

Chapter 47. Kelp Forests and Seagrass Meadows

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1. Introduction

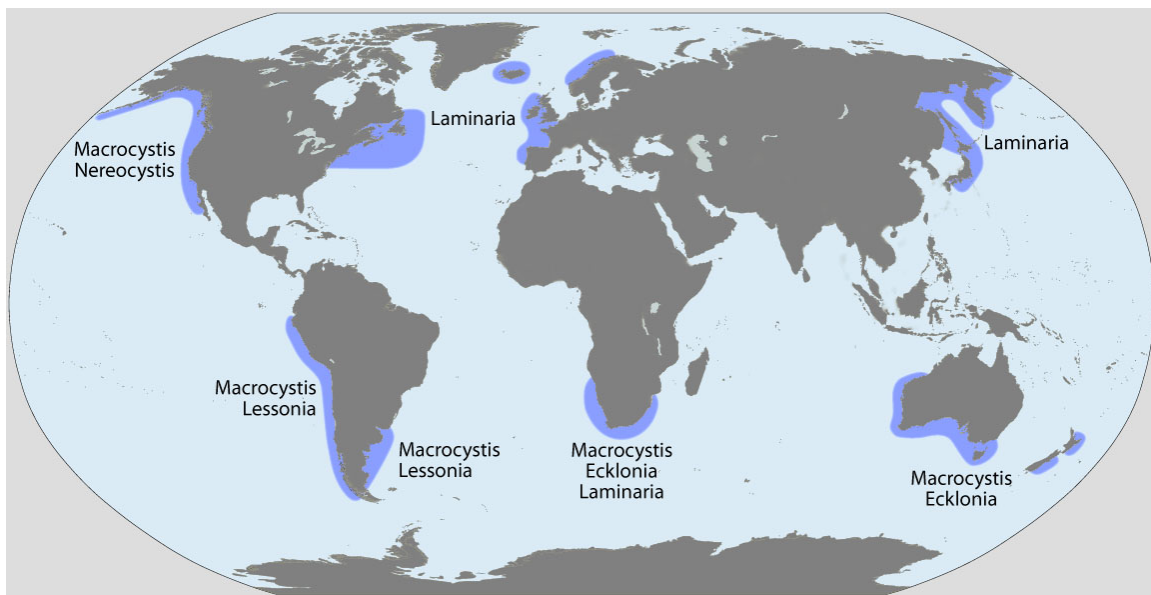
Kelp forests and seagrass meadows form shallow benthic marine habitats. Whereas kelp forests are limited to temperate areas (see Figure 47.1), seagrasses are found throughout all climatic zones (den Hartog 1970; Phillips and Meñez 1988), except in the Polar Regions (see Figure 47.2a). Both provide food and habitat to many economically exploited species, have high productivity (see Chapter 6 for values) and thus, play a significant role in ecological balance. Apart from goods (e.g. associated fisheries, food, phycocolloids) produced by these two ecosystems, kelps and seagrasses also provide many ecosystem services such as carbon sequestration and climate regulation (Raven 1997, Thom 1996; Beer and Koch 1996; Fourqurean et al., 2012), nutrient cycling (Fenchel, 1970; Robertson and Mann 1980; Suchanek et al., 1985; Wahbeh and Mahasneh, 1985; Wood et al., 1969), sediment stabilization and shoreline protection (Barbier et al., 2013), habitat and nursery functions (Duggins et al., 1990; Heck et al., 2003), especially for high value organisms such as crabs, shrimps, clams, flounder, spiny lobster (Kikuchi and Peres, 1977; Tegner and Dayton, 2000). The values of these services vary across geographic regions and cultural groups (see Barbier et al., 2011; Costanza et al., 1997; Cullen-Unsworth, 2014).

The kelp forest is characterized by about 30 species of large brown seaweeds belonging to the order Laminariales (Steneck et al., 2002). Together with its associated animals and other seaweeds, it is considered to be among one of the economically important ecosystems, especially for peoples who have traditionally used them for food, chemicals such as alkali and iodine (Robinson, 2011), and fertilizer and animal feed supplements (Stephenson, 1968). Currently, kelps are still harvested mainly for food and as source of the phycocolloid alginate, which has many uses in industry (see Chapter 14). The brown seaweeds, which are composed primarily of kelps, contribute about half of the total world seaweed production from aquaculture of about 6.8 million tons a year (averaged over a 10-year period between 2003-2012; data from FAO).

The kelp forest is structured like any forest, with different species forming layers or tiers, and large canopy species reaching heights to 45 metres (Steneck et al., 2002). Dominant species differ across regions (see Figure 47.1). Although kelps are not considered to be taxonomically diverse, because most genera are composed of only one species, they support economically important fisheries, such as abalone, lobster, and cod (Steneck et al. 2002). Some host marine mammals, such as sea otters, harbour seals and other pinnipeds (Tegner and Dayton, 2000). Species like the rockfish (*Sebastes* spp.)

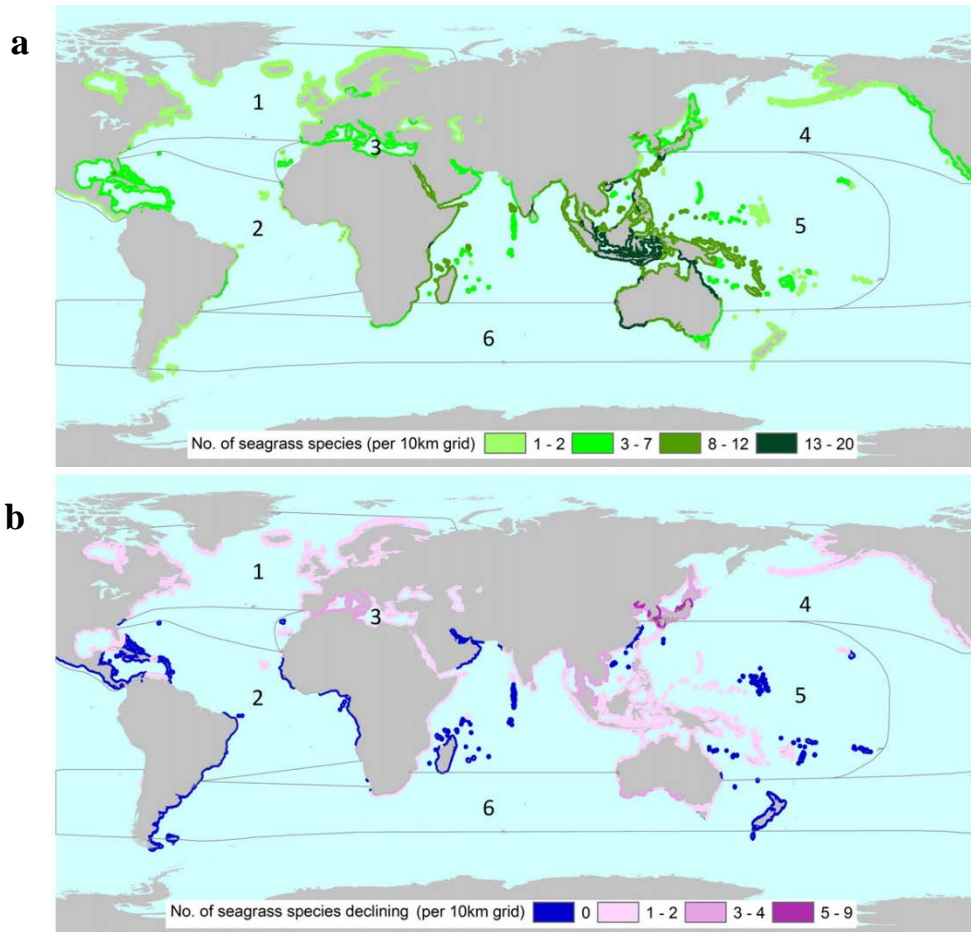
use kelp habitats during some or most of their life histories (Duggins et al., 1990; Eckman et al., 2003).

Seagrasses are a group of about 72 species of flowering plants in six families (Short et al., 2011) adapted to living and reproducing in the marine environment. They are not true grasses but are named for their close morphological resemblance to terrestrial grasses. They form underwater meadows at depths reached primarily by sunlight in the red wavelength part of the spectrum. In addition, they have unusually high light requirements, approaching 25 per cent of incident radiation for some species (Dennison et al., 1993). Tropical seagrasses tend to have deep lower limits as a result of clear water (and hence, greater light penetration) while most temperate seagrasses are limited to considerably shallower depths. Hence, only a few species grow below 20 m of depth, such as some *Halophila* species which have been reported to occur at 40 m (Philipps and Meñez, 1988) and *Posidonia* at 45 m (Pergent et al., 2010). Seagrasses are not presently harvested commercially but they are critical food sources for large herbivores that are specialized for eating seagrass such as manatees, dugongs, green turtles (Philipps and Meñez, 1988) birds, particularly Brant geese (*Branta bernicia*) as they require temperate eelgrass beds as a primary food source (Baldwin and Lovvorn, 1994), and certain commercial fish species such as rabbitfish, and for many other species that feed on the epiphytes and epifauna (Moncreiff and Sullivan, 2001).



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 1. Map showing the approximate location of kelp forests and their dominant species. Modified from: Steneck et al., 2002 extracted from http://commons.wikimedia.org/wiki/File:Kelp_forest_distribution_map.png.



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Figure 2. Map showing (a) worldwide distribution and species richness of seagrass meadows; and (b) number of species having declining population trends (sensu IUCN) from Short et al. (2011). Numbers on the map refer to Bioregions. 1-Temperate North Atlantic; 2-Tropical Atlantic; 3- Mediterranean; 4-Temperate North Pacific; 5-Tropical Indo-Pacific; 6-Temperate Southern Oceans.

2. Population trends and pressures

The harvest of kelps for food and industry is the major pressure on the kelp population worldwide (Vasquez and Santelices, 1990; Millar, 2007; see also Chapter 14). This has resulted in changes in the kelp community structure and habitat well described by McLaughlin et al. (2006) in Chapter 14, and in more recent studies conducted by Estes

2011, Ling et al., 2015; Rocha et al., 2015; Russell and Connell, 2014; Steneck et al., 2013.

Apart from overexploitation, kelp population and distribution worldwide are reported to be affected by a variety of factors. Connell et al. (2008) reported on a wholesale loss of canopy-forming kelp forests (up to 70 per cent) on the Adelaide metropolitan coast of South Australia where urbanization occurred. Overfishing of high value predators often causes explosions in herbivore populations, such as sea urchins, that feed on kelps, resulting in massive reduction of kelp cover and consequently affecting other trophic levels (see Connell et al., 2011; Moy and Christie, 2012; and also Chapter 14). Steneck et al. (2002) reported this threat to kelp beds to be highest roughly in the 40–60° latitude range in both the northern and southern hemispheres. Other mechanisms of kelp forest decline are mechanical damage from destructive fishing gears and boat propellers, pollution, nutrient availability, diseases and parasites, and climatic changes.

Kelp die-off along the coasts of Europe has been reported (Raybaud et al., 2013; Brodie et al., 2014), e.g. in Norway (Moy and Christie, 2012), as well as off the coast of Australia (Smale and Wernberg, 2013; Wernberg et al., 2013). In addition, changes in the distribution of species have been reported in the polar North Atlantic (Müller et al., 2009), and off the coasts of southern England of the United Kingdom (Brodie et al., 2014; Pereira et al., 2011), South Africa (Bolton et al., 2012) and Australia (Connell et al., 2008; Millar 2007; Russell 2011; Smale and Wernberg, 2013; Wernberg et al., 2011; Wernberg et al., 2013) due to increased seawater temperatures. In 2011, the high biodiversity Indian Ocean region of Western Australia experienced a heat wave, which raised seawater temperatures by 2–4°C, causing a significant decline in the canopy-forming brown macroalgae *Scytothalia* and *Ecklonia radiata*, which are important in stabilizing habitats. *Scytothalia* had a 100-km southward retraction from its northernmost limit (Smale and Wernberg, 2013; Wernberg et al., 2013). A similar pattern of southern retraction by other temperate macroalgae caused by seawater warming is evident along the Pacific Ocean coast of eastern Australia (Wernberg et al., 2011). Kelps are most affected by rising water temperature, because sexual reproduction (gamete formation) in most kelps will not occur above 20°C (Dayton, 1985; Dayton et al., 1999). This has been found to be amplified negatively by synergistic interactions between nutrient enrichment and heavy metals, the presence of competitors, low light and increasing temperature and competition with mat-forming seaweeds (Strain et al., 2014).

Seagrass beds are reported to be among the most threatened ecosystems on earth with an estimated disappearance rate of 110 km² per year since 1980; the rates of decline accelerating from a median of 0.9 per cent per year before 1940 to 7 per cent year⁻¹ since 1990 (Waycott et al. 2009). According to their assessment, 29 per cent of the known areal extent has disappeared since seagrass areas were initially recorded in 1879. For example, in the Baltic Sea, where only one main seagrass species (*Zostera marina*) exists, seagrass meadows have significantly declined (Boström et al. 2014). In terms of species, Short et al. (2011) reported that 22 of 72 species (31 per cent) of the world's total number of species have declining populations, 29 species (40 per cent) have stable

populations, five species (seven per cent) have an increasing population (see Figure 47.2b), and the status of 16 species (22 per cent) is unknown. Two of the species with increasing population (*Halophila stipulacea* and *Zostera japonica*) have been reported to have recently expanded across the Pacific and Atlantic Oceans (Short et al. 2007, Willette and Ambrose 2009). Reported areas of highest decline (80-100 per cent of all species) are in: (a) in China-Korea-Japan region, where the decline is associated with heavy coastal development and extensive coastal reclamation, (b) southeast Asia (one species) due to aquaculture, fisheries and heavy watershed siltation, (c) Australia (three species), and (d) the Mediterranean (four/five species). Declines in Australia and the Mediterranean are primarily attributed to mechanical damage from propellers and ship grounding, degraded water quality, and competition with introduced species such as *Caulerpa* (Williams and Smith 2007). Short et al. (2011, Table 4, p. 1969) rated coastal development as representing the highest threat (93 per cent of the species affected), degraded water quality (53 per cent), mechanical damage (44 per cent), aquaculture (39 per cent), fisheries (38 per cent), excess siltation/sedimentation (36 per cent), competition (7 per cent), and disease (2 per cent).

As for kelps, overfishing of top predators often results in an increase in herbivores, such as sea urchins, that leave barren 'halos' in seagrass beds. Another reported cause of population decline is the "wasting disease" that wiped out the seagrass meadows in the Pacific Northwest and on both sides of the North Atlantic in the 1930s, due to a marine slime mould (*Labyrinthula*) infestation (Rasmussen, 1977); this organism reappeared in New Hampshire and Maine in 1986 (Short et al., 1986). The effects of climate change on seagrasses are just beginning to be studied (Chust et al., 2013; Valle et al., 2014). Of the 72 species, 15 or 24 per cent (Short et al., 2011), are currently classified under the International Union for Conservation of Nature (IUCN) criteria as Threatened (Endangered or Vulnerable) or Near Threatened.

3. Ecological, economic, and social implications

Ecologically, the loss of these two ecosystems will reduce the amount of "blue" carbon stored in submerged marine habitats and thus, increase impacts and changes worldwide on weather patterns, directly putting coastal residents, their livelihoods and food production at risk (see Nelleman et al., 2009; Byrnes, et al., 2011; see also Chapter 6).

Losses of kelp and seagrass beds will affect populations of large marine herbivores, such as manatees, dugongs and green turtles, thus further undermining their already poor conservation status. Short et al. (2011) reported that 115 marine species that live in seagrass beds, including some invertebrates, fishes, sea turtles, and marine mammals, are listed by IUCN as threatened. In addition, reef and mangrove ecosystems biodiversity will be affected by the loss of seagrass habitats since many fish and invertebrate species found in coral reefs and mangroves have been reported to spend their juvenile stages in seagrass beds (Dolar, 1991; Orth, 2006).

Furthermore, the loss of seagrass beds and kelp forests will deprive commercially important fish (such as rabbit fish and cod) and invertebrate species (such as abalone and lobster) of food, habitat and nursery areas, thus undermining their growth and reproductive success and reducing the chances of the stocks either being maintained or being brought back to pre-depletion levels (Orth et al., 2006). This will affect catches of fishers and threaten food security.

Kelp forest losses will reduce the supply of commercially important alginates and fucoidan, thus raising their prices or making them less readily available for new applications (see further Chapter 14). Also, loss of kelp may have an adverse effect on the number of coastal residents whose livelihoods depend on kelp harvesting.

4. Management and conservation responses

Many strategies have been employed in the management of kelps and seagrass meadows. These include: protection through declaration of sanctuaries and protected areas,¹ regulation of harvesting through permitting system for kelps (Leschin-Hoar, 2014), regulation of fishing methods destructive to kelps and seagrasses, such as trawls and seines; transplantation and restoration of seagrass beds (Calumpong and Fonseca, 2001; Fonseca et al., 1998), and systematic monitoring (www.seagrassnet.org).

5. Information and knowledge gaps

The biology and population dynamics of some kelp and seagrass species are still unstudied. Nine of 72 seagrass species are designated by IUCN as Data Deficient due to lack of information about them, while population trends of 16 species remain unknown (Short et al., 2011). Data on relative impacts of anthropogenic factors as well as interactions with climatic changes are lacking (Larkum et al., 2006; Chust et al., 2013; Doney et al., 2009; Duarte, 2002; Grech et al., 2012; Roleda et al., 2012; Valle et al., 2014). Active research is being conducted in the areas of economic valuation of ecosystem services provided by these two ecosystems.

¹ See:

http://www.westcoast.fisheries.noaa.gov/habitat/habitat_types/kelp_forest_info/kelp_forest_habitat_types.html; <http://www.pcouncil.org/habitat-and-communities/habitat/>; <https://catalog.data.gov/dataset/public-seagrass-compilation-for-west-coast-essential-fish-habitat-efh-environmental-impact-stat>; <http://www.marinecadastre.gov/news/uses/seagrasses-distribution/>.

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