Associations of concern: declining seagrasses and threatened dependent species

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Seagrasses are important marine foundation species that are reported to be declining across the globe, with almost 15% of species considered threatened. Seagrasses are highly productive plants that reconfigure water flow and influence nutrient cycling, as well as providing critical habitat for a wide array of fish and invertebrate species. Yet, many of these seagrass-dependent species, including economically important fishes and invertebrates, are themselves in danger of overexploitation or extinction. In fact, there is, on average, more than one threatened associated species for every seagrass species across the globe. Links between threatened seagrasses and their dependent communities illustrate the importance of an ecosystem-based management approach that incorporates interdependencies and facilitation among species.

Front Ecol Environ 2009; 7, doi:10.1890/080041

Methods

Given the documentation of widespread seagrass decline (Orth et al. 2006) and threats to particular associated species (eg dugongs; Marsh et al. 2005), our objective was

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to conduct a systematic tally of the conservation status of seagrass species and their associates. This tally represents the first comprehensive assessment of seagrass-dependent species of conservation concern. The decline in seagrass-dependent species is often considered to be associated with seagrass decline; for example, the loss of brant geese (*Branta bernicla*) and shellfish followed the outbreak of eelgrass wasting disease in the 1930s (Rasmussen 1977). However, the causal relationship between seagrass decline and the conservation status of dependent species has been poorly quantified (but see Williams 1988). Thus, although we expect that past and continuing seagrass disappearance will contribute to conservation concerns regarding seagrass-associated species, data are insufficient to quantify the relative importance of habitat loss (ie seagrass decline) and other threats here. A comprehensive tally of seagrass-dependent species of concern will serve as important background for future studies and conservation efforts in general.

We examined the following national and international lists of threatened and vulnerable species for seagrasses and associated organisms: Agreement on the Conservation of African–Eurasian Migratory Waterbirds (AEWA); American Fisheries Society List of Marine, Estuarine, and Diadromous Fish at Risk of Extinction in North America (Musick et al. 2000); Australian Threatened Species List; Protocol for Specially Protected Areas and Biodiversity in the Mediterranean; International Union for Conservation of Nature and Natural Resources (IUCN) Red List; Monterey Bay Aquarium Seafood WATCH List; and the US Endangered Species Act. We initially identified seagrass-associated species using either the habitat information provided by the listing agency or our collective knowledge of these systems. We then searched the published scientific literature for documentation that each species utilizes seagrasses during one or more of its life history stages. Species for which we could not find independent verification (*n* = 34) were not included further in our analyses.

For each seagrass-associated species, we recorded: species name; common name; degree of threat (extinct, critically endangered, endangered, threatened, near threatened, vulnerable, species of concern); and cause(s) of threat (eg habitat loss, overfishing, reduced water quality), as given by the listing agency. Any information not provided by the listing agency was completed with the use of sources in the published literature.

To evaluate patterns of risk among seagrass-associated species, we divided species into general taxonomic groups: birds, crustaceans, fish, mammals, mollusks, and reptiles. Because most species in our analysis were fish, we subdivided this group into cartilaginous (rays, sharks, skates; Class Chondrichthyes) and ray-finned (Class Actinopterygii) fishes. We further separated seahorses and pipefish (Order Syngnathiformes) from the other ray-finned fishes, because of their extreme reliance on seagrasses and the unique threats they face. We then tabulated the number of species in each taxonomic group by degree of threat.

#### Results

Nearly 15% (8 of ~ 60) of seagrass species are currently listed as threatened in some portion of their range, including Johnson’s seagrass (*Halophila johnsonii*), Neptune grass (*Posidonia oceanica*), widgeon grass (*Ruppia maritima*), *Zostera asiatica*, *Zostera caespitosa*, *Zostera caulescens*, eelgrass (*Zostera marina*), and dwarf eelgrass (*Zostera noltii*) (Figure 1; WebTable 1). Although the specific causes of decline vary somewhat (WebTable 1), many are linked to physical disturbance (coastal development) or changes in water quality (eutrophication, sedimentation, pollution).

The number of species of concern associated with seagrasses exceeded the number of threatened seagrass species by a factor of 10 (74 species; WebTable 1; Figures 2 and 3). Indeed, there is, on average, more than one species of concern for every seagrass species across the
globe. Ray-finned fish are the most affected taxonomic group, and over half of those (31 species) are seahorses or pipefish. In fact, about 30% of all named seahorse species, all of which use seagrass habitats, are included on the IUCN Red List. Roughly 20% of the species listed as “to avoid” by Seafood WATCH, a program that alerts consumers to the sustainability of seafood, rely on seagrasses during at least part of their life cycle. In addition, nearly half of the fish species listed as vulnerable to extinction by the American Fisheries Society also use seagrasses as habitat during some portion of their life cycle (Musick et al. 2000).

In some cases, there are important linkages between species of concern within seagrass meadows. For example, Pontonia pinnophylax, which lives within the shells of fan mussels, is itself likely threatened because of an abrupt decline in the abundance of its bivalve host (Richardson et al. 1997). Thus, threatened seagrass meadows support threatened species that, in turn, support other vulnerable species.

Many seagrass-associated species are considered vulnerable or threatened, and there have been at least three extinctions already, one of which was due specifically to loss of habitat: the eelgrass limpet was the first historical extinction of a marine invertebrate in an ocean basin (Carlton et al. 1981).

A variety of threats other than habitat loss also contribute to the decline of seagrass-associated species (WebTable 2). Overfishing, including harvesting for the aquarium trade and medicinal purposes, was the most commonly listed cause of decline. Reduced water quality also impacts a large number of species. Direct physical damage and pollution were less commonly cited threats.

**Figure 2.** Species of concern associated with seagrasses. The number of species categorized by taxonomic group and level of concern.

**Discussion**

Seagrasses are well-known foundation species, providing critical habitat for a wide array of fish and invertebrate species. Many of these seagrass-dependent species, including economically important fishes and invertebrates, are themselves in danger of extinction (Figure 2). Furthermore, there are often crucial links among these threatened seagrass associates, as when one species of concern serves as host for another (Richardson et al. 1997), or when a number of threatened species are linked together through trophic interactions (eg scallops, rays, and sharks; Myers et al. 2007). Although changes in trophic structure can potentially have either positive or negative impacts on primary producers such as seagrasses, depending on the length of the food chain and which levels are affected (Stibor et al. 2004), the disappearance of these species is expected to be universally detrimental to others that depend on them.

Our analysis of the species of conservation concern associated with seagrasses probably underestimates the magnitude of the problem for a number of reasons. First, we restricted our list to those species whose association with seagrass could be confirmed in the published literature or by our own observations. (This restriction resulted in the exclusion of 34 species listed as seagrass associates by the IUCN Red List.) In addition, our analysis cannot, of course, include the large numbers of seagrass associates whose conservation status has not been assessed (eg meiofauna). Perhaps most importantly, we included only those species that utilize seagrasses directly, and not the many species that are linked indirectly, via trophic connections and subsidies (Heck et al. in press). For example, declines in seven species of threatened sharks have cascading effects on rays and scallops (Myers et al. 2007). Because both rays and scallops are documented seagrass associates (WebTable 2), these seven shark species are also indirectly linked to seagrasses, yet we only included the three species in our list that actually use seagrass habitat. Our list is therefore probably biased toward lower trophic levels, with less representation of the many top predators of conservation concern.

Although reduced rates of exploitation are certainly necessary to conserve many seagrass associates, from seahorses to snappers, conservation of these species will also
Figure 3. Representative threatened and endangered species associated with seagrasses. (a) Green sea turtle (Chelonia mydas); (b) fan mussel (Pinna nobilis); (c) dwarf seahorse (Hippocampus zosterae); (d) dugong (Dugong dugon).

Although seagrasses are protected species in many regions (eg under the US Clean Water Act), the extent of their global decline is not generally realized, and there is a general lack of awareness of the importance of these ecosystems (Duarte et al. in press). More importantly, the relationship between seagrass extent and the abundance of seagrass-associated species has not been sufficiently quantified. The true conservation costs of seagrass declines are therefore being underestimated. This is due, in part, to historical divisions in the authority for management decisions, at least in the US: seagrass regulations are generally related to limiting actions that result in water quality declines or direct loss of habitat (US Army Corps of Engineers), whereas listed species are more directly managed at the single-species level (US Fish and Wildlife Service). In addition, threats to biodiversity are often listed on a species-by-species basis (eg IUCN Red List), rather than by specific threats or habitats, obscuring

There are potentially serious economic implications for not taking action to conserve seagrasses and their associated species. In the US alone, commercial landings of several species that use seagrasses during part of their life cycle totaled over $126 million in 2005 (National Marine Fisheries Service 2007; WebTable 3). For example, Pacific rockfish landings generated $16 057 725, with commercial landings of Caribbean spiny lobster yielding an additional $16 691 634. Although striking, these figures do not include commercial landings associated with seagrasses outside the US. More importantly, they do not reflect the value in terms of the ecosystem services of non-commercially harvested seagrass associates or the seagrasses themselves.
the connections between threatened species and their habitats and, therefore, the benefits of ecosystem-based biodiversity conservation. There are exceptions to this single-species approach, such as the protection of seagrasses as “essential fish habitat” by the US National Marine Fisheries Service. Our results demonstrate the presence of multiple, interdependent species of concern in a single habitat, thereby highlighting the importance of efforts to move from a species-by-species conservation and management strategy to an ecosystem-based approach, particularly for threatened foundation species such as seagrasses and the communities that depend on them.

Acknowledgments

We thank S Olyarnik for helpful comments. J Jeffords, M Nakaoka, M Sanfelix, F Short, and R van Dam kindly shared photos. This work was conducted as part of the Global Seagrass Trajectories Working Group supported by the National Center for Ecological Analysis and Synthesis, funded by NSF (grant #DEB-00-72909), the University of California at Santa Barbara, and the state of California. Additional support was provided by NSF grant OCE-06-23641 to ARH. This manuscript is UC Davis Bodega Marine Laboratory Contribution Number 2417 and 23641 to ARH. This manuscript is UC Davis Bodega Marine Laboratory Contribution Number 2417 and 23641 to ARH. Additional support was provided by NSF grant OCE-06-23641 to ARH. This manuscript is UC Davis Bodega Marine Laboratory Contribution Number 2417 and Dauphin Island Sea Lab Contribution Number 392.

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