Bio-invasions: Breaching Natural Barriers

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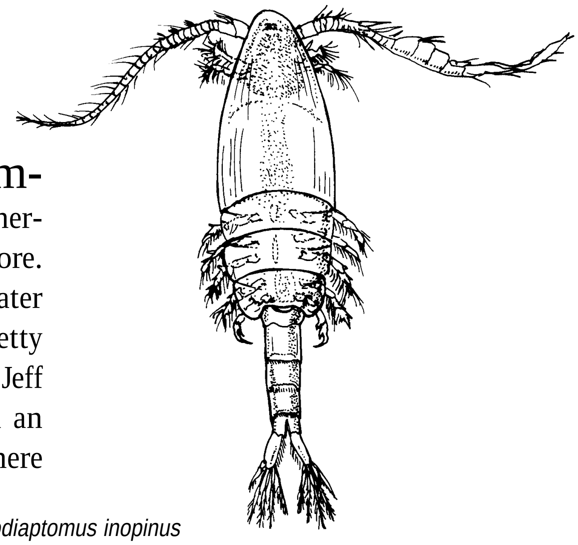
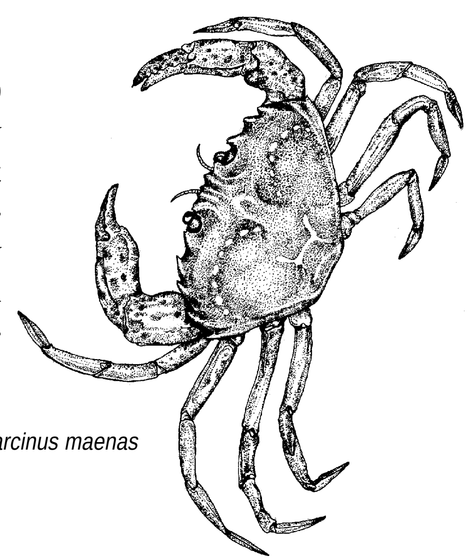


It's a bright sunny afternoon on the Columbia River estuary. Jeff Cordell, University of Washington fisheries researcher, collects water samples just as he has dozens of times before. For the past 13 years, he's been studying tiny crustaceans in the water column—important food resources for juvenile salmon. This trip is pretty routine. Or so he thought. Back in the lab examining the samples, Jeff sees something he's never seen before. An unfamiliar creature with an unusual appearance. There are lots of them. What are they? And where did they come from?

Asian copepod, Pseudodiaptomus inopinus

Dick Sheldon stares out at miles of flowing green grass edging the flat blue water of Willapa Bay. As an oyster grower and concerned citizen, he shakes his fist at the grass, loved by others in far off places, but hated by him. He has seen what the grass has done. It moves in, blankets the mud flats, changes the coastline and devalues his land as it spreads each year, acre by acre. And because it is listed as a noxious weed, he may be responsible for controlling it. Giving away some of his property to the county has become an attractive option. How did the grass get here? And who is going to stop its spread?

Atlantic smooth cordgrass, Spartina alterniflora



An uncommonly adaptable creature, it can tolerate both fresh and sea water. Known to dine on over 150 different kinds of plants and animals, it isn't a picky eater. It especially likes young clams and crabs. Females lay up to 200,000 eggs at a time. It can withstand freezing temperatures and can live in a variety of tidal habitats. Its larval form may travel well in cargo ship ballast water. Originally from western Europe, it now lives in the eastern United States, South Africa, Australia and California. It was recently seen in Oregon and Washington. What will happen if it thrives in Pacific Northwest estuaries?

European green crab, Carcinus maenas

The threat of non-native organisms

Non-native organisms are in the news. We hear about plants, animals and microbes from foreign places that have grown out of control. In our own backyard we know the impact of weedy species like Himalayan blackberries and English ivy. We see the exotic Scotch broom plant skirting our highways almost as fast as they are built. We read about the alien zebra mussel advancing into United States and Canadian waterways, encrusting everything in its path. And we wonder if deadly foreign pathogens might be lurking around every corner. How are these organisms spreading across continents and oceans? Why are some so aggressive once they get here?

What is "native"?

Before we can consider the threat of non-native organisms we need to define "native." Native essentially means living in the place of origin. In this context, origin is considered in terms of thousands of years. A native organism lives within its natural or historical range and zone of dispersal. A non-native organism lives in a place it couldn't get to by itself or through natural dispersal (such as by wind, tides, currents, etc.).

In Washington state, we often define native plants and animals as those that were here before the arrival of European settlers in the late 1700s. Until then, the influx of new organisms was infrequent. For thousands of years native peoples lived side-by-side with native flora and fauna, their movement limited to distances traveled by foot and canoe. Organisms lived only where they spread to over time, restricted by characteristics of the environment and their genetically-determined attributes.

Species interactions in natural systems

Species evolve by adapting to their local habitats. King salmon, Orca whales, Douglas fir and all forms of life we know today are a result of a continuing process of interaction between their inherited traits and characteristics of their environment.

Adapting to many stresses over thousands of years, native organisms develop unique relationships with both their physical environment and with other organisms around them. Ever wondered why native plants can be easy to grow? It's because they have adapted to local soil and weather conditions. As a result of their shared history, native vegetation attracts native species of butterflies, insects and birds. At the same time, native plants are subject to native predators, parasites and diseases that also share a part of their history.

In the marine environment, you only have to walk at low tide on any Pacific Northwest beach to see special associations among organisms. Native eelgrass, *Zostera marina*, provides the perfect nursery habitat for young fish, a substrate on which snails lay eggs, a home for Dungeness crab and a food source for brant geese. Mussels, oysters and barnacles may grow side-by-side and on top of each other, sharing and competing for the same spot on any hard surface.

Agricultural Introductions: A historian's perspective

"Agriculture as we know it in the U.S. would be impossible without introduced organisms. American agriculture is based almost entirely upon introduced species. Of all the animals involved in U.S. agriculture today only the turkey, the Muscovy duck and (maybe) one type of chicken are native to the U.S. And of the plants that are cultivated as part of the agricultural system, corn (maize), potatoes, squash, sweet potatoes, some beans and some berries are native. Everything else is introduced, including the honeybee brought by Englishmen in the 1640s in order to pollinate the fruit trees they were introducing...

"The most beneficial introductions in American history have concerned land animals and plants and those have almost entirely been associated with agriculture. There are reasons why this is so. All of the animals and plants used in agriculture had been observed in use and in close proximity for millennia. Of course, the very term "beneficial" comes totally from a European perspective, for the agricultural species were the dynamic elements of the dramatic changes in environment that occurred after 1607, crowding out native species, changing the genetic mix, changing habitat from woodlands to fields, causing erosion, etc."

Reprinted with the permission of William Steirer and South Carolina Sea Grant Consortium. Excerpted from Historical Perspectives on Exotic Species *by William F. Steirer, Jr., Department of History, Clemson University in "Introductions and Transfers of Marine Species," 1991.*

Natural distribution

Barriers determine where organisms live and how ecosystems are created. Barriers prevent species from spreading into new locations and help determine their natural range.

A clam, for example, could not move from the Pacific to the Atlantic coast by itself, even though the habitat there may be suitable. The land would represent a *physical barrier*. Mountain ranges, oceans and deserts are examples of physical barriers that can limit the dispersal or range of particular species. In the case of small organisms, an outcropping of rocks on a sandy beach or even a tide pool may form the edge of their dispersal range. When a species' salinity, temperature and chemical requirements are not met in a new area, these too, become physical barriers.

If a current or a storm sweeps the same clam or any of its tiny offspring to a new area, it might meet *biological barriers* in the form of unsuitable food and habitat, or the presence of pathogens, predators and competitors. So, even if that clam ended up in a sandy cove with perfect water temperature and plenty of plankton to eat, a resident population of sea stars could prevent it, and its offspring, from establishing a new home. Physical and biological barriers thus help determine the natural range of species and provide a foundation for ecosystems.

These barriers are not absolute. Natural systems are dynamic and species' ranges change over time, spreading or retracting as environmental conditions fluctuate and populations are influenced by food availability, predators and disease. Populations will always push and pull against the edges of their range, but generally remain within proximity of their original space.

Introduced species

Introduced species are those that have been transported beyond their natural range. It's easy to see how planting a non-native species such as a Manila clam or a Japanese oyster on the coast of Puget Sound breaches both natural barriers and time scales. Instead of being members of an ecosystem developed over time, in the relative blink of an eye these animals were transported beyond the barriers that defined their natural range.

Once thrust into a new environment, an organism faces a whole new set of conditions. Whether moved intentionally or by accident, the new habitat challenges the organism to perish or persist. All living organisms strive to survive long enough to bear offspring and ensure the future of their gene pool. Next time you see aggressive non-native species on the move, consider that their aim is not to take over the world or make our lives miserable, but rather to simply survive and reproduce.

Scientists believe that most non-native organisms fail to survive in their new environment long enough to become established (a self-sustaining population). But occasionally the introduced organism will find its new home completely livable, sometimes even optimal. An introduced species can spread rapidly, for example, when predators and pathogens normally encountered in its home territory are absent from the new environment. In this situation, introduced species flourish and potentially can reach extraordinarily high population levels. This is often called an invasion. Invasive species can inflict damage on ecosystems by outcompeting native species, preying on native species and/or dramatically altering habitat.

The zebra mussel is a good example of an introduced species that is now extraordinarily abundant and has spread rapidly from its arrival point in the Great Lakes. A native of Eastern Europe, it probably entered North American waters via the ballast water of trans-Atlantic cargo ships. First identified in the United States in 1988, zebra mussels are now found throughout the Mississippi River watershed, in

Zebra mussel

The fingernail-sized zebra mussel (*Dreissena polymorpha*) is native to the Black, Caspian and Azov Seas. Colonizing London docks by the 1820s, it became the dominant freshwater species in Britain within a century. In the United States, the zebra mussel was first found in a small lake near Detroit in 1988. It has since spread from the Great Lakes to the Mississippi, Hudson, Susquehanna and Illinois river basins.

Armed with an ability to reproduce rapidly and in large numbers, the zebra mussel can attach to any available substrate, including water pipes, intake screens, boats and buoys. Since 1989, power plants, water utilities, industrial facilities, and navigation lock and dam operators have spent more than $70 million trying to control and manage zebra mussel infestations. The fouling of boat hulls not only causes problems for owners, but provides a vector for introduction when the mussels attach to boats that are moved from infested to uninfested water systems.

In addition to the physical and economic impacts, zebra mussels severely alter habitat and affect native species. Washington state officials are on the lookout for recreational boats arriving from the Midwest carrying zebra mussels. Some biologists believe it is just a question of time before the zebra mussel arrives, but with diligence and education we may be able keep our waterways free of zebra mussels.

For more information on the zebra mussel or to report a sighting in Washington, call the Washington Department of Fish and Wildlife at 360-902-2821.

Or, visit these Web sites for national zebra mussel news:

www.usbr.gov/zebra/wzmtf.html

www.cecer.army.mil/facts/sheets/FL10.html

mdsg.umd.edu/Research/Exotics.html

seagrant.wisc.edu/advisory/nonindiginous%20species/impacts/html

19 states and 2 Canadian provinces. The damage this invasive organism has caused is dramatic in both ecological and economic terms. There is great concern that the zebra mussel may soon become established in West Coast drainages.

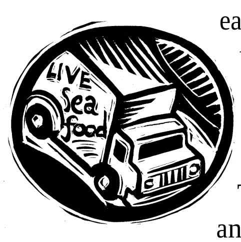
The smooth cordgrass, *Spartina alterniflora*, first arrived in Washington state over 100 years ago. The cordgrass found the wide open mud flats of Willapa Bay devoid of competing vegetation, free from predators, and with ideal temperatures and conditions in which to thrive. In *Spartina*'s home territory on the Atlantic seaboard, the cordgrass is a highly prized member of the salt marsh community and is an aid in erosion control. But on the West Coast, *Spartina* is radically changing the native ecosystem. Growing in clumps, it spreads rapidly by both seed and an expansive root system to form new colonies. With each incoming tide, the grass traps sediment. Over time, what had been a marine mudflat is now transformed into high marsh. In Willapa Bay, Grays Harbor, Puget Sound, and other affected areas on the West Coast, citizens and resource managers recognize *Spartina* as a serious threat to local economies and ecosystems, and have responded by implementing a variety of control and management programs.

Not all introductions or invasions are as obvious as *Spartina* and the zebra mussel. Without displaying obvious impacts, some invaders can quietly alter ecosystems yet never command our attention. The tiny Asian copepod, *Pseudodiaptomus inopinus*, is a good example. In 1990, a fisheries researcher discovered that the non-native copepod had taken up residence in the lower Columbia River estuary. Further studies found it living in 10 other estuaries on the Pacific coast. The abundance of the new species suggested that it might become a food source for young salmon, much like our native copepods. What would happen if the salmon became dependent on this food source over the long run? Since these copepods may not be adapted to local conditions (weather, hydrodynamics), they may prove to be an unreliable substitute. A sudden decline in their population could leave salmon without an adequate food supply until or unless native copepod populations recover. Scientists are attempting to identify what role this new species will take within estuarine communities on the Pacific coast.

The zebra mussel, *Spartina* and the Asian copepod are just a few of the species transported by humans beyond their natural range. But why are they being moved and how are they getting here?

Pathways

During the European age of exploration (mid-15th century onward), a naturalist's primary task was to "discover," document and return home with specimens representing every manner of foreign life. Later, when settlers came to the New World, they understandably wanted to bring with them the familiar plants and animals on which they relied for food, landscaping and pets. Today, as transportation becomes more sophisticated, we can enjoy fresh mangos from Mexico, Chilean-grown Atlantic salmon and Washington-grown Pacific oysters, while sitting in a garden planted with Mediterranean lavender and English roses.



Our ability to transport ourselves and our products around the planet is one of mankind's greatest achievements. This ability has brought with it the means for both intentional and unintentional transfer of organisms. Most species used today in agriculture, aquaculture and horticulture were introduced intentionally. Bringing these species to new areas was considered a safe proposition, and their establishment was viewed as a success story—but a few surprises came along with them. Ships transporting cattle also carried rats and cockroaches. Shipments of live oysters came with oyster predators and diseases. The tumbleweed was just one of many species

Green crab

The European green crab, *Carcinus maenus*, is a small shore crab (adults measure about 3" across), an able colonizer and an efficient predator that can alter any ecosystem it invades. Introduced to the Atlantic seaboard more than 150 years ago, there are now established populations in Australia and South Africa. First seen in San Francisco Bay in 1989, the green crab moved southward to Monterey Bay and northward to Humboldt Bay, California, Coos Bay, Oregon, and into many Oregon estuaries. Green crab were sighted in Willapa Bay and Grays Harbor Washington, and on the west coast of Vancouver Island, in 1998 and 1999.

The green crab is an efficient forager capable of learning and improving upon its food-gathering skills. Studies have shown that the green crab is quicker and more dextrous than most crabs, and readily opens bivalve shells. One adult crab can eat 40 half-inch clams a day and can devour a crab as large as itself. The green crab could threaten Dungeness crab, oyster, and clam fisheries and aquaculture operations in the Pacific Northwest and British Columbia; these crab are blamed for the collapse of the soft shell clam industry in Maine. Green crab prey on numerous other organisms, making them competitors for food with native fish and birds. These crab are also the intermediate host for a marine worm that can harm local shore birds.

Green crab can thrive in many coastal habitats and in wide temperature and salinity ranges. Larval green crab can live up to 80 days drifting on ocean currents. They also survive well out of water for long periods; a single female green crab may produce up to 200,000 eggs at a time.

Human activities have almost certainly contributed to the spread of green crab to Pacific Northwest and British Columbia waters.Packaging used to ship live seafood and scientific specimens from other regions may harbor green crab; recreational boaters may inadvertently bring green crab into local waters in baitwells and buckets; and people may dispose of aquarium animals and packaging bought at pet stores which includes green crab. Discharge of ballast water from ships is also thought to be a source of green crab larvae to the region.

that arrived in grain shipments from overseas. Other intentional introductions gone awry include species originally intended for sport fishing, erosion control, horticulture and as biological controls for other introduced species.

Today, after decades of experience, there are laws governing the intentional introduction of non-native species. Most of these laws are designed to regulate the influx of land-based (terrestrial) organisms, primarily to protect human health and agricultural crops. In the freshwater environment, the once popular government practice of transplanting non-native species for recreational fishing has given way to strict regulations controlling such practices. In the marine environment we are just beginning to recognize the pathways that transport new species into our coastal and inland waterways. While aquaculture practices were once the primary pathway for aquatic introductions, they too are now highly regulated. Most recently, scientists have singled out ballast water discharged from ocean-going cargo ships as a primary pathway for introductions.

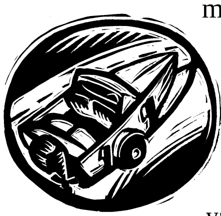
In the age of wooden-hulled ships a variety of wood-boring (shipworms, gribbles) and fouling (barnacles, mussels, seaweed) organisms were translocated between harbors around the world. Steel cargo vessels have replaced those ships. These vessels use large volumes of sea and fresh water as ballast to keep them stable and seaworthy—taking on and discharging millions of tons of ballast water daily in ports and harbors around the world. From phytoplankton to fish, ballast water has been implicated in more than 100 introductions worldwide.

Invasive species can displace native species, dramatically change natural habitats, and can have profound impacts on the economy.

One example of an introduction attributed to ballast water is the jellyfish-like animal *Mnemiopsis leidyi*. This voracious plankton-feeder, a comb jelly native to the Atlantic coast of the Americas, was found in the Black and Azov seas in Eastern Europe in 1982. By 1989, its growth to invasive levels contributed to the collapse of local anchovy populations and their commercial fisheries.

It's not just the big commercial vessels that move organisms around. Recreational boaters transport nuisance species often without realizing it. Fragments of the aquatic weed Eurasian watermilfoil, tangled on boat propellers, trailers and fishing gear, can easily spread an infestation from lake to lake. Inspections by state resource agencies have uncovered live zebra mussels attached to recreational boats trailered in from other states. How do we know if one of these activities will result in an introduction? Can we predict which species will invade?

Characteristics of bio-invasions



A "successful" introduction is a result of a match between the needs of the introduced organism and its new environment. The factors that govern this pairing are complex, and not always obvious. From subtle shifts in temperature, the time of day or the number of individuals introduced, unlimited unique variables make it difficult to predict the outcome of an individual introduction. But for introduced organisms, those with flexible living requirements and high reproductive rates have an advantage. A perfect example is the European green crab, *Carcinus maenas.*

This small crab can thrive in broad ranges of temperature, salinity, and habitats. Known to feed on a wide variety of plants and animals, this omnivore produces large numbers of offspring. It is aggressive when competing for food against other crabs and shrimp, and can drastically reduce native bivalve populations, such as the soft-shell clam along the coast of Maine. This type of organism can become established and proliferate in stable communities.

Organisms with more rigid requirements can also be introduced successfully and may become invasive. The key here is the receiving environment. Few competitors or predators and available habitat present an opportunity for entry into a community. For *Spartina*, the open mud flats of Willapa Bay represented such a situation.

Habitat alteration: putting out the welcome mat

When the environment of an existing system of species is modified or disturbed, such as a cleared forest or a polluted estuary, the opportunity for new species to move in is greater. This is one reason we see Scotch broom edging most major highways in British Columbia, Western Washington and Oregon. Once planted as an erosion control device, this aggressive species spreads quickly on cleared land. Notice that you rarely see it spreading from cleared roadway embankments into adjacent established forests.

It may be more difficult to identify disturbed habitats in aquatic environments. Oil spills, dredged harbors and seawalls are all examples of disturbed habitat. Imagine a river or harbor that has become increasingly polluted by chemical discharge. Chemically-tolerant species begin to dominate the community, while those species that cannot survive leave an opening for more tolerant new arrivals. *Tilapia* is a non-native fish that can live in low-oxygen, high-temperature water often associated with industrial pollution. Thriving in an environment where native species cannot survive, it establishes a population and then spreads to other areas, sometimes outcompeting native species.

Humans have the power to change whole systems quickly. Replacing a forest with a single crop, laying asphalt across an acre of wetland and joining two oceans with a ship canal are all examples of our technological strength. Of course there are natural forces that also dramatically alter habitats such as storms, floods and earthquakes. While we have no control over acts of nature, we can anticipate the impacts of our own activities and minimize the destruction and alteration of habitats.

Homogenization: a species-poor world

In 1958, Charles Elton published his classic chronicle on the ecology of invasions. He sounded the alarm on the human redistribution of species, writing, "Man is carrying on and accelerating an interchange of species that was going on some 15 million years ago when some of the continents were joined again." Elton explained that the Isthmus of Panama was submerged repeatedly over the course of geologic time. When separated, North and South America were island continents, each with its own rich diversity of species. When the Isthmus re-emerged and the continents were re-united, interactions between species led to the loss of many species. The Pacific and Atlantic oceans also separated and rejoined, causing a similar interaction between species. This mixing and the resulting reduction of total number of species occurred over millions of years. By building a canal or sailing a ship, humans can cause the same type of mixing between and reduction of species, but at a highly accelerated rate.

Elton warns that this continued breaching of barriers will leave us with a simpler, poorer world. As a by-product of our power, we have found ways to transcend natural time scales, to alter large expanses of habitat, and to break down and bridge barriers that would otherwise separate species. The richness of ecosystems that have evolved independently all over the world, previously contained by physical and biological barriers, could ultimately give way to a homogenized world with fewer species. As species and habitats are lost, local economies can be threatened. For example, shellfisheries on the West Coast are threatened by *Spartina* cordgrass, and the decline and collapse of the soft-shelled clam industry in Maine can be attributed to the invasion of the European green crab. Changes brought by introduced species can lead to the loss of important nursery habitat for fish such as salmon.

As the total number of species declines, plants and animals that may be important food resources, that play a critical role in the food web, or that contain medicinal qualities may disappear. Surviving species will have fewer buffers against catastrophic fluctuations in the environment. If, for example, a fish species loses many or some of its food resources, any threat or damage to the remaining food resource can be far more detrimental to the fish because alternatives have been lost. Thus homogenization of habitats and species can have far-reaching effects.

Chinese Mitten Crab

The Chinese mitten crab, *Eriocheir sinensis*, is a burrowing crab whose native range is the coastal rivers and estuaries of the Yellow Sea in Korea and China. It has recently become established in the San Francisco Bay/Delta watershed in California, posing a threat to native invertebrates and to the ecological structure of freshwater and estuarine communities, as well as disrupting some fishing, shrimping and industrial operations. Scientists predict that the mitten crab is likely to arrive in the Pacific Northwest eventually through larval dispersal or intentional release. Mitten crabs became established in many parts of Europe during the 1920s and 1930s, occasionally experiencing huge population explosions.

Mature mitten crabs have dense patches of hairs on white-tipped claws, resembling mittens. They have a carapace width of 3 inches or more. Mitten crabs spawn in estuaries; the juveniles migrate upstream to rear in freshwater, sometimes traveling many hundreds or thousands of miles. They are adept walkers on land and move readily over and around obstacles like dams, weirs and levees.

The mitten crab is an efficient predator and competitor for food and may have a profound effect on native biological communities, including salmonids. In tidal areas mitten crabs may burrow into banks and levees, causing erosion and breakdown of the banks. Mitten crabs have damaged fishing nets in Europe and caused substantial clogging of pumps, screens and intake pipes in California water diversion and fish salvage facilities. The crab may also pose a human health risk as the intermediate host for the Oriental lung fluke.

What can you do?

Non-native species introductions are a hot topic in the news because awareness is growing and action is being taken. Legislators are developing policies to prevent unintentional introductions; natural resource agencies are creating management plans to minimize and manage non-native species; and community groups are educating and involving people in activities at the local level. Even though the scales of time and space discussed here may seem overwhelming, you can make a difference. Each individual plays an important role in preventing the introduction and spread of unwanted non-native species. Here are some suggestions on how you can help.

1. ***Don't transport plants and animals when you travel or move without checking with local authorities.***

2. ***Never release pets, plants, or aquarium animals or plants into the wild.***

3. ***Look into the benefits of using native plants on your property. Contact your local Cooperative Extension.***

4. ***Study the pathways for introductions and do your part to stop accidental release or movement of non-native species.***

5. ***Teach your children about the richness of ecosystems. Explain that plants, animals and microbes all live as part of a larger system. One cannot be affected without impact on another.***

6. ***Be aware of legislation and government programs that address intentional and accidental introductions of non-indigenous species.***

7. ***Participate in community groups designed to restore habitat, survey, remove and report sightings of invasive species.***

8. ***Keep in mind that eradication of established non-natives is usually impossible. Preventing introductions is possible if we all do our part.***

Non-native aquatic species in Washington and British Columbia

The following is a partial list of introduced species with established populations in Washington and British Columbia. Some were introduced intentionally, such as game fish and aquaculture species, while others came as a result of unintentional release, such as in ballast discharge or disposal of packing materials. A number of these introduced species are considered beneficial, but many are classified as nuisance species. In all cases, we can be sure that these introductions have had some influence on the ecosystem in which they now live. This list includes fish living in fresh, brackish, and marine water habitats.

Invertebrates

Varnish or mahogany clam *Nuttallia obscurata*
Manila clam *Tapes philippinarum*
Asian clam *Corbicula fluminea*
Soft-shell clam *Mya arenaria*
Japanese trapezium *Trapezium liratum*
Japanese littleneck clam *Venerupis philippinarum*
Pacific oyster *Crassostrea gigas*
Eastern oyster† *Crassostrea virginica*
Japanese or green mussel *Musculista senhousia*
Slipper shell *Crepidula fornicata*
Mud snail *Nassarius obsoletus/Ilyanassa obsoleta*
Eastern oyster drill *Urosalpinx cinerea*
Japanese oyster drill *Ceratostoma inornatum*
Red beard sponge *Microciona prolifera*
Boring sponge *Cliona spp.*
Bowerbank's halichondria *Halichondria bowerbanki*
Asian copepod* *Pseudodiaptomus inopinus*
Bivalve intestinal copepod *Mytilicola orientalis*
Mud worm *Polydora ligni*
Wood-boring gribble *Limnoria tripunctata*
Shipworm *Teredo navalis*

Fish

American shad *Alosa sapidissima*
Grass carp* *Ctenopharyngodon idella*
Striped bass *Morone saxatilis*
Common carp *Cyprinus carpio*
Goldfish *Carassius auratus*
Largemouth Bass *Micropterus salmoides*
Smallmouth Bass *Micropterus dolomieui*
Bluegill*, Green Sunfish*, Pumpkinseed Sunfish *Lepomis spp.*
Black Crappie, White Crappie* *Pomoxis spp.*
Walleye *Stizostedion vitreum*
Yellow Perch *Perca flavescens*
Channel Catfish, Blue Catfish *Ictalurus spp.**
Flathead Catfish*, *Pylodictis olivaris*
Black Catfish, Brown Catfish†
Brown Bullhead, Yellow Bullhead*, Black Bullhead* *Ictalurus pp.*
Northern Pike, Tiger Musky* *Esox spp.*

Aquatic Plants

Brown alga or Japanese weed *Sargassum muticum*
Japanese eel grass *Zostera japonica*
Lomentaria hakodatensis
Purple Loosestrife *Lythrum salicaria*
Brazilian Elodea* *Egeria densa*
Parrotfeather Milfoil* *Myriophyllum aquaticum*
Fanwort* *Cabomba caroliniana*
Eurasian Watermilfoil *Myriophyllum spicatum*
Hydrilla* *Hydrilla verticillata*
Spartina/Cordgrasses* *Spartina alterniflora, anglica, patens*
Yellow Iris *Iris pseudacorus*
Agar weed† *Gelidium vagum*

** not established in B.C.*

† not established in Washington state

Pathways of non-native aquatic introductions

Aquaculture: Historically, culture of fin fish and shellfish was a primary path for both intentional and unintentional introductions. Culture of the non-native Pacific oyster has contributed to Washington state's status as one of the nation's top three leading oyster producers. Imports of oyster spat early in the century brought several unwanted species introductions such as the oyster drill. In addition, cultured non-native species can escape from captivity, such as Atlantic salmon that escape from net pens.

Aquarium trade: Wholesale importers, culture facilities and retail pet stores culture, transport, and sell non-native fresh and salt water plants, fish and invertebrates. The intentional and unintentional release or escape of species into the wild by the industry and the hobbyist aquarium owner has led to introductions. The common goldfish, for example, has become a nuisance species in eastern Washington.

Biological control: Selected non-native species, usually target predators, have been intentionally introduced to control the growth and spread of other introduced species. History shows that achieving the desired effect is difficult. Grass carp introduced to control unwanted aquatic plants in inland lakes resulted in native plant species being decimated.

Channels, canals, locks: The building of channels, canals and locks creates artificial connections between waterways, allowing the free movement of species across physical barriers. It also facilitates the transport of species by vessels.

Live bait: Commercially-sold live worms and other aquatic organisms for the recreational fishing industry, both the bait species and its packing material, can result in introductions through intentional and unintentional release.

Nursery industry: Nurseries, garden centers and mail-order catalogs sell non-native plants for aquatic gardens and ponds. Individuals discard non-native plants in public waterways. Non-native plants are sometimes accidentally attached to other horticultural species and discarded unintentionally or intentionally.

Scientific research institutions, schools and public aquariums: Private and public research laboratories, schools and aquariums use non-native species for testing, teaching and research. Individuals who do not follow strict protocols for animal management may accidentally release specimens. Accidental release may also occur when those protocols do not exist. Intentional release and escape from confinement are also possible.

Ships and boats: Ships and boats can introduce organisms through ballast discharge and hull fouling. Ballast water can contain aquatic plants, animals and pathogens. Scientists consider ballast water discharge a major pathway for aquatic introductions because of the huge volume of water carried as ballast. This water carries millions of single-celled and larger organisms. Fouling of vessel hulls by encrusting organisms also provides a mechanism for transfer of species. Recreational boats and boat trailers transport nuisance species including Eurasian watermilfoil and zebra mussels. Aquatic plants, in particular, are easily transported when plant fragments get tangled on boat propellers and fishing gear.

Recreational fisheries enhancement: U.S. federal and state agencies imported 19 game fish species into Washington state between 1890 and 1980, introducing them to enhance recreational fishing. While most of these introductions were intentional, there were accidental releases and the unplanned spread of some species as a by-product of this activity. Private citizens also have transported and released their favorite fish or shellfish species into a body of water, hoping a viable population survives.

Restaurants, seafood retail and processing: Shipments of live seafood, such as East Coast lobsters, provide an opportunity for species introductions when individuals dispose of unused product, packing materials and shipping containers improperly. Associated live organisms either in or on the product may pose an additional threat. Packing materials such as seaweed and seawater also contain a number of living organisms.

Policy response to non-native aquatic introductions

Biological boundaries and ecosystems have little to do with political borders. Therefore, governing species introductions is at the same time an international, national, state and local concern. For example, who has jurisdiction over ships entering Washington state or British Columbia waterways with foreign ballast water? Clearly, regulating shipping is an international issue, and the United States and Canadian governments have power over international commerce. But the state or local communities may have the most to lose in terms of impacts from non-native introductions. The result of overlapping interests is usually a multi-layered process requiring representation and coordination. Unfortunately, policy activity relating to species introductions has generally been in response to specific problems or events that have already occurred. This reactive approach, in combination with inherent jurisdictional problems, has resulted in a less-than-comprehensive policy approach.

The U.S. Congress, Office of Technology Assessment, concluded in its 1993 report "*Harmful Non-Indigenous Species in the U.S.*," that, "First, the Nation has no real national policy on harmful introductions; the current system is piecemeal, lacking adequate rigor and comprehensiveness. Second, many Federal and State statutes, regulations and programs are not keeping pace with new and spreading non-indigenous pests." Yet interest in the subject has never been greater, as evidenced by the Congressional request for this study and the recent passage of legislation on aquatic introductions.

Canadian federal officials also point to large gaps in Canadian regulations. The federal government is redrafting its national policy on introductions and transfers of all species of fish, invertebrates, sea mammals, and marine plants to make it more all-encompassing. For the first time, it will include ornamental and aquarium species. The Fish Transplant Committee is currently conducting a review of the Pacific Fisheries Regulations to address some these areas of concern, including the international importation of species, the lack of adequate training of Canadian Customs' enforcement staff, and adequate provincial border staff to check shipments of live aquatic animals from other provinces.

The following briefly identifies selected policy activity relating to non-native species introductions in the United States and Canada.

International:

"Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens" Resolution A.868(20)—Nov. 20, 1997:

Developed by the International Maritime Organization (an agency of the United Nations). These guidelines, which outline techniques for minimizing introductions from cargo ship ballast discharge, are expected to become part of the International Convention for the Prevention of Pollution from Ships (MARPOL). This would require the U.S. Congress to enact legislation detailed in the guidelines. Canada has supported the development of the guidelines and encourages shipping companies to adopt them. Canada also supports the efforts to move the guidelines to mandatory requirements by the year 2000.

"International Council for the Exploration of the Sea (ICES) Code of Practice Concerning Introductions and Transfers of Marine Species":

A regulatory framework for member states to use in managing the introduction of non-native species. This Code of Practice is continually modified to incorporate new scientific knowledge. Canada's new draft National Policy on Introductions and Transplants draws heavily from the ICES Code of Practice.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES):

Developed by the United Nations, signed by the U.S. in 1975. Designed to restrict trade in listed species to protect depletion in the habitat of origin.

The International Plant Protection Convention (IPPC):

Developed by the United Nations, signed by the U.S. in 1972 with 94 other countries. Designed to prevent the introduction and spread of agricultural pests.

U.S. Federal

Executive Order 13112, February 1999
Directs federal agencies to prevent the introduction of invasive species and provide for their control; establishes the Invasive Species Council and directs them to write an invasive species management plan within 18 months.

National Invasive Species Act of 1996:
Reauthorizes and amends the *Non-Indigenous Aquatic Nuisance Prevention and Control Act of 1990.* Requires the U.S. Coast Guard to issue voluntary national ballast water management guidelines within one year. If compliance is insufficient after three years, the guidelines could become mandatory. Also establishes a ballast research program.

Title 50, U.S. Code of Federal Regulations 58976-58981, 1993:
Enforced by U.S. Fish and Wildlife Service, Dept. of Interior prohibiting importation of specific disease agents of salmonid fish.

Federal Noxious Weed Act of 1974 (amended 1990), Federal Plant Pest Act (1957) and *Plant Quarantine Act (1912):*
Gives the U.S. Department of Agriculture the authority to regulate the movement of plants, plant products, plant pests and their vectors. Also regulates the introduction of genetically engineered organisms.

Lacey Act of 1900 (revised 1981):
Regulates the importation of certain listed animal species.

State of Washington

Aquatic Nuisance Species Bill, 2000 – SHB 2058, SSB 5315
Establishes a state-wide Aquatic Nuisance Species Coordinating Committee to manage for established and encroaching non native species through planning, education, technical assistance, and regulation.

Ballast Water Management Bill, 2000 – SSB 6293, SHB 2466
Establishes guidelines for exchange of ballast water at sea for open ocean and coastal shipping entering Washington waters through mandatory reporting by the shipping industry, with technical assistance from the state.

Revised Code of Washington (RCW) 75:
Gives the Washington Department of Fish and Wildlife authority over various activities relating to aquaculture including transfer, importing and exporting of aquatic species.

State Noxious Weed Law-Revised Code of Washington (RCW) 17.10:
Gives Washington State Department of Agriculture authority over plants identified as destructive to agricultural and natural resources.

Washington Administrative Code (WAC) 220-77:
Relates to disease control of plant and animal aquaculture species.

Washington Administrative Code (WAC) 232-12:
Allows the Washington Department of Fish and Wildlife to take action to prevent introduction and spread of the zebra mussel. Outlaws the intentional import of zebra mussels except for scientific research purposes.

State Environmental Protection Act (SEPA):
Non-native species selected for importation are subject for review to assess environmental impacts.

"Spartina" Bill, 1995—SB 5633:
Authorizes the Washington Department of Agriculture to coordinate a state-wide control program for *Spartina* species.

"Zebra Mussel and Green Crab" Bill, 1998—SB 6114:
Directs the Washington Department of Fish and Wildlife to convene a zebra mussel and green crab task force to make recommendations on prevention and control methods to the legislature by December, 1998. Also directs WDFW to prepare, maintain and publish information on the location of zebra mussel and green crab populations.

Canadian Federal

Canada Shipping Act:
Regulates shipping industry, including discharge of certain toxic substances, but does not regulate release of non-indigenous species. Ballast water restrictions are only in place for situations in which the ballast water may be contaminated with oil or other chemical residues.

Canada Fisheries Act (General Regulation Section 55 and 56):
Prohibits the release of live fish into any fish habitat or transfer of live fish into any fish-rearing facilities without a license issued by the Minister. Also pertains to invertebrates, but excludes aquatic plants.

Pacific Fishery Regulations (PFR), 1993, Section 5:
Requires approval of introduction of certain species of fish. Listed species must be imported only into inspected and approved quarantine facilities.

Pacific Fishery Regulation 1993, made under the Fisheries Act, Section 5:
Prohibits the importation of specified live fish species (Schedule VII-Prohibited Import Live Fish). The list includes 54 genera and species of fish and invertebrates, including lamprey eel, *Tilapia* spp., carp (*Cyprinus carpio)* and shad.

Canadian Fish Health Protection Regulations:
Promulgated under the Fisheries Act, requires a permit for live eggs and fish of cultured salmonids, dead cultured salmonids and eggs of wild salmonids, imported to Canada or transferred between provinces.

Canadian Provincial

The Wildlife Act:
Gives the Minister authority to create regulations to ensure protection of indigenous species of mammals, fish and invertebrates, and their habitat. Makes it an offense to possess, transport or traffic in live freshwater finfish without a permit. Goldfish and ornamental tropical fish are exempt.

Provincial Wildlife Act (BC Reg 261/83):
Made under the Wildlife Act, these regulations deal with freshwater fishes and lampreys only.

Provincial Fisheries Act (PFR), Section 8 and 9:
Regulates practices pertaining to live oysters. Excludes tropical and ornamental fish from permit requirement, as well as marine fish species, invertebrates, and plants.

Aquaculture Regulations:
Made under the PFR, these regulations govern all aquaculture in the province, including provisions for the safe distribution of fish products.

Freshwater Fish Regulations:
Requires a permit for possession, transport or traffic in specific freshwater fish species. Pertains to lampreys and bony fish, including eggs and juvenile stages, but excludes goldfish and ornamental tropical fish.

Fish Transplant Committee (BC):
Federal-Provincial committee consisting of members from the Ministry of Agriculture, Fish and Food (MAFF), the BC Ministry of Environment, Lands and Parks (MELP), and the Dept. of Fisheries and Oceans, Canada. Considers applications for non-native and native fish and invertebrate transfers into and within B.C. Currently reviewing PFR.

BC Animal Disease Control Regulations:
Develops response plans for escaped stock and disease outbreaks.

Port of Vancouver:
In the process of developing a voluntary ballast water exchange program.

Glossary

adaptation: The process by which a group of organisms becomes more suited to its environment, or the distinctive trait which helps achieve the same.

bio-invasion: From "biological invasion," refers to the unplanned growth of a population of non-native species, usually considered detrimental.

biological barrier: Ecological obstacle that prevents a particular population from expanding its range. Examples include lack of food, habitat, the presence of predators, and pathogens.

biological controls: Using natural enemies of a particular species, usually predators and pathogens, to control population.

disturbed environment: Alteration of part or all of a living community due to natural or human-induced actions. Storms, hurricanes and El Niños are examples of natural events; pollution, dredging and plowing are examples of human-mediated events.

ecosystem: All organisms in a community and the associated non-living environmental factors with which they interact.

established: A population of introduced species that has attained a self-sustaining level in a given area.

habitat: The surroundings in which individuals of a particular species usually live.

introduction: The process by which a non-native organism is transported and released into an area previously uninhabited by it. Also a general term referring to non-native species.

invasion: The dramatic increase in the number of individuals in a non-native population, accompanied by an expansion of range.

non-native: An organism living beyond its natural or historical range of distribution. Other terms commonly used are *introduced*, *alien*, *exotic* and *non-indigenous.*

pathogen: A disease-causing agent, including bacteria and viruses and fungi, usually microscopic in size.

physical barrier: Physical obstacle that prevents a particular population from expanding its range. Examples include oceans, mountains, deserts as well as temperature and chemical limitations.

species: The classification for a group of organisms that is distinct from other such groups. Breeding within the group will produce fertile offspring.

Further reading

Books

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Pathways and Management of Marine Non-Indigenous Species in the Shared Waters of British Columbia and Washington, Ralph Elston, Ph.D., Environmental Report Series, No. 5, Puget Sound/Georgia Basin International Task Force, March 1997.

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Biological Invasions, Great Lakes Panel on Aquatic Nuisance Species, August 1996.

Videos

Alien Ocean, 1997, Maryland Sea Grant College, University of Maryland, College Park, Maryland, 30 min.

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