Marine Science Review 157

Introduced species

SeaWeb
Leading Voices for a Healthy Ocean

In this review:

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

A. Recent articles with no abstract available

Sampaio, C.L.S. and Rosa, I.L. **Predation of an alien species of crab (*Charybdis hellerii* Milne Edwards) by a native octopus species on NE Brazilian reefs.** *Coral Reefs* 25(1): 58, 2006.

B. Recent articles with abstracts

Bulleri, F. and Airoldi, L. **Artificial marine structures facilitate the spread of a non-indigenous green alga, *Codium fragile* ssp *tomentosoides*, in the north Adriatic Sea.** *Journal of Applied Ecology* 42(6): 1063-1072, 2005.

Notes: 1. Artificial structures have become ubiquitous features of coastal landscapes. Although they provide novel habitats for the colonization of marine organisms, their role in facilitating biological invasions has been largely unexplored. 2. We investigated the distribution and dynamics of the introduced green alga, *Codium fragile* ssp. *tomentosoides*, at a variety of spatial scales on breakwaters in the north Adriatic Sea, and analysed experimentally the mechanisms underlying its establishment. We assessed the provision of sheltered habitats by breakwaters, the role of disturbance (e.g. from recreational harvesting and storms) acting at different times of the year, and the interactions between *Codium* and the dominant native space-occupier, the mussel *Mytilus galloprovincialis*. 3. *Codium fragile* ssp. *tomentosoides* has established viable populations on artificial structures along the shores investigated. The density, cover and size (length, branching and weight) of annual erect thalli of *Codium* was enhanced in sheltered conditions, resulting in the monopolization of landward low-shore habitats of breakwaters. 4. On the landward sides of breakwaters, disturbance enhanced recruitment of *Codium*. The time when bare space was provided within mussels beds was crucial. Removal of mussels in April or January did not affect the recruitment of *Codium*, whereas harvest in August, shortly before *Codium* gamete release, doubled its success. On the seaward sides of breakwaters, the effects of disturbance were more complex because mussels both inhibited recruitment of *Codium* and provided shelter from wave action to adult thalli. 5. Synthesis and applications. Artificial structures can provide suitable habitats for non-indigenous marine species and function as corridors for their expansion. Physical (wave exposure) and biotic (resident assemblages) features of artificial habitats can be important determinants of their susceptibility to biological invasions. Alternative options in the design of artificial structures and effective management of native assemblages could minimize their role in biological invasions. In particular, increased water motion and retention of space by mussels in spring-summer would be effective in reducing the ability of *C. fragile* ssp. *tomentosoides* to persist on the breakwaters investigated in this study.

Kahng, S.E. and Grigg, R.W. **Impact of an alien octocoral, *Carijoa riisei*, on black corals in Hawaii.** *Coral Reefs* 24(4): 556-562, 2005.

Notes: In 2001 *Carijoa riisei*, an octocoral native to the tropical Western Atlantic, was discovered overgrowing black corals in the Au'au Channel in Hawaii. In this paper data from a 2001 survey are reanalyzed and combined with new data from 2003 and 2004 to assess the ecological impact in greater detail. *C. riisei* differentially affected reproductively mature black coral colonies with maximum impact between 80 and 105 m. The pattern of *C. riisei* overgrowth on black corals and *C. riisei* on the substrata appears to be bounded by high irradiance in shallow water and cold temperature in deep water. Evidence suggests that the *C. riisei* settlement on black corals is facilitated by other epifauna. Once established, *C. riisei* spreads vegetatively and smothers the coral. The success of the *C. riisei* invasion appears to be unaided by anthropogenic disturbance and is at least partially attributable to Hawaii's depauperate shallow-water (< 100 m) octocoral fauna.

Andersen, M.C. **Potential applications of population viability analysis to risk assessment for invasive species.** *Human and Ecological Risk Assessment* 11(6): 1083-1095, 2005.

Notes: Population viability analysis, the use of ecological models to assess a population's risk of extinction, plays an important role in contemporary conservation biology. The premise of this review is that models, concepts, and data analyses that yield results on extinction risk of threatened and endangered species can also tell us about establishment risks of potentially invasive species. I briefly review important results for simple unstructured models, demographic models, and spatial models, giving examples of the application of each type of model to invasive species, and general conclusions about the applicability of each type of model to risk analysis for invasive species. The examples illustrate a portion of the range of potential applications of such models to invasive species, and some of the types of predictions that they can provide. They also highlight some of the limitations of such models. Finally, I present several conjectures and open research questions concerning the application of population viability analyses to risk analysis and control of invasive species.

Laffaille, P., Petillon, J., Parlier, E., Valery, L., Ysnel, F., Radureau, A., Feunteun, E., and Lefeuvre, J.C. **Does the invasive plant *Elymus athericus* modify fish diet in tidal salt marshes?** *Estuarine, Coastal and Shelf Science* 65(4): 739-746, 2005.

Notes: The invasion of Mont-Saint-Michel Bay salt marshes (France) by a grass species (*Elymus athericus*) has led to important changes in vegetation cover, which is likely to modify the habitat for many invertebrates. Some of them constitute the main food items for several fish species, such as young sea bass (*Dicentrarchus labrax*) and sand goby (*Pomatoschistus minutus*), that feed in salt marsh creeks during high fides. As a result, fish nursery functions of salt marshes could be modified by the *E. athericus* invasion. In order to test this hypothesis, gut contents of the two most abundant fish species (sea bass and sand goby) were compared before and after *E. athericus* invasion in the same salt marsh creek and using the same methodology. The accessibility and availability of the main food item, the semi-terrestrial amphipod *Orchestia gammarella*, were estimated and compared between invaded (dominated by *E. athericus*) and original areas (dominated by *Atriplex portulacoides*). Gut content analysis showed a significantly greater percentage of fish leaving with empty guts from *E. athericus* areas than from *A. portulacoides* areas. The sea bass diet composition study showed a major shift in the relative importance of the main food items: before *E. athericus* invasion, diets were dominated by the semi-terrestrial species *O. gammarella*, whereas after the *E. athericus* invasion they were dominated by a marine mysid *Neomysis integer*. The same trend was found for sand gobies, with a shift of the main food item from *O. gammarella* before invasion to the polychaete *Hediste diversicolor* after invasion. These trophic changes may be explained by the lower accessibility and availability of *O. gammarella* in invaded communities than in natural ones. The *E. athericus* invasion, observed throughout northern Europe, is thus likely to disturb trophic function of natural salt marshes for fish. This preliminary study of the *E. athericus* invasion is also an illustration that invasive species are an urgent problem in conservation biology.

Bart, D., Burdick, D., Chambers, R., and Hartman, J.-M. **Human facilitation of *Phragmites australis* invasions in tidal marshes: A review and synthesis.** *Wetlands Ecology and Management* 14(1): 53-65, 2006.

Notes: Efforts to manage or prevent *Phragmites australis* invasion in salt and brackish marshes are complicated by the lack of a general causal role for specific human activities. The pattern of invasion within a marsh differs among sites, and each may have different causal histories. A review of the literature finds three establishment/invasion patterns: (1) from stands established on ditch- or creek-bank levees toward interior portions of high marshes, (2) from stands along upland borders toward high marsh interiors, and (3) centroid spread from high marsh stands established in ostensibly random locations. Each invasion pattern seems to have different anthropogenic precursors, therefore preventing generalizations about the role of any one human activity in all sites. However, historical and experimental evidence suggests that regardless of invasion pattern, establishment is much more likely at sites where rhizomes are buried in well-drained, low salinity marsh areas. Any human activity that buries large rhizomes, increases drainage, or lowers salinity increases chances of establishing invasive clones. To integrate these patterns and improve our understanding of the rapid spread of *Phragmites*, recent evidence has been synthesized into a dichotomous flow chart which poses questions about current site conditions and the potential for proposed activities to change site conditions that may facilitate invasion. This simple framework could help managers assess susceptibility and take preventative measures in coastal marshes before invasion occurs or before removal becomes very expensive.

Catling, P.M. **Effects of invasive alien plants on birds : some examples from North America.** *Biodiversity* 6(3): 30-39, 2005.

Notes: Analysis of declining bird population indicates that invasive aliens are a major problem. However, in most cases the problem is visualized in terms of invasive animals and introduced diseases. The role of invasive alien plants in declining bird populations is less well known. By changing the structure and composition of vegetation and by reducing or elimination vegetative biodiversity, alien plants can reduce food, cover and optimal nesting sites for birds. The effect of alien plants is sometimes not obvious and is frequently complex with regard to management. The problem is especially evident in protected areas that are essential to bird populations and often represent the last opportunity to avoid extinction. Many biologists agree that much more research on all aspects of alien invasive plants is required and it is vital to address the problem immediately. Policy makers may be able to take advantage of the enormous popularity and economic importance of birds to deal with the invasive plant issue which affects all of biodiversity.

Cho, T.O., Won, B.Y., and Fredericq, S. ***Antithamnion nipponicum*** **(Ceramiaceae, Rhodophyta), incorrectly known as *A. pectinatum* in western Europe, is a recent introduction along the North Carolina and Pacific coasts of North America.** *European Journal of Phycology* 40(4): 323-335, 2005.

Notes: Female and male reproductive structures in material from California known as *Antithamnion hubbsii* are illustrated and described for the first time. This partly prostrate species is characterized vegetatively by pinnae arranged in distichous opposite pairs, bearing adaxial and abaxial pinnules, with the distal-most pinnules restricted to the abaxial side of pinnae. Basal cells of the pinnae produce multicellular rhizoids with digitate holdfasts as well as indeterminate lateral axes, and gland cells originate adaxially alongside the lower pinnule cells. *Antithamnion nipponicum* has been placed in synonymy with *Antithamnion pectinatum*, a species described from Auckland I., New Zealand. The latter is here recognized as a separate southern hemisphere species bearing adaxial and abaxial distal-most pinnules and new indeterminate lateral axes in place of pinnae. The correct name for the invasive species known in western Europe as *A. pectinatum* is *A. nipponicum*. Our phylogenetic analyses of rbcL sequence data also indicate that Californian *A. hubbsii* and *A. nipponicum* are conspecific, but distinct from *A. pectinatum* and *A. aglandum*. The distribution of *A. nipponicum* includes the Pacific coast of California and the Atlantic coast of North Carolina, USA. Its presence is inferred in the Mediterranean Sea. Historical reports suggest that this species was recently introduced from Japan.

Simberloff, D. **Non-native species do threaten the natural environment!** *Journal of Agricultural and Environmental Ethics* 18(6): 595-607, 2005.

Notes: Sagoff [*Journal of Agricultural and Environmental Ethics* 18 (2005), 215-236] argues, against growing empirical evidence, that major environmental impacts of non-native species are unproven. However, many such impacts, including extinctions of both island and continental species, have both been demonstrated and judged by the public to be harmful. Although more public attention has been focused on non-native animals than non-native plants, the latter more often cause ecosystem-wide impacts. Increased regulation of introduction of non-native species is, therefore, warranted, and, contra Sagoff's assertions, invasion biologists have recently developed methods that greatly aid prediction of which introduced species will harm the environment and thus enable more efficient regulation. The fact that introduced species may increase local biodiversity in certain instances has not been shown to result in desired changes in ecosystem function. In other locales, they decrease biodiversity, as they do globally.

Chikina, M.V. and Kucheruk, N.V. **Long-term changes in the structure of coastal benthic communities in the northeastern part of the Black Sea: Influence of alien species.** *Oceanology* 45: S176-S182, 2005.

Notes: Changes in the structure of benthic communities in the northeastern part of the Black Sea were determined by comparing results of surveys made in 1957, 1963, 1968; in 1980; in 1989; and in 1999-2000 with surveys made in 2001-2004. The species composition and structure of communities differed significantly between surveys, but only the southern part of the shelf (Gelendzhik-Adler) has undergone especially strong changes, while the North Caucasian coast has remained intact. Since introduction of *Mnemiopsis leidyi* (Agassiz, 1865) in 1988 a catastrophic decline of quantity and biomass of dominating bivalves has been observed. It was caused not only by *Mnemiopsis* predation, but also by the predation of *Rapana venosa* (Valenciennes, 1846). The biodiversity of benthic communities was reduced by half. Since the earlier studies, exotic bivalve *Anadara inaequivalvis* (Bruguiere, 1789) have become abundant. Plausible reasons for such drastic alterations are discussed.

Dwyer, G. and Morris, W.F. **Resource-dependent dispersal and the speed of biological invasions.** *American Naturalist* 167(2): 165-176, 2006.

Notes: Many mobile organisms exhibit resource-dependent movement in which movement rates adjust to changes in local resource densities through changes in either the probability of moving or the distance moved. Such changes may have important consequences for invasions because reductions in resources behind an invasion front may cause higher dispersal while simultaneously reducing population growth behind the front and thus lowering the number of dispersers. Intuiting how the interplay between population growth and dispersal affects invasions is difficult without mathematical models, yet most models assume dispersal rates are constant. Here we present spatial-spread models that allow for consumer-resource interactions and resource-dependent dispersal. Our results show that when resources affect the probability of dispersal, then the invasion dynamics are no different than if resources did not affect dispersal. When resources instead affect the distance dispersed, however, the invasion dynamics are strongly affected by the strength of the consumer-resource interaction, and population cycles behind the wave front lead to fluctuating rates of spread. Our results suggest that for actively dispersing invaders, invasion dynamics can be determined by species interactions. More practically, our work suggests that reducing invader densities behind the front may be a useful method of slowing an invader's rate of spread.

Igual, J.M., Forero, M.G., Gomez, T., Orueta, J.F., and Oro, D. **Rat control and breeding performance in Cory's shearwater (*Calonectris diomedea*): effects of poisoning effort and habitat features.** *Animal Conservation* 9(1): 59-65, 2006.

Notes: Introduced predators are one of the main threats to island avifaunas. However, the magnitude of their impact in the Mediterranean has not often been studied. This is the case for the introduced alien black rats *Rattus rattus*, the most destructive predator of seabirds in the Mediterranean. Here, we analyse the impact of black rats on the breeding performance of Cory's shearwater *Calonectris diomedea* breeding at the Chafarinas Islands, an archipelago with a very high density of rats. An intensive rat control campaign (through anticoagulant poison) was carried out during 1999-2004 at two shearwater sub-colonies with contrasting habitat features (vegetated vs. rocky). Breeding success of Cory's shearwaters increased in proportion to the effort of rat control. Such increase was mainly due to a decline in black rat predation on chicks, while eggs losses remained constant throughout the period. We found a differential effectiveness of rat control in each sub-colony. The increase in breeding success after rat control was higher in the sub-colony with lower breeding success (the vegetated habitat), but this parameter never reached the values shown by the other sub-colony (the rocky habitat). Our results suggest that habitat characteristics of each case of study must be taken into account when designing and evaluating specific rat control programs.

Minchinton, T.E., Simpson, J.C., and Bertness, M.D. **Mechanisms of exclusion of native coastal marsh plants by an invasive grass.** *Journal of Ecology* 94(2): 342-354, 2006.

Notes: Determining the mechanisms by which invasive species exclude natives is critical for conserving and restoring native populations in impacted habitats. In recent decades the grass *Phragmites australis* has been aggressively invading coastal marshes of North America, with monocultures often replacing diverse assemblages of plants. Our objective was to quantify how *P. australis* modifies the abiotic (soil and light conditions) and biotic (litter and shoots) environment and to determine the mechanisms by which it excludes two common forbs, the annual chenopod *Atriplex patula* var. *hastata* and the perennial aster *Solidago sempervirens*, from the highest tidal elevations of a brackish marsh in southern New England, USA. In a 3-year field experiment we added seeds of both forb species to stands of *P. australis*, where we manipulated shoots and litter in an orthogonal design, and to uninvaded marsh areas dominated by the rush *Juncus gerardi*, where we manipulated the shoots of the marsh vegetation. In general, seedling establishment and the number of plants surviving until the end of the growing season were substantially greater in areas not invaded by *P. australis*, and both shoots and litter limited the abundance of forbs within stands. Forbs surviving within stands of *P. australis* grew larger and produced more seeds than those in uninvaded areas, indicating that changes to the soil resulting from invasion do not preclude the survival of established forbs. This was confirmed by a glasshouse study where the performance of forbs in soil collected from within stands of *P. australis* was better than in soil from areas dominated by *J. gerardi*. Similar to many invasive grasses in terrestrial communities, *P. australis* excludes native forbs through competition, modifying the biotic environment of the marsh at both the ground (litter) and above-ground (shoots) levels. Our results suggest that successful invaders, such as *P. australis*, are likely to be the ones that can engineer habitats in multiple ways and limit populations of native species across several critical stages of their life history.

Kusakina, J., Snyder, M., Kristie, D.N., and Dadswell, M.J. **Morphological and molecular evidence for multiple invasions of *Codium fragile* in Atlantic Canada.** *Botanica Marina* 49(1): 1-9, 2006.

Notes: Since the first collection in 1989 from Mahone Bay (Nova Scotia), the highly invasive green macroalga *Codium fragile* has been spreading in Atlantic Canada and has become established along the coasts of Nova Scotia, Prince Edward Island and New Brunswick. Considerable morphological variation had been found among thalli from different collection sites. This variation may be caused by the presence of different subspecies, or by phenotypic plasticity of one of the subspecies. Morphometric and molecular investigations were performed on *Codium* collected from seven sites in Maritime Canada and one from Maine to evaluate these hypotheses. Based on both mucron length and ISSR markers, thalli separated into three groups, suggesting multiple introductions of *C. fragile* into Canada. A group from the eastern shore of Nova Scotia and the coast of New Brunswick is clearly ssp. *tomentosoides* that likely originates from the United States. A second group, growing in Malpeque Bay in Prince Edward Island, is possibly an asexual variant of ssp. *atlanticum*, another invasive subspecies of *C. fragile*. A third group, found in Caribou Harbour only, is an intermediate in terms of both mucron length and molecular data, suggesting a hybrid of ssp. *tomentosoides* and ssp. *atlanticum*. The origin of this intermediate group remains to be established.

Lages, B.G., Fleury, B.G., Ferreira, C.E.L., and Pereira, R.C. **Chemical defense of an exotic coral as invasion strategy.** *Journal of Experimental Marine Biology and Ecology* 328(1): 127-135, 2006.

Notes: The invasion success of exotic species has been frequently correlated to abiotic and biotic features of the receptor region and to the biological aspects of the invasive organism. There is, however, no information about defensive chemicals found in invasive species as strategy that could promote or facilitate an invasion in a marine environment. We conducted experimental field assays to verify the potential of secondary metabolites of an Indo-Pacific exotic soft coral, *Stereonephthya* aff. *curvata*, as a defensive chemical against generalist fish and as an allelopathic agent against the potential local competitor - the gorgonian *Phyllogorgia dilatata* in Arraial do Cabo, on the southeastern coast of Brazil. As a result of our experiments, it was confirmed as an efficient chemical defense against fishes by crude coral hexanic extract. In addition to its role as defense against consumers, the field experimental assay also verified that chemicals from this exotic coral had an allelopatic effect causing large necrosis on tissues of the Brazilian endemic gorgonian *P. dilatata*. Both defensive strategies observed may facilitate the perpetuation and/or expansion and characterize an expressive, invasive facilitator for *S.* aff. *curvata*. The obtained results indicate that this exotic coral species may be a real threat to the biological integrity of the Arraial do Cabo Harvest Reserve, Rio de Janeiro. In addition, the study reveals that defensive chemicals can be used to predict the potential invasiveness of introduced species.

Rossong, M.A., Williams, P.J., Comeau, M., Mitchell, S.C., and Apaloo, J. **Agonistic interactions between the invasive green crab, *Carcinus maenas* (Linnaeus) and juvenile American lobster, *Homarus americanus* (Milne Edwards).** *Journal of Experimental Marine Biology and Ecology* 329(2): 281-288, 2006.

Notes: Invasive organisms have the potential for competition with native organisms. In the Southern Gulf of St. Lawrence, juvenile American lobsters have a potential spatial overlap with adult green crabs. Crustaceans use agonistic behaviour to settle disputes, with the larger organism often winning contests for limited resources such as food and shelter. Two experiments were carried out using adult green crabs (53-76 mm carapace width) and juvenile American lobsters (28-57 mm carapace length). The first experiment used a limited food resource. We found that green crabs were the first to the food in all trials, fed in significantly more trials than lobsters and spent a significantly greater proportion of time with the food. The lobsters were only able to displace the green crabs from the food in 2 of 65 attempts. The second experiment was designed to examine shelter competition; unexpectedly some predation by green crabs on lobsters occurred, which allowed us to test hypotheses about how relative size and shelter use affect predation. Green crabs captured and consumed juvenile lobsters in 6 of 11 trials. The lobsters that survived spent significantly more time in shelter. There was no clear relationship between shelter use and size of lobster. The lobsters that were larger in relation to the green crabs suffered a higher rate of predation, which we believe was due to more conspicuous activity and less use of shelter. It appears that green crabs have the potential to negatively impact native juvenile lobster.

Kaldy, J.E. **Production ecology of the non-indigenous seagrass, dwarf eelgrass (*Zostera japonica* Ascher. & Graeb.), in a Pacific Northwest estuary, USA.** *Hydrobiologia* 553: 201-217, 2006.

Notes: The non-indigenous seagrass *Zostera japonica* Ascher. & Graeb. (dwarf eelgrass) was first identified in central Oregon (USA) estuaries about 30 years ago. The autecology of this species is poorly described at the southern end of its non-native range although several process oriented studies have been conducted. I examined the production ecology of *Z. japonica* in the Yaquina Bay estuary. Strong seasonal patterns in light and temperature appeared to control the seasonal variations in biomass and growth. Above- and below-ground biomass ranged between 40-100 and 70-170 gdw m(-2) respectively and seasonal changes in the root:shoot ratio were controlled by above-ground biomass dynamics. Shoot density ranged between 4000 and 11 000 shts m(-2). Areal leaf growth ranged between 0.1 and 1.7 gdw m(-2) d(-1) and annual production was about 314 +/- 60 gdw m(-2) y(-1) (mean SD). Nutrients were not limiting in this system as a result of coastal upwelling and watershed inputs. The *Z. japonica* population studied in Oregon exhibited different patterns of persistence, phenology and flowering intensity relative to other populations along its native and non-native range. These differences suggest that management policies developed for one site may not be appropriate for other sites. The data presented here greatly expands our knowledge base on *Z. japonica* and provides insight to the processes controlling the dynamics and spread of this non-indigenous seagrass.

Bulleri, F., Abbiati, M., and Airoldi, L. **The colonisation of human-made structures by the invasive alga *Codium fragile* ssp *tomentosoides* in the north Adriatic Sea (NE Mediterranean).** *Hydrobiologia* 555: 263-269, 2006.

Notes: Human-made structures, such as groynes, breakwaters, seawalls, pier pilings and floating pontoons, are becoming common features of the landscape in urbanised coastal and estuarine areas. Despite this tendency few studies have focused on their ecology or on their potential impacts on natural assemblages of organisms. When artificial structures are introduced in areas with little or no hard substrata, they not only provide novel habitats, which enables the colonisation of sandy areas by hard-bottom dwelling species, but they can also provide suitable habitats for exotic species. Along the north-east coast of Italy, sandy shores are protected from erosion by a line of breakwaters, which runs almost uninterrupted for about 300 km. These structures provide habitat for a variety of macroalgae and invertebrates and also for the invasive green alga *Codium fragile* ssp. *tomentosoides*. The aim of this study was, therefore, to investigate patterns of distribution of this alga on breakwaters in Cesenatico. In particular, we compared the density of thalli, biomass, length and degree of branching of C. *fragile* ssp. *tomentosoides* between the landward and the seaward sides of breakwaters, to test the hypothesis that sheltered habitats (landward) represent more suitable habitats than exposed habitats (seaward). In general, the landward side of breakwaters supported greater numbers of thalli of *C. fragile* ssp. *tomentosoides* than seaward sides. Thalli grew longer and more branched in sheltered habitats, leading to an overall larger biomass of the alga on the landward side of breakwaters. The presence of sheltered human-made hard substrata in the vicinity of major trading ports and sources of eutrophication could enhance the dispersal of invasive species across regional and geographic scales. Thus, the effects of artificial structures and introduced species on coastal assemblages cannot be evaluated separately, but their synergistic nature should be considered in planning strategies for conservation of biodiversity in coastal habitats.

---

deRivera, C.E., Ruiz, G.M., Hines, A.H., and Jivoff, P. **Biotic resistance to invasion: Native predator limits abundance and distribution of an introduced crab.** *Ecology* 86(12): 3364-3376, 2005.

Notes: Introduced species frequently escape the natural enemies (predators, competitors, and parasites) that limit their distribution and abundance in the native range. This reduction in native predators, competitors, and parasites may result in ecological release in the introduced range. However, biological interactions also can limit the establishment and spread of normative populations. The extent to which such biotic resistance occurs is poorly resolved., especially for marine ecosystems. Here we test whether a native predator, the blue crab *Callinectes sapidus*, affects the abundance and geographic range of the introduced European green crab *Carcinus maenas* in eastern North America. Both crab species occur in shallow, soft-sediment habitats of bays and estuaries, and their ranges overlap in eastern North America. First, we tested for a negative relationship in the abundances of the two species from trap samples across a 640-km (5.78º latitude) coastal transect. Second, we estimated variation in predation pressure on tethered *Carcinus maenas* across latitude and as a function of *Callinectes sapidus* abundance. Third, we measured predation rates on *Carcinus maenas* by *Callinectes sapidus* in field and laboratory experiments. Our results support the hypothesis that the native predator *Callinectes sapidus* provides biotic resistance to invasion and prevents the southward spread and establishment of *Carcinus maenas*. Within and across bays, *Carcinus maenas* were significantly less abundant at sites and depths with *Callinectes sapidus* compared with areas lacking *Callinectes sapidus*. Moreover, no *Carcinus maenas* were found in Chesapeake Bay, where *Callinectes sapidus* were most abundant. Predation of tethered *Carcinus maenas* increased with

Callinectes sapidus abundance. In laboratory and field experiments, *Callinectes sapidus* preyed readily on *Carcinus maenas*. Thus, we conclude the predation by *Callinectes sapidus*, alone or in combination with other factors, limits the abundance and geographic range of an invasive marine species.

Von Holle, B. and Simberloff, D. **Ecological resistance to biological invasion overwhelmed by propagule pressure.** *Ecology* 86(12): 3212-3218, 2005.

Notes: Models and observational studies have sought patterns of predictability for invasion of natural areas by nonindigenous species, but with limited success. In a field experiment using forest understory plants, we jointly manipulated three hypothesized determinants of biological invasion outcome: resident diversity, physical disturbance and abiotic conditions, and propagule pressure. The foremost constraints on net habitat invasibility were the number of propagules that arrived at a site and naturally varying resident plant density. The physical environment (flooding regime) and the number of established resident species had negligible impact on habitat invasibility as compared to propagule pressure, despite manipulations that forced a significant reduction in resident richness, and a gradient in flooding from no flooding to annual flooding. This is the first experimental study to demonstrate the primacy of propagule pressure as a determinant of habitat invasibility in comparison with other candidate controlling factors.

Claudi, R. and Ravishankar, T.J. **Quantification of risks of alien species introductions associated with ballast water discharge in the Gulf of St. Lawrence.** *Biological Invasions* 8(1): 25-44, 2006.

Notes: Canada has one of the longest navigable coastlines in the world, bordering the Atlantic, Arctic and Pacific Oceans, as well as the Great Lakes. Shipping is important to the Canadian national and international trade. Our coastal waters receive yearly over 52 million tonnes of ballast water from foreign ports around the world [Gauthier and Steel (1966) Canadian Manuscript Report of Fisheries and Aquatic Sciences 2380: 1-57]. Millions of tonnes of ballast water are discharged into the estuary of the St. Lawrences River and into the Gulf of St. Lawrence each year [Bourgeois et al. (2001) Rapp. Tech. Can. Sci. Halient Aquat. 2338; viii +34p]. Ballast water has been identified as one of the pathways by which alien aquatic species are introduced outside of their normal range. Under the current Canadian voluntary guidelines, all ships entering Canadian waters are expected to exchange ballast water outside of the Exclusive Economic Zone (EEZ). The 2001 Transport Canada survey showed that 77% of all ships entering the Gulf of St. Lawrence have exchanged ballast water in mid-ocean. Of the remainder, 8.5% were ships that traveled up the North American coastline and declared themselves exempt from the need to exchange. An additional 13% did not have a clear reason for not exchanging and may in fact also be part of the coastal trade. Less then 1% of all ships surveyed declared safety as a reason for not doing the exchange. The current guidelines make provisions for ballast water exchange in 'back-up areas' if, for safety reasons, exchange is not feasible offshore. Incoming foreign ships may exchange their ballast water within the Gulf of St. Lawrence and in the Laurentian Channel southeast of Anticosti Island, where the depth exceeds 300 m. The magnitude of the risk such ballast water exchanges pose, compared to risk from ballast water discharge in other areas of the Gulf of St. Lawrence, was evaluated using a probabilistic risk assessment (PRA) model. The risk was measured in terms of quantity of alien species introduced into various parts of the Gulf, including the Laurentian Channel, given current shipping patterns and practices. The relative risk to the Laurentian Channel is 0.5% of the quantity of alien species introduced in the Gulf and Estuary as a whole (including the Laurentian Channel). As the model also calculates the quantity of alien species introduced into other discreet areas of the Gulf of St. Lawrence and the freshwater estuary, it shows that under current shipping patterns and practices other areas of the Gulf of St. Lawrence are at vastly greater risk of alien species introductions through ballast water discharge. The model also shows that the greatest potential for introductions comes from the North American Atlantic Coast (FAO Region A), followed by FAO Region B, which includes the European and Scandinavian coast of the North Atlantic. To date there is no evidence, or official reports of successful ballast-water-mediated introductions of nonindigenous species to the Estuary or the Gulf of St. Lawrence. At this time, the model is restricted to predicting the risk of introductions. It does not incorporate the potential for survival of the alien species introduced. This refinement should be added if additional data can be obtained. Further, the possibility of introducing alien species into the Gulf of St. Lawrence on the hulls of incoming ships represents an additional risk to the one estimated by the model. In order to obtain a complete picture of the possibility of alien species introductions by shipping, this component of the rsk must be quantified.

Colautti, R.I., Bailey, S.A., vanOverdijk, C.D.A., Amundsen, K., and MacIsaac, H.J. **Characterised and projected costs of nonindigenous species in Canada.** *Biological Invasions* 8(1): 45-59, 2006.

Notes: Biological invasions by nonindigenous species (NIS) can have adverse effects on economically important goods and services, and sometimes result in an 'invisible tax' on natural resources (e.g. reduced yield). The combined economic costs of NIS may be significant, with implications for environmental policy and resource management; yet economic impact assessments are rare at a national scale. Impacts of nuisance NIS may be direct (e.g. loss of hardwood trees) or indirect (e.g. alteration of ecosystem services provided by growing hardwoods). Moreover, costs associated with these effects may be accrued to resources and services with clear 'market' values (e.g. crop production) and to those with more ambiguous, 'non-market' values (e.g. aesthetic value of intact forest). We characterised and projected economic costs associated with nuisance NIS in Canada, through a combination of case-studies and an empirical model derived from 21 identified effects of 16 NIS. Despite a severe dearth of available data, characterised costs associated with ten NIS in Canadian fisheries, agriculture and forestry totalled $187 million Canadian (CDN) per year. These costs were dwarfed by the 'invisible tax' projected for sixteen nuisance NIS found in Canada, which was estimated at between $13.3 and $34.5 billion CDN per year. Canada remains highly vulnerable to new nuisance NIS, but available manpower and financial resources appear insufficient to deal with this problem.

Ruesink, J.L. and Collado-Vides, L. **Modeling the increase and control of *Caulerpa taxifolia*, an invasive marine macroalga.** *Biological Invasions* 8(2): 309-325, 2006.

Notes: Population modeling based on species' demography makes it possible to predict the pace of an invasion and evaluate the likelihood of success of different control strategies. We modeled the initial (density-independent) rate of increase of *Caulerpa taxifolia* (Vahl) C. Agardh (aquarium strain), a green alga that has markedly altered marine communities where it has invaded in the Mediterranean Sea. Parameter values for patch growth (from stolon extension) and reproduction (by asexual fragmentation and reattachment) were gleaned from published studies. Only the most conservative model, invoking field growth rates and low levels of fragment reattachment (2.5 m(-2) of existing patch each summer), closely matched observed increases (4-14 x annually). The most effective times for control (greatest reduction in rate of increase) were removal of established patches before summer and removal of fragments after summer. These times correspond to just before maximum growth and just after maximum reproduction, respectively. Only a combined strategy, incorporating 99% removal of all fragments and annual removal of 99% of established patches, was predicted to eliminate *C. taxifolia* entirely (lambda < 1). This level of effort is only likely to be possible during the first few years of an invasion, arguing strongly for careful monitoring and rapid response to potential high-impact invaders.

Drake, J.M. and Lodge, D.M. **Allee effects, propagule pressure and the probability of establishment: Risk analysis for biological invasions.** *Biological Invasions* 8(2): 365-375, 2006.

Notes: Colonization is of longstanding interest in theoretical ecology and biogeography, and in the management of weeds and other invasive species, including insect pests and emerging infectious diseases. Due to accelerating invasion rates and widespread economic costs and environmental damages caused by invasive species, colonization theory has lately become a matter of considerable interest. Here we review the concept of propagule pressure to inquire if colonization theory might provide quantitative tools for risk assessment of biological invasions. By formalizing the concept of propagule pressure in terms of stochastic differential equation models of population growth, we seek a synthesis of invasion biology and theoretical population biology. We focus on two components of propagule pressure that affect the chance of invasion: (1) the number of individuals initially introduced, and (2) the rate of subsequent immigration. We also examine how Allee effects, which are expected to be common in newly introduced populations, may inhibit establishment of introduced propagules. We find that the establishment curve (i.e., the chance of invasion as a function of initial population size), can take a variety of shapes depending on immigration rate, carrying capacity, and the severity of Allee effects. Additionally, Allee effects can cause the stationary distribution of population sizes to be bimodal, which we suggest is a possible explanation for time lags commonly observed between the detection of an introduced population and widespread invasion of the landscape.

Duggan, I.C., Rixon, C.A.M., and MacIsaac, H.J. **Popularity and propagule pressure: Determinants of introduction and establishment of aquarium fish.** *Biological Invasions* 8(2): 377-382, 2006.

Notes: Propagule pressure is frequently cited as an important determinant of invasion success for terrestrial taxa, but its importance for aquatic species is unclear. Using data on aquarium fishes in stores and historical records of fish introduced and established in Canadian and United States waters, we show clear relationships exist between frequency of occurrence in shops and likelihood of introduction and of establishment. Introduced and established taxa are also typically larger than those available from stores, consistent with the propagule pressure hypothesis in that larger fish may be released more frequently due to outgrowing their aquaria. Attempts to reduce the numbers of introductions may be the most practical mechanism to reduce the number of new successful invasions.

Stohlgren, T.J., Barnett, D., Flather, C., Fuller, P., Peterjohn, B., Kartesz, J., and Master, L.L. **Species richness and patterns of invasion in plants, birds, and fishes in the United States.** *Biological Invasions* 8(3): 427-447, 2006.

Notes: We quantified broad-scale patterns of species richness and species density (mean # species/km^2) for native and non-indigenous plants, birds, and fishes in the continental USA and Hawaii. We hypothesized that the species density of native and non-indigenous taxa would generally decrease in northern latitudes and higher elevations following declines in potential evapotranspiration, mean temperature, and precipitation. County data on plants (n = 3004 counties) and birds (n = 3074 counties), and drainage (6 HUC) data on fishes (n = 328 drainages) showed that the densities of native and non-indigenous species were strongly positively correlated for plant species ($r = 0.86$, $P < 0.0001$), bird species ($r = 0.93$, $P < 0.0001$), and fish species ($r = 0.41$, $P < 0.0001$). Multiple regression models showed that the densities of native plant and bird species could be strongly predicted (adj. R-2 = 0.66 in both models) at county levels, but fish species densities were less predictable at drainage levels (adj. R-2 = 0.31, $P < 0.0001$). Similarly, non-indigenous plant and bird species densities were strongly predictable (adj. R-2 = 0.84 and 0.91 respectively), but non-indigenous fish species density was less predictable (adj. R-2 = 0.38). County level hotspots of native and non-indigenous plants, birds, and fishes were located in low elevation areas close to the coast with high precipitation and productivity (vegetation carbon). We show that (1) native species richness can be moderately well predicted with abiotic factors; (2) human populations have tended to settle in areas rich in native species; and (3) the richness and density of non-indigenous plant, bird, and fish species can be accurately predicted from biotic and abiotic factors largely because they are positively correlated to native species densities. We conclude that while humans facilitate the initial establishment, invasions of non-indigenous species, the spread and subsequent distributions of non-indigenous species may be controlled largely by environmental factors.

Leppäkoski, E. **The first twenty years of invasion biology in the Baltic Sea area.** *Oceanological and Hydrobiological Studies* 34(S1): 5-17, 2005.

Notes: The history of research into nonindigenous species and invasion biology in the Baltic Sea is briefly reviewed from faunistic notes made by the early naturalists of the early 1800s to more sophisticated and diversified studies that began in the last decade of the 20th century. In the 1990s, biologists working in the Baltic Sea area increasingly contributing to the understanding of the role of alien species as part of anthropogenically induced change in both a regional and international context.

Grabowski, M., Jazdzewski, K., and Konopacka, A. **Alien Crustacea in Polish waters (Part 1): Introduction and Decapoda.** *Oceanological and Hydrobiological Studies* 34(S1): 43-61, 2005.

Notes: The paper presents the biogeography, history, and some ecological consequences of the introduction of alien decapod species in Poland, with extensive reference to other European countries. Among some 750 species of Crustacea recorded in Polish waters, 18 representatives of five orders of macro-crustaceans are identified as alien species that either invaded or were introduced to Polish waters in historical times. Of this number, seven species are Decapoda: *Pontastacus leptodactylus*, *Pacifastacus leniusculus*, *Orconectes limosus*, *Atyaephyra desmaresti*, *Palaemon elegans, Rhithropanopeus harrisii*, *Eriocheir sinensis*. One of the species (*P. leptodactylus*) is of Ponto-Caspian origin, and of the remaining six, three (*P. leniusculus*, *O. limosus*, *R. harrisii*) came from North America, one from East Asia (*E. sinensis*), one from southern Europe (*A. desmaresti*), and one entered the Baltic from the North Sea (*P. elegans*). The first part of the paper describes the geographical and ecological aspects of the spread of aquatic fauna in Central Europe and discusses the introduction and range of extension of the seven decapod species in Polish waters.

Rolbiecki, L. and Rokicki, J. ***Anguillicola crassus*: an alien nematode species from the swim bladders of eel (*Anguilla anguilla*) in the Polish zone of the Southern Baltic and in the waters of Northern Poland.** *Oceanological and Hydrobiological Studies* 34(S1): 121-136, 2005.

Notes: The dispersal and distribution of the alien nematode *Anguillicola crassus* parasitizing the European eel (*Anguilla anguilla*) in the southern Baltic and in waters of northern Poland is analyzed. The parasite's presence in eel was first recorded in 1988 in the Vistula Lagoon when the prevalence of infection and intensity ranges were 63.3-75% and 1-25 parasites per infected eel, respectively. In 2000-2002, as many as 73.6-76.2% of the eel were affected at an intensity range of 1-53 parasites. In addition to the Vistula Lagoon, *A. crassus* was recorded in the Szczecin Lagoon, the Gulf of Gda□ sk, and the Puck Bay as well as in lakes DruSno, □ ebsko, Przyw□ oka, Sk□ pe, Wielewickie, Miedwie, I□ sko, □□ towskie, Niegocin, Mamry Pó□ nocne, StraSyn, Radu□ skie, and a lake in the village of Gaj as well as in the rivers Rega, Radew, Wieprza, and Dead Vistula. The prevalence of infection was reported to be between 26.4% and 100%. It can be assumed that the colonization of the eel by *A. crassus* and the parasite's dispersal in European waters, including Poland, will increase.

Jensen, K.R. and Knudsen, J. **A summary of alien benthic invertebrates in Danish waters.** *Oceanological and Hydrobiological Studies* 34(S1): 137-162, 2005.

Notes: There are 18 established alien marine benthic invertebrates in Danish waters. In addition, there are nine species that have been recorded one or more times in these waters, but which do not form reproducing populations in this area. The most important recipient localities in Danish waters are the Limfjord (n=4) and the Wadden Sea (n=3). The species found in these areas are mostly marine species that have spread through secondary dispersal from their original location of introduction. Data on distribution, dispersal, vectors, and donor regions are presented, and the adequacy of Danish monitoring programs is discussed.

Jazdzewski, K., Konopacka, A., and Grabowski, M. **Native and alien malacostracan Crustacea along the Polish Baltic Sea coast in the 20th century.** *Oceanological and Hydrobiological Studies* 34(S1): 175-193, 2005.

Notes: A total of 56 species of malacostracan Crustacea have been recorded along the Polish coast of the Baltic. This includes 12 species of Isopoda, one each of Tanaidacea and Cumacea, six of Mysidacea, 28 of Amphipoda, and eight of Decapoda. While the majority of these species are endemic, 11 alien species account for nearly 20% of the total malacostracan fauna. These species are *Hemimysis anomala* (a mysid), *Chelicorophium curvispinum*, *Chaetogammarus ischnus*, *Gammarus tigrinus*, *Dikerogammarus haemobaphes*, *D. villosus*, *Pontogammarus robustoides*, *Obesogammarus crassus* (amphipods), as well as *Orconectes limosus*, *Rhithropanopeus harrisii* and *Eriocheir sinensis* (decapods). Seven species - one mysid and six amphipods - are of Ponto-Caspian origin, and three species come from American waters (one amphipod and two decapod species). One of the decapods, the Chinese mitten crab, is of Asian origin. This paper presents the history of the discovery of particular taxa in Polish Baltic offshore waters and emphasizes the fact that the main wave of the invasion of alien malacostracan species began within the past few decades. The faunistic changes that have occurred in the gammarid assemblage structure in recent decades along the Polish Baltic coast, especially in its lagoons, are also presented.