

# Marine Science Review - 193

## Introduced species



### In this review:

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

### A. Recent articles – no abstract available

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Creed, J.C. **Two invasive alien azooxanthellate corals, *Tubastraea coccinea* and *Tubastraea tagusensis*, dominate the native zooxanthellate *Mussismilia hispida* in Brazil.** *Coral Reefs* 25(3): 350, 2006.

### B. Recent articles with abstracts

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Freeman, A.S. and Byers, J.E. **Divergent induced responses to an invasive predator in marine mussel populations.** *Science* 313(5788): 831-833, 2006.

**Notes:** Invasive species may precipitate evolutionary change in invaded communities. In southern New England (USA) the invasive Asian shore crab, *Hemigrapsus sanguineus*, preys on mussels (*Mytilus edulis*), but the crab has not yet invaded northern New England. We show that southern New England mussels express inducible shell thickening when exposed to waterborne cues from *Hemigrapsus*, whereas naïve northern mussel populations do not respond. Yet, both populations thicken their shells in response to a long-established crab, *Carcinus maenas*. Our findings are consistent with the rapid evolution of an inducible morphological response to *Hemigrapsus* within 15 years of its introduction.

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Simberloff, D. **Invasional meltdown 6 years later: important phenomenon, unfortunate metaphor, or both?** *Ecology Letters* 9(8): 912-919, 2006.

**Notes:** Cases in which introduced species facilitate one another's establishment, spread, and impacts are increasingly noted, and several experimental studies have provided strong evidence of a population-level impact. However, a full 'invasional meltdown', in which interspecific facilitation leads to an accelerating increase in the number of introduced species and their impact, has yet to be conclusively demonstrated. The great majority of suggested instances of 'invasional meltdown' remain simply plausible scenarios of long-term consequences based on short-term observations of facilitatory interactions between individuals of two species. There is a particular dearth of proven instances in which two invasive species each enhance the impact and/or probability of establishment and spread of the other. By contrast, in many authenticated cases, at least one partner is aided. The metaphor of meltdown focused attention on facilitation in invasion and has probably helped inspire recent studies. As have other metaphors from invasion biology and other sciences, 'meltdown' has struck a responsive chord with writers for the lay public; some have stretched it well beyond its meaning as understood by invasion biologists. There is no evidence that this hyperbole has impeded scientific understanding or caused loss of scientific credibility.

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Wolff, W.J. **Non-indigenous marine and estuarine species in The Netherlands.** *Zoologische Mededelingen* 79: 1-116, 2005.

**Notes:** An overview is presented of non-indigenous marine and estuarine plant and animal species recorded from The Netherlands. In this list both exotic species from outside NW Europe and non-indigenous species from elsewhere in NW

Europe are enumerated. Species that have been suggested to be non-indigenous in The Netherlands but for which insufficient evidence could be found are discussed shortly as well. The list is based mainly on literature data supplemented by own observations of the author. At least 99 plant and animal species have been introduced from elsewhere in the world. Another 13 species have been introduced from other parts of NW Europe. The third category of dubious non-indigenous species enumerates 37 species. The list is preceded by an introduction describing the history of Dutch research on introduced species, the origin of the marine and estuarine flora and fauna of The Netherlands, natural and human-induced dispersal processes, and a summary of the geographic patterns of introduced species.

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Ross, D.J., Johnson, C.R., and Hewitt, C.L. **Abundance of the introduced seastar, *Asterias amurensis*, and spatial variability in soft sediment assemblages in SE Tasmania: Clear correlations but complex interpretation.** *Estuarine, Coastal and Shelf Science* 67(4): 695-707, 2006.

**Notes:** The northern Pacific seastar, *Asterias amurensis*, was first collected in southeast Tasmania in 1986. Mistaken for the endemic asteroid *Uniophora granifera*, its true identity was not realised until 1992. It is now a conspicuous predator in soft sediment habitats in this region, and is considered a major threat to native assemblages and commercial species. We examined the structure of soft sediment assemblages at different spatial scales in southeast Tasmania, and correlated spatial variation in community composition with seastar abundances. We found that the structure of soft sediment assemblages is highly variable at a range of spatial scales from metres to tens of kilometres. Clear differences in the composition of assemblages and abundances of major taxa were detected between areas with and without seastars and between areas with low and high seastar densities. However, the nature of these patterns suggests that they are more likely due to differences in sediment characteristics than due to impacts of the seastar. Thus, spatial differences in soft sediment assemblages might have been erroneously attributed to seastars without detailed information on important physical factors such as sediment characteristics. A second survey, using larger sampling units (1 m<sup>2</sup>) but across a more limited spatial extent, targeted bivalves and heart urchins that were identified as important prey of the seastar in observations of feeding and in experimental studies. Large-scale patterns of abundance and size structure were consistent with seastar effects anticipated from small-scale experimental and feeding studies for some, but not all, species. While the field survey ultimately provided evidence about the presence or absence of seastar impacts at large-scales, the identification of key ecological variables in experimental and feeding studies proved crucial to both the design and interpretation of patterns observed in the large-scale surveys. Overall, this work highlighted the necessity to consider multiple lines of evidence rather than relying on a single 'inferential' test, in the absence of pre-impact data.

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Roman, J. **Diluting the founder effect: cryptic invasions expand a marine invader's range.** *Proceedings of the Royal Society B* 273(1600): 2453-2459, 2006.

**Notes:** Most invasion histories include an estimated arrival time, followed by range expansion. Yet, such linear progression may not tell the entire story. The European green crab (*Carcinus maenas*) was first recorded in the US in 1817, followed by an episodic expansion of range to the north. Its population has recently exploded in the Canadian Maritimes. Although it has been suggested that this northern expansion is the result of warming sea temperatures or cold-water adaptation, Canadian populations have higher genetic diversity than southern populations, indicating that multiple introductions have occurred in the Maritimes since the 1980s. These new genetic lineages, probably from the northern end of the green crab's native range in Europe, persist in areas that were once thought to be too cold for the original southern invasion front. It is well established that ballast water can contain a wide array of nonindigenous species. Ballast discharge can also deliver genetic variation on a level comparable to that of native populations. Such gene flow not only increases the likelihood of persistence of invasive species, but it can also rapidly expand the range of long-established nonindigenous species.

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Neira, C., Grosholz, E.D., Levin, L.A., and Blake, R. **Mechanisms generating modification of benthos following tidal flat invasion by a *Spartina* hybrid.** *Ecological Applications* 16(4): 1391-1404, 2006.

**Notes:** Many coastal habitats are being substantially altered by introduced plants. In San Francisco Bay, California, USA, a hybrid form of the eastern cordgrass *Spartina alterniflora* is rapidly invading open mudflats in southern and central sections of the Bay, altering habitat, reducing macrofaunal densities, and shifting species composition. The invasion has resulted in significant losses of surface-feeding amphipods, bivalves, and cirratulid polychaetes, while subsurface feeding groups such as

tubificid oligochaetes and capitellid polychaetes have been unaffected. In the present paper, we document the causes and mechanisms underlying the changes observed. Through a series of in situ manipulative experiments we examined the influence of hybrid *Spartina* canopy on a range of physical, chemical, and biological properties. The hybrid *Spartina* canopy exerted a strong influence on the hydrodynamic regime, triggering a series of physical, chemical, and biological changes in the benthic system. Relative to tidal flats, water velocity was reduced in hybrid patches, promoting deposition of fine-grained, organic-rich particles. The resulting changes in the sediment environment included increased porewater sulfide concentrations and anoxia, which led to poor survivorship of surface feeders such as, bivalves, amphipods, and polychaetes. These are key taxa that support higher trophic levels including migratory shorebirds that feed on tidal flats. Altered flow in the *Spartina* canopy further contributed to changes in barnacle recruitment and resuspension of adult benthic invertebrates. Increased crab-induced predation pressure associated with *Spartina* invasion also contributed to changes in benthic invertebrate communities. Our results suggest that multiple physical, chemical, biotic, and trophic impacts of the *Spartina* invasion have resulted in substantial changes in benthic communities that are likely to have important effects on the entire ecosystem.

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Gribben, P.E. and Wright, J.T. **Sublethal effects on reproduction in native fauna: are females more vulnerable to biological invasion?** *Oecologia* 149(2): 352-361, 2006.

**Notes:** Although invasive species are a major threat to survivorship of native species, we know little about their sublethal effects. In soft-sediment marine systems, mat-forming invasive species often have positive effects, facilitating recruitment and enhancing the diversity and abundance of native invertebrates. However, because mat-forming invasive species change the habitat in which they invade, and benthic invertebrates are sensitive to environmental disturbance, important sublethal effects on native species may exist. Using a model marine system we show that the widespread mat-forming invasive alga *Caulerpa taxifolia* (Vahl) C. Agardh has strong negative effects on the reproductive traits of a native bivalve *Anadara trapezia* (Deshayes, 1840) (e.g. timing of reproductive development and spawning, and follicle and gamete production) even though the invader has positive effects on recruitment. Moreover, gender specific responses occurred and indicated that females were more susceptible to invasion than males. Our results indicate that sublethal effects of an invasive species on reproductive traits will have severe consequences for fitness of the native species.

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Coles, S.L., Kandel, F.L.M., Reath, P.A., Longenecker, K., and Eldredge, L. **Rapid assessment of nonindigenous marine species on coral reefs in the main Hawaiian islands.** *Pacific Science* 60(4), 2006.

**Notes:** Coral reefs at Kaua'i, O'ahu, Moloka'i, Maui, and Hawai'i were surveyed using a rapid assessment method for marine nonindigenous and cryptogenic species commonly found in Hawaiian harbors and embayments with restricted circulation. In 41 sites surveyed by rapid assessment 26 nonindigenous and cryptogenic species (three algae, 19 invertebrates, and four fishes) were recorded from a total of 486 total taxa identified, and 17 of the nonindigenous and cryptogenic species occurred at only one or two sites. No more than six nonindigenous and cryptogenic species were recorded at any one site, and 21 of the 41 sites had fewer than three. By comparison, laboratory identification of samples collected from seven of the sites closest to harbors found 6-23 nonindigenous and cryptogenic species per site. Values for nonindigenous and cryptogenic species from rapid assessment were compared with factors potentially influencing spread and proliferation of introduced marine species. These factors included distances from harbors, boat-launching ramps, stream mouths, and shorelines; degree of shoreline urbanization; quantity of artificial surfaces in the water; reef condition and isolation from the open ocean; and native species richness. A best subsets regression model explained over 65% of the variance in nonindigenous and cryptogenic species from two predictor variables and their interaction: isolation from the open ocean and number of native taxa, with most of the variance explained by a highly significant relationship of nonindigenous and cryptogenic species with isolation from open-ocean conditions.

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Neill, P.E., Alcalde, O., Faugeton, S., Navarrete, S.A., and Correa, J.A. **Invasion of *Codium fragile* ssp. *tomentosoides* in northern Chile: A new threat for *Gracilaria* farming.** *Aquaculture* 259(1-4): 202-210, 2006.

**Notes:** Invasive species are key components of the burgeoning global change in ecological communities. The green alga *Codium fragile* ssp. *tomentosoides* (Chlorophyta) is a recognized invader in marine ecosystems around the world, with described ecological effects ranging from minor changes in native species abundance to major changes in community structure, as well as

negative economic effects on aquaculture species. The objective of this work is to provide an assessment of the extension of the *C. fragile* invasion along the coast of Chile, and characterize the pattern of temporal fluctuations in abundance, and potential economic effects of this algal invader in a *Gracilaria chilensis* farm in northern Chile. In 2005 we recorded *C. fragile* at 34 of 123 sites sampled along the Chilean coast, with over half of the invaded sites occurring between 26° and 30°S latitude. At 12 sites *C. fragile* was present only on artificial substrata, suggesting that artificial structures may act as corridors for the dispersal of this alga into subtidal or intertidal habitats where it is otherwise not able to survive. At one site (Calderilla Bay) *C. fragile* has reached high levels of abundance within *G. chilensis* farms. At this site we observed marked seasonality in the monthly *C. fragile* abundance index, with greater *C. fragile* abundances in summer and fall months, associated with higher sea surface temperatures (SST). In addition, we report a significant long-term trend of increasing *C. fragile* abundances over the 5 years of observations in the plantation. If the distribution of *C. fragile* in Chile is largely determined by SST, we expect faster spread of northern populations towards the north. Weedy species had a negative effect on the farmed species, *G. chilensis*. During the 4 months in which algae wet weights were measured, the estimated *C. fragile* biomass averaged 22.9 kg m<sup>-2</sup>, compared with an estimated average of 18.5 kg m<sup>-2</sup> of the harvested red alga, *G. chilensis*. In addition, we recorded a negative effect of *C. fragile* abundances on the Catch Per Unit Effort (CPUE) of *G. chilensis* with a significant upper limit to CPUE at the 94th quantile. Since weedy species generate a great loss of time and money in *G. chilensis* farms, it is likely that without intervention, the costs associated with the *C. fragile* invasion threaten the persistence of *G. chilensis* farms in northern Chile. Stakeholders should implement preventative measures to stop *C. fragile* spread from focal points.

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Haefliger, P., Schwarzlaender, M., and Blossey, B. **Impact of *Archanara geminipuncta* (Lepidoptera: Noctuidae) on aboveground biomass production of *Phragmites australis*.** *Biological Control* 38(3): 413-421, 2006.

**Notes:** Management of invasive plants with biological control rests on the assumption of herbivores as structuring forces of plant community composition, but only 30% of programs achieve substantial plant suppression. Control is often caused by a few successful agents, and improvements in the ability to select the most promising species would greatly improve weed biocontrol programs. We evaluated impact of different larval stages and larval densities of the stem boring noctuid *Archanara geminipuncta* on height and biomass production of *Phragmites australis* in the field and in a common garden in the native European range. In the field, stem biomass was reduced 21.5-64.5% by *A. geminipuncta* attack with the largest reduction due to early larval feeding. In the common garden, *P. australis* performance declined linearly (stem height 40%, biomass 50%; and percentage of flowering stems 90%) as attack rates increased. Significant field and common garden impact and the large Eurasian distribution indicate great potential of *A. geminipuncta* for biocontrol of introduced *P. australis* in North America if host specificity tests produce favorable results. If approved for release, we anticipate that *A. geminipuncta* could establish throughout the range of introduced *P. australis* in North America. We also anticipate that this moth will build high populations with significant impact on height, aboveground biomass, and clonal expansion of *P. australis*. This attack is expected to reduce competitive ability of *P. australis*, favoring native wetland species and preventing further negative ecological impacts associated with the current spread of introduced *P. australis* in North America.

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Martin, S., Thouzeau, G., Chauvaud, L., Jean, F., Guerin, L., and Clavier, J. **Respiration, calcification, and excretion of the invasive slipper limpet, *Crepidula fornicata* L.: Implications for carbon, carbonate, and nitrogen fluxes in affected areas.** *Limnology and Oceanography* 51(5): 1996-2007, 2006.

**Notes:** We measured in situ respiration, calcification, and excretion of the slipper limpet, *Crepidula fornicata* L., and considered both seasonal variations and individual size, to estimate the effects of this exotic species on annual budgets of carbon, carbonate, and nitrogen in the Bay of Brest (France). Respiration, calcification, and excretion rates changed significantly with size and season. Oxygen consumption varied from 6 to 63  $\mu\text{mol O}_2 \text{ g}^{-1}$  ash-free dry weight (AF dry wt) h<sup>-1</sup>, which corresponded to a carbon dioxide release that ranged from 2 to 44  $\mu\text{mol CO}_2 \text{ g}^{-1}$  AF dry wt h<sup>-1</sup>. Maximum respiration rates were observed in summer, and minimum rates were observed in winter. CaCO<sub>3</sub> production ranged from -4 to 44  $\mu\text{mol CaCO}_3 \text{ g}^{-1}$  AF dry wt h<sup>-1</sup> from winter to summer, respectively. Ammonium release varied from 0.7 to 3.1  $\mu\text{mol NH}_4^+ \text{ g}^{-1}$  AF dry wt h<sup>-1</sup>, with the highest excretion rate in spring. Total carbon release by *C. fornicata* in highly colonized zones in the Bay of Brest averaged 290 g C m<sup>-2</sup> yr<sup>-1</sup>, carbonate production was  $\sim$  515 g CaCO<sub>3</sub> m<sup>-2</sup> yr<sup>-1</sup>, and nitrogen production by ammonium excretion was  $\sim$  25 g N m<sup>-2</sup> yr<sup>-1</sup>. *C. fornicata* respiration and excretion account for 55% and 85% of the benthic community respiration and excretion, respectively. These results illustrate the importance of this invasive species to carbon and nitrogen cycles, including biogenic carbonate production, in coastal ecosystems.

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Pertola, S., Faust, M.A., and Kuosa, H. **Survey on germination and species composition of dinoflagellates from ballast tanks and recent sediments in ports on the South Coast of Finland, North-Eastern Baltic Sea.** *Marine Pollution Bulletin* 52(8): 900-911, 2006.

**Notes:** Cyst beds in ships and ports in Finland have previously been unstudied. Therefore, sediments from ships' ballast water tanks and four Finnish ports were sampled for dinoflagellate cysts and other phytoplankton. Untreated sediments were incubated at 10°C and 20°C in the local 6 psu salinity for 1, 4 and 7 days, and vegetative cells were examined with light and scanning electron microscope. Sediments were inhabited by various dinoflagellates, diatoms, chlorophytes, cyanophytes and small flagellates. Germinated dinoflagellates were found in 90% of ballast tanks and in all ports. *Gymnodiniales* spp. and *Heterocapsa rotundata* formed a major proportion of the proliferating dinoflagellate cells. One species, *Peridinium quinquecorne*, not previously reported from the Baltic Sea, was identified with SEM. The study emphasises that ships are potential transport vehicles for dinoflagellate cysts even in the low salinity Finnish waters, and small-sized dinoflagellates should be focused upon in ballast water studies.

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Morton, B. and Tan, K.S. ***Brachidontes striatulus* (Bivalvia: Mytilidae) introduced into Singapore.** *Raffles Bulletin of Zoology* 54(2): 435-439, 2006.

**Notes:** *Brachidontes striatulus* (Hanley) is reported for the first time from Singapore. This highly variable species from India was found either in monospecific byssus aggregates or nestled amongst the byssal mats of another invasive species, *Mytilopsis sallei*, in tidal monsoon drains. Densities of up to 75 individuals/100cm<sup>2</sup> were recorded in salinities ranging between 12 and 20 parts per thousand. Size-frequency relationships of live and dead shells suggested that the mussel has established itself recently and is likely to spread.

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Miura, O., Torchin, M.E., Kuris, A.M., Hechinger, R.F., and Chiba, S. **Introduced cryptic species of parasites exhibit different invasion pathways.** *Proceedings of the National Academy of Sciences [USA]* 103(52): 19818-19823, 2006.

**Notes:** Sometimes infectious agents invade and become established in new geographic regions. Others may be introduced yet never become established because of the absence of suitable hosts in the new region. This phenomenon may be particularly true for the many parasites with complex life cycles, where various life stages require different host species. Homogenization of the world's biota through human-mediated invasions may reunite hosts and parasites, resulting in disease outbreaks in novel regions. Here we use molecular genetics to differentiate invasion pathways for two digenean trematode parasites and their exotic host, the Asian mud snail, *Batillaria attramentaria*. All of the snail haplotypes found in introduced populations in North America were identical to haplotypes common in the areas of Japan that provided oysters for cultivation in North America, supporting the hypothesis that the snails were introduced from Japan with seed oysters. Two cryptic trematode species were introduced to North American populations in high frequencies. We found a marked reduction of genetic variation in one of these species, suggesting it experienced a bottleneck or founder event comparable to that of the host snail. In contrast, no genetic variation was lost in the other parasite species. We hypothesize that this parasite was and is dispersed naturally by migratory shorebirds and was able to establish only after the host snail, *B. attramentaria*, was introduced to North America. Evaluation of the nature of invasion pathways and postinvasion consequences will aid mitigation of spreading diseases of humans, livestock, and wildlife in an increasingly globalized world.

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Hasson, K.W., Fan, Y., Reisinger, T., Venuti, J., and Varner, P.W. **White-spot syndrome virus (WSSV) introduction into the Gulf of Mexico and Texas freshwater systems through imported, frozen bait-shrimp.** *Diseases of Aquatic Organisms* 71(2): 91-100, 2006.

**Notes:** We analysed 20 boxes of, frozen imported bait-shrimp (China: *Parapenaepsis* sp. and *Metapenaepsis* sp.) and 8 boxes of native, frozen bait-shrimp (Gulf of Mexico: *Litopenaeus setiferus* and *Fartantepenaeus duorarum*) by RT-PCR or PCR for Taura syndrome virus (TSV), yellowhead virus/gill-associated virus (YHV/GAV), white-spot syndrome virus (WSSV) and infectious hypodermal and hematopoietic necrosis virus (IHHNV). All 28 boxes of shrimp were negative for TSV, YHV/GAV and

IHHNV; 2 boxes of imported bait-shrimp were WSSV-positive by 3 different PCR assays. Intramuscular injection of replicate groups of SPF (specific pathogen-free) *L. vannamei* juveniles with 2 different tissue homogenates prepared from the 2 WSSV-positive bait boxes resulted in 100% mortality of the test shrimp within 48 to 72 h post-injection. No mortality occurred among injected negative control groups. Histological and in situ hybridization analyses of 20 moribund treatment-shrimp demonstrated severe WSSV infections in each sample. Oral exposure of SPF *L. vannamei* postlarvae, PL (PL 25 to 30 stage; ~ 0.02 g) to minced tissue prepared from the 2 WSSV-positive bait-lots did not induce infection, possibly because of an insufficient infectious dose and/or viral inactivation resulting from multiple freeze-thaw cycles of the bait-shrimp during PCR testing. Use of an electric drill and collection of drill-tailings (tissue from ~ 20 to 30 shrimp) from frozen blocks of shrimp was successfully employed as an alternate tissue-sampling method without thawing. Our findings indicate that imported WSSV-infected bait shrimp, originating from China, are being sold in Texas for the purpose of sport fishing and represent a potential threat to freshwater and marine crustacean fisheries, as well as to coastal US shrimp farms.

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Gollan, J.R. and Wright, J.T. **Limited grazing pressure by native herbivores on the invasive seaweed *Caulerpa taxifolia* in a temperate Australian estuary.** *Marine and Freshwater Research* 57(7): 685-694, 2006.

**Notes:** *Caulerpa taxifolia* is an invasive alga threatening biodiversity in invaded regions. Its proliferation in recipient communities will be due to several factors including limited grazing effects by native herbivores. However, little is known about grazing pressure exerted by native herbivores on *C. taxifolia* relative to native macrophytes or its attractiveness to them as habitat. The present study determined which herbivores co-occurred with invasive *C. taxifolia* in a temperate Australian estuary and documented their abundance, relative grazing effects, habitat preference and survivorship on *C. taxifolia* compared with native macrophytes. Four herbivores co-occurred with *C. taxifolia* and their densities were often low or zero at the sites studied. Feeding experiments showed that compared with *C. taxifolia*: the fish, *Girella tricuspidata*, preferred *Ulva* sp.; the sea-hare, *Aplysia dactylomela*, preferred *Laurencia* sp.; whereas the mesograzers, *Cymadusa setosa* and *Platynereis dumerilii antipoda*, both consumed *Cystoseira trinodus* and *Sargassum* sp. at higher rates. The two mesograzers also showed strong habitat preference for *C. trinodus* and *Sargassum* sp. *Cymadusa setosa* had poor survivorship on *Caulerpa taxifolia* whereas *P. dumerilii antipoda* had 100% survivorship on *C. taxifolia* after 41 days. We consider that the low diversity and abundance of native herbivores, their weak grazing pressure on *C. taxifolia* and its low attractiveness as habitat may facilitate further local spread in this estuary, and potentially in other invaded locations.

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Hunter, K.L., Fox, D.A., Brown, L.M., and Able, K.W. **Responses of resident marsh fishes to stages of *Phragmites australis* invasion in three mid Atlantic estuaries.** *Estuaries and Coasts* 29(3): 487-498, 2006.

**Notes:** Modification of brackish marshes by nonindigenous *Phragmites australis* has occurred across a broad geographical area in eastern North America. Among its effects on marsh processes, *Phragmites* may be increasingly unfavorable to marsh surface fishes as its invasion progresses within an estuary. We assessed the effect of the *Phragmites* invasion on resident marsh surface fishes by examining the population response of *Fundulus heteroditus* (mudminnow, 5-48 mm TL) and *F. luciae* (spotfin killifish, 5-41 mm TL) to four distinct invasion stages in three estuaries of the U.S. mid-Atlantic region (New Jersey, Delaware, and Maryland). We documented precipitous declines in mean catch per unit effort of *F. heteroditus* in pit traps from natural marsh (51.6), through initial (33.8), early (12.3), and late invasion stages (2.4) across all sites. A similar pattern was documented for *F. luciae*, with mean catch per unit effort in pit traps declining from natural marsh (48.9), through initial (39.1), early (9.3), and late invasion stages (2.7). Population structure of both species also changed somewhat across invasion stages such that we collected a narrower size range of individuals of both species from late invasion stages. Patterns suggest that as the *Phragmites* invasion progresses, there is a decline in habitat function for larval and juvenile *F. heteroditus* and an increased risk of extirpation of *F. luciae* from brackish marshes along the east coast of the U.S.

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Thomsen, M.S., McGlathery, K.J., and Tyler, A.C. **Macroalgal distribution patterns in a shallow, soft-bottom lagoon, with emphasis on the nonnative *Gracilaria vermiculophylla* and *Codium fragile*.** *Estuaries and Coasts* 29(3): 465-473, 2006.

**Notes:** We determined the distribution of macroalgae in Hog Island Bay, a shallow coastal lagoon in Virginia, USA, seasonally at 12 sites from 1998 to 2000 and at 3 representative sites from 2000 to 2002. We analyzed macroalgal biomass, taxonomic

richness, and abundance of two non-native species, the cryptic invader *Gracilaria vermiculophylla* and the conspicuous *Codium fragile*, with respect to season, location (mainland, mid lagoon, barrier island sites), and elevation (intertidal, subtidal). Taxonomic richness, total algal biomass, and normative biomass peaked in the summer months when temperature and light availability were highest. A few stress tolerant and ephemeral algae dominated the algal assemblage. *G. vermiculophylla* constituted 74% of the entire algal biomass, was the most abundant alga in all seasons, locations, and elevation levels, and was positively correlated with taxonomic richness and abundance of filamentous species. *Ulva curvata*, *Bryopsis plumosa*, and *C. fragile* accounted for an additional 16% of the algal biomass. There are distinct habitats in Hog Island Bay that can be classified into low diversity-low biomass regions near the mainland and barrier islands and high diversity-high biomass regions in the open mid lagoon, where abundant shells for attachment and intermediate levels of water column nutrients and turbidity likely create better growth conditions. Taxonomic richness and biomass were higher in subtidal than intertidal zones, presumably due to lower desiccation stress. This study provides an example of how a single invasive species can dominate an entire assemblage, both in terms of biomass (being most abundant in all seasons, locations, and tidal levels) and species richness (correlating positively with epiphytic filamentous taxa). By adding hard-substratum structural complexity to a relatively homogenous soft-substratum system, *G. vermiculophylla* increases substratum availability for attachment and entanglement of other algal species and enhances local diversity. Without widespread and abundant *G. vermiculophylla*, taxa like *Polysiphonia*, *Ceramium*, *Bryopsis*, *Ectocarpus*, and *Champia* would likely be much less common. This study also highlights the importance of using DNA analysis of voucher specimens in monitoring programs to accurately identify cryptic invaders.

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Litvinchuk, L.F. and Telesh, I.V. **Distribution, population structure and ecosystem effects of the invader *Cercopagis pengoi* (Polyphemoida, Cladocera) in the Gulf of Finland and the open Baltic Sea.** *Oceanologia* 48: 243-257, 2006.

**Notes:** Spatial distribution, density, biomass, population structure, predation effects, and the influence of abiotic environmental characteristics (salinity, water temperature, transparency, and depth) on a population of the Ponto-Caspian invasive cladoceran *Cercopagis pengoi* (Ostroumov, 1891) were studied in the Gulf of Finland and the open Baltic Sea (August 1999 and 2004). In our study in 1999, this species was first recorded in plankton of open south-eastern Baltic waters. The age and sexual structure of the *C. pengoi* population were interrelated with population density. The strongest impact of *C. pengoi* predation on the pelagic community in the Gulf of Finland was registered at the stations where the percentage of *C. pengoi* in the total zooplankton biomass was the highest. The calculated impact values of *C. pengoi* exceeded those registered a decade ago, during the first years after *Cercopagis* had invaded the eastern Gulf of Finland.

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Radziejewska, T., Gruszka, P., and Rokicka-Praxmajer, J. **A home away from home: a meiobenthic assemblage in a ship's ballast water tank sediment.** *Oceanologia* 48: 259-265, 2006.

**Notes:** The world-wide research on ship-aided dispersal of marine organisms and invasions of non-indigenous species focuses primarily on the plankters, which show the greatest potential for invading new areas and establishing viable populations in them, either in the water column (holoplankton) or on the bottom (meroplanktonic larvae of benthic species settling on the sea floor). As meiobenthic animals usually lack a pelagic larval stage in their life cycle, no biological invasion study has, to our knowledge, ever specifically targeted marine transport as a means of meiofaunal dispersal. Here we present a set of data showing that the sediment deposited in a ship's ballast water tank does support a viable meiobenthic assemblage. We examined 0.015-dm<sup>3</sup> aliquots of a 1 dm<sup>3</sup> sample from a c. 1.5-cm thick layer of sediment residue in the ballast tank of MS Donnington, brought to the 'Gryfia' Repair Shipyard in Szczecin (Poland). The samples were found to contain representatives of calcareous Foraminifera, hydrozoans, nematodes, turbellarians, harpacticoid copepods and their nauplii, and cladocerans, as well as meiobenthic-sized bivalves and gastropods. Nematodes proved to be the most constant and most numerous component of the assemblage. The sediment portions examined revealed the presence of 1-11 individuals representing 11 marine nematode genera. The viability of the meiobenthic assemblage was evidenced by the presence of ovigerous females of both nematodes and harpacticoids. Survival of the meiobenthos in shipborne ballast tank sediment residues may provide at least a partial explanation for the cosmopolitan distribution of meiobenthic taxa and may underlie the successful colonisation of new habitats by invasive meiofaunal species.

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Loebl, M., van Beusekom, J.E.E., and Reise, K. **Is spread of the neophyte *Spartina anglica* recently enhanced by increasing temperatures?** *Aquatic Ecology* 40(3): 315-324, 2006.

**Notes:** The introduced cordgrass *Spartina anglica*, a fertile hybrid of *S. maritima* and *S. alterniflora*, grows as a pioneer plant in the upper intertidal zone and has invaded most sheltered shorelines of the Wadden Sea. After its introduction in 1927 *S. anglica* has spread vigorously along the mainland shore and on some of the more southern islands. In contrast, it has later established on Sylt and spread at a lower pace. On the island of Sylt it occurs near at its northern limit in Europe. Due to rising sea level and storm frequency a decrease or steady state of *S. anglica* was expected because its niche is narrowing rather than widening and plants are more frequently eroded. Contrary to that, many new sites were colonized and dense monotypic swards have formed after 1985. This new spread coincided with a shift in the local temperature regime around 1987. The monthly mean temperature from January to April has increased significantly after 1987. Furthermore, the important physiological thresholds of 4°C for germination and 7°C for photosynthesis were more often exceeded during spring after 1987 than before. We suggest that warmer spring seasons since 1988 could have promoted germination, growth and the recent accelerated spread of this neophyte.

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Rajagopal, S., Venugopalan, V.P., van der Velde, G., and Jenner, H.A. **Greening of the coasts: a review of the *Perna viridis* success story.** *Aquatic Ecology* 40(3): 273-297, 2006.

**Notes:** The green mussel *Perna viridis* has been receiving a lot of attention from workers working in the research areas of intertidal ecology, aquaculture, pollution monitoring, biofouling, zoogeography and invasion biology. *P. viridis* is a remarkable species in terms of its ability to reach very high biomass levels, to withstand environmental fluctuations, to concentrate a variety of organic and inorganic environmental pollutants, to colonise artificial marine habitats and to invade new geographic territories. This review collates data available on salient aspects of the distribution, biology and ecology of *P. viridis*. It is argued that the remarkable success of *P. viridis* as an invasive species basically stems from its long larval duration, fast growth rate, high fecundity, early maturity, high productivity and ability to withstand fluctuating environmental conditions (temperature, salinity, water turbidity and pollutants). Relevant aspects of the data are compared with the data available for a similar species *Perna perna*, which too is an invasive species, but to a more limited extent.

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Sanchez, I. and Fernandez, C. **Resource availability and invasibility in an intertidal macroalgal assemblage.** *Marine Ecology Progress Series* 313: 85-94, 2006.

**Notes:** The invasibility of a low intertidal macroalgal assemblage was experimentally tested from March 2003 to April 2004 at 1 locality in northern Spain. It was hypothesised that a community becomes more susceptible to invasion when there is an increase in the amount of key resources. A bifactorial ('nutrient supply' and 'macroalgal biomass removed') orthogonal experiment was designed with 3 levels in each factor (high, medium and control). Fertile plants of *Sargassum muticum* (Yendo) Fensholt were transplanted to each plot to simulate the arrival of an invader. The invasibility of the assemblage was quantified in the pre- (density of recruits) and post-settlement (percentage cover, size and density of *S. muticum* at the end of the experiment) phases of *S. muticum*'s life cycle. Results supported the initial hypothesis. Both space availability and nutrient enrichment facilitated the establishment and spread of *S. muticum* in the experimental plots. Established *S. muticum* plants grew faster in enriched plots than in controls. Furthermore, different successional assemblages played different roles in resisting invasion as *S. muticum*'s life cycle progressed. In the initial stage of the invasion, the *Bifurcaria bifurcata* canopy inhibited recruitment by *S. muticum*, whereas understory species did not have a significant effect on invasion success. In contrast, an increased survivorship of *S. muticum* beneath the canopy of *B. bifurcata* was observed in those plots where *S. muticum* had successfully recruited. This study shows that the invasibility of this low intertidal assemblage is mediated by a complex interaction of several resources acting at different stages during *S. muticum*'s invasion.

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Dudas, S.E. and Dower, J.F. **Reproductive ecology and dispersal potential of varnish clam *Nuttallia obscurata*, a recent invader in the Northeast Pacific Ocean.** *Marine Ecology Progress Series* 320: 195-205, 2006.

**Notes:** The fecundity, larval development, and temperature and salinity tolerances were determined for the varnish clam *Nuttallia obscurata* (Reeve 1857), a recently introduced species in the Northeast Pacific. Adult varnish clams from 2 populations

were collected in British Columbia, Canada throughout the spawning season to determine sex, fecundity, and timing of spawning. Adult varnish clams were also spawned in the laboratory and the larvae reared at a range of temperatures and salinities. The highest larval growth rates were observed in the 20°C and 20 psu treatments. Planktonic duration ranged from 3 to potentially 8 wk, with higher temperatures and salinities resulting in a shorter planktonic phase. Larvae reared at 9°C, and at 10 and 15 psu, grew slowly and survived for a minimum of 1 mo but did not reach metamorphosis. These results indicate that varnish clam larvae have a wide range of salinity and temperature tolerances, but grow optimally at warmer temperatures and higher salinities. Varnish clams have comparable larval environmental tolerances and spawning duration to co-occurring bivalves. However, their fecundity appears to be slightly higher and they reach sexual maturity earlier, potentially providing an advantage in establishing new populations. The lengthy planktonic phase, combined with favourable oceanographic circulation patterns, has contributed to the rapid dispersal and geographic range expansion of the varnish clam in the Northeast Pacific.

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Strong, J.A., Dring, M.J., and Maggs, C.A. **Colonisation and modification of soft substratum habitats by the invasive macroalga *Sargassum muticum*.** *Marine Ecology Progress Series* 321: 87-97, 2006.

**Notes:** *Sargassum muticum* is an invasive brown macroalga that originates from Japan. In the introduced range, thalli can grow in soft substratum habitats attached to embedded rock fragments and shells. Within Strangford Lough, Northern Ireland, *S. muticum* has rapidly colonised large areas of soft substrata, where dispersal by peripatetic or 'stone-walking' plants is very effective. Sediment cores were collected under and outside canopies of *S. muticum* in Strangford Lough (*S. muticum* first recorded there in 1995) and Langstone Harbour, English Channel (*S. muticum* first found there in 1974) to investigate modification of the infaunal assemblages. At both study sites, community analyses highlighted significant differences between the assemblages under the canopies and those in adjacent unvegetated areas. In Strangford Lough, the invertebrate community under the canopy contained a higher abundance of smaller, opportunistic, r-selected species than outside the canopy. By contrast, the communities under and outside the canopy at Langstone Harbour were similar in species composition, diversity and dominance, but overall faunal abundance was greater under the canopy. Sediment characteristics were not affected by *S. muticum* canopies, but the infaunal changes may be related to environmental modification; shading, flow suppression and temperature stratification were also investigated. The differences between these 2 sites indicate that localised conditions and/or the duration of colonisation of *S. muticum* are important in determining the nature of habitat modification.

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Colautti, R.I., Grigorovich, I.A., and MacIsaac, H.J. **Propagule pressure: A null model for biological invasions.** *Biological Invasions* 8(5): 1023-1037, 2006.

**Notes:** Invasion ecology has been criticised for its lack of general principles. To explore this criticism, we conducted a meta-analysis that examined characteristics of invasiveness (i.e. the ability of species to establish in, spread to, or become abundant in novel communities) and invasibility (i.e. the susceptibility of habitats to the establishment or proliferation of invaders). There were few consistencies among invasiveness characteristics (3 of 13): established and abundant invaders generally occupy similar habitats as native species, while abundant species tend to be less affected by enemies; germination success and reproductive output were significantly positively associated with invasiveness when results from both stages (establishment/spread and abundance/impact) were combined. Two of six invasibility characteristics were also significant: communities experiencing more disturbance and with higher resource availability sustained greater establishment and proliferation of invaders. We also found that even though 'propagule pressure' was considered in ~ 29% of studies, it was a significant predictor of both invasiveness and invasibility (55 of 64 total cases). Given that nonindigenous species are likely introduced non-randomly, we contend that 'propagule biases' may confound current paradigms in invasion ecology. Examples of patterns that could be confounded by propagule biases include characteristics of good invaders and susceptible habitats, release from enemies, evolution of 'invasiveness', and invasional meltdown. We conclude that propagule pressure should serve as the basis of a null model for studies of biological invasions when inferring process from patterns of invasion.

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Perez, J.E., Nirchio, M., Alfonsi, C., and Munoz, C. **The biology of invasions: The genetic adaptation paradox.** *Biological Invasions* 8(5): 1115-1121, 2006.

**Notes:** One of the most relevant topics in the biology of invasion concerns the genetic changes that occur subsequent to a species invasion, an issue of particular focus among conservation biologists. Colonizing a novel environment presents a

genetic challenge to invading species because such species surely have not experienced the selective pressures presented by the environment. Here we ask, by what mechanisms and processes do alien species genetically naive to their new environment, become successful invaders? We attempt to resolve this paradox by considering the interplay between an invader's ability to modify its new environment, and genetic modifications imposed by the new environment. We postulate that epigenetic adaptations, and adaptive mutations are likely play a role in enhancing invasion success.

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Bastrop, R. and Blank, M. **Multiple invasions - a polychaete genus enters the Baltic Sea.** *Biological Invasions* 8(5): 1195-1200, 2006.

**Notes:** Since 1985, the nonindigenous polychaete species *Marenzelleria neglecta* has been found in the Baltic Sea. The species, which was introduced by ship ballast water, spreads rapidly and dominates in many habitats today. Using three gene segments of the mitochondrial DNA (16S rDNA, Cytochrom oxidase I, Cytochrom b), we investigated four populations of the western and northern Baltic Sea in a preliminary survey and compared them with four other populations from the North Sea, the Baltic Sea and from the Arctic. First, we could demonstrate the applicability of the markers to discriminate the species with certainty. Second, with *M. viridis* and *M. arctia*, we could detect two more species of the same genus, which have recently been introduced into the Baltic Sea. One of these, *M. arctia*, was hitherto known as an exclusive arctic member of the genus. The impact of these two recently invaded *Marenzelleria* species onto the autochthonous fauna needs to be evaluated in the future. The Baltic Sea as a 'natural aquarium' now offers the possibility to investigate sibling species simultaneously. However, correct identification and denomination of *Marenzelleria* species are indispensable prerequisites for all future studies. Molecular markers allow the exact identification of all *Marenzelleria* species and must be used whenever a classical taxonomic identification is uncertain.

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Falk-Petersen, J., Bohn, T., and Sandlund, O.T. **On the numerous concepts in invasion biology.** *Biological Invasions* 8(6): 1409-1424, 2006.

**Notes:** The study of biological invasions has triggered the production of a diversity of concepts. The terminology has, however, often been applied inconsistently and inaccurately. This article lists and assesses the most commonly used terms and concepts in invasion ecology. In each case the most coherent definition and use is suggested.

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