubiquitous and ecologically and economically worrisome that it has spawned a new scientific discipline — "invasion ecology". Its practitioners are trying to understand how such large-scale, rapid movements of species happen, what their ecological effects are and what can be done to slow or halt their spread.



A Zebra Mussel, and what happens when large numbers of them grow on fishing nets or other submerged objects.
Photo: U.S. Army Corps of Engineers

Many labels have been attached to organisms that suddenly, and often explosively, spread into a new territory, including: "invasive", "non-native", "alien", "exotic", "non-indigenous", "opportunistic" and "introduced" species. An organism that manages to sneak in unnoticed along with a species that is purposely imported is labeled a "fellow traveler". These terms all refer to an organism that has evolved and adapted for aeons in one part of the world and is then suddenly introduced, either by accident or intent, into another distant region where it has never before been present. Not all such introductions are successful. Often, the new environment is too inhospitable (for instance, too cold, too salty, not enough food or too many predators) for the invader to establish a foothold and it soon dies. Some species that are successful are sometimes able to adapt to the local conditions and find a comfortable, limited niche in their new home without aggressively disrupting local biological communities or causing significant problems. However, far too often, more aggressive invaders muscle their way into the new habitat and reproduce and grow so rapidly that they soon overwhelm some native species and disrupt food webs and other key relationships within the biological community. Unfortunately, it is usually impossible to dis-

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tinguish beforehand those invaders that are going to be unsuccessful, or successful but benign, from those that are likely to explode on the scene with ruinous ecological or costly economic consequences.

Turning Up the Tempo

The phenomenon of species moving into new habitats and regions is not particularly new, unnatural or unusual. Environments everywhere are continually changing, perhaps warming up or cooling down, getting wetter or drier etc., usually much too slowly for us to perceive. Confronted by such changing conditions, animals and plants have to gradually adapt to them, move to areas where conditions are more to their liking, or simply die. Such change has always been the great engine of evolution, spawning subspecies and ultimately new species to take advantage of novel circumstances and to exploit promising new opportunities. Invasions of new territory are going on all around us, usually in the form of "range extensions". By such means, species may slowly but steadily expand the area that they occupy, often as a result of subtle changes in the regional environment. A familiar local example is the gradual northward spread of that striking, scarlet bird, the Northern Cardinal, *Cardinalis cardinalis*, into southwestern Nova Scotia. Once a rarity causing an excited flutter in the birding community, it has over the last decade become a fairly common year round resident and welcome visitor at bird feeders. Whether their spread is attributable to a warming climate, the expanding availability of a winter food supply at feeders, or some other factor is not known

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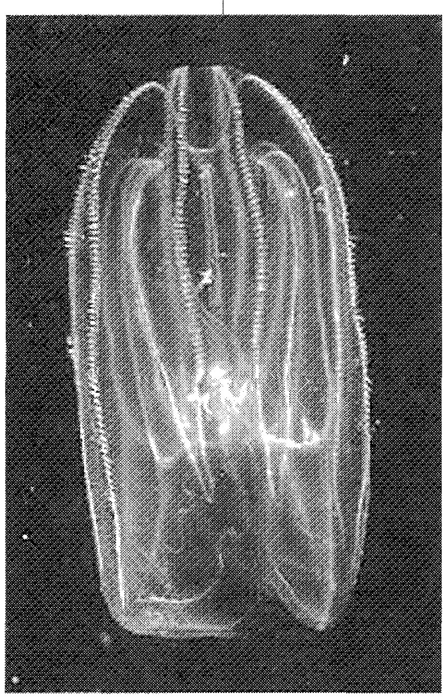
If such "natural" movements of animals, plants and microorganisms have always happened and are still going on around us, why are strident alarms now being raised about the ominous threat from invasive species. One major difference is that the natural spread involves slow, gradual shifts of populations over short distances by normal ecological processes. The new area often has similar ecological conditions and familiar predators that control the invader's abundance. The slowness of the process typically allows the invader to adapt to its new home and the host community to absorb its presence with little disruption. In contrast, exotic invasions are usually associated with the rapid, human-assisted, transport of many species over very great distances. Ever since continental drift began separating the Earth's major landmasses over 100 million years ago, the deep ocean basins have presented formidable barriers to the movements of most terrestrial, freshwater and coastal marine species between continents. However, within the last few centuries, swelling human migrations and expanding commercial activities have greatly increased the opportunities for species to be carried ever more quickly to inviting new habitats in all corners of the globe. A report of the Pew Oceans Commission in Arlington, Virginia in 2001 revealed that the rate of exotic invasions into U.S. coastal waters has increased exponentially during the past two centuries. Ominously, the rate at which species worldwide are successfully invading new habitats is still rising - more and more rapidly.



Mnemiopsis leidyi, a deadly invader outbound from our coastal waters.

Photo: European Environment Agency

Nowadays too, global warming is raising the temperature of some coastal waters, such as the Gulf of Maine and Bay of Fundy, just the few degrees necessary to make them tolerable habitats for aggressive species from more southerly climes. In addition, some opportunistic, exotic species are often quick to colonize the polluted or degraded habitats that human activities have created worldwide. For example, the devastating spread of the ctenophore (comb jelly), *Mnemiopsis leidyi,* after its introduction into the Black Sea in ballast water, may have been hastened by the reduction of predators because of overfishing and of competitors because of water pollution. Incidentally, *M. leidyi* is a native of our Eastern North American coastal waters, illustrating that the movement of invasive species is a decidedly two-way street. This experience with *Mnemiopsis* also teaches us that degraded environments may be much more susceptible to occupation by invasive species than healthy ones.

Ecological Effects

The ecological and economic problems posed by invasive species are just as diverse as the invaders themselves. Sometimes, they simply prey far too effectively on native species, which, never having encountered the predator before, have not developed abilities to recognize, avoid or resist its attack. Often, the invaders eat the same food as some native species and, being more aggressive or faster reproducing, consume the lion's share of the available food and starve out the locals. Sometimes, as in the case of the Zebra Mussel, the aliens attach to and grow densely on every available solid surface, smothering or crowding out other species. In some cases, the invaders carry with them parasites or pathogenic microbes as "fellow travelers". Typically, the invaders themselves have acquired a resistance to these noxious hangers-on. Not so the hapless natives; they are encountering the pathogens for the first time and are thus highly susceptible and often succumb in large numbers. Ecologists are especially concerned about the added pressures that invading species may put on the many native species that are already rare or endangered because of overexploitation or loss of habitat. This may be the proverbial "last straw" that leads to their extirpation (disappearance locally) or extinction (disappearance from the Earth, permanently). Canada's Commissioner of the Environment and Sustainable Development in her 2002 Report noted that alien invasions are a major cause of declining biodiversity in Canada, second only to habitat loss. Also, it is estimated that almost half the species at risk in the United States are threatened by introduced species.

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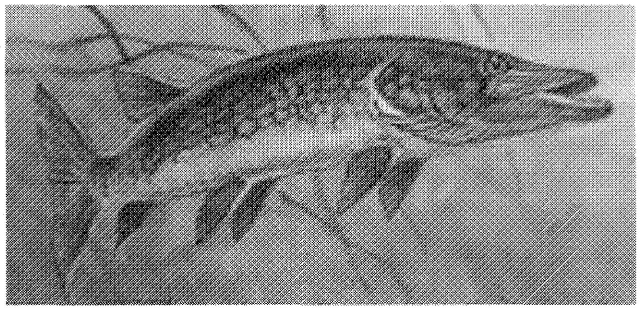
Commercial Consequences

Alien species often come with a high price tag attached. In addition to reducing the diversity of native species, they can also alter the interactions among species, disrupt critical food webs and ultimately devastate animals or plants that are commercially important. As well as such direct losses of harvestable resources, there are also the indirect costs of monitoring and controlling the spread of the aliens and attempting to minimize their impacts. In the United States, it has been estimated that the invasion of exotic weeds and plant pests alone costs the agricultural industry US$80 billion dollars every year, and that the total costs of all invasive species probably exceeds US$137 billion annually. Introduced agricultural and forestry pests are thought to impact the Canadian economy to the tune of at least CAN$7.5 billion dollars a year. The costs attributable to aquatic invaders are much more difficult to determine, but are probably comparable in magnitude. On top of such obvious direct and indirect economic losses and costs, the presence of invasive species in an area may also devastate trade in natural or agricultural products because of fears of introducing the aliens to new areas.

Given their potential for widespread ecological disruption, degradation of habitat quality and severe economic impacts, it is not surprising that the quickening proliferation of invasive species is sometimes referred to as "biological pollution". However, unlike other pollutants that usually break down and disappear with time, invasive species reproduce rapidly and spread throughout suitable habitats, causing more and more damage. The classic example of this phenomenon was the introduction of the European Rabbit, *Oryctolagus cuniculus,* to Australia in the mid 19th century. Breeding "like rabbits", they soon earned a well-deserved reputation for causing habitat destruction, extinction of native animals and plants, erosion of the landscape, and destruction of agricultural crops.

Getting from A to B

Some pioneering organisms have always managed to find ways of dispersing into new hospitable areas where food is plentiful and enemies few. For example, small aquatic invertebrates sometimes hitch a ride from one lake to another tucked securely among the feathers of migrating waterfowl. Some plants or animals have resistant eggs, seeds or resting stages that drift with currents for extended periods or are blown hither and yon by the winds. Some coastal, bottom-dwelling animals traverse considerable distances over deep water simply by clinging tightly to floating debris. The big difference nowadays is that human activities offer an even wider range of new ways for species to travel safely, swiftly and in large numbers all around the globe.



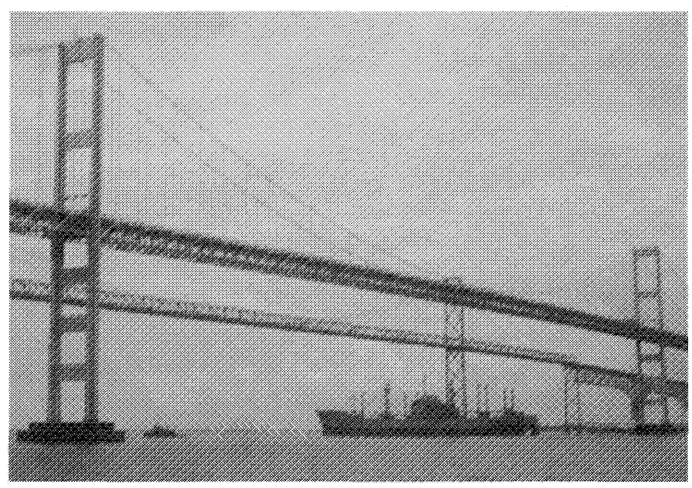
Chain Pickerel

Sometimes, alien species have been purposely introduced into new habitats for a variety of seemingly good reasons. The landscape around the Bay of Fundy boasts many foreign plant species, such as Daphne, *Daphne mezereum,* and Tansy, *Tanacetum vulgare*, that were brought over and grown by early European settlers for ornamental, nutritional, medicinal or other purposes. Game fish, such as Largemouth and Smallmouth Bass, *Micropterus salmoides* and *M. dolomieui,* and Chain Pickerel, *Esox niger*, have also been brought in and illegally released into some Maritime waterways by misguided anglers oblivious to their effects on native fish such as trout and salmon. Pet stores and gardening centres sell exotic aquatic species to those wanting something unusual for their aquarium or backyard pond - and inevitably some of these are eventually dumped or escape into nearby waterways. Anglers who fish with live bait are a growing market for many imported aquatic animals, particularly different types of marine worms. At the end of the day's fishing, leftover worms in the bait bucket are often simply tipped over the side. Exotic live seafood imported for specialty markets are another means by which invasive species can escape and spread. Baitworms and live seafood are often packed in damp seaweed for shipment. At the destination this live packing material may be dumped into or near waterways. The discarded seaweed may shelter a host of other alien species or their eggs that are thus also inadvertently introduced into the new habitat. Marine gear such as fishing nets, floats, docks, or navigation buoys being transported from place to place can also transfer a variety of encrusting or clinging organisms. It is believed that Asian Shore Crabs traveled along with large marine floats towed from New Jersey to Massachusetts, hence entering the Gulf of Maine. Coastal and ocean-going vessels also transport on their hulls luxuriant growths of seaweeds and other fouling species as well as the myriad organisms that dwell amongst them.

Beasts in the Ballast

Undoubtedly, one of the surest and most common ways for aquatic organisms to move rapidly over great distances is floating in the ballast water of coastal and ocean-going ships. To increase their draft when empty of cargo, and thus improve their stability in rough seas, such vessels fill large ballast tanks with water before venturing onto the open sea. This can be fresh, brackish or seawater, depending on where they set out from. Once they reach a port where they are to load cargo, they have to pump the ballast water overboard. Inevitably, a diverse assemblage of freshwater, estuarine or marine organisms present in this ballast water is thus dumped with it. This may include not only planktonic species dwelling in the water column, but also the floating eggs and swimming larvae of many different types of bottom-living organisms such as mollusks, crustaceans and polychaetes.

With increasing globalization of markets, more, larger and faster cargo vessels are plying the world's oceans providing greater opportunities for long distance voyaging by many different types of animals, plants and microbes. The greater volumes of ballast water carried by these larger vessels and the shorter travel times between distant ports means that the ballast water remains well-oxygenated for the duration of the trip, enhancing the survival of water-borne organisms. Recent estimates suggest that as many as 84,000 seagoing vessels carry and discharge 10 to 12 billion tonnes of ballast water every year worldwide. In the 2001 report of the Pew



A freighter heading out to sea with its ballast tanks full of seawater .... and who knows what else?

Photo: NOAA Photo Library.

Oceans Commission, author James Carlton concluded that on any given day at least 7,000 species of "aquatic hitchhikers" are probably present in the ballast water en route between continents. Every 12-14 weeks on average, yet another alien species manages to establish itself in U.S. coastal waters. Some of the more notorious international aquatic pest species such as Zebra Mussels and various types of Sea Lice such as *Caligus spp.* and *Lepeophtheirus salmonis,* that cause serious problems in salmon farms, have almost certainly been widely disseminated in ballast water.

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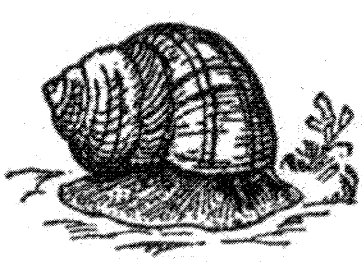
Foreigners in Fundy

Over the years, many alien species have managed to establish themselves in the waters of Canada's East Coast, including the Bay of Fundy. Some of these reached our shores many decades or even centuries ago and have since become so well entrenched that they are now a familiar part of our coastal ecosystems. The ecological effects of their initial arrival are largely unknown, because knowledge about the biological communities at the time is scarce. Other species are much more recent arrivals in Maritime coastal waters and some of them may still be trying to spread into the Bay of Fundy. A number of other worrisome species have already established a firm beachhead much further south along the eastern seaboard or in the Gulf of Maine and are now relentlessly spreading northwards towards our waters. Let's take a closer look at a few of the more notable alien plants and animals and consider the possible ecological and economic threats that they pose.

Early invaders - The Common Periwinkle, *Littorina littorea*, may be one those early immigrants from Europe that has long-since been granted "ecological citizenship" status in Eastern North America. The gray-brown, marble-sized mollusks are found in dense clusters in rocky and muddy intertidal areas along much of the Fundy coast. Although there are some who argue that it has "always" been here, the conventional belief is that it crossed the Atlantic to Nova Scotia in the mid 1800s, possibly along with discarded ballast rocks, but more likely as an attempt by immigrants to introduce a popular working class food to the region. From there, it spread rapidly to become a common intertidal species along the eastern seaboard from Labrador to New Jersey, as well as the dominant snail species in the Bay of Fundy. The overall ecological effects of its introduction are unknown, but it has been theorized that some native mollusks, such the Eastern Mud Snail, *Ilyanassa obsoleta*, were unable to compete and thus declined considerably in particular areas. A small-scale commercial hand-harvesting of the abundant periwinkles occurs on both sides of the Bay of Fundy, limited largely by the low market demand in North America.

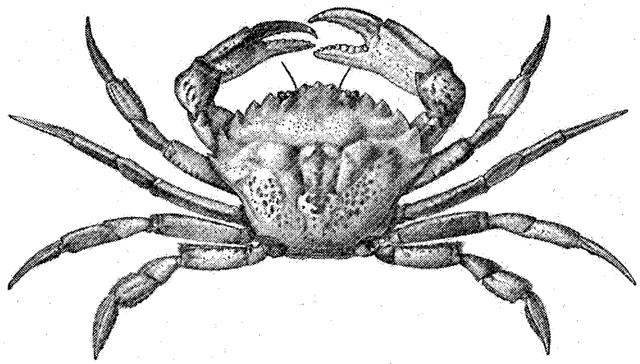


Common Periwinkle Introduced or Indigenous?

The rockweed, *Fucus serratus*, is another European species that successfully made the crossing, possibly while growing on ballast rocks that were dumped. It first showed up at Pictou, Nova Scotia in the late 19th century. However, unlike the Common Periwinkle, it has never become plentiful and appears to pose no threat to the dominant native rockweeds such as *Fucus vesiculosus* and *Ascophyllum nodosum* or the biological communities that they support.

It is not clear when or how the so-called Mud Shrimp (actually an amphipod), *Corophium volutator,* made the long journey to the Fundy mudflats from its native European waters. There, it occurs widely from Scandinavia to the Mediterranean. However, in North America it is restricted to the Gulf of Maine and Bay of Fundy. Speculation that it may have arrived with early settlers is not supported by recent genetic studies that suggest that the two populations have been separated for a much longer period. Whatever its origin, *Corophium* is today a vitally important member of the mudflat community in the Upper Bay, particularly as a reliable, abundant and energy-rich food for millions of migrating shorebirds (see Fundy Issues #3 and 13 for that particular story!)

European Green Crab - *Carcinus maenas* may be only the size of person's palm, but it is one of the feistiest crabs in our coastal waters with a voracious appetite and a catholic taste to match. It eats more than 100 different species, particularly mollusks and crustaceans, with clams, mussels, oysters, scallops, periwinkles, barnacles,



European Green Crab,
a voracious predator on shellfish.
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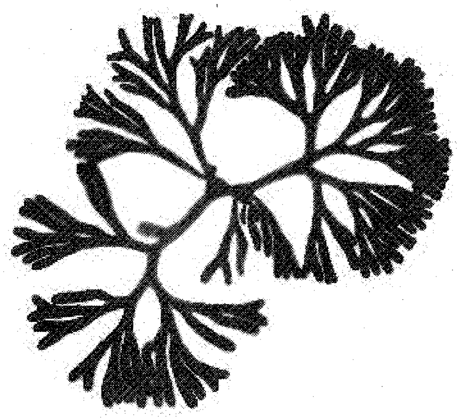
whelks, marine worms, sea urchins, other crabs and even small lobsters all being grist for its gastric mill. A study carried out in the Bay of Fundy showed that this glutton's diet depends chiefly on what foods are present in the largest quantities. They are also much faster, more adept and have a greater repertoire of techniques for opening bivalves than most other crabs. A single green crab can open and consume as many as three dozen mussels in a day and can also ferret out clams buried up to 15 cm (6 inches) deep.

They were probably accidentally introduced to North America somewhere near Long Island, New York in the early to mid 1800s. Their tolerance for a wide range of temperatures and salinities, coupled with their prodigious rate of egg production, assured success in their adopted home and hastened their spread to the north and south. Prior to 1900, they weren't found north of Portland, Maine. However, by mid century the Maine Department of Fisheries had to undertake a major offensive against them to try to protect the lucrative Soft-shell Clam fishery. The crab turned up in Passamaqoddy Bay in 1952, from where it spread across the Bay of Fundy, along the eastern coast of Nova Scotia and into the Gulf of St. Lawrence by 1995. Nowadays, it is the most common shore crab in much of the region. It has menaced the shellfish industry on both coasts of North America, devastating populations of Manila Clams in California, Bay Scallops off Martha's Vineyard and Soft-shell Clams in the Gulf of Maine. Andrea Locke, Mark Hanson and their team at DFO's Gulf Fisheries Centre in Moncton, NB have the challenging task of monitoring the crab's spread in the Maritimes and determining what effects it may be having on coastal ecosystems and shellfisheries.

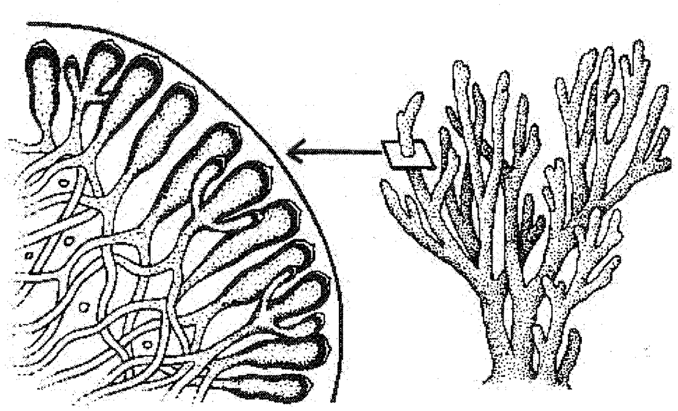
Membranipora - At first glance, the Lace Bryozoan, *Membranipora membranacea,* doesn't seem like much of a threat to anything. Its delicate, white lacey growth on submerged surfaces looks very decorative and plant-like. It only on closer microscopic examination that it is apparent that this is really an animal, or more precisely a whole lot of animals. The individuals are less than a millimetre wide and are clustered tightly together to form a large, flat, one layered, encrusting colony. Superficially, they resemble the more familiar corals, in that each animal dwells in a tiny box-like cell with limestone walls that it secretes to protect itself. It extends its tentacles out of the top of the cell to trap particles of food drifting by in the currents. Its ability to form very large, heavy encrusting limestone colonies over surfaces is what causes the problems. Often, the surfaces that it grows on are the leaf-like blades and stalk-like stipes of larger seaweeds such as kelp. If this encrustation is great enough, the kelp plant is weighed down, rendered very brittle and is easily torn loose or broken into fragments by turbulence. Whole kelp beds in the Gulf of Maine have been devastated in this manner. There is concern that if large areas of productive kelp beds in Maritime waters are thus destroyed, another opportunistic invader, the seaweed *Codium*, will move in, take over and keep the kelp from reestablishing itself. This would have dramatic consequences for the many animals and plants that dwell among the kelp frond "forests", including the young of several commercially important fish species.

Native to European waters, the Lace Bryozooan has spread throughout the temperate zones of both the northern and southern hemispheres. It has probably been spread by growing on the hulls of seagoing ships or as free swimming larval stages transported in ballast water. The first successful invasion of Eastern North America was detected on kelp growing near the Isles of Shoals in the Southern Gulf of Maine in 1987. From here it spread rapidly both north and south and within a few years *Membranipora* was firmly established and abundant in the coastal waters of New Hampshire and Maine. It continues to spread. Scuba surveys reveal that it is now widespread along Nova Scotia's southern shore. Neither its detailed distribution in the Maritimes and the Bay of Fundy, nor the rate at which it is spreading, are known.

Codium - The "Green Sea Fingers" seaweed, *Codium fragile* subspecies *tomentosoides*, is also called "Dead Man's Fingers" and "Oyster Thief", suggesting that it is not held in high regard in some quarters. The "finger" reference is apt because the bushy plant consists of a series of vivid green finger-like branches arising from the circular holdfast by which it adheres to solid surfaces. It is sometimes also called Green Sponge because the long fingers are porous and sponge-like in appearance and texture. It grows densely on available surfaces and in rocky subtidal areas may form expanses of "bushy meadows". Its lush, dense growth can easily choke out native seaweeds. This is particularly worrisome in the rocky coastal water off Nova Scotia. Studies have demonstrated a periodic cycle, involving a natural fluctuation in the bottom habitat between kelp beds and "barrens" of low-growing encrusting algae. This cycle occurs because heavy feeding by sea urchins removes the kelp and creates the barrens. However, periodically, diseases kill off most of the urchins allowing the kelp to reestablish itself. Unfortunately, if *Codium* moves into the newly created barrens, there is little chance that the kelp will ever be able to recolonize the area. This could seriously affect the foraging of urchins, lobsters and host of other native species that rely on the kelp habitat. The aggressive growth of *Codium* not only destroys economically important seaweeds such as Irish Moss, *Chondrus crispus*, and Dulse, *Rhodymemia palmate*, but it can also wipe out shellfish beds. The name "Oyster Thief" alludes to the fact that gas bubbles trapped in its buoyant, spongy fingers enables it to lift and carry away the shellfish that it is growing on. The lush growth can foul structures such as net pens and shellfish growing rafts used in aquaculture and also clog fishing nets. In some areas it washes up on sandy beaches in such large quantities that it spoils them for recreational purposes.

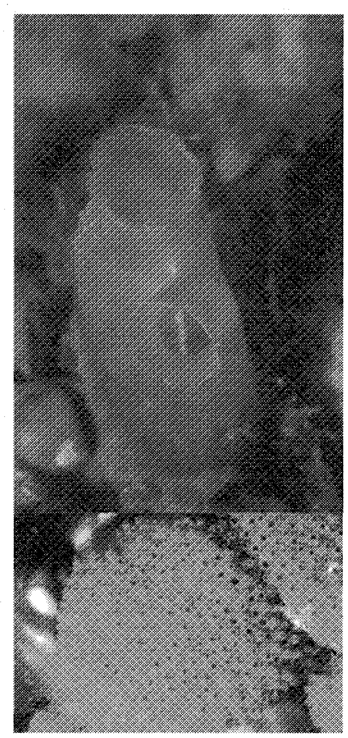


Codium fragile,* *Green Sea Fingers.



A cross-section through a Codium "finger", showing its porous and spongy interior that enables it to float and carry away oysters.

This resilient and aggressive species, originally from the Pacific Ocean around Japan, has become one of the most invasive species of seaweed worldwide. It reached Europe (Holland) in the early 1900s, possibly attached to ships' hulls. Once introduced to an area, it spreads naturally by free-floating reproductive cells or the rafting of entire plants with currents. Its local spread may also be hastened by transport in ballast water, fouling on ships' hulls or fishing gear, on transplanted shellfish or along with the seaweed packing of fresh seafood. It was first reported on the East Coast of North America in 1957 at Long Island, New York, from where it spread rapidly north and south. By 1991, its range extended from Bar Harbor Maine to South Carolina. It was thought that the colder waters of Fundy might halt its northward spread. However, in late 1991 it was found in Mahone Bay and has since continued to spread eastward. Although it hasn't yet gained a major foothold in the Bay of Fundy, there are reports of its presence in St. Mary's Bay along the Nova Scotian coast. If it ever does get firmly established, it may become a costly nuisance for the area's aquaculture industry. Its distribution along the southern shore of Nova Scotia is being carefully monitored by the SCUBA surveys of Dr. Robert Scheibling and colleagues at Dalhousie University.



Ciona intestinalis, alone and in a large colony.
Photo: M-I. Buzeta

Tunicates - A number of invasive tunicates, or "Sea Squirts" can also create ecological and economic problems because of their rapid

Clubbed Tunicates foul ropes and net bags at a mussel aquaculture site.

Photo: Department of Fisheries and Oceans, Gulf Region.

growth and habit of forming dense colonies on submerged surfaces. The most widespread in this region is the Sea Vase, *Ciona intestinalis,* which was probably introduced from Europe a long time ago. Each individual greenish-yellow, translucent, sac-like animal can be up to 15 cm. long. The mat-like colonies prevent the settlement of other larvae, compete for space and hamper the feeding of many other bottom dwelling animals such as sea urchins, mussels and lobsters. They can be a nuisance to aquaculture operations, fouling the netting of sea pens or the bags of shellfish suspended from rafts. Mussel growers in the region have suffered heavy losses because of infestations of *Ciona*. Another equally invasive species, the Clubbed Tunicate, *Styela clava*, was found in southeastern Prince Edward Island in 1998. Individuals of this native of the Western Pacific, are comparable in size to *Ciona*, and although not colonial in habit, cause similar problems for the aquaculture industry. DFO is carefully regulating the movements of aquaculture products from the affected area in an attempt to limit the further spread of this serious pest.

Waiting on the doorstep? - Many of our current exotic problem species first settled in coastal waters far to the south of us before beginning their inexorable march northward. Thus, it shouldn't surprise us that there are still other invasive species ominously lurking about our southerly doorstep. One such is the Japanese or Asian Shore Crab, *Hemigrapsus sanguineus*. It was first reported in New Jersey in 1988 and has since spread between Maine and North Carolina. Like its European Green Crab cousin, it too is aggressive, tough, fecund and eats copious amounts of shellfish and other invertebrates. It is probably only a matter of time before it reaches our waters and begins to wreak ecological havoc here. Some New England States are already raising alarms about other species that may soon become serious problems. The Veined Rapa Whelk, *Rapana venosa,* a large marine snail that preys on bivalves, has recently been found in the lower Chesapeake Bay. It is not clear how this native of the Sea of Japan arrived, but if it thrives it could have devastating effects on commercially harvested shellfish. Although not yet in East Coast waters, the Chinese Mitten Crab, *Eriocheir sinensis*, named after its hairy claws, reached European waters in the early 1900s, was found in California in 1992, and is still spreading rapidly. Recently, there have been proposals to introduce and culture the Suminoe Oyster, *Crassostrea ariakensis,* in Chesapeake Bay. However, there are concerns about possible unforeseen ecological consequences of such an introduction. The aquaculture industry is continually looking into the feasibility of introducing various other exotic species. Unfortunately, no one knows which of the hundreds of exotic species accidentally or purposely released into our waters every year will find conditions just to their liking, spread rapidly and devastate coastal ecosystems and fisheries resources.

Intercepting Intruders

Effective ways have to be found to protect our coastal ecosystems from the ravages of aggressively invasive species if we are to preserve coastal habitats, conserve marine biodiversity, and protect important fisheries. The most effective control measure is, of course, to prevent such introductions in the first place. Once an invading species becomes established in a new, congenial home it is a costly and usually losing battle to be rid of it. There must be stringent regulations and strict enforcement measures to prevent any more of the undesirables reaching our shores. The possession, transport, import or release of potentially invasive, live, exotic species without a permit has to be banned. Seaweed used as packing material for imported seafood or other marine products has to be disposed of properly to destroy "fellow travelers" hidden among the vegetation. In some situations, such as shellfish or their spat imported for used in aquaculture, shell surfaces need to be chemically disinfected to kill any attached exotic organisms. An educational campaign aimed at those most likely to unwittingly bring in nuisance species is an approach that has enjoyed some success. Informative fact sheets, posters or pamphlets detailing ways to identify and avoid spreading invasive species are often distributed to commercial fishermen, boaters, aquaculture operators, anglers, bait shops, aquarium enthusiasts and pet stores.

Ocean going vessels are unquestionably the principal carriers of exotic, aquatic species between distant countries. Ships once carried a virtual ecosystem of exotic species adhering to the outside of their hulls and introduced many species to new homes. The use of anti-fouling paint to inhibit such growth, although done primarily for economic rather than ecological motives, has probably much reduced but not entirely eliminated this means of transport. Nowadays, it is what is carried inside the hull rather than what is growing on the outside that is a major cause for concern. Ballast water can harbour a wide variety of animals, plants and microbes. However, a variety of steps could be taken to ensure that these hitchhikers don't reach our coastal waters alive. An obvious step would be for ships to pump out their foreign ballast water into holding tanks onshore where it could be treated and disposed of safely. Because this is costly and time consuming, few such treatment facilities exist. An approach that is used more often is for the ships to dump their ballast water far offshore and replace it with oceanic seawater. This effectively prevents coastal species being transported to foreign coastal waters. In Canada, such offshore ballast exchange, out beyond the 200 mile Exclusive Economic Zone, is presently a voluntary guideline rather than an enforceable regulation. Storms often prevent such an at-sea exchange, cargo vessels from the southern U.S. don't venture far enough offshore, and many vessels simply ignore the guidelines because skippers generally don't like changing ballast at sea. Transport Canada doesn't monitor or report on compliance, so the effectiveness of the guidelines is largely unknown. American Coast Guard studies indicate that only 20 percent of vessels file the voluntary, ballast-water management report recommended by that country's guidelines. Another novel approach is to try to kill the potential invaders by treating the water on board before dumping it. This could be done by disinfecting it with chlorine or other chemicals, sterilizing it with ultraviolet light, heating it to a lethal temperature, or removing the oxygen from it. The water might also be filtered during discharge to trap harmful organisms. Each of these approaches is now getting much more study to determine if they are feasible and effective, but none of them are likely to be routinely used soon. Before implementing such measures, the United Nations International Maritime Organization (IMO) is going through a lengthy process of developing international standards and regulations, following which, ship owners would probably be granted a lengthy grace period to retrofit their vessels with the needed equipment. In her 2002 Report to the House of Commons, Canada's Commissioner of the Environment and Sustainable Development noted that Transport Canada estimates that this process will probably take up to 30 years to complete. This means that exotic species will likely continue to enjoy comfortable, free cruises to our shores well into the foreseeable future.

If we can't stop all the invaders from coming, then the

What boaters, ship operators and others can do to halt aquatic invaders.

Before trailering your boat:

- Wash boat, anchor, trailer and other equipment with fresh water and/or spray with undiluted vinegar.
- Remove any plants or animals.
- Drain water from your boat motor, bilge, and wells.
- Let equipment dry completely, if possible.

For larger vessels:

- Use anti-fouling paint to reduce settlement of organisms on the hull.
- Don't take on or release ballast water in port, near aquaculture facilities, or at night.

For others:

- Never release live bait, aquarium fish, crayfish, or plants into the water.
- Clean clams or other shellfish in the water where they were collected. Move them with a minimum amount of water.
- Learn to identify invasive species in your area and report any sightings.

From DFO "Aquatic Invaders" Website:
http://www.glf.dfo-mpo.gc.ca/sci-sci/inva-enva/index-e.html

next best line of defense is to eliminate them, or at least try to control their spread, immediately they arrive. For this to have any chance of success, the invasion has to be detected quickly while their numbers are still small. Along many coastlines, there isn't an adequate record of all the species that are already there, so it could be difficult to pick out newcomers among the numerous, rare natives. For this approach to be effective a costly and complex monitoring program involving specialists to regularly survey an area for any possible new species is required. There is a greater chance of success if the search can be focused on a single likely invader that is readily visible and identifiable, such as the Japanese Shore Crab. Observers can then be trained, and sampling techniques designed, to look for just the species of interest. This type of early warning system has been used to monitor the spread of Green Crabs, with trained volunteers periodically checking baited traps. But unfortunately, while we are busy keeping an eye out for the crabs, many foreign plankton and microbial organisms will probably slip in undetected.

> ***"The most effective control measure is, of course, to prevent such introductions in the first place. Once an invading species becomes established in a new, congenial home it is a costly and usually losing battle to be rid of it."***

Once an invasive species has gained a firm foothold, it is impossible to eradicate it. Probably the best that can be hoped for is to control the growth of the population, slow down its spread and keep it away from sensitive areas or valuable assets. Chemical control measures, such as pesticides, are not a viable option because of their toxicity to native species and the likelihood of accumulation in species used as seafood. Trapping and killing can be a feasible method of controlling populations of some pest species, particularly when supported by a bounty for the animals removed. New England towns paid a bounty on European Green Crabs in an attempt to protect scallop beds in coastal lagoons. However, this approach can be expensive, and may be abused, such as by importing target organisms from elsewhere just to collect the bounty. Biological control methods, involving the use of predators, parasites or diseases to control the invasive species, have worked in some situations on land. For example, various insects are being used to control Purple Loosestrife, *Lythrum salicaria*, an invasive wetland plant. There have been attempts to use a parasitic barnacle, *Sacculina carcini,* to control Green Crabs. However, in this, as in most such situations, there is not enough known about the effects of the imported control organism on native species. Thus, there is considerable risk of simply exacerbating the ecological havoc. Keeping the pest species away from aquaculture operations, such as by fencing small shellfish beds or placing net enclosures around cultured shellfish, are costly solutions yielding mixed results. When all else fails, it may be possible to control pest species that are marketable by encouraging a fishery. The authors of a recent paper in the scientific journal "Ecology" wryly noted that "...after all, fisheries are a proven way to eradicate a species". In May 2001, legislators in Maine approved the licensing and management of a fishery for the European Green Crab and a few groups are now studying the feasibility of developing a specialty market for this small but edible crustacean. Given the considerable difficulties in successfully using any of these control methods, one can but reiterate that the only really effective approach is to keep out the invaders in the first place.

Aquaculture - Vector and Victim

Aquaculture has become an important industry along both coasts of the outer Bay of Fundy *(See Fundy Issue # 7)*. Experiences here and elsewhere have shown that activities associated with aquaculture are a significant way of introducing exotic species into a region. Ironically, aquaculture operations are also particularly vulnerable to the devastating effects of alien invasive species, especially predators, fouling organisms, parasites and disease causing viruses, bacteria or fungi. For example, *Furunculosis*, a bacterial disease of salmon was spread from Scotland to aquaculture sites in Norway by the import of infected smolts (young salmon). Within a few years, the disease spread to most Norwegian salmon farms and to wild salmon in at least 74 rivers. Closer to home, Infectious Salmon Anemia (ISA), a viral disease common in Europe, made its North American debut in New Brunswick salmon pens, where it killed large numbers of fish. The only known treatment is to destroy all infected fish and remove all salmon farms from the area for a few years until the virus disappears. As we have already seen, introduced organisms, such as tunicates or seaweeds, that grow on submerged surfaces can severely foul aquaculture gear,

> ***"activities associated with aquaculture are a significant way of introducing exotic species into a region. Ironically, aquaculture operations are also particularly vulnerable to the devastating effects of alien invasive species"***

inhibiting the growth of the cultured species and necessitating costly cleaning and maintenance. There is also growing concern that popular aquaculture species, such as the Atlantic Salmon, are being farmed in places well outside their normal range, such as in the fjords of British Columbia. Inevitably, penned fish escape in large numbers and mix and compete with native salmon species, with long-term consequences that are not fully understood. Problems can even arise when the farmed fish are the same species as the local wild ones. Fish for use in aquaculture are increasingly being bred for rapid growth and other traits that make them more amenable to captivity. They are gradually becoming genetically different from the native wild stocks and are less and less adapted for existence in the wild. In fact, genetic engineering, by which genes from other types of fish are inserted into salmon DNA to further enhance their suitability for aquaculture, is speeding up this process of making the farmed fish even more genetically alien. The long-term ecological consequences of such genetically different escapees breeding with and thus passing the modified genes to wild salmon stocks are largely unknown. In many New Brunswick rivers, escapees from salmon farms are now far more numerous than the wild fish, sometimes by a factor of ten. Clearly, a lot more research, education and regulation is needed immediately to reduce the potential adverse impacts of the aquaculture industry upon itself and upon the natural ecosystem as a whole.

Who is Winning the War?

The Canadian Food Inspection Agency has long played an important role in attempting to prevent the import and control the spread of exotic species that could threaten the well-being of our valuable forestry and agriculture industries. However, their inspections, quarantines and permits are primarily designed to address economic rather than ecological concerns. Until recently, there has been no comparable comprehensive program in Canada, or in most other countries, to tackle the problem of aquatic invaders. In recent decades, deteriorating ecosystems and diminishing biodiversity worldwide have prompted a number of international conservation efforts. Canada was one of 168 countries that agreed to the United Nations Convention on Biological Diversity in 1992. Among other things, this involved a pledge to work towards preventing the introduction of alien species and controlling or eradicating those that had invaded Canada and threatened ecosystems, habitats or native species. Environment Canada had already set up a Biodiversity Convention Office in 1991 to coordinate Canada's efforts. In 1995 it unveiled a Canadian Biodiversity Strategy that laid out the framework for addressing this formidable challenge. In addition to Environment Canada, other government departments play key roles in this endeavor. Fisheries and Oceans has a responsibility to protect fisheries and aquatic habitats as well as to provide the necessary research capabilities in aquatic ecology and ecosystem dynamics. To this end, DFO in 2002 developed a "National Code on Introductions and Transfers of Aquatic Organisms", the aim of which is "to protect aquatic ecosystems while encouraging responsible use of aquatic resources for the benefit of Canadians". The Department created Introductions and Transfers Committees to assess any proposals for moving aquatic organisms between water bodies and also agreed to develop a registry of introductions and transfers and issue regular reports. However, the code only deals with intentional introductions and transfers and doesn't cover the more pressing issue of accidental or inadvertent introductions. Surprisingly, the code doesn't cover aquarium fish, bait organisms, live market-bound fish, organisms used for research or teaching, and transgenic aquatic organisms. Transport Canada is largely responsible for regulating and monitoring ballast water discharge in Canadian waters. However, it has a largely inactive program at present and only voluntary guidelines are being considered.

"Canada was one of 168 countries that agreed to the United Nations Convention on Biological Diversity in 1992. Among other things, this involved a pledge to work towards preventing the introduction of alien species and controlling or eradicating those that had invaded Canada and threatened ecosystems, habitats or native species."

"it seems rather ironic that we humans, Homo sapiens, are not only the principal agent of their rapid spread, but are also the ultimate invasive species on the planet."

The Canadian Commissioner of the Environment and Sustainable Development noted in her 2002 Report that "the federal government has not responded effectively to invasive species that threaten Canada's ecosystems, habitats, and other species….. in spite of commitments under UN Convention on Biological Diversity or the Canadian Biodiversity Strategy". She found little agreement on priorities or meaningful coordination among the various departments and agencies responsible. There was also a " tendency to continuing discussion and study, but no concrete actions to control invasives". In particular, there isn't a comprehensive Canadian catalogue of invasive species and little effort has been made to determine the relative ecological danger posed by different species in order to establish priorities for preventing, controlling or eradicating them. Furthermore, there aren't adequate monitoring tools to assess the effectiveness of any measures that might be taken. She recommended that Environment Canada develop a " national invasive species action plan" that would create a database of problem species and also identify specific objectives, roles, responsibilities and resources needed for effectively dealing with them.

It seems that Canada and other countries are only slowly developing the expertise and tools needed to cope with the threat of invasive species. How successful we are in the battle against these opportunistic adventurers remains to be seen. Nevertheless, it seems rather ironic that we humans, *Homo sapiens*, are not only the principal agent of their rapid spread, but are also the ultimate invasive species on the planet. Certainly in our small region of North America, the immigration of Europeans to Fundy's shores some 400 years ago profoundly disrupted the lives and the livelihoods of the indigenous peoples who had arrived much earlier and had dwelt in relative ecological balance for many thousands of years. This 17th century invasion also changed forever the entire natural ecosystem and the pattern of natural resource use throughout the region. But that is another interesting tale to be told in the next Fundy Issues #24.

Further Information

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The Fundy Issues Series is an initiative of the Bay of Fundy Ecosystem Partnership. These publications describe our present scientific understanding of some of the environmental issues confronting the Bay. We hope that they will enhance your understanding of the biological richness and complexity of this unique marine area and the problems confronting it. Such awareness may encourage you to help in protecting it for the use and enjoyment of all, so that future generations may also share and appreciate its bounty and rare beauty.

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