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QUANTIFYING THE EFFECTS OF HABITAT LOSS ON MARINE DIVERSITY

Valutazione degli effetti della perdita di habitat sulla diversità marina

Abstract - We explore the multiple ways habitat loss affects marine species diversity, and propose a conceptual model that identifies the main interactions and feedbacks between these processes. The loss of habitat structure generally leads to lower abundances (biomasses) and often to declines in species richness. There is often also a suite of colonizing species that prosper from these transitions. These sets of expanding species can amplify the changes to the system, cause variable effects on species richness and other components of diversity, feed back to affect the various components of habitat loss (e.g. maintain new environmental conditions) and prevent the recovery of the system. Less well studied are the effects on between-habitat diversity and functional diversity. We argue that we need to understand these latter changes to better manage and conserve the structure and function of ecosystems and the diverse services that humans continue to expect from them.

Key-words: habitat loss, species diversity, marine systems, conservation.

Introduction - Structurally complex habitats are becoming rarer across temperate marine environments at local, regional and global scales. In Europe, it is estimated that for each day between 1960 and 1995, a kilometre of coastline was developed, causing losses of coastal wetlands and seagrasses exceeding 50% of original area with peaks above 80% for many regions (Airoldi & Beck 2007). Conspicuous declines, sometimes to virtual local extinction of kelps and other complex macroalgae have been observed in several countries around the world (Benedetti-Cecchi et al., 2001). Biogenic temperate reefs are probably among the most threatened habitats globally (Roberts & Hirschfield, 2004; Airoldi & Beck, 2007), and much of the continental shelf and some deeper ocean seafloors have been homogenized by bottom trawling and dredging (Thrush & Dayton, 2002). Habitat loss, however, is not as much a focus of marine science and conservation as in terrestrial environments. We argue this is due to the fact that the consequences of habitat loss in the marine realm are not fully explored. We explore the multiple ways habitat loss affects marine diversity based on available information from the scientific literature, and propose a conceptual model that identifies the main interactions and feedbacks between these processes. We also discuss how this work can focus efforts in research, conservation and management.

Definitions - Here ‘habitat’ indicates a focus on the predominant features that create structural complexity in the environment, such as plants (e.g., seagrass meadows, kelp forests), or animals (e.g. oyster reefs, burrowing fauna in sandflats), and ‘loss’ indicates a focus on a measurable reduction in habitat abundance and distribution (Airoldi & Beck, 2007). Frequently, the loss also initiates a transition from a more complex to a less complex habitat, e.g., shellfish reefs or seagrasses are dredged and mud or sandflats are created, or perennial macroagal canopies are lost leaving space to turf-forming algae. The most common usage of species ‘diversity’ refers to the number of species in a given area of habitat (species richness) and on their rela-
tive abundances. There are other fundamental but often overlooked components of diversity (Gray, 1997), related to species composition (i.e. species are not equivalent from a conservation point of view), between-habitat diversity (where the focus is on boundaries between habitats) and functional diversity (where the focus is on the range of functional traits of organisms).

**Relationships between habitat loss and species diversity** - Based on available information from the literature, we propose an hypothetical model that synthesizes the complex direct and indirect effects of habitat loss and replacement on the components of species diversity at a community level. In this model we identify:

1) **The major components of habitat loss.** Studies generally identify three major components of habitat loss, that are: (a) the loss of resident species. Communities consist of species that differ greatly in their ecology and how they respond to habitat loss. The major threats are reported for species that have narrow distributions up to being exclusive to certain habitats (Thrush *et al.*, 2006); (b) the loss of food resources. Seagrass meadows, kelp forests and other biogenic habitats are known to be highly productive compared to structurally simpler habitats such as sandy flats. They export vast quantities of carbon, nitrogen and phosphorus to coastal food webs either through direct transfer of animal biomass (i.e. predation, movements of individuals) or outwelling of dissolved and particulate organic matter. There is evidence that the loss of these food resources can affect negatively the productivity of individual species or groups of species, with effects that are likely to propagate along food chains (Jackson *et al.*, 2001; Graham, 2004; Dobson *et al.*, 2006); (c) the loss of ecosystem functions and properties related to the influence of the habitat on the environment. Structurally complex habitats strongly shape the physical environment, e.g. by modifying light conditions, hydrodynamism, sedimentation, providing shelter and refuges, and buffering the effects of disturbances. When these habitats are lost, many of these functions are also lost (Dobson *et al.*, 2006) but direct research to quantify these effects and the underlying mechanisms is surprisingly scarce.

2) **The consequences of these losses on species diversity.** The main reported effects of marine habitat loss are reductions in overall abundance and biomass often associated with declines in species richness although these latter effects are much less studied. Frequently, the biological and environmental changes determined by the loss of native habitats promotes the colonization or expansion of sets of species that seem to do well in the new disturbed conditions. One example is the expansion of turf-forming, filamentous or other ephemeral seaweeds following the regression of algal canopies in many regions worldwide. Colonizing species sometimes also include aliens (Galil, 2007), that tend to invade disturbed environments more easily than undisturbed environments (Britton-Simmons, 2006). These sets of expanding species can amplify the changes to the system, cause variable effects on species richness and other components of diversity, feed back to affect the various components of habitat loss (e.g. maintain new environmental conditions) and prevent the recovery of the system, but these effects are largely overlooked.

3) **The resulting large-scale homogenization of marine systems.** At large spatial scales the loss of habitat can be rendered as a biotic homogenization. Biotic homogenization occurs as a reduction in overall structural complexity, native biota, functional traits and the expansion of few widespread and less complex broadly tolerant biota (Mckinney & Lockwood, 1999). The biotic homogenization amplifies and at the same time is amplified by the homogenization of environmental conditions which is occurring globally via direct and indirect anthropogenic effects, such as replacing wetlands with aquaculture ponds or through largescale increases of turbidity and nutrients. Lotze *et al.*, 2006) illustrate the consequences of these feedback among anthropogenic activities, habitat loss and biotic-environmental homogenization in a dozen estuaries globally.
Conclusions - Habitat loss leads to many significant changes in composition, species richness and abundance. While these effects are being increasingly recognised and studied, the declines in between-habitat and functional diversity have been overlooked. Current research on habitat loss also tends to overlook the possible synergic problems caused by the parallel local, regional and global expansion of small and previously less abundant species, with a clear trend towards generalistic, opportunistic and/or invading traits. The ultimate effects and feedbacks of the overall simplification and homogenization of marine seafloors on ecosystems functions are largely unexplored in marine systems. These ecosystem functions are critical and closely tied to the delivery of ecosystem services to humans. The conservation of coastal and marine habitats has been driven in part by the effects of habitat loss on declines in species richness, which has been one of the major focus of recent research (Wolff, 2000). However, looking at the effects of habitat loss just on species richness is not sufficient. For example, estuaries are characterized by relatively low richness but are extremely productive and unique systems and they provide some of the most substantial services to human through their ecosystem functions (e.g., Gray, 1997; Costanza et al., 2003). Recently developed models also suggest that the loss of ecological functions that occurs as habitats are lost can be disproportionately greater than what would be predicted from a decline in species richness (Dobson et al., 2006; Thrush et al., 2006). This is because the species that are most lost are not randomly distributed among ecological and functional categories, but include large, specialist species that often affect disproportionally the biological and physical environment. While the general appreciation of ecosystem functions and services can help bolster the impetus for action, we need better science on effects of habitat loss on species diversity and functions to inform decisions. With this understanding we can begin to better prioritize and manage coastal habitats based on the functions and services they provide.

References