11 What can be done to prevent seagrass loss?

The presence and distribution of seagrass beds depend on many complicated environmental factors and conditions. Nevertheless, the main factors responsible for loss of seagrass beds can often be clearly identified and addressed in the management of coastal zones. Efficient remedial actions may sometimes involve high-cost regulation of land use but in other instances can be based on simple, low-cost means or be taken into account during planning and implementation of human activities.

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The most important factors for seagrass growth and distribution have been identified as: water column light conditions affected by nutrient loading and siltation, water column and sediment oxygen conditions affected by organic loading, chemical pollutants in the form of e.g. pesticides and antifouling agents and, finally, physical disturbance generated by coastal constructions, fisheries, boating, clam digging, etc. (see chapter 4 and 6). In addition to these common disturbances, local conflicts between human activities and seagrass conservation may arise in connection with e.g. cooling water from power plants or high salinity water from desalination plants. At the other end of the spatial scale, global climate changes may in the future have marked influence on the abundance of seagrasses.

A wide range of management tools are available to prevent or reverse seagrass loss, but their efficiency and costs vary substantially, and remedial actions must be selected depending on the nature, source and strength of the human disturbance causing the loss of seagrass beds.

Nutrient loading

Nitrogen and phosphorous are the most important nutrients regulating planktonic algae, and hence water transparency and light conditions for seagrasses. Nutrients also stimulate growth of algae living on seagrass leaves causing additional shading. Nitrogen and phosphorus derive from a variety of sources, some of which are of regional importance, others of local importance. The most important sources of nutrient loading to coastal areas are urban sewage outlets, industrial outlets, runoff from fertilized agricultural areas and atmospheric deposition of nutrients originating from agriculture and fossil fuels. Fish farms, small point sources from industries, houses and from boats are often minor contributors to nutrient loading but may be of large local importance in lagoons or embayments with low water exchange.

Nutrient loading is beyond comparison the most important factor responsible for deterioration of seagrass beds on national and regional scales. As an example, the effects of anthropogenic nutrient loading from urban sewage and agricultural runoff can be traced in all marine waters in the Baltic along the coast of northern Germany, Denmark, Sweden, southern Norway and even in the open part of the North Sea. This nutrient loading has resulted in a decline of seagrass depth penetration and area distribution of 40-50% within the last century. Hence, it is obvious to address nutrient loading as a first priority issue in coastal management.

Efficient remedial actions against regional nutrient loading may require high-cost intervention against sewage disposal, agricultural runoff and the use of fossil fuels. Urban and industrial sewage must be diverted to sewage treatment plants with efficient means of nutrient removal (Fig. 11.1). The techniques are well known but investments and running costs are high. Similarly, efficient reduction of agricultural runoff requires major, integrated remedial actions with limits on the use of fertilizers and restrictions on land use in catchment areas. As an example, narrow zones of uncultivated soils along streams and rivers together with undisturbed wetlands have significant potentials for intercepting nutrient runoff before reaching the water and, therefore, such zones should be established and protected through legislation. Such remedial actions are being implemented in several North European countries. Marsh areas similarly function as extensive and important buffer zones with substantial capacity to capture nutrients, and marsh areas must be protected against disturbance and exploitation.

Smaller point sources with nutrient loading to lagoons and embayments can be addressed by legislation. Fish farms, industrial outlets and sewage disposal should not be allowed in lagoons and embayments but must be re-located to areas with more efficient water exchange or preferably be diverted to sewage treatment plants. Even sewage from small boats may constitute a problem in popular anchoring sites, especially in nutrient poor Mediterranean embayments, and should be avoided through legislation on sewage containment aggregates and by implementing codes of conduct.

Loading of organic matter

Inputs of organic matter consume oxygen in the water column and sediment. Seagrasses need oxygen for respiration in leaves and roots and as a protection against invasion of toxic compounds from the sediment (see chapter 4). During daytime the plants produce oxygen by photosynthesis, but in the dark, oxygen is supplied from the water to the leaves. Therefore, poor oxygen conditions due to organic loading are important stress factors for seagrass growth and survival.

The sources of organic loading are often the same as those of nutrient loading but the impact of the organic loading is more local and often less severe. Sewage treatment plants may efficiently remove organic wastes at relatively low cost by simple mechanical treatment means (filtration or sedimentation tanks). However, outlets of untreated sewage are still very common in some contries, even from larger cities and industries, but most untreated sewage originates from numerous small settlements and smaller industries. Where sewage treatment cannot be applied, remedial actions may be taken to ensure that outlets are positioned outside the seagrass beds and in areas with high water exchange to ensure efficient dilution of the organic matter.

Figure 11.1. Negative impacts of nutrients, organic matter and industrial wastes on coastal waters, including seagrass beds, can be substantially reduced by treating waste water in advanced sewage treatment plants (with permission from Lynettefællesskabet I/S).

Fish farms constitute a local but very substantial source of organic matter because of inefficient utilization of the fish feeds. The sea floor below fish farms receives large amounts of organic matter and as a general rule the farms should be placed outside areas with seagrass beds. If this is not possible, addition of iron to the sea floor or to the fish feeds may be considered as possible means to reduce the negative impact on seagrass beds, because iron has a positive effect on plant performance and survival. Organic loading from small boats may locally, in areas with low current and water exchange, have a substantial negative impact on seagrass beds.

Siltation

Siltation is the process where fine silt particles (mud and clay) originating from land or from the sea floor are suspended in the water column creating turbid water and poor light conditions for seagrass growth. Hence, the consequences of siltation are almost the same as those of nutrient loading. In addition, the silt may settle on the seagrass leaves, and at very high siltation rates, the plants may even be buried.

Siltation originating from land is the result of land use (agriculture or deforestation) or construction activities (e.g. road construction) in the catchment areas or coastal zone. Siltation may, however, also arise, at least temporarily, during human disturbance of the sea floor in connection with dredging and sand reclamation.

Agriculture, forestry and construction activities in coastal areas must be planned and conducted taking actions to minimize siltation to streams and rivers or directly to coastal waters. For agriculture, uncultured buffer zones along streams and rivers can, like for nutrients, function as efficient filters for runoff of silt. With respect to deforestation there are well-known procedures such as strip cutting to reduce soil erosion and subsequent siltation from forests growing on high slope grounds. In contrast to the land based siltation sources, it is impossible to avoid siltation in connection with dredging, sand reclamation and marine constructions. However, sand reclamation can be conducted in areas outside the seagrass beds and dredging can be conducted with equipment minimizing silt loss. In addition, dredging and sand reclamation can be restricted to short, intensive periods as seagrasses can overcome shorter periods (days) with poor light conditions without major problems.

Mechanical disturbance and coastal constructions

Direct mechanical disturbance and uprooting of seagrasses have long-term impacts on seagrass beds because seagrasses are in general slow-growing plants requiring long periods for recolonization. Mechanical disturbance is caused by dredging, sand reclamation, land reclamation for agriculture or clam culture and by trawling within the seagrass beds. Anchoring and boat propels may also give rise to scars in the stands. Coastal constructions, such as bridges and piers, directly on seagrass beds are obvious and fatal mechanical disturbances but even small scale disturbances such as clam digging inside intertidal seagrass beds may have substantial negative impacts on seagrass growth and survival.

Dredging is often necessary to ensure boat access, but dredging channels should be placed outside the most important seagrass beds if possible (Fig. 11.2). Similar considerations can be taken when constructing bridges and piers although public interest in infrastructure often will

Figure 11.2. Dredging and sand reclamation from shallow coastal areas with seagrass beds has major detrimental impacts due to direct destroyment of the beds and due to resuspension of sediments and reduction of the light conditions for plant growth. Photo: Rui Santos

have first priority. In contrast to this, sand reclamation within seagrass beds can easily be prohibited by legislation without any socioeconomic consequences.

Disturbances caused by boating, anchoring, trawling and clam digging may similarly be controlled through legislation, local regulations or codes of conduct based on awareness. Damage caused by anchoring may seem to be a minor problem but in popular anchoring sites, e.g. with beds of the slow-growing *Posidonia*, anchoring scars are a major problem with long-term consequences. In such areas permanent anchoring buoys can be established and damage to the seagrass bed completely avoided. Trawling and clam digging activities should to the widest possible extent be held outside the seagrass beds.

Heat and salinity stress

Like all other marine organisms, seagrasses are adapted to certain temperature and salinity regimes and anomalies compared to these regimes may result in decline of plant performance or even mortality.

Salinity anomalies in the form of too low or too high salinity may occur when water exchange between lagoons and open sea is regulated through dam construction or floodgate control. There are several examples from lagoons adjacent to the Wadden Sea and the North Sea of how control of water exchange has reduced salinity to an extent where seagrasses are not able to survive, and large seagrass beds have been destroyed. In areas with low precipitation and low freshwater runoff, removal of water exchange may result in too high salinities similarly resulting in seagrass mortality. Very high salinities also occur around outlets of desalination plants operating to extract freshwater.

Heat stress may occur in connection with power plants using salt water as a cooling agent. In addition to these local human disturbances, the ongoing global climate change will affect temperatures with the possibility of increased heat stress in the southern and eastern parts of Europe, while a potential cooling of the climate in northern Europe due to changes in oceanic circulation may move the northernmost distribution limits of the *Zostera* species southwards.

Actions to prevent occurrence of heat and salinity stress on seagrass beds consist of means to ensure sufficient water exchange with the open

Text box 11.1. The most important actions to prevent seagrass loss are:

- Control and treatment of urban and industrial sewage to reduce the loading with nutrients, organic matter and chemicals
- Regulation of land use in catchment areas to reduce nutrient runoff and siltation due to soil erosion
- Regulation of land reclamation, coastal constructions and downscaling of water exchange between open sea and lagoons
- Regulation of aquaculture, fisheries and clam digging in or adjacent to seagrass beds
- Create awareness of the importance of seagrasses and implement codes of conduct to reduce small-scale disturbances

sea or ensure fast dilution of high salinity or high temperature outlets. Outlets with high salinity from desalination plants or cooling water from power plants should not be positioned in shallow waters inhabited by seagrass beds but instead be diverted to deeper waters with higher currents and dilution capacities. To counteract effects of global climate change, however, calls for actions at the international scale.

Contaminants

Pollution with man-made chemicals, such as pesticides, polyaromatic hydrocarbons, oil spills or anti fouling agents, may in certain areas constitute a substantial problem to seagrass performance and survival. These compounds have different effects on the physiology of seagrasses and other organisms and should in general be avoided through proper sewage treatment, regulation of industrial waste disposal or substitution of hazardous compounds.

The sources of chemical pollutants are numerous with crop cultivation as main responsible for pesticide contamination, industrial activities responsible for the disposal of a very large number of chemicals and ships and ship building industries as responsible for release of anti-fouling agents.

Actions to reduce pollutants must target the sources directly through legislation to implement adequate treatment of disposals and to substitute chemicals with unintended environmental impact by alternative and less toxic agents. These actions typically require national and international legislation while few means exist on regional or local scales. The fact that many chemicals may be transported over long distances in the atmosphere further stresses the importance of international legislation or agreements.

Invasive species and diseases

Seagrass loss may occur as a consequence of biological invasion of non-native species either competing with or feeding on the seagrass beds. Sudden outbreaks of mass destructive diseases are another potential cause of seagrass loss (chapter 6). There is an ongoing debate on the negative impact of the Mediterranean invasion of the green algae, *Caulerpa taxifolia*. Another example is the invasion of the Asian exotic mussel, *Muculista senhousia*, which can build up very high densities and have a negative impact on eelgrass beds. Finally, the outbreak of the eelgrass "wasting disease" caused by a slime mold in the early 1930s had dramatic consequences for eelgrass stands along the coasts of North America and Europe.

Introduction of new species with potential negative impacts on seagrass beds is an increasing threat due to the continuous increase in shipping transport between different regions of the world, mariculture based on foreing species and import of exotic species for aquaria. There are efficient means to reduce the risk of introducing invasive species with ship ballast water and a few contries (e.g. Australia and New Zealand) have implemented strictly enforced regulations to prevent intentional import of new species. Such regulations should also be implemented within the European Community. However, invasions of non-native species and outbreaks of diseases are very difficult to prevent and control. Fortunately, most introductions are non-successful because the non-native organisms are less fit than their native competitors. However, under conditions where the seagrasses are under environmental pressure due to human stress factors, they may be less able to overcome pressure from invading species. Accordingly, the best defence against the threat from invading species and diseases is to ensure otherwise undisturbed environmental conditions for seagrass growth.

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