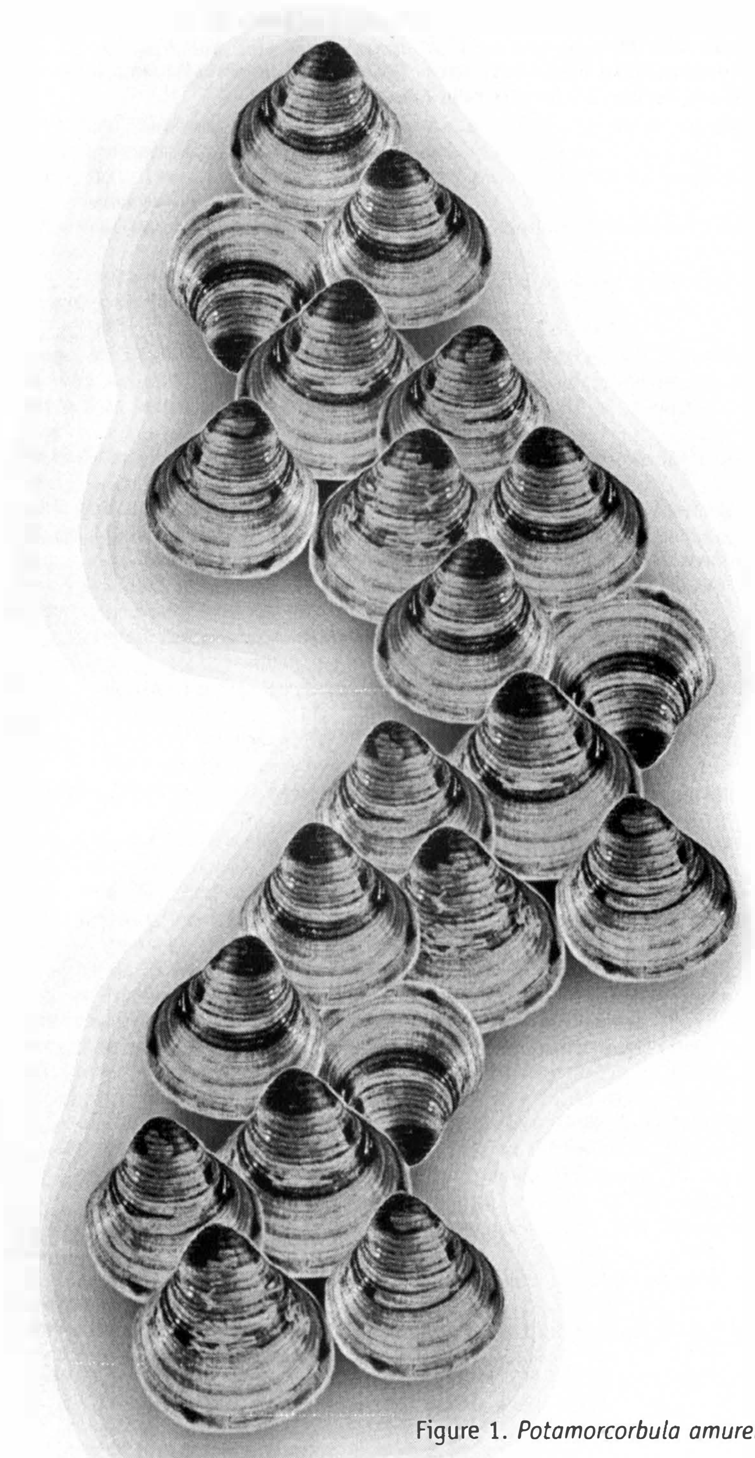

Figure 1. *Potamorcorbula amurensis*

California's Asian Clam
(Potamorcorbula amurensis)
and the
Rhetoric of Alien Invasions

Dianne Meredith
University of California Davis

Abstract: Invasion Ecology has contributed a questionable rhetoric to Biogeography which employs language and nomenclature seemingly borrowed from the volatile discourse surrounding the invasion of alien peoples across national borders. A case study from the San Francisco Bay Delta is presented (the invasion of Potamocorbula amurensis) as an introduction to the very real problem of exotic, alien species invasions. The contributing modern invasion mechanisms are discussed in the light of the social, cultural, and economic forces which began to unlock biogeographical closures around 1500 AD. Finally, a tour of the environmental perceptions surrounding alien species invasions reveals socialized rhetoric employed by both scientists and lay environmentalists.
Key Words: Environmental Perception, Biogeography, Alien Invasions, Human Geography.

Introduction

An ideological framework from the field of Invasion Ecology has come to the forefront of recent conservationist and biogeographical thought as a result of the escalation and speed of transfer of species across great distances, both voluntarily and involuntarily. The perceived problem is directly related to human activity in an increasingly globalized, borderless world. I would like to draw the attention of social theorists as well as scientists to the misplaced rhetoric employed by invasion ecologists and biogeographers, which uses value-laden terms and descriptive nomenclature borrowed (seemingly) from the volatile discourse surrounding the movement/invasion of alien peoples across national borders. I will illustrate this by beginning with a case study of the invasion of *Potamocorbula amurensis* ("Asian clam") into the San Francisco Bay-Delta followed by a discussion of modern invasion mechanisms. I will then take the reader on a tour of environmental perceptions as evidenced by the social/scientific rhetoric of alien invasions.

Timing and Vulnerability

In 1986, a biology class from Diablo Valley College was doing field work in Suisun Bay, part of the eastern San Francisco Bay-Delta Estuary. They were surprised when they came upon a handful of small clams, not previously seen in the area. These individuals were later identified as *Potamocorbula amurensis*, named for the Amur River in eastern Russia and northern China. This species has an extensive natural range, from the mouth of the Amur River at the northern end of the Tartar Straits to the Pearl (Zhu) River west of Hong Kong. It is also found in Korea, the shores, inlets, and estuaries of the Bo Sea, the Yellow Sea, the East China Sea, and the west and east coasts of Japan. Clearly at home in a wide latitudinal area along the western Pacific Rim, why was it now being seen thousands of miles away in Northern California? Not only was it present, *Potamocorbula amurensis* was amazingly successful. From the few individuals noted in 1986, the population increased so rapidly that by the following year it was the most abundant benthic organism in the northern part of the San Francisco Bay-Delta with densities of up to 16,000 clams per square meter. [Cohen 1995] By late 1988, the alien clam comprised 95% of the total benthic faunal abundance. Not only that, but 70% of the remaining 5% were barnacles attached to the shells of *Potamocorbula amurensis*. [Nichols 1990] This foreign invader quickly became the object of great concern as well as intensive study. The questions were "Why here?" and "Why now?"

In 1986, the San Francisco Bay-Delta ecosystem was responding to two years of climate extremes capped by the flood of 1986 which killed off many organisms in the estuary. Prior to 1986, the Bay-Delta had been a non-equilibrium habitat with a regular change of abundance of benthic species, depending on the relative salinity of the water. [Nichols 1979] During high flows in the winter and spring, freshwater species would migrate westward into the San Francisco Bay. During the summer or extended drought, organisms from the South Bay which were more salinity-tolerant would migrate north and east as far as their tolerances would allow. This regular movement of organisms in concert with river outflow was a feature of predictably changing estuarine conditions. However, the flood of 1986 was particularly intense and it would be more than a year before the normal salinity regime reasserted itself. The freshwater-intolerant benthic community was eliminated not only due to salinity conditions, but also due to high suspended load and scouring of the bed. [Cohen 1995] Even so, it was expected that the community would eventually swing back to its usual rhythms of advance and retreat with changing estuarine conditions. It was expected that this new "Asian clam" would do likewise and retreat back to the southern, more saline reaches of the Bay. But in 1986, *Potamocorbula amurensis* entered a depauparate community not as an invader, but as a colonizer and "exploited a naturally disturbed, sparsely occupied habitat rather than injecting itself among and displacing existing species". [Nichols et al, 1990, p.100] The timing was connected to habitat disturbance; it colonized an "underexploited habitat". [Nichols et al, 1990, p. 96]

Potamocorbula amurensis is an effective colonizer and invader. It has a broad range of salinity tolerance, from 33 ppt to 1 ppt, though individuals are smaller at the lower range. It can survive in a wide temperature range, from 8 to 23 degrees C. Because it can exploit a broad range of habitat, it is widespread where it is present. It is also flexible in its food preferences, consuming phytoplankton, zooplankton, and bacterioplankton, thus occupying multiple levels of the food chain. In fact, it exploited the habitat so successfully that the benthic community which was expected to return in the dry period following the 1986 flood was completely excluded, with the resources of space and food made unavailable by the unusual success of *Potamocorbula amurensis*. The new clam from the western Pacific Rim was now the dominant filter-feeder, capable of filtering the entire water column once per day, and the shallows 13 times per day. Plankton populations in the northern parts of the estuary are now to a great degree controlled by *Potamocorbula amurensis*. The summer diatom bloom has disappeared [Cohen 1995] and there has been a large decline in abundance of zooplankton as well, particularly copepods. [Kimmerer 1996]

Geological Context

The San Francisco Bay-Delta Estuary system is very young and has only been flooded for less than 10,000 years. Prior to then (15,000 to 18,000 years ago) the Farallon Islands marked the shoreline of the Pacific Ocean. As sea level began to rise following the last glacial episode, the ocean entered through the Golden Gate and began to fill the San Francisco Bay at a rate of 100 feet per year, slowing around 5,000 years ago when most of the current glacial melt was completed and sea level became relatively stable. The "Delta" formed within San Francisco Bay 4,000 to 6,000 years ago as the sediments from the Sacramento and San Joaquin Rivers were empounded by the bedrock barrier of the Carquinez Strait. Braided distributary channels, interspersed with wet freshwater marsh, covered a 540 square mile area, flowing out to the ocean through the narrow "notch" of the Carquinez Strait. [Ross et al, 1996] The significance of this history is that the Bay-Delta is geologically young, relatively depauparate in its native biota, and therefore susceptible to invasion. [Nichols et al 1986; Bennet and Moyle 1996]

Potamocorbula amurensis was by no means the first significant molluskan invasion in the area. The first actual record of an introduced species was for the Atlantic barnacle, *Balanus improvisus*, in 1885, [Carlton 1979], but introductions of marine organisms were likely long before that. Ships sailed along the California coast in the 1500s and the first ship to enter San Francisco Bay was the *San Carlos* in 1775, with its inevitable wood-boring fauna. In the 1780s, shipping increased from both the Atlantic and Pacific Oceans and increased again dramatically during the California Gold Rush. In 1851 alone, over 800 ships were at anchor or abandoned in San Francisco Bay [Carlton 1979]. ejecting their dry ballast made up of sand, gravel, seaweeds, and associated organisms from foreign ecosystems, long prior to any biological studies of native species. Judging from the rapid diffusion of *Potamocorbula amurensis*, many of these organisms may have become so widespread as to be considered endemic. Most reliable distribution data is from the twentieth century, although paleoecological studies continue to clarify the histories of many of these species.

Unlike the cultivated and edible *Corbicula fluminea*, the most abundant freshwater clam in California, *Potamocorbula amurensis* was not an intentional introduction. While both are colloquially termed Asian clam, the first came by invitation (though later became unwelcome) [Cohen 1995], but the second simply arrived stealthily, as a stowaway from China, ejected in a blast of ballast water release in the San Francisco Bay, probably with thousands of other organisms.

Ballast as Vector

The common role of ballast is to add weight for the empty return voyage or to lose weight to cross shallows. Clearly necessary for the safety of ocean passage, ballast controls not only weight distribution, but also density relationships and temperature. It is also used to decrease or increase speed according to weather conditions. The Committee on Ships Ballast Operations defines ballast as "any solid or liquid placed in a ship to increase the depth of submergence to change the trim, to regulate the stability, or to maintain stress loads..." [Committee on Ships Ballast Operations 1996, p. vii]

Ballast water is taken on in port, either pumped or gravitated into a tank, and is then released at another port, usually in a bay or an estuary. Over two million gallons of ballast water, most with living organisms, are ejected every hour at different ports in the United States. It is estimated that a single ballast release can contain ten million larvae. For the past 100 years, water ballast has provided "invasion corridors" [Carlton 1995, p. 195] for the inoculation of new, exotic species at an unprecedented rate. Suspended sediments settle to the tank bottoms of ships and are often carried over from port to port, taking up new water as the old is released, adding to the biotic soup which is mixed and released at the next port. [Carlton 1994] Some unpumpable ballast water almost always stays on board in the sediment layer, forming a ballast tank substrate which theoretically could support a living, benthic community. Ballast water is thus a species "conveyor belt" [Smith 1996, p. xi] and is a "dispersal mechanism with no analog in terrestrial systems". [Carlton 1993]

Since early history, marine organisms have attached themselves to ship hulls or have been carried in wet or dry ballast. The *San Augustin*, which sank in Drake's Bay in 1595, no doubt had its accompanying fouling and boring fauna. Beginning in about 1880, it became common practice to switch from dry ballast to wet ballast – seawater instead of gravel and sand. Ballast water commonly carries phytoplankton, floating and detached plants, seaweed and seagrasses, kelp, and diverse zooplankton including larvae. Plankton samples taken from Japanese ballast water in Oregon recorded over 367 taxa. [Carlton 1993] There is a differential survival; most species do not survive, but simply disappear. However, those like *Potamocorbula amurensis*, benign where endemic, can wreck havoc once they gain a foothold in a compromised, disturbed community such as the San Francisco Bay-Delta in 1986. Significantly, the arrival of *Potamocorbula amurensis* was concurrent with a relaxation of trade barriers with China and an increase of shipping.

There are no easy solutions to the problem of unwanted organisms in ballast water. Over 80% of the world's commodities move along shipping routes so there is a potential for the continued introduction of nonindigenous species. In fact, the Committee on Ships Ballast Operations in their study for the National Research Council said that "it can be stated with confidence that further introductions will take place and that ballast water is an important vector contributing to the dispersal of nonindigenous aquatic organisms". [Committee on Ships Ballast Operations 1996, p.2]

Various discharge treatments are under study: biocides, filtration, thermal or electrical treatment, ultraviolet radiation, sound or magnetic waves, and deoxygenation. Some of these methods are potentially dangerous to use in a "closed" system on board a ship. Others require unusual safety precautions and may have dangerous byproducts as releases. The most promising method appears to be more sophisticated filtration methods, but environmental perception of the danger of introducing nonindigenous species is not strong in the shipping community. The few regulations in effect are primarily voluntary in nature and compliance is most often in terms of petroleum-tainted waters.

Regulations Without Teeth

The regulatory measures so far enacted are the equivalent of "be careful and think". [Kohler 1986] They do not reflect an environmental perception of imminent risk. The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (Public Law 101-646) authorizes shipping *studies* to determine the "degree to which shipping may be a pathway of transmission of aquatic nuisance species..." [Smith 1996, p. xi] It goes to far as to establish task forces – but no further – with NOAA and the Fish and Wildlife Service as Co-Chairs.

The International Marine Council (IMO) agreed on International voluntary guidelines at the 31st session of the Marine Environmental Protection Committee. They also now have a working group to *consider* added regulatory measures, which would range from voluntary to mandatory. [Brown 1993] Strategies would include further investigation into the treatment of ballast water itself and the timing and location of loading and discharge.

Federal Laws regarding ballast are in effect in the Great Lakes and in the Hudson River, directed mainly to their zebra mussel problem. California legislation to regulate ballast water discharge has been unsuccessful so far, due to legislative resistance and to the fear of international lawsuits based on "undue burden". [Committee on Ships Ballast Operations 1996, p. 46] Some studies are being done on environmental risk a alysis, asking the question, how clean is clean enough? What is our comfort level with the introduction of unwanted organisms? How many unwanted organisms can we live with and is there a threshold level that is perceived to be environmentally unacceptable?

In 1996, the National Invasive Species Act was written, again with voluntary guidelines, and primarily for the Great Lakes and their zebra mussel problem. The suggestion is to release ballast water "beyond the exclusive economic zone", in other words, a *not-in-my-backyard* approach so that "the exchange does not pose a threat of infestation… in waters of the United States". [Public Law 104-332, p. 4076] The National Invasive Species Act also authorizes further study including ecological surveys in San Francisco Bay in order to make examinations and estimates of the problem. It authorizes the creation of a Western Regional Panel to identify the priorities, make recommendations, develop an emergency response strategy for "stemming new invasions", and to write an annual report for discussion of prevention, research, and control. Meanwhile, 11 billion gallons of ballast water continue to be released annually, much of that in sensitive estuarine locations throughout the United States. The differential survival rate of nonindigenous species is only partially comforting.

The Invasion Continuum

Clearly there is more travel today on an international scale and, at the same time, more artificially disturbed areas. Organisms are now successfully invading where previously, in less humanly "disturbed times", they were unable to gain a foothold. [Shigesada and Kawasaki 1997]

Invasions have always been a driving force in biological history, but today they represent something more – a "continuum between the geological and human dimensions of history". [di Castri 1989, p. 18] The social, cultural, and economic forces which began to unlock biogeographical closures around 1500 AD changed the rules of the game. Francesco di Castri considers the understanding of both human-historical impact and geological-ecological variables to be crucial in his model of the dynamics of invasions:

Ecological and Genetic Attributes of Species ↔ Chance, Timing, and Human-Derived Opportunities

↓ Geologically-Based Studies For Emergence of Genetic And Ecological Attributes

↓ Human-Historical Studies To Explain the Background

Taken together, the human and geological-ecological factors represent a continuum, although today there is a breakdown in scaling, with space extended through globalization and time shortened through technological advances in communication and transportation. Today we have a "complete multi-focal globalization of the human-governed forces that promote biological invasions". [di Castri 1989, p. 27] Also, since humans are the primary vector of any biological invasion, a vilification of either ballast water of the organism it carries (such as *Potamocorbula amurensis*) is ultimately misplaced.

Today, species invasions are a global rather than a local event. With long distance travel, mass transport, and human-induced alteration of habitat, a "new biological order" [Mooney 1993, p. 503] has been established which has old invaders being replaced by new invaders. Much of the benthic fauna replaced by *Potamocorbula amurensis* may have been nonindigenous or at least cryptogenic (not decisively native in origin), and today San Francisco may be the chief global exporter of the so-called "Asian clam". One school of thought contends that most of the coastline biota of the world has been homogenized long ago, accelerating dramatically in the sixteenth century with the expansion of European trade routes. The California coastline may have been inoculated with foreign species so long ago that they are now widespread and interpreted as natural in distribution. [Carlton 1994] Human impact has already unnaturally removed biogeographical barriers and one result is that estuarine bodies have a global commonality of many species. [Drake 1996] There may be clues which can be used to identify true natives, including assessments of global distributions, genetic lineage, the presence or absence of parasites or commensals, historical presence or absence (for example, shell middens), anomalous disjunctions without ready explanation, and assemblages with other species. Still, many species will remain cryptogenic, with no clear resolution of status. [Cohen 1995; Carlton 1995]

If the human-historical role in transporting species has been greatly underestimated, and our biological surveys postdate transport events, then the widely held idea of natural cosmopolitanism among coastal species could be more a matter of environmental perception than reality. Biologists may "perceive" cosmopolitanism in coastal areas, invoking factors of tectonics, corridors, glaciations, and ocean currents. Others believe that today's distributions are instantaneous in geological time, involving hundreds rather than thousands of years. [Carlton 1989]

This idea extends further to the perception of estuarine sanctuaries. Are these truly naturally functioning systems or just the most recent "older" assemblages? Are they natural reserves deserving protection, or are they assemblages of invaders to be protected from newer invasions? In Man's Role in Changing the Face of the Ocean, James Carlton suggests that perhaps we have been led to the "anomalous situation of protecting 'natural areas' that have in fact already been altered in large part by exotic species". [Carlton 1989, p. 269]

Invasion Rhetoric: A Tour of Perceptions

We are told that there are "thousands of species on the invasion horizon". [Carlton 1995, p. 102] How then should we view these species? There is a world of difference between a colonization and an invasion and the difference is one of both scale and perception of scale. Two very small juvenile specimens of *Potamocorbula amurensis* became the "vanguard of a major recruitment event". [Nichols et al 1990, p. 98] In the Sacramento Bee on April 4, 1996, Nancy Vogel informs us that "Invader species tighten grip on Bay, Delta" and "one after another, species from foreign shores and seas have taken hold in the bay..." If that weren't enough, next to come is a "strange new crab with velvety claws" (the Chinese mitten crab). In a 1995 quarterly newsletter *Watershed* from the Save San Francisco Bay Association, scholars Cohen and Carlton describe how a Dungeness Crab "gingerly picks its way among the crowds of foreign organisms" which are so numerous there are millions within a single glance. [Cohen and Carlton 1995] We are told they are troublemakers, exotic, there are "too many of them". They are "ruthless in their quest for light, water, space, nutrients or the very flesh of their victims".

[Flack and Furlow 1998] We are warned of hostile takeovers, infiltrations of escaped invasives who have secreted themselves in ballast water. They are "specimens", timebombs waiting to go off. One in ten introduced "goes bad". What are the older invasives? Troublemakers under control? Model minorities? How much depends upon point of origin? We are told that a "transplant" is an introduction from any part of the United States, while an exotic comes from a foreign country, as though organisms have nationalities. [Kohler 1986] Ultimately, whether the invasion is exotic or transplanted, the impact on the receiving ecosystem is the same. [McCann 1996]

The U.S. Geological Survey discusses invasives in a webpage section called "biological contamination", while the Nature Conservancy has issued a small booklet, "America's Least Wanted: Alien Species Invasions of U.S. Ecosystems" [Stein and Flack 1996], accompanied by exquisite pen and ink drawings of the aforementioned invasives. Meanwhile, Andrew Cohen, in one of his case studies, gives a poetical description of members of the invasive community, which reads like the best of nature writing:

> At the Bay's mouth, under the shadow of the Golden Gate Bridge, orange-red clumps of the Indo-Pacific bryozoan Watersipora, 30 centimeters across and 20 centimeters deep, cover the docksides. To the north, in San Pablo and Suisun bays, the Chinese clam Potamocorbula forms thick beds in the mud while Japanese gobies and Korean shrimp swim overhead. In the brackish water a few kilometers distant, large, coral-like masses formed from the calcareous tubes of an Australian serpulid worm harbor an abundant population of the Atlantic shore crab Rhithropanopeus. Upstream in the Delta a Eurasian freshwater hydrioid forms thick colonies on ropes and marina floats. [Cohen 1995, p. 167]

If we acknowledge these creatures as nature, is there then a bad nature? In a Science article, "Biological Immigrants Under Fire", we learn there is "nothing more insidious as an agent of extinction than exotic species" and that more and "more stowaways are expected to arrive uninvited". [Culotta 1991, p. 1444] One wonders at the intent of these party crashers, and at who inevitably invited them. War-like, Culotta refers to invasion theory and the need for an anti-exotic campaign against species who "worm their way" into human culture. "Never, never let exotics be legitimized!" Culotta quotes Bruce Coblentz of Oregon State University, because "nothing is more difficult than to predict what will happen to an exotic". What is more, "typical invader[s] tend to eat like whiteflies, breed like rabbits and colonize like crabgrass". [Culotta 1991, p. 1446] We know of course who is being referred to: it's that infamous bivalve, the yellow "Asian" clam, who is outcompeting the indigenous species.

The Smithsonian Institution, a venerable American organization, cries out for "our living, native American biota" which is being "biologically polluted through the introduction of living exotic (foreign) life". [Lackner et al, 1972] *On the Rhode*, newsletter of the Smithsonian Environmental Research Center, echoes the same rhetoric in 1994 in an article, "The Aliens Among Us". These aliens among us are "often unrecognized by the casual observer as aliens", making it even more important that we "try to learn their numbers, where they came from, how and when they arrived, where they live now locally, and what they do here functionally". [Ruiz 1994] In other words, what are their intentions?

The New Zealand-based International Union for the Conservation of Nature (ISSG) is a global group of scientific and policy experts that has an Invasive Species Specialist Group (by invitation only). Making no bones about their stance, their quarterly newsletter is boldly entitled *Aliens*. They suggest the term *Homogecene* for this epoch of global species invasions into "otherwise intact, pre-existing native ecosystems". [Lowe 1998] In another part of the former British Empire, the Botany Department of the University of Western Cape in South Africa has an Environfacts webpage that describes *alien* as a species that has been unnaturally introduced by people, and an *invader* that which reproduces and spreads, "unassisted by man, into areas where they are not wanted" (the wrong neighborhood?) so that "drastic measures are required" to control them. [Collins 1998] Is this an "irrational zenophobia that resembles the inherent fear and intolerance of foreign races..."? [Brown 1989, p. 105]

The Northeast Sea Grant network, in their newsletter *Aquatics Exotics News* declares "Tankers, cargo ships and container ships among culprits! Ballast water contains international mix of organisms!" [NE Sea Grant Network 1998]. In reality, their bombast is tongue-in-cheek, for they end with an acknowledgement of the relative recentness of biological distribution data available which makes it difficult to ascertain which species are actually native, or immigrants of long ago.

Conclusions

Meanings are inevitably based on interpretations and different philosophies, and word choice appears to be governed by a limited number of terms that now exist. [Shafland and McLewis 1983] It seems unfortunate that terminology with such obvious socio-cultural overtones should be applied to environmental or biological problems, as though they are one and the same process. Invasion is a military expression referring to a deliberate, initial assault, but when the invading population becomes established it becomes "colonization", a more benign state. The invasion of Neolithic farmers into Europe spread through both cultural and biological waves of advance, gradually co-opting the resources of indigenous hunters and gatherers. [Hengeveld 1989] The descendants of these alien opportunists took to sailing vessels and colonized much of the rest of the world over the next ten centuries. As a result, the world became smaller, trade became vaster, and the opportunity for globalization (or homogenization) of flora and fauna was inevitable. The question of blame ultimately depends on the perception of Neolithic invasion as either involuntary dispersal or voluntary migration.

America's least wanted alien invaders, by all accounts, do excessive harm to ecosystems and contribute to an increasing decline in the diversity of global biota. There is no great pride in the San Francisco Bay-Delta now being the greatest global exporter of *Potamocorbula amurensis*. There is a great deal of sadness and sense of irretrievable loss, though as Marston Bates pointed out in 1964, "Man started to be 'unnatural' a long time ago and there is no way back." [Bates 1964, p. 74] Still, one would have to be insensitive to be indifferent to the dangers. Whether we are living in the Homogecene, the Psychozoic Era, the Anthropozoic Era, or the McDonaldsphere, the trend towards global community is clearly on the agenda.

Europeans came to the New World, homogenizing it with their weeds and invasive cattle. Perhaps Asian invasions such as *Potamocorbula amurensis* are part of the so-called "New World Order", or maybe they are just a series in a sequence of succession. What is important is to remember the ultimate vector – human activity – and not to vilify the pest. The biogeography of invasions has such a strongly human component that it becomes part of human, cultural geography. A neutral, scientific stance is probably not entirely possible, as evidenced by the rampant social crossover rhetoric used by lay environmentalists as well as by biologists and biogeographers. If not careful, we run the risk of biological fascism in attempting to intervene in the results of our own interventions. [Tenner 1996]

References

Bates, Marston: 1964. *Man in Nature*. Prentice-Hall, Inc., New Jersey.
Bennett, W.A. and Moyle, P.B.: 1996. "Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento-San Joaquin estuary", in Hollinbaugh, James T., ed., San Francisco Bay: The Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, California.
Brown, James H.: 1989. "Patterns, Modes and Extents of Invasions by Vertebrates" in Drake, J.A., Mooney, H.A., di Castri, F., Groves, R.H., Kruger, F.J., Rejmanek, M., and Williamson, M., eds., *Biological Invasions: A Global Perspective*. John Wiley & Sons, New York.
Carlton, James T.: 1979. "Introduced Invertebrates of San Francisco Bay", in Conomos, T. John, Ed., *San Francisco Bay: The Urbanized Estuary*. Pacific Division of the American Association for the Advancement of Science, San Francisco, California.

Carlton, James T.: 1989. Man's Role in Changing the Face of the Ocean: Biological Invasions and Implications for Conservation of Near-Shore Environments. *Conservation Biology 3(3), 265–273.*
Carlton, James T., Thompson, Janet K., Schemel, Laurence E., and Nichols, Frederic H.: 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam Potamocorbula amurensis, Part I. Introduction and dispersal. *Marine Ecology Progress Series 66: 81–94.*
Carlton, James T. and Geller, Jonathan B.: 1993. Ecological Roulette: The Global Transport of Nonindigenous Marine Organisms. *Science, 261, 78–82.*
Carlton, James T.: 1993. "Biological Invasions and Biodiversity in the Sea: The Ecological and Human Impacts of Nonindigenous Marine and Estuarine Organisms" in U.S. Department of Commerce, *Proceedings of the Conference and Workshop, Nonindigenous Estuarine and Marine Organisms (NEMO)*, Seattle, Washington.
Carlton, James T., Reid, Donald M. and van Leeuwen, Henry: 1995. *Shipping Study: The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options.* The National Sea Grant College Program/Connecticut Se Grant Project R/ES-6. Maritime Studies Program, Williams College, Mystic, Connecticut.
Cohen, Andrew N. and Carlton, James T.: 1995a. *Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta.* United States Fish and Wildlife Service, Washington, D.C.
Cohen, Andrew N. and Carlton, James T.: 1995b. Intruders in the Estuary. *Watershed, Quarterly Newsletter of Save San Francisco Bay Association* (F-1995).
College of Natural and Agricultural Sciences, University of California, Riverside. Center for Exotic Pest Research: http://cnas.ucr.edu/~cnas/centers/cepr.html (5-27-98)
Collins, Jocelyn: 1998. Environfacts Index Page: Indigenous, Alien and Invaders. University of Western Cape, South Africa: http://www.botany.uwc.ac.za/EnvFacts/facts/aliens.htm (5-31-98)
Committee on Ships Ballast Operations: 1996. *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ships Ballast Water.* Marine Board Commission on Engineering and Technical Systems, National Research Council. National Academy Press, Washington, D.C.
Culotta, Elizabeth: 1991. Biological Immigrants Under Fire. *Science, 254: 1444–1447.*
di Castri, Francesco: 1989. History of Biological Invasions with Special Emphasis on the Old World, in Drake, J.A., Mooney, H.A., di Castri, F., Groves, R.H., Kruger, J.F., Rejmanek, M., and Williamson, M., eds., *Biological Invasions: A Global Perspective.* Wiley & Sons, New York.
Flack, Stephanie and Furlow, Elaine: The Dirty Dozen: Review of America's Least Wanted. The Nature Conservancy Magazine, web edition: http://www.tnc.org/news.magazine/nov_dec/ (5-31-98)
Galveston Bay, National Estuary Program, Chapter One: On Knowing the State of the Bay. "Priority Seventeen: Exotic Species": http://riceinfo.rice.edu/armadillo/Galveston/Chap1/exotic.html (5-20-98)
Hengeveld, Rob: 1989. *Dynamics of Biological Invasions.* Research Institute for Nature Management, The Netherlands. Chapman and Hall, New York.
Kimmerer, W.J. and Orsi, J.J.: 1996. "Changes in the zooplankton of the San Francisco Bay estuary since the introduction of the clam Potamocorbula amurensis" in Hollinhaugh, James T., ed., *San Francisco Bay: The Ecosystem.* Pacific Division of the American Association for the Advancement of Science. San Francisco, California.
Kohler, Christopher C.: 1986. Strategies for Reducing Risk from Introductions of Aquatic Organisms. *Fisheries,* 11(2), 2–3.
Kohler, Christopher C. and Courtenay, Jr., Walter R.: 1986. Regulating Introduced Aquatic Species: A Review of Past Initiatives. *Fisheries,* 11(2), 34–38.
Kohler, Christopher C., and Courtenay, Jr., Walter R.: 1986. American Fisheries Society Position on Introductions of Aquatic Species. *Fisheries,* 11(2), 39–42.

Lachner, Ernest A., Robins, Richard C., and Courtenay, Jr., Walter R.: 1970. Exotic Fishes and Other Aquatic Organisms Introduced into North America. *Smithsonian Contributions to Zoology*, 59: 1-29.

Lowe, S.: 1998. IUCN (International Union for the Conservation of Nature), Invasive Species Specialist Group Home Page. http://indaba.iucn.org/external/themes/ssc/programs/invasives/issg/ (5-20-98)

McCann, James A., Arkin, Hori N., and Williams, James D.: 1996. *Nonindigenous Aquatic and Selected Terrestrial Species of Florida, Pathways of Introduction*. Published on the Internet, March 1996, by the University of Florida, Center for Aquatic Plants: http://aquat1.ifas.ufl.edu/mcintro2.html (5-20-98)

Mooney, H.A. and Drake, J.A.: 1989. "Biological Invasions: a SCOPE Program Overview", in Drake, J.A., et al, eds., *Biological Invasions: A Global Perspective*. John Wiley & Sons, New York.

Nichols, F.H.: 1979. "Natural and Anthropogenic Influences on Benthic Community Structure in San Francisco Bay", in Conomos, T.J., ed., *San Francisco Bay: The Urbanized Estuary*. Pacific Division of the American Association for the Advancement of Science. San Francisco, California.

Nichols, F.H., Cloern, James, E., Luoma, Samuel N. and Peterson, David H.: 1986. The Modification of an Estuary. *Science*, 231: 567-573.

Nichols, Frederic H., Thompson, Janet K., and Schemel, Laurence E.: 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam Potamocorbula amurensis, Part II: Displacement of a former community. *Marine Ecology Progress Series 66*: 95-101.

Northeast Sea Grant Network: Aquatic Exotics News: http://www.ucc.uconn.edu/~wwwsgo/ballast.html (5-20-98)

Ross, B., Taylor, K., and Larson, E.: 1996. Chapter 4, "Affected Environment" in *Long-Term Management Strategy (LTMS) for the Placement of Dredged Material in the San Francisco Bay Region, Draft*. Programmatic Environmental Impact Report prepared for LTMS Management Committee. Oakland, California.

Ruiz, Greg: 1994. The Aliens Among us. *On the Rhode: Newsletter of the Smithsonian Environmental Research Center*, Spring 1994. http://www.serc.si.edu/OTR/spring94/aliens.html (5-28-98)

Shafland P.L and Lewis, W.M.: 1983. Terminology Associated With Introduced Organisms. *Transactions of the American Fisheries Society, 102: 268-269.*

Shigesada, Nanako and Kawasaki, Kohkichi: 1997. Biological Invasions: Theory and Practice. Oxford University Press, Oxford, U.K.

Smith, L. David, Wonham, Marjorie J., McCann, Linda D., Reid, Donald M. and Carlton, James T.: 1996. *Shipping Study II: Biological Invasions by Nonindigenous Species in United States Waters: Quantifying the Role of Ballast Water and Sediments, Parts I and II*. Smithsonian Environmental Research Center (SERC). Edgewater, Maryland.

Stein, Bruce A. and Flack, Stephanie R.: 1996. *America's Least Wanted: Alien Species Invasions of U.S. Ecosystems*. The Nature Conservancy. Arlington, Virginia.

Tenner, Edward: 1996. *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*. Alfred A. Knopf Publishing, New York.

U.S. Government: 1996. Public Law 104-332-Oct. 26, 1996. "National Invasive Species Act of 1996". Environmental Protection, Maritime Affairs, 16 USC 4701.

Vogel, Nancy: 1994. Crab in Bay Puts Diners, Delta at Risk. *Sacramento Bee Newspaper, November 30, 1994.*

_____, _____: 1996. Invader Species Tighten Grip on Bay, Delta. Sacramento Bee Newspaper, April 1, 1996.