



INSTITUTIONEN FÖR MARINA VETENSKAPER

Restoration and management of eelgrass (*Zostera marina*) on the west coast of Sweden

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ABSTRACT

Since the 1980s over 60% of eelgrass (*Zostera marina*) habitats have been lost from the Swedish NW coast, resulting in significant losses of the valuable ecosystem services provided by these habitats. The eelgrass loss has largely been attributed to the effects of eutrophication and overfishing, but coastal development could constitute an additional threat, since eelgrass often reside in shallow sheltered areas, where pressure from exploitation is high. In response to the historical losses, restoration of eelgrass ecosystems is being proposed by national agencies to assist recovery, but methods have not been available for high latitude environments, where the short growth season, ice-formation in the winter and muddy, organic-rich sediments present unique challenges for restoration. The overall aim of this thesis was to 1) develop methods suitable for large-scale restoration of eelgrass in high latitude, Scandinavian waters, 2) increase our understanding of environmental conditions that promote or impede eelgrass growth along the NW coast of Sweden and 3) assess the local and large-scale effect of shading by docks and marinas on eelgrass and identify problems with the current management, which allows for continued exploitation along the Swedish coast. The results presented in this thesis demonstrate that shading from docks and marinas constitutes a significant threat to the already decimated coverage of eelgrass along the NW coast of Sweden. In total, 480 ha of eelgrass habitat was estimated to be negatively affected, corresponding to more than 7% of the present areal coverage of eelgrass in the region. Results also show that eelgrass habitats are rarely assessed or considered within decisions for dock construction, and 80% of applications in areas with eelgrass were approved. Furthermore, the presence of protected areas only marginally reduces the number of approved cases. In order to stop this gradual deterioration of eelgrass habitats, and to achieve both national and international goals on environmental status, there is a need to revise management practice and include a large-scale perspective when assessing the effects of small-scale development. Results from field and laboratory studies demonstrate that eelgrass shoots have a strong capacity to acclimatize when transplanted between different depth, light- and hydrodynamic exposure conditions, through adjustments in morphology, pigmentation and growth strategy. They further show that transplants have the ability to store carbohydrates at light levels down to 11% of the surface irradiance (SI), but that light levels above 18-20% of SI are needed to ensure positive growth, and that even greater levels likely are required to ensure high vegetative reproduction and winter survival at sites targeted for restoration. Results from field studies in the southern parts of the NW coast demonstrate that water quality conditions have deteriorated in many areas where large historical meadows have been lost (1-2 m reduction in the maximum depth distribution of eelgrass). Eelgrass recovery and restoration in these areas are presently not possibly due to sediment resuspension and bottom drifting algal mats, suggesting that a local regime shift has occurred after the loss of eelgrass. It is therefore critical that management efforts focus on the protection of the remaining eelgrass beds in these areas, since losses may be irreversible over the foreseeable future and affect the water quality negatively also in neighbouring areas. The results from these studies further demonstrate that careful site selection is imperative for successful eelgrass restoration along the Swedish NW coast, where light attenuation, sediment grain size and the presence of drifting algal mats are key variables to consider. Results from method assessments for eelgrass restoration suggest that both shoot- and seed methods can be successfully used to restore eelgrass at this latitude and that high vegetative reproduction occur in shallow areas, where shoot densities can increase with >500% over 2 growth seasons. In deeper areas slow vegetative reproduction, a shorter growth season and high winter losses make restoration difficult. The high losses of seeds, particularly in shallow areas, as a result of transport by currents, bioturbation and predation, make restoration with seeds inefficient. The recommended method for large-scale restoration of eelgrass along the Swedish NW coast includes transplantation of single unanchored shoots without sediment from the donor meadow.

Keywords: Eelgrass, Restoration, Management, High latitude, Method assessment, Environmental requirements, Acclimatization, Carbohydrate storage, Vegetative reproduction, Seed loss, Coastal development, Legal challenges