

Marine Science Review – 256

Introduced Species

In this review:

- A. Recent articles – no abstract available
- B. Recent articles with abstracts

O/A denotes an open access article or journal

A. Recent articles – no abstract available

Le Corre, M. **Cats, rats and seabirds.** *Nature* 451(7175): 134-135, 2008.

B. Recent articles with abstracts

Whittington, R.J. and Chong, R. **Global trade in ornamental fish from an Australian perspective: The case for revised import risk analysis and management strategies.** *Preventive Veterinary Medicine* 81(1-3): 92-116, 2007.

Notes: Over 1 billion ornamental fish comprising more than 4000 freshwater and 1400 marine species are traded internationally each year, with 8-10 million imported into Australia alone. Compared to other commodities, the pathogens and disease translocation risks associated with this pattern of trade have been poorly documented. The aim of this study was to conduct an appraisal of the effectiveness of risk analysis and quarantine controls as they are applied according to the Sanitary and Phytosanitary (SPS) agreement in Australia. Ornamental fish originate from about 100 countries and hazards are mostly unknown; since 2000 there have been 16-fold fewer scientific publications on ornamental fish disease compared to farmed fish disease, and 470 fewer compared to disease in terrestrial species (cattle). The import quarantine policies of a range of countries were reviewed and classified as stringent or non-stringent based on the levels of pre-border and border controls. Australia has a stringent policy which includes pre-border health certification and a mandatory quarantine period at border of 1-3 weeks in registered quarantine premises supervised by government quarantine staff. Despite these measures there have been many disease incursions as well as establishment of significant exotic viral, bacterial, fungal, protozoal and metazoan pathogens from ornamental fish in farmed native Australian fish and free-living introduced species. Recent examples include *Megalocytivirus* and *Aeromonas salmonicida* atypical strain. In 2006, there were 22 species of alien ornamental fish with established breeding populations in waterways in Australia and freshwater plants and molluscs have also been introduced, proving a direct transmission pathway for establishment of pathogens in native fish species. Australia's stringent quarantine policies for imported ornamental fish are based on import risk analysis under the SPS agreement but have not provided an acceptable level of protection (ALOP) consistent with government objectives to prevent introduction of pests and diseases, promote development of future aquaculture industries or maintain biodiversity. It is concluded that the risk analysis process described by the Office International des Epizooties under the SPS agreement cannot be used in a meaningful way for current patterns of ornamental fish trade. Transboundary disease incursions will continue and exotic pathogens will become established in new regions as a result of the ornamental fish trade, and this will be an international phenomenon. Ornamental fish represent a special case in live animal trade where OIE guidelines for risk analysis need to be revised. Alternatively, for countries such as Australia with implied very high ALOP, the number of species traded and the number of sources permitted need to be dramatically reduced to facilitate hazard identification, risk assessment and import quarantine controls.

Williams, S.L. and Smith, J.E. **A global review of the distribution, taxonomy, and impacts of introduced seaweeds.** *Annual Review of Ecology, Evolution, and Systematics* 38: 327-359, 2007.

Notes: We reviewed over 407 global seaweed introduction events and have increased the total number of introduced seaweed species to 277. Using binomial tests we show that several algal families contain more successful invaders than would be expected by chance, highlighting groups that should be targeted for management. Hull-fouling and aquaculture are the most significant sources of seaweed invaders and should be carefully regulated. The ecological effects of introduced seaweeds have been studied in only 6% of the species, but these studies show mostly negative effects or changes to the native biota. Herbivores generally prefer native to introduced seaweeds, and are unlikely to control spread, as they can do in other habitats. Undisturbed marine communities can be at least initially resistant to most introduced seaweeds aside from the siphonous green species; however, disturbances and eutrophication can facilitate invasion. Major research gaps include community-level ecological studies and economic assessments.

Batabyal, A.A. **International aspects of invasive species management: a research agenda.** *Stochastic Environmental Research and Risk Assessment* 21(6): 717-727, 2007.

Notes: We propose a research agenda for studying six basic questions about the impacts of alternate international invasive species control mechanisms on economic agents in a nation such as the USA. The six questions are as follows. First, when can one justify a trade ban as an effective regulatory policy? Second, what are the properties of control rules that vary by port of entry and whether a shipment is viewed as a routine or as a first-time entry? Third, when should a port manager in the USA use information about the dollar value of the products being transported by ships from two exporting firms and the expected time it takes to inspect ships from these two firms to grant preferential treatment to one or the other firm? Fourth, what are some reasonable measures of the trade related risk from invasive species? Fifth, how useful is strategic trade policy as an invasive species management tool? Finally, when analyzing a biological invasion, is it more appropriate to focus on the likelihood of this event or, instead, on the magnitude of the event?

Foss, S.F., Ode, P.R., Sowby, M., and Ashe, M. **Non-indigenous aquatic organisms in the coastal waters of California.** *California Fish and Game* 93(3): 111-129, 2007.

Notes: This study combined numerous field surveys with a literature review to document the location of non-indigenous aquatic species (NAS) in the estuarine and coastal waters of California. Substantial numbers of aquatic species have been introduced to the coast of California. Although all areas of the coast showed some evidence of introductions, NAS totals were generally highest in the two major commercial ports, San Francisco and Los Angeles/Long Beach. Statewide, 360 distinct non-indigenous and 247 distinct cryptogenic taxa were identified from the literature and field investigations during the course of this investigation. Annelids, primarily polychaete worms, were the dominant phylum, comprising 33% of the NAS observed. Eleven NAS were found in the current survey that had not been reported from California in previous studies. The majority of organisms introduced to the California coast are native to the northwest Atlantic, the northwest Pacific, and the northeast Atlantic, all regions from which California receives a considerable amount of ship traffic as well as the source materials for much of its aquaculture. Shipping is the most likely vector for the majority of NAS introductions; specifically, ballast water and hull fouling were identified as the most common subvectors. We identified a number of NAS that co-occur in the major ports, which may indicate intracoastal spread of non-indigenous taxa. However, the mechanisms of NAS movement within California are poorly understood and should be addressed in future research.

Griffen, B.D., Guy, T., and Buck, J.C. **Inhibition between invasives: a newly introduced predator moderates the impacts of a previously established invasive predator.** *Journal of Animal Ecology* 77(1): 32-40, 2008.

Notes: 1. With continued globalization, species are being transported and introduced into novel habitats at an accelerating rate. Interactions between invasive species may provide important mechanisms that moderate their impacts on native species. 2. The European green crab *Carcinus maenas* is an aggressive predator that was introduced to the east coast of North America in the mid-1800s and is capable of rapid consumption of bivalve prey. A newer invasive predator, the Asian shore crab *Hemigrapsus sanguineus*, was first discovered on the Atlantic coast in the 1980s, and now inhabits many of the same regions as *C.*

maenas within the Gulf of Maine. Using a series of field and laboratory investigations, we examined the consequences of interactions between these predators. 3. Density patterns of these two species at different spatial scales are consistent with negative interactions. As a result of these interactions, *C. maenas* alters its diet to consume fewer mussels, its preferred prey, in the presence of *H. sanguineus*. Decreased mussel consumption in turn leads to lower growth rates for *C. maenas*, with potential detrimental effects on *C. maenas* populations. 4. Rather than an invasional meltdown, this study demonstrates that, within the Gulf of Maine, this new invasive predator can moderate the impacts of the older invasive predator.

Becker, L.A., Pascual, M.A., and Basso, N.G. **Colonization of the southern Patagonia ocean by exotic Chinook salmon.** *Conservation Biology* 21(5): 1347-1352, 2007.

Notes: Anadromous salmonids have been particularly successful at establishing wild populations in southern Patagonia, in contrast to their limited success elsewhere outside their native ranges. The most recent such discovery is a spawning population of Chinook salmon in the Santa Cruz River, which flows into the Atlantic Ocean from Argentina. We used mitochondrial DNA analysis to discriminate between alternative potential sources of this population and were able to discard in situ introductions of fish imported directly from California in the early twentieth century. Our results showed that the fish most likely came from Puget Sound, Washington, imported into southern Chile for salmon-ranching experiments in the 1980s. This finding provides concrete evidence of colonization of Atlantic rivers from Pacific locations. The southern Pacific and Atlantic oceans provide a favorable marine environment for the success of invading salmon. In particular, the waters associated with fjords, southern channels, and the inshore portion of the Patagonian shelf provide a rather bounded, continuous waterway for exotic anadromous salmonids, rich in diverse forage species.

Flagella, M.M., Verlaque, M., Soria, A., and Buia, M.C. **Macroalgal survival in ballast water tanks.** *Marine Pollution Bulletin* 54(9): 1395-1401, 2007.

Notes: Despite a large amount of research into invasive species and their introductions, there have been no studies focused on macroalgal transport in ballast water. To address this, we collected replicate samples of ballast water from 12 ships in two Mediterranean harbours (Naples and Salerno). Filtered samples were kept in culture for a month at Mediterranean mean conditions (18°C, 12:12 h LD, 60 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$). Fifteen macroalgal taxa were cultured and differed according to the geographic origin of the ballast water. Most of the cultured algae were widely distributed species (e.g. *Ulva* spp. and *Acinetospora*-phase). However, *Ora obnoi* Hiraoka and Shimada, described from Japan, was hitherto unknown in the Mediterranean Sea. We show for the first time that ballast water can be an important vector for the transport of microscopic stages of macroalgae and that this can be a vector for the introduction of alien species.

Hershler, R., Davis, C.L., Kitting, C.L., and Liu, H.P. **Discovery of introduced and cryptogenic cochliopid gastropods in the San Francisco Estuary, California.** *Journal of Molluscan Studies* 73: 323-332, 2007.

Notes: We report the first discovery in the San Francisco Estuary ('Estuary') of two cochliopid gastropods, *Littoridinops monroensis* and *Tryonia porrecta*. These identifications were based on morphological criteria and supported by analysis of mitochondrial DNA (cytochrome c oxidase subunit I, COI) sequence data. We also report the first discovery of males in parthenogenetic *T. porrecta*. The new records represent large range extensions for both of these North American species, which were previously recorded from predominantly brackish habitats along the western Atlantic-Gulf Coast (*L. monroensis*) and thermal springs in the Great Basin and lower Colorado River region (*T. porrecta*). The COI haplotype observed in Estuary specimens of *L. monroensis* differed from those detected in two western Atlantic populations by only 1-3 bp, suggesting recent divergence which is not consistent with the separation of these two areas by imposing terrestrial barriers since at least the Pliocene. We suggest that *L. monroensis* was recently introduced to the Estuary by transoceanic shipping, adding to the large exotic biota that has invaded this highly disturbed ecosystem. The COI haplotype observed in Estuary specimens of *T. porrecta* is closely similar to haplotypes detected in Nevada and Utah populations and highly divergent relative to the single haplotype observed in other California populations. The implications of these findings for the status of *T. porrecta* in the Estuary are unclear, because the native range of this parthenogen has not been established and its scattered distribution in the West may be attributable to natural dispersal across land (on birds) and/or anthropogenic spread. Although we suggest treating *T. porrecta*

as cryptogenic in the Estuary, a native status may be suggested by independent (subfossil) evidence that this snail was locally present prior to establishment of the area as a major centre of human population and commerce in the 1850s.

Leprieur, F., Beauchard, O., Blanchet, S., Oberdorff, T., and Brosse, S. **Fish invasions in the world's river systems: When natural processes are blurred by human activities.** *PLoS Biology* 6(2): e28, 2008. **O/A**

Notes: Because species invasions are a principal driver of the human-induced biodiversity crisis, the identification of the major determinants of global invasions is a prerequisite for adopting sound conservation policies. Three major hypotheses, which are not necessarily mutually exclusive, have been proposed to explain the establishment of non-native species: the "human activity" hypothesis, which argues that human activities facilitate the establishment of non-native species by disturbing natural landscapes and by increasing propagule pressure; the "biotic resistance" hypothesis, predicting that species-rich communities will readily impede the establishment of non-native species; and the "biotic acceptance" hypothesis, predicting that environmentally suitable habitats for native species are also suitable for non-native species. We tested these hypotheses and report here a global map of fish invasions (i.e., the number of non-native fish species established per river basin) using an original worldwide dataset of freshwater fish occurrences, environmental variables, and human activity indicators for 1,055 river basins covering more than 80% of Earth's surface. First, we identified six major invasion hotspots where non-native species represent more than a quarter of the total number of species. According to the World Conservation Union, these areas are also characterised by the highest proportion of threatened fish species. Second, we show that the human activity indicators account for most of the global variation in non-native species richness, which is highly consistent with the "human activity" hypothesis. In contrast, our results do not provide support for either the "biotic acceptance" or the "biotic resistance" hypothesis. We show that the biogeography of fish invasions matches the geography of human impact at the global scale, which means that natural processes are blurred by human activities in driving fish invasions in the world's river systems. In view of our findings, we fear massive invasions in developing countries with a growing economy as already experienced in developed countries. Anticipating such potential biodiversity threats should therefore be a priority.

Moss, J.A., Burreson, E.M., Cordes, J.F., Dungan, C.F., Brown, G.D., Wang, A., Wu, X., and Reece, K.S. **Pathogens in *Crassostrea ariakensis* and other Asian oyster species: implications for non-native oyster introduction to Chesapeake Bay.** *Diseases of Aquatic Organisms* 77(3): 207-223, 2007.

Notes: With the drastic decline of eastern oyster *Crassostrea virginica* populations in the Chesapeake Bay due to over-fishing, diseases and habitat destruction, there is interest in Maryland and Virginia in utilizing the non-native oyster species *Crassostrea ariakensis* for aquaculture, fishery resource enhancement, and ecological restoration. The International Council for the Exploration of the Sea (ICES) recommends that non-native species be examined for ecological, genetic and disease relationships in the native range prior to a deliberate introduction to a new region. Therefore, a pathogen survey of *C. ariakensis* and other sympatric oyster species was conducted on samples collected in the PR China, Japan and Korea using molecular diagnostics and histopathology. Molecular assays focused on 2 types of pathogens: protistan parasites in the genus *Perkinsus* and herpesviruses, both with known impacts on commercially important molluscan species around the world, including Asia. PCR amplification and DNA sequence data from the internal transcribed spacer region of the rRNA gene complex revealed the presence of 2 *Perkinsus* species not currently found in USA waters: *P. olseni* and an undescribed species. In addition, 3 genetic strains of molluscan herpesviruses were detected in oysters from several potential *C. ariakensis* broodstock acquisition sites in Asia. Viral gametocytic hypertrophy, *Chlamydia*-like organisms, a *Steinhausia*-like microsporidian, *Perkinsus* sp., *Nematopsis* sp., ciliates, and cestodes were also detected by histopathology.

Lyons, D.A. and Scheibling, R.E. **Differences in somatic and gonadic growth of sea urchins (*Strongylocentrotus droebachiensis*) fed kelp (*Laminaria longicruris*) or the invasive alga *Codium fragile* ssp *tomentosoides* are related to energy acquisition.** *Marine Biology* 152(2): 285-295, 2007.

Notes: The rocky subtidal community off the Atlantic coast of Nova Scotia has historically undergone a cyclical transition between *Laminaria*-dominated kelp beds and sea urchin-dominated barrens. Since the introduction of the invasive alga *Codium fragile* ssp. *tomentosoides*, a third community state has emerged: *Codium*-dominated algal beds. We conducted a 42-week feeding experiment in the laboratory, which mimicked the quantity and quality of food available to urchins (*Strongylocentrotus*

droebachiensis) in each of these community states. Feeding rate, growth, reproduction, and survival of urchins fed either *Laminaria longicurris* or *C. fragile* ad libidum, or *L. longicurris* 2 days per month, were measured. Although the ad libidum feeding rate on *C. fragile* was higher than that on kelp, energy intake was lower. Urchins in the ad libidum kelp treatment were larger and had larger gonads than those in the *C. fragile* treatment. Urchins fed kelp infrequently exhibited little somatic and gonadic growth over the course of the experiment. Regression analysis revealed that urchin performance on these diets was strongly related to energy intake. Diet treatment had no effect on survival or gonad maturation. Although urchins can consume substantial amounts of *C. fragile*, it appears that they cannot, or do not, feed quickly enough to compensate for its lower nutritional value. Our results suggest that, although urchins feeding on *C. fragile* are capable of surviving, growing, and reproducing, the replacement of kelp by *C. fragile* in some areas might negatively affect urchin populations as they continue to repopulate the shallow subtidal zone.

Griffen, B.D. and Delaney, D.G. **Species invasion shifts the importance of predator dependence.** *Ecology* 88(12): 3012-3021, 2007.

Notes: The strength of interference between foraging individuals can influence per capita consumption rates, with important consequences for predator and prey populations and system stability. Here we demonstrate how the replacement of a previously established invader, the predatory crab *Carcinus maenas*, by the recently invading predatory crab *Hemigrapsus sanguineus* shifts predation from a species that experiences strong predator interference (strong predator dependence) to one that experiences weak predator interference (weak predator dependence). We demonstrate using field experiments that differences in the strength of predator dependence persist for these species both when they forage on a single focal prey species only (the mussel *Mytilus edulis*) and when they forage more broadly across the entire prey community. This shift in predator dependence with species replacement may be altering the biomass across trophic levels, consistent with theoretical predictions, as we show that *H. sanguineus* populations are much larger than *C. maenas* populations throughout their invaded ranges. Our study highlights that predator dependence may differ among predator species and demonstrates that different predatory impacts of two conspicuous invasive predators may be explained at least in part by different strengths of predator dependence.

Hamner, R.M., Freshwater, D.W., and Whitfield, P.E. **Mitochondrial cytochrome *b* analysis reveals two invasive lionfish species with strong founder effects in the western Atlantic.** *Journal of Fish Biology* 71(Suppl. B): 214-222, 2007.

Notes: Lionfish (Scorpaenidae, Pteroinae) are venomous predatory fish that are native to the Indo-Pacific region and have recently become established in the western Atlantic Ocean. Since the invasion was first documented in 2000, the number of lionfish in the Atlantic has increased substantially and spurred a series of investigations regarding their biology and potential impacts on the ecosystem. The present study uses haplotypes from the mitochondria-encoded cytochrome *b* (*cyt b*) locus to determine the number of lionfish species involved in the Atlantic invasion and the decrease in genetic diversity that accompanied the invasion. The *cyt b* data reveal that *Pterois volitans* along with a small number of *Pterois miles* are present in the Atlantic Ocean and that a strong founder effect has resulted in a large decrease in genetic diversity compared with native lionfish populations.

Haslob, H., Clemmesen, C., Schaber, M., Hinrichsen, H.H., Schmidt, J.O., Voss, R., Kraus, G., and Koster, F.W. **Invading *Mnemiopsis leidyi* as a potential threat to Baltic fish.** *Marine Ecology Progress Series* 349: 303-306, 2007.

Notes: The occurrence of the ctenophore *Mnemiopsis leidyi* as a new invasive species in the Baltic Sea and the potential consequences for fish stock recruitment was investigated in spring 2007. The study focused on the Bornholm Basin, which serves as the major spawning ground for cod and sprat, the commercially most important fish stocks in the Baltic. The distribution pattern of *M. leidyi* revealed a substantial overlap with cod eggs. The observed predation of *M. leidyi* on eggs has the potential to alter the recruitment success of cod, which is the top predator in the system and, thus, to change the Baltic food-web structure.

Knowlton, J.L., Donlan, C.J., Roemer, G.W., Samaniego-Herrera, A., Kertt, B.S., Wood, B., Aguirre-Munoz, A., Faulkner, K.R., and Tershy, B.R. **Eradication of non-native mammals and the status of insular mammals on the California Channel Islands, USA, and Pacific Baja California Peninsula Islands, Mexico.** *Southwestern Naturalist* 52(4): 528-540, 2007.

Notes: The California Channel Islands, USA, and Pacific Baja California Peninsula Islands, Mexico (hereafter referred to as the California islands), are known for their high levels of biodiversity and globally important colonies of seabirds. We document the history, impacts, and management of non-native mammals and summarize the current status of native, non-volant mammals on the California islands. Of the 26 species of native mammals on the California islands, including 6 species and 41 subspecies that are endemic, ≥ 10 populations have suffered extirpation or global extinction. All recent extirpations and extinctions resulted directly from non-native mammalian predators or indirectly via habitat degradation by non-native herbivores. In light of the devastating effects non-native mammals have had on the native insular biotas of the California islands, a variety of organizations have collaborated to eradicate 44 populations of non-native mammals from 19 California islands. Documentation of impacts of non-native mammals and timely implementation of successful eradication efforts are essential to the conservation of these and other insular ecosystems.

Kurle, C.M., Croll, D.A., and Tershy, B.R. **Introduced rats indirectly change marine rocky intertidal communities from algae- to invertebrate-dominated.** *Proceedings of the National Academy of Sciences [USA]* 105(10): 3800-3804, 2008.

Notes: It is widely recognized that trophic interactions structure ecological communities, but their effects are usually only demonstrated on a small scale. As a result, landscape-level documentations of trophic cascades that alter entire communities are scarce. Islands invaded by animals provide natural experiment opportunities both to measure general trophic effects across large spatial scales and to determine the trophic roles of invasive species within native ecosystems. Studies addressing the trophic interactions of invasive species most often focus on their direct effects. To investigate both the presence of a landscape-level trophic cascade and the direct and indirect effects of an invasive species, we examined the impacts of Norway rats (*Rattus norvegicus*) introduced to the Aleutian Islands on marine bird densities and marine rocky intertidal community structures through surveys conducted on invaded and rat-free islands throughout the entire 1,900-km archipelago. Densities of birds that forage in the intertidal were higher on islands without rats. Marine intertidal invertebrates were more abundant on islands with rats, whereas fleshy algal cover was reduced. Our results demonstrate that invasive rats directly reduce bird densities through predation and significantly affect invertebrate and marine algal abundance in the rocky intertidal indirectly via a cross-community trophic cascade, unexpectedly changing the intertidal community structure from an algae- to an invertebrate-dominated system.

Leloup, F.A., Desroy, N., LeMao, P., Pauly, D., and Le Pape, O. **Interactions between a natural food web, shellfish farming and exotic species: The case of the Bay of Mont Saint Michel (France).** *Estuarine, Coastal and Shelf Science* 76(1): 111-120, 2008.

Notes: To ensure sustainable uses of the coastal zone, an integrated ecosystemic approach and ecosystem models are required to frame ecological processes and evaluate environmental impacts. Here, a mass-balance trophic (Ecopath) model of the Mont Saint Michel Bay (MSMB) was developed, to analyze the bay's functioning as an ecosystem. This bay, intensively exploited by fishing and for shellfish farming, is also suffering from the proliferation of the gastropod *Crepidula fornicata*, an exotic species. The MSMB model has 18 compartments, from the primary producers to top predators, and emphasizes the large biomass of filter feeders. The model identified the MSMB as a highly productive ecosystem controlled largely from the bottom-up, and strongly impacted by huge biomasses of filter feeders. However, the low transfer efficiency rates imply that a large part of the primary production is not transferred upward to higher trophic levels, but is lost in high hydrodynamic exchanges and in the trophic impasse represented by a large biomass of *Crepidula fornicata*.

Piazzi, L. and Balata, D. **The spread of *Caulerpa racemosa* var. *cylindracea* in the Mediterranean Sea: An example of how biological invasions can influence beta diversity.** *Marine Environmental Research* 65(1): 50-61, 2008.

Notes: The present study aims to evaluate if invasion of *Caulerpa racemosa* var. *cylindracea* can affect both alpha and beta diversity in Mediterranean coastal system. The following hypotheses were tested: (i) measures of alpha diversity differ between invaded and non-invaded assemblages (ii) this pattern is consistent between different habitats, (iii) assemblages from habitats which are naturally very different tend to be more similar when invaded compared to non-invaded situations. Results showed that Mediterranean benthic assemblages invaded by *C. racemosa* var. *cylindracea* were characterized by lower values of alpha diversity than non-invaded assemblages; moreover, differences between deep (25 m) and shallow water (5 m) assemblages appeared lower in invaded than in non-invaded areas, with a decrease of beta diversity. This homogenisation of habitats was related to a lack of several characteristic species and to a higher abundance of few opportunistic species in invaded areas, particularly turf-forming algae. Moreover, variability in taxa composition was lower in invaded than in non-invaded assemblages in both habitats.

Williams, S.L. **Introduced species in seagrass ecosystems: Status and concerns.** *Journal of Experimental Marine Biology and Ecology* 350(1-2): 89-110, 2007.

Notes: A literature review revealed that at least 56 non-native species, primarily invertebrates and seaweeds, have been introduced to seagrass beds, largely through shipping/boating activities and aquaculture. Four seagrass species also have been introduced. The introductions of the seaweeds *Caulerpa taxifolia*, *C. racemosa* v. *cylindracea*, *Codium fragile* ssp. *tomentosoides*, *Sargassum muticum*, the Asian mussel, *Musculista senhousia*, and the seagrass, *Zostera japonica*, are the best-known examples in seagrass beds. The ecological effects on seagrasses and associated communities have been examined for slightly less than half of the introduced species, which have predominantly negative effects. There is a paucity of experimental data for ecological effects, particularly for seagrass community structure and function. The exception to this finding is the introduction of the seagrass *Z. japonica* with oyster aquaculture to native eelgrass beds on the Pacific coasts of Canada and the USA. Recent experiments in several different seagrass ecosystems confirmed that disturbance contributes to the invasibility of seagrass beds. More definitive studies are required to elucidate the relative effects of nutrient pollution and introduced species in causing seagrass decline, particularly where reduced herbivory and boating activity also covary. Seagrass beds often are subject to multiple introduced species, but their cumulative effect has been virtually unstudied. The potential for compounded negative effects merits serious attention. Heightened attention to the issue of introduced species in seagrass beds is called for given the evidence that introduced species can contribute to seagrass decline, to biodiversity changes that could affect seagrass ecosystem functions, and that they can compromise seagrass restoration. Comprehensive surveys in seagrass beds, complemented by more stringent experimental and mensurative sampling designs, are needed. In the interim, conserving seagrass density and bed size can offer resistance to introduced species. Managing to prevent the introductions, including restricting transplantations of non-native biota during seagrass restorations, is likely to bear positive benefits for seagrass ecosystems.

Hietanen, S., Laine, A.O., and Lukkari, K. **The complex effects of the invasive polychaetes *Marenzelleria* spp. on benthic nutrient dynamics.** *Journal of Experimental Marine Biology and Ecology* 352(1): 89-102, 2007.

Notes: The effects of the polychaetes *Marenzelleria* sp. (Polychaeta, Spionidae), nonindigenous, rapidly increasing species in the Baltic Sea, on benthic nutrient fluxes, denitrification and sediment pore water nutrient concentration were studied in laboratory experiments using a flow-through setup with muddy sediment from coastal regions of the Gulf of Finland. In addition, different forms of sediment phosphorus (P), separated by chemical fractionation, were studied in three sediment layers. At a population density corresponding to about half the highest measured in the northern Baltic Sea, *Marenzelleria* sp. increased the fluxes of P and ammonium to the water column. No effect could be recorded for denitrification. Since the previously dominant species of the area, *Monoporeia affinis*, can enhance denitrification and lower the amount of dissolved P in the pore water, the replacement of *M. affinis* with *Marenzelleria* spp. may lead to increased P flux to the water column and decreased denitrification, further increasing the ammonium flux to the water column. However, sediment reworking by *Marenzelleria* spp. also oxidizes the surface sediment in the long run, improving its ability to retain P and support nitrification. Therefore, the impact of *Marenzelleria* spp. on sediment nutrient release may not be as drastic as the initial reactions seen in our experiments suggest.

Schwindt, E. **The invasion of the acorn barnacle *Balanus glandula* in the south-western Atlantic 40 years later.** *Journal of the Marine Biological Association of the United Kingdom* 87(5): 1219-1225, 2007.

Notes: The acorn barnacle *Balanus glandula* (Darwin 1854) is native to the Pacific coast of North America and was accidentally introduced in Argentina in the early 1970s. Here the invasion status of this species is reviewed in the south-western Atlantic focusing on geographical patterns of density, cover, biomass, size and recruitment, and also estimating its rate of spread. Field surveys along rocky shores and a literature review show that *B. glandula* invaded most of the rocky shores of Argentina at a high rate of spread. Density and cover of barnacles do not follow a latitudinal trend; instead both variables show a bimodal pattern with the highest values in two distant locations (Puerto Lobos and Bahia Bustamante). However, the size of the barnacles increases with latitude, and is positively related to biomass. Recruitment of this species varies between wave exposed and protected areas, and over time. At lower latitudes barnacles recruit in winter, while at higher latitudes they recruit in spring and summer. The differences observed in density and recruitment suggest that along the Argentinean coast, oceanographic processes have a stronger influence in the distribution and success of the barnacles than the gradient in wave exposure. *Balanus glandula* is a successful invader which has completely re-shaped the native intertidal landscape. Moreover, considering the wide temperature range that this barnacle tolerates in native and invaded regions, the entire coastline of South America could be colonized by this species in the future.

Harries, D.B., Harrow, S., Wilson, J.R., Mair, J.M., and Donnan, D.W. **The establishment of the invasive alga *Sargassum muticum* on the west coast of Scotland: a preliminary assessment of community effects.** *Journal of the Marine Biological Association of the United Kingdom* 87(5): 1057-1067, 2007.

Notes: Comparative studies were conducted on intertidal algal and faunal communities associated with *Sargassum muticum* and native algae on the Isle of Cumbrae, Scotland. Significant differences were detected in the structure and composition of the communities. The abundance of the dominant native algae *Dictyota dichotoma* was found to be reduced in areas dominated by *S. muticum* and displacement through competition for substrate or light is inferred. Elevated faunal abundances were associated with *S. muticum* and evidence indicates that increased detrital input may be a possible contributory factor. Differences in faunal community composition were most pronounced in the sessile epifauna below the *S. muticum* canopy. Faunal communities associated with *S. muticum* were less heterogeneous in composition than those associated with native algae at equivalent shore positions. Some of the compositional differences may be coincidental and attributable to factors favouring the establishment of *S. muticum* rather than to the direct influence of the *S. muticum* canopy.

van Soest, R.W.M., de Kluijver, M.J., van Bragt, P.H., Faasse, M., Nijland, R., Beglinger, E.J., de Weerd, W.H., and de Voogd, N.J. **Sponge invaders in Dutch coastal waters.** *Journal of the Marine Biological Association of the United Kingdom* 87(6): 1733-1748, 2007.

Notes: Continuous monitoring by scientists and volunteers of the Biological Working Group of the Dutch SubAqua Union and the 'Anemoon' foundation over the past four years, yielded a surprising six new records of sponges for Dutch coastal waters. *Oscarella lobularis*, *Celtodoryx girardae*, *Suberites virgulatus*, *Haliciona (Haliciona) simulans*, *Halisarca* aff. *dujardini*, and a species identified as *Leucosolenia somesii* were unknown from Dutch coastal waters before 2000. The latter is a giant calcareous sponge, seemingly belonging to the common *Leucosolenia variabilis*, but here assumed to be an invader as well, as it has spicular characters well outside the variation found in the majority of Dutch *L. variabilis* specimens. It is likely a member of a 'forgotten' species, *L. somesii*. Habit photographs, SEM images of the spicules, and for *O. lobularis* and *H. aff. dujardini*, photographs of histological sections are provided to substantiate these new records. With the exception of *C. girardae*, most of the species resemble previously described widespread north-east Atlantic species, occurring in the area to the south and west of the Netherlands, so it is assumed pending future genetic research that at least several of the invaders comprise range extensions related to rising winter temperatures. Possibly, recent shellfish imports may be an additional causal agent. We also report the occurrence of unprecedented spicular deviations observed in three sponge species commonly occurring in Dutch waters, *Halichondria (Halichondria) panicea*, *Hymeniacidon perlevis* and *Haliciona (Soestella) xena*, which grew in small inland water bodies. Possibly, the limited space in these inland waters with possible stress factors for sponges such as reduced water exchange, and deviating chemistry, have caused the sponges to form stunted growth in spicules varying from rhabds with rounded endings to silica spheroids. We provide an updated list of sponges found in Dutch waters and a list of suspected or proven invaders of Dutch waters.

MacDonald, J.A., Roudez, R., Glover, T., and Weis, J.S. **The invasive green crab and Japanese shore crab: behavioral interactions with a native crab species, the blue crab.** *Biological Invasions* 9(7): 837-848, 2007.

Notes: Blue crabs, *Callinectes sapidus* (Rathbun), are an ecologically and commercially important species along the East coast of North America. Over the past century and a half, blue crabs have been exposed to an expanding set of exotic species, a few of which are potential competitors. To test for interactions with invasive crabs, juvenile *C. sapidus* males were placed in competition experiments for a food item with two common non-indigenous crabs, the green crab *Carcinus maenas* (L.) and the Japanese shore crab, *Hemigrapsus sanguineus* (De Haan). Agonistic interactions were evaluated when they occurred. In addition, each species' potential to resist predators was examined by testing carapace strength. Results showed that *C. maenas* was a superior competitor to both *C. sapidus* and *H. sanguineus* for obtaining food, while the latter two species were evenly matched against each other. Regarding agonism, *C. sapidus*, was the "loser" a disproportionate number of times. *C. sapidus* carapaces also had a significantly lower breaking strength. These experiments suggest that both as a competitor, and as potential prey, juvenile blue crabs have some disadvantages compared with these common sympatric exotic crab species, and in areas where these exotics are common, juvenile native blue crabs may be forced to expend more energy in conflict that could be spent foraging, and may be forced away from prime food items toward less optimum prey.

Neira, C., Levin, L.A., Grosholz, E.D., and Mendoza, G. **Influence of invasive *Spartina* growth stages on associated macrofaunal communities.** *Biological Invasions* 9(8): 975-993, 2007.

Notes: In coastal wetlands, invasive plants often act as ecosystem engineers altering flow, light and sediments which, in turn, can affect benthic animal communities. However, the degree of influence of the engineer will vary significantly as it grows, matures and senesces, and surprisingly little is known about how the influence of an ecosystem engineer varies with ontogeny. We address this issue on the tidal flats of San Francisco Bay where hybrid *Spartina* (*foliosa* x *alterniflora*) invaded 30 years ago. The invasion has altered the physico-chemical properties of the sediment habitat, which we predicted should cause changes in macrofaunal community structure and function. Through mensurative and manipulative approaches we investigated the influence of different growth stages of hybrid *Spartina* on macrobenthos and the underlying mechanisms. Cross-elevation sampling transects were established covering 5 zones (or stages) of the invasion, running from the tidal flat (pre-invasion) to an unvegetated dieback zone. Additionally, we experimentally removed aboveground plant structure in the mature (inner) marsh to mimic the 'unvegetated areas'. Our results revealed four distinct faunal assemblages, which reflected *Spartina*-induced changes in the corresponding habitat properties along an elevation gradient: a pre-invaded tidal flat, a leading edge of immature invasion, a center of mature invasion, and a senescing dieback area. These stages of hybrid *Spartina* invasion were accompanied by a substantial reduction in macrofaunal species richness and an increase in dominance, as well as a strong shift in feeding modes, from surface microalgal feeders to subsurface detritus/*Spartina* feeders (mainly tubificid oligochaetes and capitellid polychaetes). Knowledge of the varying influence of plant invaders on the sediment ecosystem during different phases of invasion is critical for management of coastal wetlands.

Chapman, J.W., Carlton, J.T., Bellinger, M.R., and Blakeslee, A.M.H. **Premature refutation of a human-mediated marine species introduction: the case history of the marine snail *Littorina littorea* in the Northwestern Atlantic.** *Biological Invasions* 9(8): 995-1008, 2007.

Notes: The closely documented spread of the European periwinkle snail, *Littorina littorea* from Pictou, Nova Scotia in 1840 to New Jersey by 1870, its near absence in pre-European fossil deposits, and its close association with human mechanisms of transport from Europe, are among the clearest evidence of a human-mediated marine introduction ever reported. Genetic data were recently proposed as evidence that North American *L. littorea* predate European contact and thus, are not introduced. Review of these genetic data and all other data reveals that the simplest explanation of the modern occurrence of this snail in North America is by human introduction.

Russell, L.K., Hepburn, C.D., Hurd, C.L., and Stuart, M.D. **The expanding range of *Undaria pinnatifida* in southern New Zealand: distribution, dispersal mechanisms and the invasion of wave-exposed environments.** *Biological Invasions*

Notes: Very few studies have addressed how the invasive kelp *Undaria pinnatifida* (Harvey) Suringar spreads beyond initial founding populations in harbours. Surveys of the harbours and accessible areas of open coast throughout southern New Zealand were conducted to determine how far *U. pinnatifida* populations had extended since initial incursions. Our findings clearly demonstrate that *U. pinnatifida* is capable of invading native communities and can establish reproductive populations in locations subjected to significant and consistent wave action. The extent of spread from source populations differs between harbours in which it has established. Dispersal is greatest in harbours with long established populations, those where populations have not been strategically managed, harbours with high water exchange with surrounding coastal waters, and where prevailing currents allow establishment of *U. pinnatifida* on suitable substrata close to harbour entrances. Dispersal along the open coast is primarily achieved by drifting adult sporophytes that are washed up in the rocky intertidal zone. Founding populations are most often found in the intertidal zone, primarily within rockpools. Subtidal transects and observations indicate that *U. pinnatifida* is well adapted to invade exposed coastlines and can establish within a broad range of niches in wave-exposed areas including rockpools, the low intertidal, shallow subtidal, *Macrocystis pyrifera* kelp forests, and in low light areas beyond the vertical extent of large native macroalgae. The current range of *U. pinnatifida* is much greater than expected and appears to be expanding. Due to its ability to grow in a broad range of environments and to form dense monospecific stands, *U. pinnatifida* has the potential to strongly modify almost all rocky subtidal and intertidal communities in temperate locations.

Suarez, A.V. and Tsutsui, N.D. **The evolutionary consequences of biological invasions.** *Molecular Ecology* 17(1): 351-360, 2008.

Notes: A major challenge of invasion biology is the development of a predictive framework that prevents new invasions. This is inherently difficult because different biological characteristics are important at the different stages of invasion: opportunity/transport, establishment and spread. Here, we draw from recent research on a variety of taxa to examine the evolutionary causes and consequences of biological invasions. The process of introduction may favour species with characteristics that promote success in highly disturbed, human-dominated landscapes, thus exerting novel forms of selection on introduced populations. Moreover, evidence is accumulating that multiple introductions can often be critical to the successful establishment and spread of introduced species, as they may be important sources of genetic variation necessary for adaptation in new environments or may permit the introduction of novel traits. Thus, not only should the introduction of new species be prevented, but substantial effort should also be directed to preventing the secondary introduction of previously established species (and even movement of individuals among introduced populations). Modern molecular techniques can take advantage of genetic changes postintroduction to determine the source of introduced populations and their vectors of spread, and to elucidate the mechanisms of success of some invasive species. Moreover, the growing availability of genomic tools will permit the identification of underlying genetic causes of invasive success.

Carroll, S.P. **Facing change: forms and foundations of contemporary adaptation to biotic invasions.** *Molecular Ecology* 17(1): 361-372, 2008.

Notes: Ongoing adaptation in native populations to anthropogenic change both facilitates and challenges ecologically appropriate and sustainable management. Human disturbance promotes adaptive responses at the genomic, individual and population levels. Traits vary widely in whether adaptation occurs through plasticity or evolution, and these modes interact within and among traits. For example, plasticity in one trait may be adaptive because it permits homeostasis and lessens the intensity of selection in another. Both opportunity and catastrophe generate adaptive responses. Recently evolved adaptations characterize the responses of many native species to biotic invasions. Several well-known examples involve native phytophagous insects colonizing introduced plants. For example, our studies of North American and Australian soapberry bugs on nonindigenous plants demonstrate both diversifying and homogenizing contemporary evolution. Modes of adaptation differ among traits and populations and as a function of the host on which they develop. The genetic architecture of the evolving adaptations involves a substantial degree of nonadditive genetic variation. One important consequence of contemporary adaptation may be an enhanced capacity of native communities to provide adaptive biological control of invasive species. Conservation scientists may manipulate adaptation to achieve conservation goals, but must also decide how deeply they wish to attempt to control the phenotypes and genotypes of other species.

Kinnison, M.T., Unwin, M.J., and Quinn, T.P. **Eco-evolutionary vs. habitat contributions to invasion in salmon: experimental evaluation in the wild.** *Molecular Ecology* 17(1): 405-414, 2008.

Notes: Although trait evolution over contemporary timescales is well documented, its influence on ecological dynamics in the wild has received much less attention particularly compared to traditional ecological and environmental factors. For example, evolution over ecologically relevant timescales is expected in populations that colonize new habitats, where it should theoretically enhance fitness, associated vital rates of survival and reproduction, and population growth potential. Nonetheless, success of exotic species is much more commonly attributed to ecological aspects of habitat quality and 'escape from enemies' in the invaded range. Here, we consider contemporary evolution of vital rates in introduced Chinook salmon (*Oncorhynchus tshawytscha*) that quickly colonized New Zealand and diverged over c. 26 generations. By using experimental translocations, we partitioned the roles of evolution and habitat quality in modifying geographical patterns of vital rates. Variation in habitat quality within the new range had the greatest influence on broad geographical patterns of vital rates, but locally adapted salmon still exhibited more than double the vital rate performance, and hence fitness, of nonlocal counterparts. The scope of this fitness evolution far exceeds the scale of divergence in trait values for these populations, or even the expected fitness effects of particular traits. These results suggest that contemporary evolution can be an important part of the eco-evolutionary dynamics of invasions and highlight the need for studies of the emergent fitness and ecological consequences of such evolution, rather than just changes in trait values.

Dlugosch, K.M. and Parker, I.M. **Founding events in species invasions: genetic variation, adaptive evolution, and the role of multiple introductions.** *Molecular Ecology* 17(1): 431-449, 2008.

Notes: Invasive species are predicted to suffer from reductions in genetic diversity during founding events, reducing adaptive potential. Integrating evidence from two literature reviews and two case studies, we address the following questions: How much genetic diversity is lost in invasions? Do multiple introductions ameliorate this loss? Is there evidence for loss of diversity in quantitative traits? Do invaders that have experienced strong bottlenecks show adaptive evolution? How do multiple introductions influence adaptation on a landscape scale? We reviewed studies of 80 species of animals, plants, and fungi that quantified nuclear molecular diversity within introduced and source populations. Overall, there were significant losses of both allelic richness and heterozygosity in introduced populations, and large gains in diversity were rare. Evidence for multiple introductions was associated with increased diversity, and allelic variation appeared to increase over long timescales (~ 100 years), suggesting a role for gene flow in augmenting diversity over the long-term. We then reviewed the literature on quantitative trait diversity and found that broad-sense variation rarely declines in introductions, but direct comparisons of additive variance were lacking. Our studies of *Hypericum canariense* invasions illustrate how populations with diminished diversity may still evolve rapidly. Given the prevalence of genetic bottlenecks in successful invading populations and the potential for adaptive evolution in quantitative traits, we suggest that the disadvantages associated with founding events may have been overstated. However, our work on the successful invader *Verbascum thapsus* illustrates how multiple introductions may take time to commingle, instead persisting as a 'mosaic of maladaptation' where traits are not distributed in a pattern consistent with adaptation. We conclude that management limiting gene flow among introduced populations may reduce adaptive potential but is unlikely to prevent expansion or the evolution of novel invasive behaviour.