# Invasive Species



## History

Invasive species are the number two threat to rare, threatened or endangered species nationwide, second only to habitat destruction. Commercial fishermen nationwide are seeing significant impacts on local fish populations from invasive marine life. Indeed, coastal systems, including tidal flats and salt marshes, have been particularly susceptible, possibly because they are typically high-stress, species-poor environments. California water agencies have expressed alarm at the "potentially devastating" impacts that invasive species can have on California's waters. Unlike threats posed by most chemical or other types of pollution, biological pollution by invasive species normally will have permanent impacts, as they are virtually impossible to eradicate once established.

Specific environmental threats from invasive organisms include consumption of natives and their food sources, genetic dilution of native species through cross-breeding, alteration of the physical environment, introduction of non-native parasites and diseases, and poisoning of native species through bioaccumulation of toxics that are passed up the food chain. For example:

- In the former Soviet Union, a species of comb jelly was introduced into the Black and Azov Seas through ships' ballast and played a significant role in virtually destroying an entire fishery. Since the introduction of this species, fishing harvest in those seas dropped 200,000 tons in a five-year period.
- Microscopic neurotoxin-producing organisms called dinoflagellates have been transported in the sediments carried with ballast water and discharged into new regions of the world, where they have produced toxic red tides, including red tides in southern Australia that probably originated in ballast water.
- Scientists have warned that a non-native goby now found in the Great Lakes raises toxin levels in indigenous fish and could pose a serious health risk to humans who eat game fish.
- Microbial studies conducted in Canada on ships arriving in winter from Europe found that more than 50 percent of the ships carrying ballast water violated water discharge standards with fecal coliform bacteria. The authors surmised that ships arriving in the summer, or from Asian ports, would be likely to have substantially higher rates of contamination.

Here in California, numerous studies indicate that San Francisco Bay is already severely impacted by harmful non-native species. These studies have identified at least 234 nonindigenous plant and animal species that now live in San Francisco Bay. Moreover, the rate at which aquatic invasive species are becoming established in San Francisco Bay has increased from an average of one every 55 weeks before 1960, to one every 14 weeks between 1961 and 1995. Invasive species that have been positively identified as permanent residents of the Bay include Asian clam, the European green crab, the New Zealand sea slug, the Chinese mitten crab, and several species of sponges, jellyfish, fish, anemones, snails, mussels, clams, and barnacles. Indeed, San Francisco Bay is likely the most invaded estuary in the world.

The discharge of ships' ballast water from foreign ports is currently the single largest source of coastal, aquatic invasive species. A recent survey found that 53-88 percent of the aquatic invasive species introduced into San Francisco Bay in the last decade originated in ballast water discharges, and there is evidence that the number of ballast-related introductions of aquatic invasive species is steadily growing. According to estimates by the San Francisco Estuary Institute, between half a billion and a billion gallons of ballast water are discharged into the San Francisco Bay/Delta Estuary each year by ships arriving from foreign ports. Aquaculture, unintentional introductions via recreational vehicles, deliberate introductions (*i.e.*, to establish a fishery), and importation of live marine organisms for human consumption, bait, pets or research are other important vectors of aquatic invasive species.

## Examples of Significant Invasive Species

Numerous invasive species threaten the health of marine life both directly and indirectly through alteration of coastal ecosystems and habitats. This section highlights three of the more significant species, which are a particular problem in the San Francisco Bay and surrounding areas, and reviews the status of invasions elsewhere in the state.

### The European Green Crab (*Carcinus maenas*)

The green crab, native to the Atlantic coasts of Europe and northern Africa, occupies protected rocky shores, sandflats and tidal marshes. In 1989-1990, it was discovered in San Francisco Bay, and has since spread as far north as Washington and southern British Columbia and south to Morro Bay. It may have entered California through the discharge of ballast water from trans-oceanic ships, although spread is also possible through discard of seaweed packing material used in shipping live shellfish and the interstate transport of shellfish aquaculture products and equipment.

The green crab is a voracious predator that feeds on many types of organisms, particularly bivalve mollusks, polychaetes, and small crustaceans. The green crab is

European Green Crab, *Carcinus maenas*
Credit: DFG

capable of learning and can improve its prey-handling skills while foraging. The crab is quicker, more dexterous and can open shells in more ways than other types of crabs. In its native range, the green crab feeds heavily on mussels. On the East Coast, the crab is believed to have played a role in the demise of Atlantic soft-shell clam fisheries in the 1950s. In Bodega Harbor, California, records show a significant reduction in clam and native shore crab population abundance since the arrival of green crabs in 1993. Furthermore, laboratory studies show that the green crab preys on Dungeness crab of equal or smaller size. Dungeness crab spend part of their juvenile life in the intertidal zone, and may therefore be at risk from green crab predation. Besides its threat as a predator, the green crab may carry a parasite, the acanthocephalan worm, which can infect local shore birds.

## The Chinese Mitten Crab (*Eriocheir sinensis*)

The Chinese mitten crab is native to the coastal rivers and estuaries of the Yellow Sea. It was first collected in the San Francisco estuary in 1992 by commercial shrimp trawlers in South San Francisco Bay and has since spread rapidly throughout the estuary. Mitten crabs were first collected in San Pablo Bay in fall 1994, Suisun Marsh in February 1996, and the delta in September 1996. The Chinese mitten crab now extends at least from north of Colusa in the Sacramento River drainage, east to eastern San Joaquin County near Calaveras County, and south in the San Joaquin River near the San Luis National Wildlife Refuge. The most probable mechanism of introduction to the estuary was either deliberate release to establish a fishery or accidental release via ballast water. In Asia, the mitten crab is a delicacy and crabs have been imported live to markets in Los Angeles and San Francisco.

The mitten crab is catadromous - adults reproduce in salt water and the offspring migrate to fresh water to grow. A single female can carry 250,000 to a million eggs. After hatching, larvae are planktonic for one to two months. The small juvenile crabs settle in salt or brackish water in late spring and migrate to freshwater. Young juvenile mitten crabs are found in tidal freshwater areas, and usually burrow in banks and levees between the high and low tide marks. In China and Europe, older juveniles have been reported several hundred miles from the sea. Maturing crabs move from shallow areas to the channels in late summer and early fall and migrate to salt water in late fall and early winter to complete the life-cycle.

Mitten crabs are adept walkers and readily move across banks or levees to bypass obstructions such as dams or weirs. They are omnivores, with juveniles eating mostly vegetation, but preying upon animals, especially small invertebrates, as they grow.

Mitten crabs pose several possible threats. Their burrowing activity may accelerate the erosion of banks and levees, disturbing local habitat. In addition, the crab can disrupt needed water deliveries to estuarine habitats by clogging the pumps that deliver the water. The mitten crab also has become a nuisance for commercial bay shrimp trawlers in south bay, who have reported mitten crabs damaging nets and killing shrimp. The crab may also compete in the delta with an exotic crayfish that is the basis for a small commercial fishery. The mitten crab may also be the secondary intermediate host for the Oriental lung fluke, with mammals, including humans, as the final host.

The ecological impact of a large mitten crab population is the least understood of all the potential impacts. It could reduce populations of native invertebrates through predation and change the structure of the estuary's fresh and brackish water benthic invertebrate communities.

Chinese Mitten Crab, *Eriocheir sinensis*
Credit: DFG

## An Asian Clam (*Potamocorbula amurensis*)

In October 1986, the first Asian clams found in California were collected in San Francisco Bay by a community college biology class. Just nine months later, the Asian clam had become the most abundant clam in the northern part of the bay, averaging over 2000 clams per square meter.

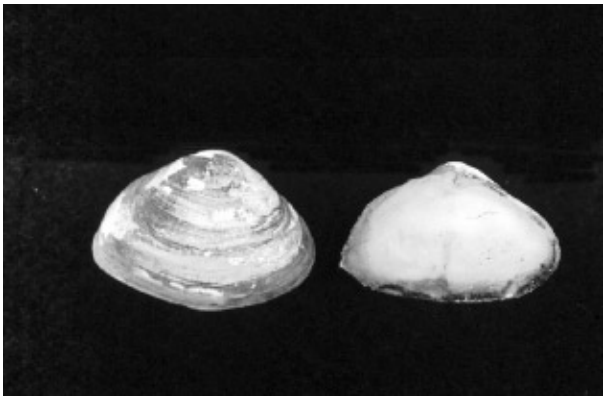
The clam is a highly efficient filter feeder, ingesting bacteria and small zooplankton as well as phytoplankton. At year 2000 densities in the bay, virtually the entire water column may pass through the filtering apparatus of these clams between once and twice a day. Since its arrival, the clam has eliminated annual phytoplankton blooms that had previously characterized this ecosystem, disrupted food webs, reduced the populations of native zooplankton species, and possibly increased the vulnerability of the ecosystem to invasions by exotic zooplankton, many of which have since occurred. This clam is also thought responsible for a reduction in particulate organic carbon. With less food available for larval and other benthic filter feeders, the relative populations of native species could shift.

The clam may also be acting as an accumulator of contaminants, concentrating selenium in bottom-feeding fish and birds at levels that are high enough to cause reproductive defects. This magnification of selenium concentrations in the food chain could also affect fish- and shellfish-eating marine mammals such as harbor seals, sea lions, and the sea otters, which are returning to the bay.

## A South African Sabellid Worm (*Terebrasabella heterouncinata*)

The South African sabellid worm is a parasitic polychaete worm that infests mollusks. It was introduced into California waters in the mid-1980s with abalone imported into a California aquaculture facility. The worm spread rapidly among abalone facilities through the transfer of infested seed stock and proved difficult to control once established. The worm infests only the abalone's shell, significantly reducing the growth rates of cultured abalone. A heavy infestation can cause shell deformation, elevate mortality as the shell becomes brittle, and reduce reproductive capacity as more energy is channeled into shell production.

Introduction in state waters is highly likely, given the species' broad host specificity. Sabellids have been detected in a native gastropod mollusk, in the intertidal zone adjacent to the discharge pipe from an abalone facility in central California. Attempts to eradicate this invasive species at this site and at culture facilities are ongoing.



Asian Clam, *Potamocorbula amurensis*
Credit: DFG

The California Department of Fish and Game (DFG) has established inspection requirements for abalone stock transfers, required detailed clean-up plans from all infested aquaculture facilities, prohibited out-planting, and added the sabellid to the Fish and Game Commission's significant disease list. Such controls appear to be having some effect, as most abalone culture facilities report some level of control and eradication of this worm. However, there have been reports of re-infestation by abalone shipments that had been inspected and certified by the DFG. The inspection protocols used have been mathematically demonstrated to be unlikely to detect a low level of infestation in transferred abalone, such as one to five percent or lower. Moreover, the mesh on the screens of the discharge pipes of onshore culturing facilities are far too large to prevent the release of eggs or larvae, and the openings in offshore barrel and cage culture are even larger. Subtidal inspection of possible release sites for the sabellid worm has been very limited, and the locations of some of these possible release sites are simply unknown. Further work is needed to ensure that all infestations are removed and effective controls are in place to prevent reinfestation.

## A Tropical Seaweed (*Caulerpa taxifolia*)

An invasive green algae dubbed the "killer algae," was discovered in the waters of southern California off Carlsbad in early 2000. Native to tropical waters, it became popular in the aquarium trade in the late 1970s and either escaped or was released into the Mediterranean Sea in the mid-1980s. It is now widespread throughout much of the northwestern Mediterranean. It appears that the algae found off southern California is a clone of the released Mediterranean plant, and can grow in deeper and colder waters than the tropical populations. Its impacts have been compared to unrolling a carpet of Astroturf across

the sea bed. In areas where it has become well-established, it has caused economic and ecological devastation by overgrowing and eliminating native seaweeds, seagrass reefs, and other communities.

In southern California, the algae poses a significant threat to eelgrass meadows and other benthic environments that are essential to the survival of native invertebrates, fish and aquatic birds. If the algae spread from the coastal lagoons to the nearshore reefs, it could inhibit the establishment of juveniles of many species, including kelp and the biota associated with kelp beds. Efforts to destroy this patch of algae have involved tarping off the area and injecting chlorine under the tarp.

### Other Invasives

Invasive species are present not only in San Francisco Bay but are common as well in other harbors and bays in California and along the Pacific Coast. For example, recent compilations list about 25 invasive species in Morro Bay in central California, and about 80 invasive species in the bays and harbors of southern California. One such organism is an Australasian isopod that significantly erodes the banks of salt marsh channels and marsh edges in San Diego Bay, resulting in reduction of already-limited coastal habitat.

Once established in one area, exotic organisms may quickly spread to another through either natural or anthropogenic transport. Invasive species initially established in bays may subsequently invade the open coast. A predatory New Zealand sea slug that was collected in San Francisco Bay in 1992 may have spread north to Bodega Bay and south to near San Diego, though further taxonomic work is needed to identify which of the two to four species of invasive sea slugs are involved and the locations of their spread.

## Existing Regulatory Regime and Regulatory Gaps

### National Invasive Species Act of 1996

Existing regulation of the major vector of invasive species introduction - ballast water discharges - is generally limited in its reach. The primary federal law regulating ballast water discharges, the National Invasive Species Act (NISA), calls primarily for voluntary ballast water exchange by vessels entering the U.S. after operating outside of the EEZ (mandatory ballast water exchange requirements exist only in the Great Lakes). Some of the limitations of NISA are that while it states that the voluntary program could become mandatory after several years, there are currently no criteria in the statute or accompanying regulations to guide that decision. Moreover, it addresses only vessels entering the U.S. from outside the EEZ, and ignores, for example, coastwise traffic from areas contaminated with problematic invasive species (such as the San Francisco Bay area).

NISA requires annual reporting to assess the ongoing effectiveness of the program. The first interim report by the National Ballast Information Clearinghouse, issued in October 2000, found that over the first 12 months (July 1999-2000) that the rule was in effect, only 20.8 percent of the vessels that entered U. S. waters from outside the EEZ filed the mandatory reports required under NISA and pursuant to U.S. Coast Guard regulations. For the entire U.S., compliance with reporting improved only slightly over the 12-month period, remaining between 23 percent and 29 percent from October 1999 through June 2000. Only for the West Coast of the contiguous U.S. did compliance with the reporting requirement increase markedly over time, primarily from an increase in California, which receives the most ship arrivals. This increase coincided with implementation of a 1999 California state law that requires submission of copies of the federal ballast water management reports to the State Lands Commission, authorizes monetary and criminal penalties for noncompliance, and utilizes an active boarding program that targets 20-30 percent of arrivals. As a result, compliance with reporting in California increased over the past 12 months to approximately 75 percent.

The report concluded that due to the poor nationwide reporting rate (20.8 percent), it is difficult to estimate reliably (a) the patterns of ballast water delivery and (b) the compliance with NISA's voluntary guidelines for ballast water management. Based on the information that was submitted, the report found that nationwide, approximately 42 percent (10.2 million metric tons) of the foreign water reported discharged into the U. S. had not been exchanged completely as requested in the voluntary guidelines. The report also noted that although it is clear that many vessels that discharge ballast water in the U.S. are not in compliance with voluntary guidelines, based upon their reports, the extent of non-compliance with these guidelines simply cannot be estimated accurately due to the very low rate of reporting.

### Clean Water Act

The Clean Water Act prohibits the discharge of "any pollutant by any person" into waters of the United States, unless done in compliance with specified sections of the Act, including the permit requirements in Section 402. National Pollution Discharge Elimination System (NPDES) permits issued to discharges into the territorial sea also must comply with "ocean discharge criteria" specifically

designed to prevent the degradation of those waters, pursuant to Clean Water Act Section 403.

Currently, an EPA regulation adopted in the 1970s specifically exempts ballast water from the NPDES permit program. In January 1999, a petition was made to the EPA by the Pacific Environmental Advocacy Center, on behalf of conservation groups, commercial and recreational fishing interests, American Indian tribes and California water agencies, to regulate ballast water discharges under the NPDES permit program in Section 402, arguing that the regulatory exemption adopted by EPA exceeded their authority and violated the mandates of the Clean Water Act. Moreover, the assumption that ballast discharges are harmless is clearly no longer the view of the EPA or other federal agencies. After two years of waiting, the petitioners filed suit against EPA in January 2001 to respond to the 1999 petition.

If a pollutant is threatening or impairing use of a water body, the water body violates water quality standards and must be listed under Section 303(d) of the Clean Water Act as "water quality limited" for that pollutant. EPA or the state then must establish the "total maximum daily load" (TMDL) of the offending pollutant that can be released into the water body and still ensure that the water meets water quality standards, within a "margin of safety." A water body whose use is impaired by aquatic invasive species could be "listed" under Section 303(d); if so, EPA or the state must identify the maximum load of problem aquatic invasive species that can be safely discharged into that water body. Given the significant and ongoing impacts associated with numerous aquatic invasive species, it may be difficult for the applicable agency to set a TMDL for aquatic invasive species other than zero and still meet Section 303(d)'s "margin of safety" requirement. Currently, many reaches of the San Francisco Bay are listed as impaired by invasive species under Section 303(d).

## National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires that federal agencies prepare an Environmental Impact Statement (EIS) for "major federal actions significantly affecting the quality of the human environment." NEPA may be used to require further examination of federal projects that may result in increased discharges of ballast water containing invasive species. At least one circuit court has recognized that NEPA requires federal agencies to evaluate a project's indirect impacts on the spread and introduction of aquatic invasive species.

## Endangered Species Act

Under Section 7 of the federal Endangered Species Act (ESA), federal agencies must ensure that their actions are "not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species…" In addition, federal agencies must consult with the Secretary of the Interior and/or Commerce, as appropriate, "on any agency action which is likely to jeopardize the continued existence of any species proposed to be listed…or result in the destruction or adverse modification of critical habitat proposed to be designated for such species."

Section 7 of the ESA should be used to examine the impacts of a federal project that may result in increased discharges of ballast containing invasive species, where such discharges may affect endangered or threatened species.

## Presidential Executive Order 13112

On Feb. 3, 1999, President Clinton issued an Invasive Species Executive Order creating a Cabinet-level National Invasive Species Council. The Council was charged with creating a National Invasive Species Management Plan that would address all types and sources of invasive species, including aquatic invasive species in ballast water. An Invasive Species Advisory Committee made up of a range of stakeholders has been working with the Council on a draft management plan. The draft management plan was released for review in October 2000 and was finalized in early 2001.

## California Environmental Quality Act

The California Environmental Quality Act (CEQA) requires appropriate mitigation of projects that contain significant environmental impacts. A "significant" impact is a "substantial, or potentially substantial, adverse change in any of the physical conditions within the area affected by the Project including land, air, water, minerals, flora, [and] fauna…" The documented adverse impacts associated with invasive species appear to fit this broad definition. In addition to meeting the general definition of "significant effect," the impacts associated with increased discharges of invasive species may require a mandatory finding of significance under CEQA, thus mandating feasible mitigation of those impacts or an alternative project.

## California Porter-Cologne Water Quality Control Act

Under California's Porter-Cologne Water Quality Control Act "any person discharging waste, or proposing to discharge waste, within any region that could affect the quality of the waters of the state" must file with the appropriate Regional Water Quality Control Board a report of the discharge. Pursuant to the act, the regional board then prescribes "waste discharge requirements" related to control of the discharge. The act defines "waste" broadly and the term has been applied to a diverse array of materials. The San Francisco Bay Regional Water Quality Control Board has determined that "ballast water and hull fouling discharges cause pollution as defined under the Porter-Cologne Water Quality Control Act," raising the possibility that the act may be actively used to regulate such discharges.

## California Fish and Game Code

State fish and wildlife laws contain provisions that relate to the control of aquatic invasive species from a variety of vectors. Some examples in the California Fish and Game Code include the following:

- Section 2271. "No live aquatic plant or animal may be imported into this state without the prior written approval of the department."
- Section 6603. "All fish, amphibia, or aquatic plants which the department determines are merely deleterious to fish, amphibia, aquatic plants or aquatic animal life, shall be destroyed by the department, unless the owner or the person in charge . . . ships them out of the state . . . ."
- Section 6400. "It is unlawful to place, plant, or cause to be placed or planted, in any waters of this state, any live fish, any fresh or salt water animal, or any aquatic plant, whether taken without or within the state, without first submitting it for inspection to, and securing the written permission of, the department."
- Section 15200. "The commission may regulate the placing of aquatic plants and animals in waters of the state."
- Section 15600. "No live aquatic plant or animal may be imported into this state by a registered aquaculturist without the prior written approval of the department pursuant to the regulations adopted by the commission."

## Public Resources Code

In 1999, California became the first state in the nation to enact legislation mandating exchange of ships' ballast water in an effort to control the introduction of invasive species. The Public Resources Code requires vessels carrying foreign ballast to exchange that ballast in open seas. It also requires specified state agencies to analyze the status of invasions, the effectiveness of the ballast exchange program, and alternatives for ballast treatment; sets penalties for noncompliance; and levies fees on regulated vessels to pay for the program. Washington state passed a mandatory ballast water exchange law modeled on California's law in 2000. California's mandatory law, clear penalties, and an active ship boarding program has resulted in its taking the lead in the nation on the control of ballast water, as the Clearinghouse report conclusively found.

Controlling the introduction of invasive species is well within the traditional police powers of the states. As long as the proposed legislation does not dictate the specific type of ballast water treatment techniques that vessels must use and does not favor "local" shipping over "foreign," then state ballast water management laws do not appear to be preempted by constitutional law or by NISA.

## Local Application of State and Federal Laws

Place-based management of invasive species introductions can occur where agencies implement state and federal laws on a local level. For example, in response to a petition from conservation groups, the San Francisco Bay Regional Water Quality Control Board identified invasive species as "pollutant stressors" subject to Clean Water Act Section 303(d) in lower, south and central San Francisco Bay, Richardson Bay, Suisun Bay, San Pablo Bay, Carquinez Strait and the delta. The regional board ranked invasive species as a high priority for action in all affected water bodies. The listing was approved by the State Water Resources Control Board and U.S. EPA (see above discussion of TMDL requirements).

The regional board approved a resolution to transmit to U.S. EPA an Exotic Species TMDL Report on impairment of the San Francisco Bay estuary by invasive species. Among other things, the regional board asserts in its report that a water quality-based endpoint to achieve the estuary's water quality standards is no exotic species introductions. In other words, an acceptable TMDL of exotic species or organisms is zero.

## Conclusions

The legal frameworks that apply, and may apply, to control of aquatic invasive species introductions are broad and varied. Many of these legal tools are just beginning to be utilized. As the costs associated with aquatic invasive species continue to mount, it appears likely that additional research and regulatory actions will be taken to reduce such discharges. To maximize the effectiveness of regulatory regimes, stakeholder input - from the conservation, shipping, port, fishing, utility and other communities - should be encouraged and carefully considered.

In spite of the significance of the impacts of invasive species, relatively little research has been done to date on the status of current invasions (particularly outside of San Francisco Bay). Research is also needed on the potential for new invasions and on methods for preventing and addressing invasions. California's 1999 ballast water exchange law requires the state to complete, by 2002, research and reports on existing coastal aquatic invasions, the effectiveness of ballast water exchange in controlling invasions, and the potential for other methods to control the discharge of invasives in ballast water.

The San Francisco estuary Institute, under an array of federal and state grants, is taking a lead on needed research. They have received funding to investigate and report on invasions in southern California marine waters and to sample ballast water coming into the San Francisco estuary for invasive species. They are examining ballast water treatment through two projects: one with the city and county of San Francisco and the University of California, Berkeley Department of Civil and Environmental Engineering to research treatment of ballast water in municipal wastewater systems, and one to analyze more generally the potential for onshore treatment of ballast water in municipal and industrial treatment plants and ballast-specific treatment plants.

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