

Marine Science Review - 181

Introduced species



In this review:

- A. Recent articles – no abstract available
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A. Recent articles – no abstract available

Timofeev, S.F. and Selifonova, Z.P. **Euphausiid larvae in the ballast waters of commercial ships: Evidence for a possibility for biological invasion.** *Crustaceana* 78: 1395-1398, 2005.

Calado, R. and Chapman, P.M. **Aquarium species: Deadly invaders.** *Marine Pollution Bulletin* 52(6): 599-601, 2006.

B. Recent articles with abstracts

Powers, S.P., Bishop, M.A., Grabowski, J.H., and Peterson, C.H. **Distribution of the invasive bivalve *Mya arenaria* L. on intertidal flats of southcentral Alaska.** *Journal of Sea Research* 55(3): 207-216, 2006.

Notes: The bivalve *Mya arenaria* L. is a common inhabitant of intertidal sediments along the southcentral Alaskan coastline. Its current distribution along the Pacific coast of the continental USA, Canada and Alaska has resulted from a series of intentional and unintentional introductions as well as larval transport between points of introduction over the previous century. Despite the apparent success of *M. arenaria* in intertidal habitats of coastal Alaska, no study has examined its distribution in this environment. We sampled four times over a two-year period (2001-2002) to document the distribution of *M. arenaria* in intertidal sedimentary habitats of the Copper River Delta and adjacent Orca Inlet (southeastern Prince William Sound), Alaska. Sampling was performed along a gradient of tidal elevations at three sites (Hartney Bay, Eyak and Pete Dahl) chosen to represent the range of physical/chemical settings of protected intertidal sand and mud flats within the study area. Among the three sampling sites, abundance of *M. arenaria* was lowest at sites near the outflow of the Copper River (Pete Dahl) and highest in areas of higher salinity and water clarity (Hartney Bay and low tidal elevation plots at Eyak). Within each of the two sites located on the Copper River Delta (Eyak and Pete Dahl), abundances of *M. arenaria* were highest at low tide plots (+1.1 m for Eyak, +1.4 m for Pete Dahl), a pattern consistent with the distribution of *M. arenaria* within tidal flats in Europe (Wadden and White Seas). For the third site located in Orca Inlet (Hartney Bay), *M. arenaria* was found at all tidal elevations; however, distinct differences in the distribution of newly recruited *M. arenaria* (< 10 mm shell length [SL]) and older juveniles and adults (> 10 mm SL) were evident. Density and growth of *M. arenaria* in southcentral Alaska were most similar to values reported for the White Sea (Russia); both areas are located at similar latitude and represent the northern extreme of *M. arenaria* distribution.

Wonham, M.J. and Pachevsky, E. **A null model of temporal trends in biological invasion records.** *Ecology Letters* 9(6): 663-672, 2006.

Notes: Biological invasions are a growing aspect of global biodiversity change. In many regions, introduced species richness increases supralinearly over time. This does not, however, necessarily indicate increasing introduction rates or invasion success. We develop a simple null model to identify the expected trend in invasion records over time. For constant introduction rates and success, the expected trend is exponentially increasing. Model extensions with varying introduction rate and success can also generate exponential distributions. We then analyse temporal trends in aquatic, marine and terrestrial invasion records. Most data sets support an exponential distribution (15/16) and the null invasion model (12/16). Thus, our model shows that

no change in introduction rate or success need be invoked to explain the majority of observed trends. Further, an exponential trend does not necessarily indicate increasing invasion success or 'invasional meltdown', and a saturating trend does not necessarily indicate decreasing success or biotic resistance.

Salgado-Barragan, J. and Toledano-Granados, A. **The false mussel *Mytilopsis adamsi* Morrison, 1946 (Mollusca: Bivalvia: Dreissenidae) in the Pacific waters of Mexico: A case of biological invasion.** *Hydrobiologia* 563: 1-7, 2006.

Notes: The false mussel *Mytilopsis adamsi*, originally described from the Pacific coast of Panama, is reported for the first time as an introduced species in the Urias estuary and an adjacent shrimp farm, on the Pacific coasts of Mexico. In the 19th century, this species was transported from the Pacific coast of Panama, reaching the Indo-Pacific Ocean, but it had not been previously reported in other coasts of the American Pacific. Its recent and irregular presence in this small estuary near shore the Mazatlan harbor and an adjacent shrimp farm suggests that the species was introduced into the area but it cannot still be considered as a harmful invader. The presence of the species in the shrimp farm may indicate that it was introduced along with shrimp stocks from Central America, although its passive transportation to the estuary via ballast water or attached to hulls is not discounted.

Kushner, R.B. and Hovel, K.A. **Effects of native predators and eelgrass habitat structure on the introduced Asian mussel *Musculista senhousia* (Benson in Cantor) in southern California.** *Journal of Experimental Marine Biology and Ecology* 332(2): 166-177, 2006.

Notes: The ability of predators to control the abundance of non-native species has been little explored in marine systems. Native predators may be used to control non-native species or may confer invasion resistance to communities if predation rates on invaders are density-dependent. We studied the response of southern California native predators to the density of *Musculista senhousia* (Benson in Cantor, 1842), a small, fast growing mussel that has been introduced from Japan to several coastlines worldwide. We performed field experiments to determine if *M. senhousia* proportional mortality is density-dependent and if eelgrass *Zostera marina* L. habitat structure influenced mussel density-dependent mortality. We also evaluated the effect of seagrass habitat structure on the aggregative and functional responses of the predatory gastropod *Pteropurpura festiva* (Hinds, 1844) to Asian mussel density. In the summer of 2002, *P. festiva* aggregated in plots with high mussel density and was responsible for nearly all predation on *M. senhousia*. However, *M. senhousia* proportional mortality was inversely density-dependent at all levels of eelgrass above-ground and below-ground habitat structure. Asian mussel proportional mortality also was inversely density-dependent and was not influenced by eelgrass habitat structure in the spring of 2004 when wading birds were the chief predator of mussels. In contrast to results for mussel proportional mortality, the aggregative and functional responses of *P. festiva* varied with seagrass habitat structure. *P. festiva* density increased with Asian mussel density in plots with low simulated habitat structure, but the relationship between *P. festiva* density and Asian mussel density was parabolic at zero, intermediate and high levels of habitat structure. In field enclosures, *P. festiva* exhibited a Type I (linear) functional response to Asian mussel density at low levels of eelgrass structure, and a Type II (hyperbolic) functional response to mussel density at high levels of eelgrass structure. Our results and those of others suggest that the degree to which local benthic communities in southern California are resistant to Asian mussel invasion depends on habitat structure, mussel settlement rates, and the density and diversity of predators.

Braby, C.E. and Somero, G.N. **Following the heart: temperature and salinity effects on heart rate in native and invasive species of blue mussels (Genus *Mytilus*).** *Journal of Experimental Biology* 209(13): 2554-2566, 2006.

Notes: The three species of blue mussels, *Mytilus trossulus* Gould 1850, *M. edulis* Linnaeus 1758 and *M. galloprovincialis* Lamarck 1819, have distinct global distribution patterns that are hypothesized to reflect differences in their tolerances of temperature and salinity. We examined effects on heart rate (beats min⁻¹) of acute exposure and acclimation to different combinations of temperature and salinity to test this hypothesis and, in the context of the invasive success of *M. galloprovincialis*, to gain insights into the factors that may explain the replacement of the temperate Pacific native, *M. trossulus*, by this Mediterranean Sea invader along much of the California coast. Heart rate of *M. trossulus* was significantly higher than that of *M. galloprovincialis*, consistent with evolutionary adaptation to a lower habitat temperature (temperature compensation) in the former species. Heart rates of *M. trossulus*/*M. galloprovincialis* hybrids were intermediate between those of the parental species. Following acclimation to 14°C and 21°C, heart rates of all species exhibited partial compensation to temperature. Heart rate increased

with rising temperature until a high temperature was reached at which point activity fell sharply, the high critical temperature (H-crit). H-crit increased with increasing acclimation temperature and differed among species in a pattern that reflected their probable evolutionary adaptation temperatures: *M. galloprovincialis* is more heat tolerant than the other two congeners. Ability to sustain heart function in the cold also reflected evolutionary history: *M. trossulus* is more cold tolerant than *M. galloprovincialis*. Heart rates for all three congeners decreased gradually in response to acute reductions in salinity until a low salinity (S-crit) was reached at which heart rate dropped precipitously. S-crit decreased with decreasing salinity of acclimation and was generally lowest for *M. galloprovincialis*. Mortality during acclimation under common garden conditions was greatest in *M. trossulus* and was highest at high acclimation temperatures and salinities. These intrinsic differences in basal heart rate, thermal and salinity responses, acclimatory capacity, and survivorship are discussed in the contexts of the species' biogeographic patterning and, for the invasive species *M. galloprovincialis*, the potential for further range expansion along the Pacific coast of North America.

Wikstrom, S.A., Steinarsdottir, M.B., Kautsky, L., and Pavia, H. **Increased chemical resistance explains low herbivore colonization of introduced seaweed.** *Oecologia* 148(4): 593-601, 2006.

Notes: The success of introduced species is often attributed to release from co-evolved enemies in the new range and a subsequent decreased allocation to defense (EICA), but these hypotheses have rarely been evaluated for systems with low host-specificity of enemies. Here, we compare herbivore utilization of the brown seaweed, *Fucus evaneszens*, and its coexisting competitors both in its native and new ranges, to test certain predictions derived from these hypotheses in a system dominated by generalist herbivores. While *F. evaneszens* was shown to be a preferred host in its native range, invading populations supported a less diverse herbivore fauna and it was less preferred in laboratory choice experiments with important herbivores, when compared to co-occurring seaweeds. These results are consistent with the enemy release hypothesis, despite the fact that the herbivore communities in both regions were mainly composed of generalist species. However, in contrast to the prediction of EICA, analysis of anti-grazing compounds indicated a higher allocation to defense in introduced compared to native *F. evaneszens*. The results suggest that the invader is subjected to less intense enemy control in the new range, but that this is due to an increased allocation to defense rather than release from specialized herbivores. This indicates that increased resistance to herbivory might be an important strategy for invasion success in systems dominated by generalist herbivores.

Piazzzi, L. and Ceccherelli, G. **Persistence of biological invasion effects: Recovery of macroalgal assemblages after removal of *Caulerpa racemosa* var. *cylindracea*.** *Estuarine, Coastal and Shelf Science* 68(3-4): 455-461, 2006.

Notes: The present study evaluated the capability of recovery of Mediterranean macroalgal assemblages on rocky bottom invaded by *Caulerpa racemosa*. A manipulative experiment was performed to compare the structure of native assemblages that: (a) were invaded by the alga, (b) were invaded, but where the invasive alga was removed, and (c) had never been invaded. Macroalgal assemblages differed significantly between areas invaded by *C. racemosa* and control areas. Moreover, one year after removal of the invader, the recovery of community was minimal. Overall, recovery consisted of a significant increase in species richness and cover of macroalgae, but cover of each vegetation layer (encrusting, turf and erect) did not vary significantly between cleared and invaded plots through time. Results showed that the effects of the colonization persist after the removal of the alga and the process of recovery of the assemblages appears to be quite slow. This finding might be an important contribution to evaluate invasion costs and thus potentially useful for an effective addressing of control strategies.

Taraschewski, H. **Hosts and parasites as aliens.** *Journal of Helminthology* 80(2): 99-128, 2006.

Notes: Over the past decades, various free-living animals (hosts) and their parasites have invaded recipient areas in which they had not previously occurred, thus gaining the status of aliens or exotics. In general this happened to a low extent for hundreds of years. With variable frequency, invasions have been followed by the dispersal and establishment of non-indigenous species, whether host or parasite. In the literature thus far, colonizations by both hosts and parasites have not been treated and reviewed together, although both are usually interwoven in various ways. As to those factors permitting invasive success and colonization strength, various hypotheses have been put forward depending on the scientific background of respective authors and on the conspicuousness of certain invasions. Researchers who have tried to analyse characteristic developmental patterns, the speed of dispersal or the degree of genetic divergence in populations of alien species have come to different conclusions. Among parasitologists, the applied aspects of parasite invasions, such as the negative effects on economically important hosts,

have long been at the centre of interest. In this contribution, invasions by hosts as well as parasites are considered comparatively, revealing many similarities and a few differences. Two helminths, the liver fluke, *Fasciola hepatica*, of cattle and sheep and the swimbladder nematode, *Anguillicola crassus*, of eels are shown to be useful as model parasites for the study of animal invasions and environmental global change. Introductions of *F. hepatica* have been associated with imports of cattle or other grazing animals. In various target areas, susceptible lymnaeid snails serving as intermediate hosts were either naturally present and/or were introduced from the donor continent of the parasite (Europe) and/or from other regions which were not within the original range of the parasite, partly reflecting progressive stages of a global biota change. In several introduced areas, *F. hepatica* co-occurs with native or exotic populations of the congeneric *F. gigantica*, with thus far unknown implications. Over the fluke's extended range, in addition to domestic stock animals, wild native or naturalized mammals can also serve as final hosts. Indigenous and displaced populations of *F. hepatica*, however, have not yet been studied comparatively from an evolutionary perspective. *A. crassus*, from the Far East, has invaded three continents, without the previous naturalization of its natural host *Anguilla japonica*, by switching to the respective indigenous eel species. Local entomostrac crustaceans serve as susceptible intermediate hosts. The novel final hosts turned out to be naive in respect to the introduced nematode with far reaching consequences for the parasite's morphology (size), abundance and pathogenicity. Comparative infection experiments with Japanese and European eels yielded many differences in the hosts' immune defence, mirroring coevolution versus an abrupt host switch associated with the introduction of the helminth. In other associations of native hosts and invasive parasites, the elevated pathogenicity of the parasite seems to result from other deficiencies such as a lack of anti-parasitic behaviour of the naive host compared to the donor host which displays distinct behavioural patterns, keeping the abundance of the parasite low. From the small amount of available literature, it can be concluded that the adaptation of certain populations of the novel host to the alien parasite takes several decades to a century or more. Summarizing all we know about hosts and parasites as aliens, tentative patterns and principles can be figured out, but individual case studies teach us that generalizations should be avoided.

Chimner, R.A., Fry, B., Kaneshiro, M.Y., and Cormier, N. **Current extent and historical expansion of introduced mangroves on O'ahu, Hawai'i.** *Pacific Science* 60(3): 377-384, 2006.

Notes: In Hawai'i, mangrove trees are introduced species that can rapidly colonize many nearshore environments. Mangroves have been introduced on O'ahu, and *Rhizophora mangle* in particular has created numerous problems that have led to several mangrove removals and increased interest in long-term management of mangroves. The objective of this project was to quantify current locations of mangroves and their historical rate of expansion on O'ahu. We used the Geographic Information System (GIS) to map mangroves from digitized air photographs from six time periods: 1951-1953, 1963-1965, 1978, 1982, 1991, and 2001. We found that mangroves are still expanding at a rapid rate on O'ahu 80 yr after their introduction. Mangroves have colonized many different landforms, including tidal flats, riverbanks, fishponds, canals, protected reefs, embayments, lagoons, and other protected areas. Currently, mangroves are widely distributed and occur on all coasts except the dry leeward coast and occupy a total of 147 ha. Roughly 70% (102 ha) of all mangroves occur in Pearl Harbor.

Bailey, S.A., Nandakumar, K., and MacIsaac, H.J. **Does saltwater flushing reduce viability of diapausing eggs in ship ballast sediment?** *Diversity and Distributions* 12(3): 328-335, 2006.

Notes: Flushing of ballast tanks with seawater has been proposed to reduce the risk of invasion associated with residual ballast in 'no ballast on board' ships. The efficacy of this procedure, however, has not been determined. Using diapausing eggs isolated from ballast sediments - as well as from Lake Erie sediment - this study investigated the impact of salinity (0, 8 and 35 parts per thousand) and temperature (10, 20 and 30°C) on the cumulative abundance and species richness of hatched zooplankton taxa. The rate and amount of hatching varied dramatically between sediments and across salinity-temperature regimes. Although exposure to saline water inhibited emergence of freshwater taxa during the exposure phase of all trials, mixed results were evident after diapausing eggs were returned to freshwater. The efficacy of salinity as a ballast treatment method was temperature dependent, although the direction of the effect was case-specific. Exposure of eggs to saline water was less effective at 10 and 30°C than at 20°C. Although flushing ballast tanks with open ocean water is expected to significantly reduce the number of active invertebrates living in residual ballast water (a potentially larger source of invaders), our results indicate that the most effective treatment conditions for reduction of diapausing egg viability is 8 parts per thousand salinity at 20°C.

White, E.M., Wilson, J.C., and Clarke, A.R. **Biotic indirect effects: a neglected concept in invasion biology.** *Diversity and Distributions* 12(4): 443-455, 2006.

Notes: Indirect effects involve more than two species and are defined as how one species alters the effect that another species has on a third. These complex interactions are often overlooked in studies of interactions between alien and native species, and their role in influencing biological invasions has been rarely considered. Based on a comprehensive review of the invasion biology literature, we examine the evidence for the occurrence of four of the most commonly documented indirect effects (apparent competition, indirect mutualism/commensalism, exploitative competition, and trophic cascades) in the invasion process. Studies investigating indirect effects in the context of invasion biology are relatively rare, but have been increasing in recent years, and there are sufficient examples to indicate that this kind of interaction is likely to be more common than is currently recognized. Whether indirect interactions are mediated by an alien or a native species, and whether they occur between ecologically similar or dissimilar alien and native species, depends in part on the type of interaction considered and no predictable patterns were detected in the literature. Further empirical studies will help to elucidate such patterns. At this stage, the inherent unpredictability of indirect interactions means that their impacts in relation to invasions are particularly challenging for land managers to deal with, and their role in invasions is a complex, but is a valuable area of investigation for researchers.

Genzano, G., Mianzan, H., Acha, E.M., and Gaitan, E. **First record of the invasive medusa *Blackfordia virginica* (Hydrozoa: Leptomedusae) in the Rio de la Plata estuary, Argentina-Uruguay.** *Revista Chilena de Historia Natural* 79(2): 257-261, 2006.

Notes: *Blackfordia virginica* is a well-known invasive medusa inhabiting estuarine areas. It was recently detected in northern Argentina, constituting the first record of invasive hydromedusa for the Argentine Sea. In this work more than 1,500 plankton samples in the southwestern Atlantic Ocean (34-55°S) from 1983 to 2000 were analyzed. More than 5,000 specimens per sample of *B. virginica* were found in Rio de la Plata estuary for the first time in February 2000. This river is one of the large waterways of South America with an intense nautical traffic and several exotic species has been recorded here, mainly due to trans-oceanic shipping traffic. It is important to point out that we found medusae of both sexes (therefore this species could be introduced in either the medusa or the polyp stages or both), different size classes (including very small juveniles) and maturation stages, and in such high numbers that would suggest local reproduction. For this reason the recent finding of this hydromedusa could represent the starting point of an successful introduction.

Moreno, R.A., Neill, P.E., and Rozbaczylo, N. **Native and non-indigenous boring polychaetes in Chile: a threat to native and commercial mollusc species.** *Revista Chilena de Historia Natural* 79(2): 263-278, 2006.

Notes: Boring polychaetes infesting the shells of aquacultured molluscs affect host fitness and cause serious economic problems for the aquaculture industry. In Chile, knowledge of the native and non-indigenous polychaete fauna associated with mollusc hosts is limited, in spite of the fact that numerous native and non-indigenous mollusc species are actively harvested. We present the first complete list of boring polychaete species present in Chile, with a review of the information regarding each species' status as a native or non-indigenous species (NIS), together with information on native and introduced ranges, affected host species, likely vectors of introduction and donor areas. We recorded a total of nine boring polychaetes present along the Chilean coast including native and NIS. Within the NIS category we provide the first published report of the Sabellid *Terebrasabella heterouncinata* in South America. Boring polychaetes utilized both native and introduced host species. The finding of polychaete species which utilized multiple native and NIS hosts, indicates a potential risk for spread between aquaculture facilities and the natural environment. Our analysis suggests that aquaculture activities are probably the primary introduction vector for boring polychaete species to Chile and that this region does not differ in the magnitude of introduced boring polychaetes relative to other regions of the world. We discuss current laws and management regarding polychaete infestations and make recommendations for future management in Chile, which should contemplate a rational compromise between the socio-economic needs of the country and plans to protect and preserve the nation's biodiversity.

Hacker, S.D. and Dethier, M.N. **Community modification by a grass invader has differing impacts for marine habitats.** *Oikos* 113(2): 279-286, 2006.

Notes: There is increasing recognition of invasive species impacts but less is known about how modifications may differ under variable environmental contexts. In particular, it is generally unknown whether impacts of single invasive species can vary among habitats and what the consequences of this variability may be. We used a multi-site comparative approach to examine the impacts of a single invader, the marine grass *Spartina anglica*, on estuarine habitats with different native species assemblages and physical conditions. We found that range (extent), abundance, and effects on sediment and native plant species vary depending on the habitat invaded. *S. anglica* has by far the greatest range and abundance in mudflats and low salinity marshes compared to high salinity marshes and cobble beaches. Changes in sediment characteristics also substantially differed among habitats, with invaded areas in some habitats experiencing greater sediment accretion, water content, and salinity than other habitats. In addition, in opposition to the theory that strong invaders decrease species diversity, we found that native plant diversity in our plots increased within invaded areas in some habitats while it declined in others. These variable modifications suggest that single invaders, even species that are considered strong interactors, do not produce the same effect in all habitats. We suggest that understanding impact variability can help predict how invasive species will respond to environmental changes, new habitats, and management strategies.

Britton-Simmons, K.H. **Functional group diversity, resource preemption and the genesis of invasion resistance in a community of marine algae.** *Oikos* 113(3): 395-401, 2006.

Notes: Although many studies have investigated how community characteristics such as diversity and disturbance relate to invasibility, the mechanisms underlying biotic resistance to introduced species are not well understood. I manipulated the functional group composition of native algal communities and invaded them with the introduced, Japanese seaweed *Sargassum muticum* to understand how individual functional groups contributed to overall invasion resistance. The results suggested that space preemption by crustose and turfing algae inhibited *S. muticum* recruitment and that light preemption by canopy and understory algae reduced *S. muticum* survivorship. However, other mechanisms I did not investigate could have contributed to these two results. In this marine community the sequential preemption of key resources by different functional groups in different stages of the invasion generated resistance to invasion by *S. muticum*. Rather than acting collectively on a single resource the functional groups in this system were important for preempting either space or light, but not both resources. My experiment has important implications for diversity-invasibility studies, which typically look for an effect of diversity on individual resources. Overall invasion resistance will be due to the additive effects of individual functional groups (or species) summed over an invader's life cycle. Therefore, the cumulative effect of multiple functional groups (or species) acting on multiple resources is an alternative mechanism that could generate negative relationships between diversity and invasibility in a variety of biological systems.

France, K.E. and Duffy, J.E. **Consumer diversity mediates invasion dynamics at multiple trophic levels.** *Oikos* 113(3): 515-529, 2006.

Notes: Theory and recent experiments, mostly focused on plants, indicate that biodiversity can reduce invasion success, but diversity effects on mobile animal invasion have received little attention. We tested effects of mobile crustacean grazer diversity (species richness) on the establishment of invaders at multiple trophic levels in flow-through seagrass mesocosms. On average, increasing diversity of resident grazers reduced population growth and biomass of experimentally introduced grazers. This increase in invasion resistance was concurrent with reductions in food and habitat availability and increases in resident density, paralleling previous results with plants. In many cases, mixtures of resident species resisted invasion better than did any single resident species, arguing that interactions among residents, rather than a sampling mechanism, explained diversity effects on invasion. Higher grazer diversity also generally reduced biomass of naturally recruiting invertebrates and algae and shifted epiphytic community dominance from algae to sessile invertebrates. Exploitation competition, then, appears to contribute to the diversity effect on invasion in both plant and animal systems. Our results further suggest that resident competitive advantage may also be at work in multi-trophic level systems. Thus, negative effects of local diversity on invasion appear general, and trophically mediated processes can also strongly influence invader success and identity in multi-trophic level systems.

Mann, R., Harding, J.M., and Westcott, E. **Occurrence of imposex and seasonal patterns of gametogenesis in the invading veined rapa whelk *Rapana venosa* from Chesapeake Bay, USA.** *Marine Ecology Progress Series* 310: 129-138, 2006.

Notes: The prevalence and intensity of imposex and observations on the seasonal gametogenic cycle are reported for the Asian veined rapa whelk *Rapana venosa* (Valenciennes, 1846), an invader of the Chesapeake Bay on the North American Atlantic coast. Adult whelks from opportunistic collections by commercial fishermen demonstrated inactivity from mid-November through early March, copulation from February through mid-November, and egg-laying activity from late May through August. All imposex females examined did not have a functional vas deferens (below Stage 3 on the vas deferens scale of Gibbs et al. 1987; *J Mar Biol Assoc UK* 67:507-523) and were expected to function normally in reproduction. Although a preponderance of imposex females over 'normal' females by a ratio exceeding 2:1 was observed in 4 out of 5 regions examined in lower Chesapeake Bay, there was no significant difference in the numbers of functional females (imposex females and normal females) observed in any region. Shell lengths and wet tissue weights (g) of both imposex females and males were approximately the same and sexual dimorphism was not apparent at the population level. However, true female rapa whelks had lower wet tissue weights than either imposex females or males. Individual rapa whelks did not appear to be food-limited in the Chesapeake Bay, and the described reproductive activity suggests continued invasion within Chesapeake Bay habitats.

Ruesink, J.L., Feist, B.E., Harvey, C.J., Hong, J.S., Trimble, A.C., and Wisheart, L.M. **Changes in productivity associated with four introduced species: ecosystem transformation of a 'pristine' estuary.** *Marine Ecology Progress Series* 311: 203-215, 2006.

Notes: Multiple stressors in estuaries can cause declines in native species and impairment of ecosystem goods and services. In contrast, one stressor - the introduction of non-native species - actually leads to higher local richness. We examined the changes in ecosystem function associated with introductions into Willapa Bay, Washington, USA, a relatively undeveloped estuary with 45 documented exotic marine species. The replacement of native oysters by 2 new bivalve species has increased secondary production of harvested suspension feeders by 250% over peak historic values (3.3×10^5 vs. 0.9×10^5 kg dry wt yr⁻¹), based on > 150 yr of records of harvested biomass. Key aspects of aquaculture - particularly planted area - have remained constant over time, so we attribute much of the altered secondary production to higher growth rates of non-native species. The addition of 2 tracheophytes has increased primary production on the tideflats by > 50%, (5.3×10^7 vs. 3.5×10^7 kg dry wt yr⁻¹), which we calculated by scaling up local measurements of plant growth to the total area occupied by each species. These changes in production are also associated with altered detritus, water filtration, and biogenic habitat. Because other stressors are largely absent from Willapa Bay, the addition of particular exotic species has dramatically enhanced system production, while fundamentally reshaping the ecological character of the estuary. These strong ecological impacts of introduced species have rarely been measured at whole-ecosystem scales, and they occur in part because new species occupy habitats where similar native species were not present.

Zaleski, S.F. and Murray, S.N. **Taxonomic diversity and geographic distributions of aquarium-traded species of *Caulerpa* (Chlorophyta: Caulerpaceae) in southern California, USA.** *Marine Ecology Progress Series* 314: 97-108, 2006.

Notes: We identified 14 taxa (10 species) of *Caulerpa* from retail aquarium outlets in southern California, USA, suggesting that the aquarium industry has the potential to be an important vector for transporting these non-native seaweeds into distant geographic regions. Seaweeds were sold in 58% and species of *Caulerpa* in 52% of the 50 stores visited between November 2000 and August 2001. *C. serrulata* var. *hummii* (18%), *C. taxifolia* (14%), *C. racemosa* (14%), and *C. racemosa* var. *lamourouxii* (14%) were the most commonly encountered taxa. The 14 aquarium-traded *Caulerpa* taxa were distributed from tropical to temperate waters. Only 3 (*C. ashmeadii*, *C. serrulata* var. *hummii* and *C. microphyssa*) were confined to the tropics, whereas 12 had distributions extending into temperate seas. These temperate components to their distributions indicate that, if introduced, several other taxa of aquarium-traded *Caulerpa* besides *C. taxifolia* might be capable of establishing populations in southern Californian or other temperate waters.

Petersen, C. **Range expansion in the northeast Pacific by an estuary mud crab - a molecular study.** *Biological Invasions* 8(4): 565-576, 2006.

Notes: The potential habitat of the introduced estuary crab *Rhithropanopeus harrisi* (Gould, 1841) in Oregon and central California was surveyed to discover current sites of presence. In order to infer the direction of range expansion and attempt to trace the source population, a 523 bp sequence of the mitochondrial gene Cytochrome c oxidase I was compared between three Pacific populations (28-39 individuals/population), with one mid-Atlantic population included for assessment as a hypothetical source. Notably, this species persists at fairly low densities in the Pacific despite its apparent habitat tolerance, and range expansion and establishment over a broad geographic area. It was possible to deduce that the current Pacific populations descend from a single introduction event. Despite a genetic bottleneck, the historical record of range expansion in a northward direction is reinforced by the molecular data. In order to consider the plausibility of coastal advective transport versus ballast water or aquaculture transport, the new genetic information is evaluated together with the records of northward range expansion for this and other species introduced into San Francisco Bay, including the European green crab, which has had a similar population trajectory. The genetic and temporal patterns that should be expected under these contrasting mechanisms are discussed for typical NE Pacific oceanic conditions, and during years influenced by the El Niño-Southern oscillation.

Freshwater, D.W., Montgomery, F., Greene, J.K., Hamner, R.M., Williams, M., and Whitfield, P.E. **Distribution and identification of an invasive *Gracilaria* species that is hampering commercial fishing operations in southeastern North Carolina, USA.** *Biological Invasions* 8(4): 631-637, 2006.

Notes: A newly abundant *Gracilaria* species in the sounds of southeastern North Carolina has become a problem for commercial fishing and industries drawing water from the lower Cape Fear River. DNA sequence analyses have shown that this species is *Gracilaria vermiculophylla*, a taxon originally described from East Asia. Surveys for *G. vermiculophylla* have shown that it has a discontinuous distribution in the sounds of southeastern North Carolina, and suggest that it is spreading. *Gracilaria vermiculophylla* meets 6 of the 10 criteria used to help identify invasive species in that it has only recently appeared in southeastern North Carolina; is associated with human mechanisms of dispersal; has a restricted distribution; has disjunct populations in isolated oceans; no means of active dispersal, and an exotic evolutionary origin. The species may also meet two additional criteria as its local range is believed to be expanding, and it is filling a previously unoccupied seasonal niche. These factors taken together strongly suggest that *G. vermiculophylla* is an invasive species in southeastern North Carolina.

Bolton, T.F. and Graham, W.M. **Jellyfish on the rocks: bioinvasion threat of the international trade in aquarium live rock.** *Biological Invasions* 8(4): 651-653, 2006.

Notes: So-called "live rock" - coral rock that harbours a vast array of marine organisms that enhance the aesthetics and function of aquariums - is an increasingly valuable commodity in the aquarium industry. Live rock is primarily collected from the edges of reefs in the Indo-Pacific, where its export is an important source of revenue for many small subsistence communities. The trade in live rock is not subject to quarantine restrictions in its principal markets, yet poses a serious threat of bioinvasion because of the potential for inadvertent or deliberate release of the organisms that reside on its surfaces. This threat is demonstrated here by the transportation of jellyfish polyps of a species of *Cassiopea* (upside-down jellyfish) on live rock imported to the USA from the Indo-Pacific. Jellyfish have recently come into the spotlight as significant bioinvaders. The transportation of jellyfish on live rock provides the first direct evidence of a translocation vector for these organisms. Invasive species are a principal threat to biodiversity and are responsible for enormous economic losses globally. The unregulated trade in live rock presents a serious bioinvasion risk that warrants the urgent attention of regulatory bodies.

Lewis, J.A., Watson, C., and ten Hove, H.A. **Establishment of the Caribbean serpulid tubeworm *Hydroides sanctaecrucis* Kroyer [in] Morch, 1863, in northern Australia.** *Biological Invasions* 8(4): 665-671, 2006.

Notes: The serpulid tubeworm *Hydroides sanctaecrucis* is recorded from tropical northern Australia for the first time. This species is native to the Caribbean, where it is common in coastal lagoons, and has not previously been reliably recorded from the western Pacific. The species was identified after heavy and unusual serpulid fouling was noted on vessel hulls in Cairns, north Queensland, and hull fouling is considered the most probable vector for its translocation to the western Pacific. In

northern Australia, *H. sanctaecrucis* displays similar traits to other fouling and now widely dispersed fouling serpulids such as *Hydroides elegans*, *H. exoensis* and *Ficopomatus enigmaticus*.

Spivak, E.D., Boschi, E.E., and Martorelli, S.R. **Presence of *Palaemon macrodactylus* Rathbun 1902 (Crustacea: Decapoda: Caridea: Palaemonidae) in Mar del Plata harbor, Argentina: first record from southwestern Atlantic waters.** *Biological Invasions* 8(4): 673-676, 2006.

Notes: Adults of the palaemonid prawn *Palaemon macrodactylus* Rathbun, 1902 were reported for the first time from the southwestern Atlantic waters. Males and ovigerous females were collected in Mar del Plata harbor (38°03' S; 57°31'W), Argentina; larvae obtained from one of the collected females were reared in the laboratory until the juvenile stage. The geographical range of *P. macrodactylus* was previously restricted to the Pacific Ocean: it was originally described in Japan and has been reported as an invasive species in the western coast of USA in the 1950's and in Australia in the 1970's. Recently, this prawn has been also reported from European waters.

Brusati, E.D. and Grosholz, E.D. **Native and introduced ecosystem engineers produce contrasting effects on estuarine infaunal communities.** *Biological Invasions* 8(4): 683-695, 2006.

Notes: Cordgrasses in the genus *Spartina* are good examples of ecosystem engineers that modify habitat structure in estuaries throughout the world. In San Francisco Bay, California, USA, marshes containing native California cordgrass (*Spartina foliosa*) are being invaded by a hybrid (*S. alterniflora* x *S. foliosa*) formed after introduction of *S. alterniflora*. This study compared vegetation, sediment structure, and infaunal invertebrates in native and invaded marshes. We hypothesized that differences in the physical structure between *S. foliosa* and hybrid *Spartina* would be reflected in differences in density, biomass, diversity, and taxonomic composition of infauna. Hybrid *Spartina* modifies habitat structure more than *S. foliosa* by producing taller stems, and greater plant biomass both above- and belowground while occupying a much wider tidal range, thereby transforming open mudflats to a vegetated habitat. In general, *S. foliosa* areas contained significantly higher densities of benthic infauna than adjacent mudflats, while hybrid *Spartina* areas never contained greater infaunal densities than mudflats. This is because *S. foliosa* produces a moderate level of structure that can facilitate benthic invertebrates, whereas hybrid *Spartina* produces so much structure, particularly belowground, that it actually excludes invertebrates. Therefore, we suggest that these two closely related species both act as ecosystem engineers, but with opposing effects on invertebrate communities.

Bushek, D. and Boyd, S. **Seasonal abundance and occurrence of the Asian isopod *Synidotea laevidorsalis* in Delaware Bay, USA.** *Biological Invasions* 8(4): 697-702, 2006.

Notes: In 1999 the marine isopod *Synidotea laevidorsalis* (Miers 1881), indigenous to the northwest Pacific, was first documented in Delaware Bay, USA. We monitored weekly recruitment of this isopod and several other motile species in the Maurice River, a tributary of Delaware Bay. A spatial survey was also conducted. Abundance of *S. laevidorsalis* varied seasonally but overwhelmingly dominated other co-occurring species by an order of magnitude or more throughout most of the year. Isopod abundance increased through the summer of 2004 and peaked in September, coincident with the passing of Hurricane Ivan. Field observations documented large populations, frequently associated with pilings and buoy lines, throughout Delaware Bay in salinities of 4 through 22 ppt. The dramatic abundance of this isopod indicates that there is considerable potential for altering community structure. This isopod has yet to be observed along the Atlantic Coast of New Jersey or in Chesapeake Bay, but it has been reported near Charleston, SC.

Bando, K.J. **The roles of competition and disturbance in a marine invasion.** *Biological Invasions* 8(4): 755-763, 2006.

Notes: Two hypotheses for the decline of native species are the superior exploitation of disturbance by exotic species and the competitive displacement of native species by their exotic counterparts. Theory predicts that functional similarity will increase the intensity of competition between native and invasive species. Ecologically important "foundation" species, *Zostera marina* and other seagrasses have globally declined during the past century. This study used transplant and vegetation removal

experiments to test the hypotheses that disturbance and competitive interactions with an invasive congener (*Z. japonica*) are contributing to the decline of native *Z. marina* in the northeastern Pacific. Interspecific competition reduced *Z. marina* and *Z. japonica* above-ground biomass by 44 and 96%, respectively, relative to intraspecific competition. Disturbance substantially enhanced *Z. japonica* productivity and fitness, and concomitantly decreased *Z. marina* performance, effects that persisted two years following substratum disturbance. These results demonstrate that disturbance and competitive interactions with *Z. japonica* reduce *Z. marina* performance, and suggest that *Z. japonica*'s success as an invasive species stems dually from its ability to persist in competition with *Z. marina* and its positive response to disturbance. These results highlight the importance of understanding the interconnected roles of species interactions and disturbance in the decline of seagrass habitats, and provide a rationale for amending conservation policy in Washington State. In the interest of conserving native eelgrass populations, the current policy of protecting both native and invasive *Zostera* spp. should be refined to differentiate between native and invader, and to rescind the protection of invasive eelgrass.

Lewis, P.N., Bergstrom, D.M., and Whinam, J. **Barging in: A temperate marine community travels to the subantarctic.** *Biological Invasions* 8(4): 787-795, 2006.

Notes: A diverse fouling community discovered encrusting a barge intended for deployment at subantarctic Macquarie Island is described and its role as a transport vector for non-indigenous marine organisms is discussed. The barge proved to be a potential vector capable of transporting entire epibenthic communities, 20 species in total, from a temperate estuarine system (Derwent River, Tasmania, Australia) into the subantarctic. For one invasive amphipod species *Monocorophium acherusicum*, over 136 000 individuals including ovigerous females were calculated to be associated with the barge fouling community. Although distinct differences exist between the thermal ranges of Macquarie Island and the Bruny bioregion of Tasmania, a hazard assessment based on the Gower similarity coefficient suggested sufficient similarity between the two environments to allow for survival of transported organisms for eight months of the year. Several invasive species are able to survive the thermal conditions of the subantarctic irrespective of the time of year. This study identifies the need for effective quarantine measures aimed at identifying and managing marine biosecurity hazards in association with human activities in high latitude regions.

Krakau, M., Thielges, D.W., and Reise, K. **Native parasites adopt introduced bivalves of the North Sea.** *Biological Invasions* 8(4): 919-925, 2006.

Notes: Introduced species may have a competitive advantage over native species due to a lack of predators or pathogens. In the North Sea region, it has been assumed that no metazoan parasites are to be found in marine introduced species. In an attempt to test this assumption, we found native parasites in the introduced bivalves *Crassostrea gigas* and *Ensis americanus* with a prevalence of 35% and 80%, respectively, dominated by the trematode *Renicola roscovita*. When comparing these introduced species with native bivalves from the same localities, *Mytilus edulis* and *Cerastoderma edule*, trematode intensity was always lower in the introduced species. These findings have three major implications: (1) introduced bivalves are not free of detrimental parasites which raises the question whether introduced species have an advantage over native species after invasion, (2) introduced bivalves may divert parasite burdens providing a relief for native species and (3) they may affect parasite populations by influencing the fate of infectious stages, ending either in dead end hosts, not being consumed by potential final hosts or by adding new hosts. Future studies should consider these implications to arrive at a better understanding of the interplay between native parasites and introduced hosts.

Rodriguez, L.F. **Can invasive species facilitate native species? Evidence of how, when, and why these impacts occur.** *Biological Invasions* 8(4): 927-939, 2006.

Notes: Although the predatory and competitive impacts of biological invasions are well documented, facilitation of native species by non-indigenous species is frequently overlooked. A search through recent ecological literature found that facilitative interactions between invasive and native species occur in a wide range of habitats, can have cascading effects across trophic levels, can re-structure communities, and can lead to evolutionary changes. These are critical findings that, until now, have been mostly absent from analyses of ecological impacts of biological invasions. Here I present evidence for several mechanisms that exemplify how exotic species can facilitate native species. These mechanisms include habitat modification, trophic subsidy, pollination, competitive release, and predatory release. Habitat modification is the most frequently documented mechanism, reflecting the drastic changes generated by the invasion of functionally novel habitat engineers.

Further, I predict that facilitative impacts on native species will be most likely when invasive species provide a limiting resource, increase habitat complexity, functionally replace a native species, or ameliorate predation or competition. Finally, three types of facilitation (novel, substitutive, and indirect) define why exotic species can lead to facilitation of native species. It is evident that understanding biological invasions at the community and ecosystem levels will be more accurate if we integrate facilitative interactions into future ecological research. Since facilitative impacts of biological invasions can occur with native endangered species, and can have wide-ranging impacts, these results also have important implications for management, eradication, and restoration.

Towns, D.R., Atkinson, I.A.E., and Daugherty, C.H. **Have the harmful effects of introduced rats on islands been exaggerated?** *Biological Invasions* 8(4): 863-891, 2006.

Notes: Introduced rats are now being eradicated from many islands. Increasingly, these eradications are contested by activists claiming moral, legal, cultural, historic or scientific reasons and poorly documented evidence of effects. We reviewed the global literature on the effects of rats on island flora and fauna. We then used New Zealand as a case study because of its four-decade history of rat eradications and many detailed and innovative studies of how rats affect native species. These include use of exclosures, local manipulations of rat populations, video surveillance, and measurements of responses following eradications. The most intensive studies have been on the Pacific rat (*Rattus exulans*), a small South-East Asian species spread by Polynesians throughout the Pacific. These and the more recently introduced Norway rat (*R. norvegicus*) and ship (roof) rat (*R. rattus*) suppress some forest plants, and are associated with extinctions or declines of flightless invertebrates, ground-dwelling reptiles, land birds, and burrowing seabirds. On islands off France, Norway rats are also implicated in declines of shrews. Globally, ship rats were associated with declines or extinctions of the largest number of indigenous vertebrate species (60), including small mammals such as deer mice and bats. Effects of rats on forest trees and seabird populations are sufficiently pervasive to affect ecosystem structure and function. However, the data are patchy. Deficiencies in our knowledge would be reduced by documenting distribution and abundance of indigenous species before and after eradications. Comprehensive measurements of the responses of indigenous species to rat eradications would enable the development of testable models of rat invasion effects.