BIOLOGICAL INVASIONS AND OPPORTUNITIES FOR THEIR REGULATION ON THE WEST COAST OF THE UNITED STATES

Andrew N. Cohen
San Francisco Estuary Institute
180 Richmond Field Station, 1325 South 46th Street
Richmond, CA 94804 U.S.A.

The introduction of exotic organisms may constitute the largest current threat to biological diversity in marine and freshwater ecosystems. Invasions are a common—in some studies, the most common—contributing factor to the endangerment and extinction of freshwater fish, crayfish and other freshwater organisms (Miller et al. 1989; Richter et al. 1997). Although few global extinctions have yet been documented in marine systems from any cause (Carlton et al. 1991; Carlton 1993), several marine invasions have been credited with large reductions in native organisms, potentially leading to at least local extinctions (e. g. Glude 1955; Travis 1993; Kimmerer et al. 1994; Grosholz & Ruiz 1995). Biological invasions are generally irreversible, and in both freshwater and marine ecosystems the rate of invasions has been dramatically increasing (Mills et al. 1993; Cohen & Carlton 1998), and will likely further accelerate with our current headlong rush toward promoting global markets and international trade.

On the West Coast of North America, aquatic invasions have been most intensively studied in the San Francisco Bay/Delta Estuary, where the establishment of over 200 exotic species has been documented, including plants, protists and invertebrate and vertebrate animals (Cohen & Carlton 1995). Another 100-200 species should be considered cryptogenic—species that, based on current knowledge, could be either native or exotic (Carlton 1996). Aside from the sheer number of exotic species, they dominate many habitats, accounting for 40% to 100% of the common species at many sites in the Estuary. The majority of the organisms living on the muddy bottom of the Bay and on the sides of the docks derive from the northern Atlantic or the western Pacific. Most of the Delta's fish are native to the eastern United States (Moyle 1976). The crustacean zooplankton fauna in the northern part of the Estuary is now primarily composed of species from across the Pacific, and almost every year seems to bring us yet another Asian copepod or mysid shrimp (Orsi 1995). Many of the introduced gelatinous zooplankters, on the other hand, are from the Black Sea (e. g. Mills & Sommer 1995). Our common crabs include species from Europe (the green crab *Carcinus maenas*), the eastern United States (the mud crab *Rhithropanopeus harrisii*), and China (the mitten crab *Eriocheir sinensis*); our common clams come from the Western Atlantic and the Western Pacific; our mussels from the Atlantic, the Mediterranean and the South Seas; our snails from the Western Atlantic; and our sea slugs from Asia and New Zealand (Cohen & Carlton 1995). As with the human population of California, it is often difficult to find a native.

The introduction of these exotic organisms has had both ecological and economic impacts. Introduced competitors, predators or parasites have contributed to declines in various native species. The flows of nutrients and contaminants have been dramatically altered (Alpine & Cloern 1992; Werner & Hollibaugh 1993). Exotic plants have invaded beaches, tide flats and marshes (Grossinger et al. 1998), and threaten to alter key winter feeding sites for the Pacific Flyway's migratory shorebirds.

Some intentionally introduced fish and shellfish supported commercial fisheries for a time, although they only support a recreational harvest in the Estuary now. Overall, most of the economic effects have been negative, especially for unintentionally introduced species. One exotic marine wood-boring organism (the Atlantic shipworm *Teredo navalis*) caused an estimated $2-20 billion of damage in two years' time (Cohen 1996). Hull fouling, due in part to introduced organisms, increases fuel consumption and vessel maintenance costs, as has been extensively documented by military and other authorities (e. g. Woods Hole

1952; Haderlie 1984). California has spent millions trying to control introduced aquatic plants and fish in the watershed. Current control activities (for exotic fouling, plants and fish) release toxins into the environment, with additional environmental, occupational and possibly public health risks. By contributing to the endangerment of native species and by continually changing the biota and making the ecosystem more difficult to manage, the introduction of exotic species threatens to hinder water diversions and other economic activities in the Estuary, with implications for the whole of California's economy (Cohen & Carlton 1995).

Exotic species have been reported in virtually all harbors and bays along the Pacific Coast (Carlton 1979). Once established in one bay, organisms may readily invade another. For example, the European green crab *Carcinus maenas*, first reported in 1989-90 from San Francisco Bay, was found in estuaries from Elkhorn Slough to Humboldt Bay by 1995, reached southern Oregon in 1997, and was found in Willapa Bay, Washington in 1998 (Cohen et al. 1995; Grosholz and Ruiz, 1995; Miller, 1996; N. Richmond, pers. comm.; A. Cohen, unpublished data). Exotic species may also deploy out of the bays to invade the open coast. A predatory New Zealand sea slug *Philine auriformis* that was collected in San Francisco Bay in 1992 (Gosliner 1995) and is now found from southern California to Bodega Harbor, has become the most commonly collected sea slug in the Southern California Bight (D. Cadien, pers. comm.).

Issues of this sort have resulted in some efforts to deal with the more egregious mechanisms that are importing exotic organisms into U. S. coastal waters, particularly the transport of organisms in ships' ballast water. In the early 1990s, ships entering the Great Lakes and upper Hudson River from overseas ports were required to adopt measures, such as the exchange of ballast water on the high seas, to prevent the discharge of exotic species. In 1996, oil tankers selling Alaskan oil overseas became subject to similar requirements under a federal rule. However, despite those promising initial steps, the disappointing National Invasive Species Act passed in 1996 only made it "officially voluntary" for ships to do anything about their discharge of exotic species.

Responding to that display of federal inaction, efforts have developed at state and local levels to regulate the dumping of exotic species into coastal waters. In May 1997, the San Francisco BayKeeper, assisted by the Environmental Law Community Clinic, petitioned California's Regional Water Quality Control Boards to have ballast water discharges regulated as a waste discharge of a biological pollutant under California's Porter-Cologne Water Quality Act. In February 1998, the San Francisco Bay Regional Water Quality Control Board listed exotic species discharged in ships' ballast water as a high priority pollutant causing impairment of the water quality of San Francisco Bay, under provisions of the federal Clean Water Act. And in March 1998, the Center for Marine Conservation and seven other environmental and fishing organizations charged that the Port of Oakland is required under state and federal environmental law to mitigate for any increase in the number of exotic organisms carried into San Francisco Bay in ships' ballast water as a result of the Port's proposed dredging and expansion project. Several other similar actions are apparently pending in California, Oregon and Washington. Indeed, if the federal government waits much longer to address this issue through effective regulations, it may ultimately be determined through litigation that shipping companies (and other importers of exotic species) are financially responsible for the impacts of the exotic species that they release.

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