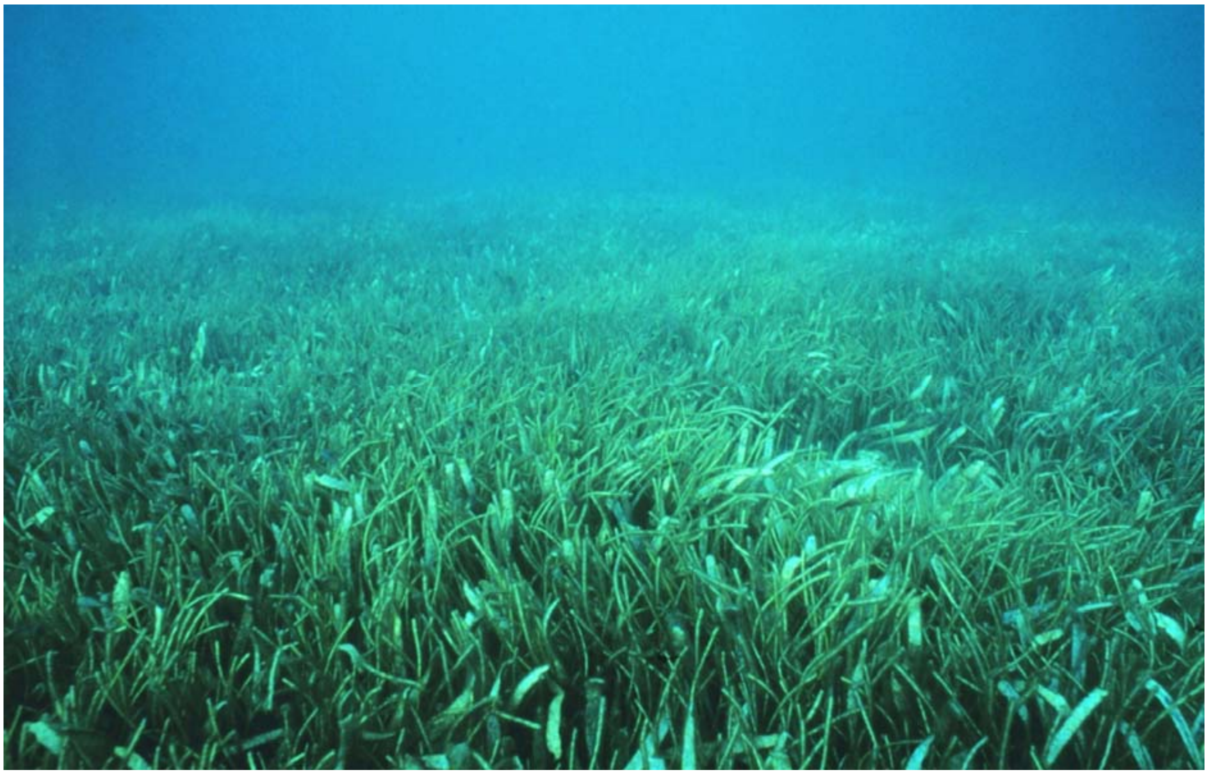
Seagrass monitoring and management: Is it enough?

Are the current seagrass conservation methods in temperate areas enough to predict the decline of seagrass populations?



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Abstract

Seagrasses are an important underappreciated part of the marine ecosystems. They play a significant role in the carbon cycle and primary production and they serve as important habitats for other marine organisms. Decreases in seagrass populations occur frequently as natural variations but added anthropogenic effects are creating a problem since the seagrasses are now disappearing. The main problem is the rapid growth in human activities along coastlines, such as: boating, fishing, dredging, altered water flow and poor land management. The most influential problem for the seagrasses themselves is the increase in turbidity and nutrient loading. To prevent the seagrasses from disappearing measures need to be taken to protect them.

Monitoring programs observe seagrass populations and their habitat and detect any changes in population size and density thus detecting fluctuations. Focusing only on abundance and density however, is not sufficient because once a decline is detected it may be too late too counter the effect. Programs should focus on monitoring habitat quality; early detection of changes in habitat quality could help detect the source before the seagrass populations are affected. For an increase in predictiveness of the programs more research needs to be done to create a better understanding of seagrass ecology and evolution.

Seagrass conservation still consists of many challenges such as; communication problems between different parties (scientists, managers, public), low public interest and awareness, low predictiveness of monitoring programs and the lack of knowledge on seagrasses. For seagrass transplanting efforts to work the source of seagrass decline needs to be dealt with first. Management plans such as the Habitat Directive and Water Framework Directive aim at protecting the seagrasses from human activities and improving the water quality.

The current conservation efforts done to protect seagrasses are not enough but they are improving. It is very important to increase the knowledge we have on seagrasses through research and use this knowledge to improve the predictiveness of monitoring programs allowing managers to intervene before the seagrasses are affected. Genetics and genomics could create a better insight into how seagrasses were effected by certain effects in the past giving us insight into what might happen in the future. But before this is done a clear protection plan has to be created in which it clearly states how seagrasses are protected. This plan then needs to be executed which will hopefully result in an improvement of habitat quality followed by restoration attempts.

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Introduction

Seagrasses belong to the class monocotyledons and are angiosperms which grow in marine environments under fully saline conditions (den Hartog 2006, Orth et al. 2006). They occur in shallow and sheltered waters along most of the temperate and tropical coasts throughout the world (Orth et al. 2006). There are approximately 60 species of seagrasses (Orth et al. 2006) divided into four families, of which three purely consist of seagrasses, namely: Cymodoceaceae, Posidoniaceae and Zosteraceae (den Hartog 2006).

The importance of seagrass beds is very high in many ecosystems since they create habitats for other species as well as provide many other ecological services. Carbon fixation into the ocean sediments is one of those services that seagrasses provide (Duarte and Cebrián 1996). The natural variation of seagrass beds is being pushed towards a rapid decline due to disturbing anthropogenic effects. These effects, such as nutrient loading, pollution, fishing, habitat alteration, together with other anthropogenic effects and natural stressors are causing the seagrass populations to decrease and in some cases completely disappear (Orth et al. 2006, Duarte et al. 2006).

The disappearing of seagrass beds needs to be stopped if we want to be able to keep the ecological services that these beds provide. To do this seagrasses and water quality need to be monitored closely to locate any changes that could have a negative influence on the seagrass populations. Together with monitoring, management and conservation plans need to be created to protect seagrass meadows and to prevent further declines in the existing populations. There are many monitoring programs (e.g. SeagrassWatch, SeagrassNet, COMBINE, CARICOMP) out there, both on a global and local scale, but the question is in what way are these programs predictive enough to prevent further losses? Another question that can be asked is whether or not the current seagrass conservation and management methods are sufficient enough to protect existing populations and to bring back populations that have already been extinct by human impacts. This paper will focus mainly on seagrasses that occur in temperate waters such as the Zosteraceae and the Posidoniaceae families.

Why are seagrasses so important?

Seagrass meadows play an important role in marine ecosystems and provide many important ecological services (figure 1). They serve for example as shelter, food source and nursery ground for many marine organisms leading to high levels of abundance and diversity of flora and fauna within the seagrass meadows (Terrados 2006), including many economically important finfish and shellfish (Heck et al. 2003). Seagrasses are also used as an indicator species, the presence or absence of seagrass in an area can be an indicator of the quality of a certain habitat (Kenneth and Short 2006). Seagrass populations are some of the most productive autotrophic communities on earth (Duarte and Chiscano 1999). The primary production of seagrass meadows is relatively high; although only 0.15% of the ocean surface is covered by seagrass they still provide a moderate 1% primary production to the net primary production of the oceans (Duarte and Cebrián 1996). Seagrasses play an even larger role in the global carbon cycle; 12% of the total amount of carbon stored in the ocean sediment is done by seagrasses (Duarte and Cebrián 1996). The structure of seagrass beds decreases the water flow during which retention of suspended particles takes place allowing the seagrasses to act as a filter for coastal waters. During this process the seagrasses together with the organisms living in its leaves are responsible for trapping and storing both nutrients and sediments. This process leads to a decreased turbidity and an increased quality of coastal waters which is necessary for seagrasses and many other benthic plants to thrive (Terrados 2006, Orth et al. 2006). Finally seagrass also functions as an ecosystem engineer. It stabilizes the sediment due to its network of rhizomes and roots and it decreases water motion due to friction with the canopy. The decrease in water motion can be very important to protect the coastline against erosion (Terrados 2006).

Due to the many ecological services that seagrass meadows provide they can be placed among the most valuable ecosystems in the oceans. Together with algae beds seagrasses have an estimated value of approximately $19.000 per hectare per year, which is twice as high compared to the value of mangroves and marshes or even three times as high as the value of coral reefs (Costanza et al. 1997).

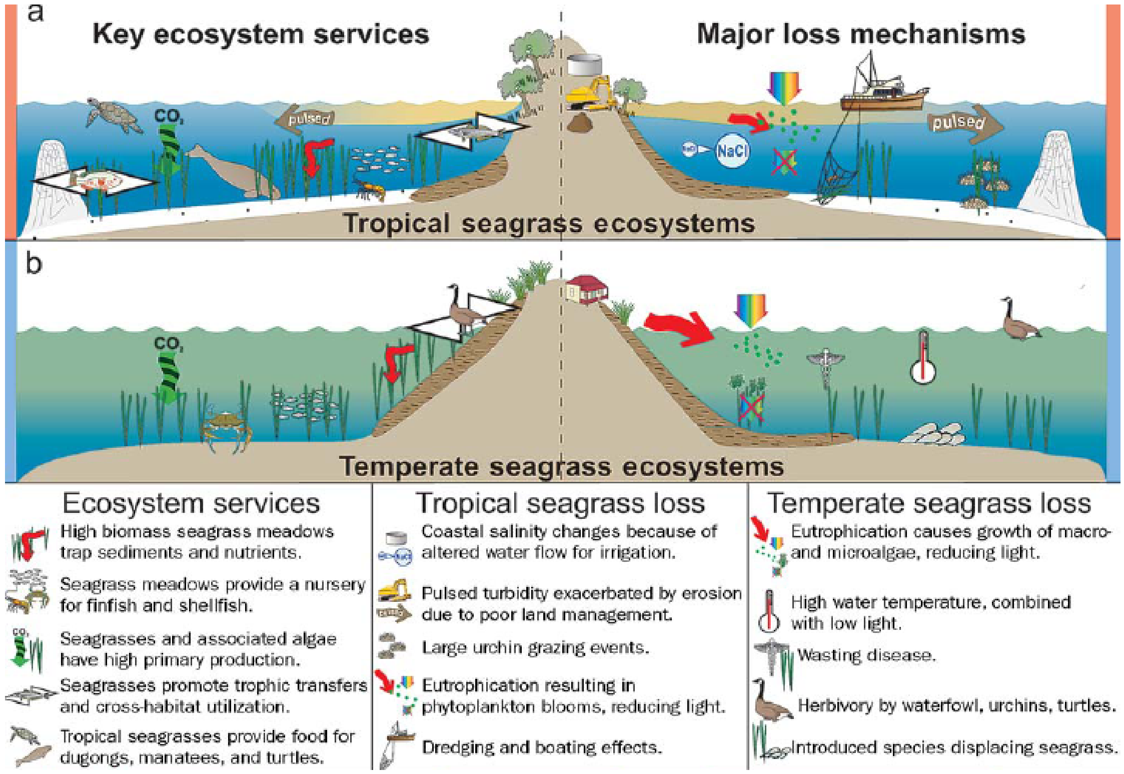

Figure 1: Key ecosystem services of seagrass beds and the major loss mechanisms responsible for seagrass declines, a) Tropical seagrass ecosystems, b) Temperate seagrass ecosystems. (Orth et al. 2006)

What is causing seagrass decline?

Variation in population numbers is something that occurs naturally in many species. Due to natural changes in the marine environment such as temperature and CO_2 concentrations seagrass populations have also experienced many fluctuations in the past (Orth et al. 2006). However, anthropogenic effects have led to an increased change rate of the coastal environment. The change rates of the environment could be to fast to allow the seagrasses to adapt, leading to a decrease in seagrass populations and diversity in many human populated coastal areas (Orth et al. 2006, Duarte et al. 2006). It has been estimated that over the last two decades approximately 18% of the known seagrass areas have been lost due to anthropogenic impacts (Duarte et al. 2006). The main reason for the recent increase in seagrass loss is due to the increase in water turbidity (Orth et al. 2006). The rising human population numbers along the world's coastlines have led to an increase in nutrient loading from watersheds, soil erosion due to poor land management and pollution (Duarte et al. 2006). All these factors increase the amount of sediments and nutrients in the water leading to a decrease in suitable seagrass environment, even populations located far from the disturbing source can be affected.

There are also many direct effects that cause a threat to local seagrass populations, such as: fishing and aquaculture, introduced exotic species, boating and anchoring, and habitat alteration (dredging, reclamation and coastal construction) (Duarte et al. 2006).

The many anthropogenic effects, together with global climate changes and natural occurring diseases, put the seagrasses under a lot of pressure. In the 1930's for example a wasting disease affected many *Zostera marina* populations eventually leading to large scale eradications along the temperate Atlantic coastlines. This wasting disease was a parasitic slime mold and it only became pathogenic due to a decrease in habitat quality of *Z. marina*. After the wasting disease recolonization was hindered because of anthropogenic disturbances that made the previous habitats unsuitable for Zostera marina to return (Kenneth and Short 2006, Plus et al. 2003, Rasmussen et al. 1977). Another example is the disappearance of *Z. noltii* and *Z. marina* in the Dutch Wadden Sea in the 1960's. Here *Z. marina* was unable to reestablish after a wasting disease due to a major increase in water turbidity by eutrophication and other human activities such as fishing and dredging (Philippart et al. 1995, Giesen et al. 1990). To prevent seagrass populations from decreasing any further, measures need to be taken to lessen the effects of human impacts on coastal ecosystems and to increase the habitat quality for seagrasses.

Monitoring

At the beginning of the 1980's the first seagrass monitoring programs started to evolve in the USA, Australia and France. People started to realize that seagrasses played an important part in the marine ecosystems and in the 1990's monitoring programs experienced a rapid increase (Duarte et al. 2004) (figure 2). In 2004 over 40 countries have established seagrass monitoring programs, monitoring over 2000 seagrass meadows and 31 species across the globe, most of which in Australia (Duarte et al. 2004, Orth et al. 2006). These monitoring programs vary greatly in their structure, there are programs which consist mostly of volunteers and others mostly of scientists or technical personnel, some programs work on a global scale whilst others work on a local scale. The programs also differ in target groups. Some programs just want to increase public awareness and, therefore, use a different approach compared to groups that need more complex data for scientific research.

Figure 2: Global increase in seagrass monitoring efforts (Orth et al. 2006)

The most common observed parameters for seagrass monitoring are population cover and density (Duarte et al. 2004). These parameters give a quick view of the status of seagrass meadows and show whether or not a seagrass population is decreasing in size and/or numbers. Population cover and density can be calculated by doing direct observations or by using remote sensing. Direct observations are effective in showing decline but they are also very time consuming, therefore remote sensing (airborne/satellite photography, sonar scans) is the preferred alternative for the calculation of seagrass cover and density. Remote sensing makes it possible to assess changes across entire meadows instead of small areas giving a larger and more complete picture of the meadows status. By monitoring these parameters it is possible to locate declines in seagrass populations but this does not necessarily have to be a threatening effect due to natural cover and density variations which occur among seagrass meadows (Orth et al. 2006). Once a seagrass meadow starts to decline research needs to be done to find out if there are any anthropogenic effects that are causing alterations to the seagrass habitat. If there are no detectable anthropogenic effects it is likely to be a natural variation but if this research is not done before the seagrass population declines beyond a certain point and it turns out not to be a natural variation then it could be too late to respond (figure 3). Whenever an anthropogenic effect (e.g. poor land management, boating, dredging, nutrient loading) is discovered it is important to find out what effects (increased water turbidity, pollution, direct destructions) are causing the decrease in the population. To do this, more detailed monitoring needs to be conducted, looking not only at seagrass changes such as cover, density, distribution and size but also looking at the habitat quality; water turbidity, water quality, sediment quality, temperature, salinity, nutrient availability etc (figure 3). Doing this allows researchers to find the source of the seagrass decline and once the source is found it makes it easier to create the correct measures against the decline. The downside of this monitoring strategy is that a seagrass meadow needs to decline first before any measures are taken including the risk that the meadow could have already declined beyond the point of restoration. The predictiveness of this monitoring strategy is very low. Monitoring seagrass habitat (e.g. sediment and water quality) instead of seagrass itself could make it possible to detect any negative changes in an early stage allowing for measures to be taken before the seagrass population is affected. To accomplish this, a complete assessment of the "perfect" seagrass habitat needs to be created. This is a very time consuming task and a lot of research needs to be carried out since there are so many different species each with their own variations and unique "perfect" habitats. Genetics can be a very useful tool for this; genetic diversity data can provide insight into a lot of evolutionary and ecological processes (Waycott et al. 2006) allowing for a better understanding of how seagrasses thrive and what kind of habitat they need to sustain themselves.

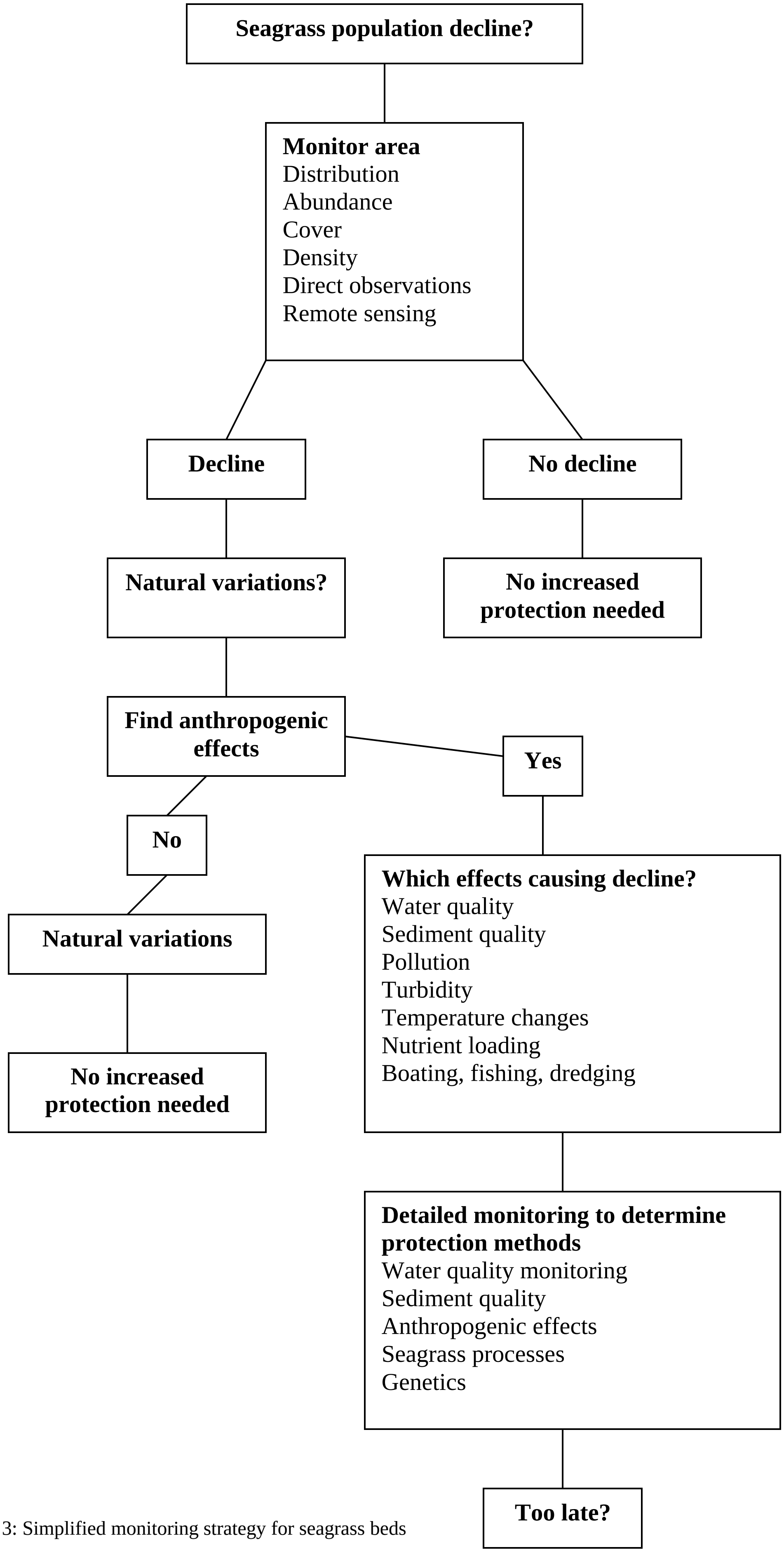

Figure 3: Simplified monitoring strategy for seagrass beds

Although the predictiveness of seagrass monitoring programs is still low many of them are now trying to focus on increasing their predictiveness (SeagrassWatch, CARICOMP). This does not mean that all the programs should focus on predictiveness. The differences in program structure are important, some programs increase public awareness (SeagrassNet) whilst others are there purely for attaining scientific data (CARICOMP). All these different strategies are needed for a complete seagrass protection program and global cooperation's between countries and monitoring programs will make it possible to better protect and understand seagrasses.

Management, conservation and restoration.

Seagrass monitoring programs are responsible for detecting changes in seagrass populations and discovering the source of possible population declines however this is only half of the solution. The other half consists of actually returning seagrass populations and habitats to their natural state. This can be done in many ways for example by transplanting seagrasses to a habitat from which they have been eradicated or by managing anthropogenic coastal activities to improve water quality.

The Zosteraceae family and in particular *Zostera marina* is the most widely transplanted seagrass species in coastal areas (Christensen et al. 2004). Seagrass transplantations can be used to build up population numbers in declining seagrass meadow or even to return seagrass meadows that have been completely destroyed. Seagrasses have a slow growth rate (Hemminga and Duarte 2000) and therefore adding transplants to a recovering population allows for an increased recovery rate. However, the success rate of seagrass transplants is not very high; globally the success rate is about 30% including high costs for the process itself (Orth et al. 2006). There are a lot of transplanting methods varying from stapling the plants to the sediment to plugging them into the sediment using tubes or even by transplanting the seeds (Christensen et al. 2004). For *Zostera* most of these transplants however occur on a small scale as test transplants consisting of areas smaller than 0.01 ha (Table 1) (Kenneth and Short 2006). In 1993 in the Dutch Wadden Sea (Balgzand) transplantation attempts were made for both *Z. noltii* and *Z. marina*. The *Z. noltii* transplants were successful, in 2006 the populations where still present and expanding. The *Z. marina* transplants where not that successful the populations lasted for about 8 years and after many fluctuations they eventually disappeared (van der Heide et al. 2009, van Katwijk et al. 2009). The difference in reproductive strategy was most likely the reason that *Z. noltii* was more successful (van Katwijk et al. 2009). This indicates that before transplant efforts are made detailed research needs to be done to both the seagrass species themselves and their habitat to prevent any unsuccessful transplants. Models can then be created that monitor habitat suitability in potential seagrass transplant sites (van der Heide et al. 2009). In the Delmarva Bay, USA *Z. marina* transplant efforts have been significantly successful in areas where small populations still existed whereas larger transplant efforts remain challenging and mainly unsuccessful. The areas where there was a low success rate showed a lower water quality compared to successful areas indicating the importance of habitat and water quality for seagrass transplants (Orth et al 2004).

Seagrass transplants also increase the genetic diversity of a meadow. This in turn increases the survivability of the seagrass population decreasing the chance of the entire population being effected by changes in the habitat (Waycott et al. 2006). Restoring seagrass in a habitat where it has recently been extinct due to a decreased habitat quality is a waste of time, accordingly before seagrass restoration or mitigation can take place the quality of its habitat needs to be improved.

To increase the habitat quality for seagrasses a lot of management and conservation plans need to be created. By attacking the source affecting the habitat quality, seagrass populations could once again thrive and return to their habitats. Low water clarity is one of the main reasons keeping seagrasses from returning to their habitats (Kenneth and Short 2006); therefore it is important to improve the water clarity before any restoration attempts are made. Take for example the wasting disease in the 1960's responsible for the disappearance of *Z. noltii* and *Z. marina* in the Dutch Wadden Sea. The disappearance of *Z. noltii* and *Z. marina* loosened up the sediment increasing the turbidity of the water and together with anthropogenic effects such as the building of dams and dikes the water turbidity increased tremendously hindering the return of the seagrasses (Giesen et al 1990). To allow for restoration processes to take place the turbidity first needs to be returned to an acceptable state, this can be done by reducing nutrient inputs into coastal areas by human activities.

Table 1: *Zostera* restoration projects. Full scale transplant efforts in hectares and test sites (T) smaller than 0.01 ha (Kenneth and Short 2006).

Location	Project	Sites attempted	Sites successful	Area planted	Source
Netherlands	Wadden Sea	3	2	T	Hily et al. (2003), van Katwijk (2000)
Maine	Wells NERR Project	2	0	T	Short et al. (1993a)
New Hampshire	NH Port Mitigation Project	5	2	2.52 ha	Short et al. (2002a)
	NH TERFS Method Development	6	2	T	Short et al. (2002b)
	US ACE Dredging Mitigation	3	2	2 ha	Davis and Short (2003)
Massachusetts	NOAA New Bedford Harbor Project	4	2	0.8 ha	Kopp and Short (2000), Short et al. (2002a)
	EPA Boston Harbor Project	2	0	T	Chandler et al. (1996)
Rhode Island	RI Aqua Fund Project	6	1	T	Kopp et al. (1994), Kopp unpublished
	NOAA World Prodigy Mitigation	10	2	T	Fonseca et al. (1997); Fonseca (personal communication)
	RI DEM Narragansett Bay Project	2	0	T	Adamowics (1994).
	Save the Bay Wickford Harbor	1	1	T	Richardson (personal communication)
	NOAA/NERR Seeding Project	3	1	T	Granger (personal communication)
Connecticut	Niantic River Pilot Eelgrass Restoration	1	1	0.04 ha	Short (1988)
New York	NY Sea Grant, Great South Bay Project	1	1	T	Churchill et al. (1978)
New Jersey	NOAA/NMFS Raritan Bay Project	5	0	T	Reid et al. (1993).
Maryland	Chesapeake Bay and Maryland Coastal Bays	<10	<5	T	MD DNR (unpublished)
Virginia	Chesapeake Bay and Virginia Coastal Bays	<30	<15	T and 100 ha.	Orth (personal communication)
North Carolina	Beaufort area	5	5	T	Fonseca et al. (1982)
	Back Sound	1	1	T	Kenworthy et al. (1980)
California	Mission Bay	6	6	3.5	Hoffman (1988)
	San Diego Bay	5	2	6.8	Merkel and Hoffman (1990)
	San Diego Bay	5	?	1.62	Goforth and Peeling (1980)
	San Francisco Bay	3	?	T	Fredette et al. (1988)
Pacific Northwest	Review—CA, OR, WA, BC	17	11	T	Thom (1990)
British Columbia	Strait of Georgia	4	4	T	Harrison (1990)
Japan	Review—Japan			T	Terawaki et al. (1999)
	Sea of Japan			T	Tamaki et al. (1999)

There are already several instances such as the EU habitats directive, water framework directive (WFD) and OSPAR commission which indirectly and directly put the seagrass habitats under protection. Natura-2000 for example is a directive for the EU habitats directive and it protects the European biodiversity. Mudflats, sandflats and Large shallow inlets and bays are all a part of the natura-2000 network and they are therefore protected areas, since seagrasses are a characteristic feature of these habitats they are also protected. The plan is to improve the water quality and minimize human activity in these areas to an acceptable state by the year 2016 and thus allowing seagrass to return (Website: Het Ministerie van landbouw, natuur en voedselkwaliteit). The WFD is a directive that also aims at reducing water pollutants and preventing the deterioration of seagrass beds. The goal of this directive is to return seagrasses to a good status by 2015 (TMAP handbook 2008). OSPAR is a commission for the protection of the marine environment of the North-East Atlantic and it helps at creating standards to which Marine Protected Areas (MPA's) should suffice, OSPAR has added seagrasses to its endangered species list and is a important supervisor to other EU directives (TMAP handbook 2008) (figure 4). It is still to be seen if the goals that have been created by these directives will be achieved since the protecting of seagrass habitats requires the management and monitoring of many variables (turbidity, activity, temperature…etc.) affected by many different sources (fishing, land runoffs, pollutants…etc

Level of management programs		
EC directives	*International supervision*	*National supervision*
Habitats Directive	OSPAR MPA programme	Local
Natura 2000 network	OSPAR programmes for nutrient reduction	National
Water Framework Directive	Trilateral Waddensea programmes	National parks
EU Nitrates Directive		Water management boards
Bird Directive		

Figure 4: *Management programs under European commission directive, international and national supervision that benefit seagrass meadows.*

Challenges

When it comes to seagrass conservation there are still a lot of challenges that need to be dealt with to ensure the return and preservation of seagrass beds. These challenges need to be overcome in order to create a better understanding of seagrass habitats and to implement the best conservation methods under certain circumstances.

As mentioned before the predictiveness of seagrass monitoring strategies is very important (Kenworthy et al. 2004). Increasing the predictiveness of monitoring programs will allow for a quicker response when it comes to seagrass management. Changes in habitat quality should be monitored closely and in particular water clarity. Once a change in for example water clarity has been detected the source can be located and actions can be taken to counter the decrease in habitat quality preventing the seagrass beds from being influenced. This will then in turn prevent the need for any other measures such as restoration projects which are costly and time consuming. Creating predictive programs that managers can use is still a challenge for scientists (Kenworthy et al. 2004).

The problem with increasing the predictiveness of monitoring programs is that there is still a lot of research that needs to be done to create a better understanding of seagrasses ecology (Kenworthy 2000, Orth et al. 2006, Williams 2001). By creating a better understanding restoration projects can take place in suitable habitats creating founder populations by transplanting and then allowing natural recovery to take over. Genetics is a key factor that still needs a lot of research (Kenneth 2006, Waycott et al. 2006), especially in *Z. marina* since little is known about the genetics of this species compared to the other seagrass species. Population genetic analyses allow for a better understanding in how seagrass ecosystems interact and it will give us better knowledge of the Zostera genus and its evolution. The reconstruction of historical events using genetics will allow us to find out what caused certain decreases and disappearances making it easier to prevent this in the future. Genetics is also a very useful tool when it comes to transplanting. The understanding of genetics in transplanting methods will allow us to figure out how important it is to maintain a high genetic diversity in populations and it will help us to find suitable donor beds (Waycott et al. 2006, Fonseca et al. 1998). Until more is known in general about seagrass ecology and their genetics management programs should focus more on the systemwide approach to protect these ecosystems (Orth et al. 2006).

Another problem with seagrass conservation is communication. Scientists and managers both work on a different scale; scientists would like to do detailed research whereas managers need a quick and effective solution. To solve this, good communication between the different groups is essential. Scientists need to provide the mangers with understandable data and tools which are needed for conservation. Scientists are also required to occasionally make uncertain predictions and recommendations with limited data, in return the scientists need feedback from the managers and the public on the status of the seagrass (Kenworthy et al. 2004). Scientists need to educate the managers and the public on the importance of the seagrass biome to create an interest. The current interest for the seagrass biome is very low and this is also known as the tragedy of the commons. The tragedy of the commons implies that there are many management organizations which are all working in their own self-interest Not sharing information will lead to nowhere and the seagrasses will then deplete which is in no ones interest (Hardin 1968). The lack of cooperation and well worked out policies leads to a lot of mismanagement which in the end could still have a negative effect on the seagrass populations.

The recent increase in scientific publications on seagrasses has sadly not increased the public awareness. The number of seagrass reports in the media is extremely low compared to that of salt-marshes, mangroves and especially coral reefs (orth et al. 2006). This is mainly due to the fact that seagrasses are an invisible species. First of all seagrasses grow underwater in shallow areas which are mostly avoided by many boaters, second of all although seagrasses maintain a high biodiversity many of the organisms are very small and, for the public, far less exciting than organisms that occur for example in coral reefs (Orth et al. 2006). The few megafauna that do exist in seagrass beds occur in very low numbers because of over harvesting and habitat destruction (Jackson et al. 2001) and can therefore also be seen as invisible species. Organizations such as SeagrassNet, SeagrassWatch and Seagrass Recovery are important factors in increasing the public awareness of seagrasses. Not only do they publish their data on websites, making it accessible for everyone, they also use volunteers for their monitoring projects. This is especially important in less developed countries. Using volunteers brings the public closer to the seagrasses and it directly shows them how important the seagrasses are.

Another challenge for scientists and managers are jurisdictional boundaries. Effects caused in a certain country could affect seagrass meadows in the next. This makes it difficult for managers to create plans to stop the effect since they need the cooperation of another country where the laws could be different. Therefore it is important for managers and scientists to work together and create global conservation efforts. Many of the effects causing seagrass decline occur on a global scale due to the connectivity of the coastal areas such as increased water turbidity, changes in water flow and of course global warming. Working together and creating global conservation efforts will allow for better communication between different parties and the sharing of information. The previously mentioned organizations (SeagrassNet, SeagrassWatch) are examples of some organizations that are already working on a global scale.

What needs to be done?

It is clear now that a lot of research still needs to be conducted before seagrass protection can be improved, but what actually needs to be researched? To improve seagrass restoration research should focus on finding suitable habitats for seagrass to grow in. Genetics and genomics can be very useful tools for doing this. By looking at the distribution of seagrass beds in the past together with the water quality surrounding them we can try and create a picture of what kind of water quality is needed for restoration projects to be successful. This together with an increased understanding of the importance of genetic diversity will allow for an increased success rate of seagrass restoration and transplantation efforts. Phylogeographic surveys which study the historical processes possibly responsible for the current distribution of populations can provide an insight into how seagrasses have reacted to certain events in the past allowing us to predict the consequences of future events (Procaccini et al.).

Although improving restoration attempts is helpful it is even more important to attack the source of the problem which is the increase in anthropogenic effects. To do this, stricter guidelines need to be created to what is and what is not permitted. The current directives (Habitats directive, WFD, Natura 2000) all include seagrasses in their protected species list but the details that say how they are protected remain unclear or at least difficult to obtain. To improve their protection it would be much better to create one clear directive which focuses on seagrasses. This directive should then focus on decreasing the influence of anthropogenic effects on the seagrasses by for example:

- Researching the effects of activities beforehand and using that to determine whether or not the activities are to be permitted. This research should then at least partly be financed by the party willing to perform these activities.
- Stricter control on seagrass populated areas followed by significant penalties to those damaging the seagrass beds.
- Clearer guidelines to what is and is not permitted in a seagrass area.

By creating clearer guideline which are easily accessible it will become clearer to the public that seagrasses are a protected species and it will also increase the awareness of seagrass importance compared to "hiding" seagrass protection into large and complicated directives. After creating clear plans on protecting seagrasses and actually seeing an increase in population stability the focus can be shifted towards possibly restoring certain seagrass beds to increase populations.

Conclusion

The current monitoring methods need to increase their predictiveness if they want to prevent seagrasses from disappearing (Kenworthy et al. 2004). Once seagrass declines are detected it could be too late to reverse the effect and therefore the focus should be on improving the habitat quality of the seagrasses and maintaining it. To increase the predictiveness of the monitoring programs a lot of research needs to be conducted to the ecology of seagrasses and their genetics. This will increase the knowledge of how seagrasses function, how they have evolved and what kind of habitat they require for survival (Waycott et al. 2006). Once more information is available the predictiveness of seagrass monitoring programs can be increased which will allow managers to detect changes in an early stage making it easier to act before the seagrasses are affected. Genetics and genomics can play a crucial role in obtaining this information.

The main problem with seagrass management is the lack in communication between scientists and mangers. Improving this will allow for easier information exchange thus improving the quality of the management programs. The management programs should try and focus on the sources of the problems which are the anthropogenic effects which will in turn return the water quality to its original state, after this they should focus on restoring the seagrass beds. There are a couple of directives which include seagrass beds but this does not seem very successful. By creating one clear, accessible plan it could become a lot clearer allowing the public to easily see what is actually meant by seagrasses are a "protected" species.

Although seagrasses are an invisible species and are uninteresting for most of the public they still form an important part of the marine ecosystem. They play a role in many ecological processes such as the carbon cycle and primary production as well as serving as habitat and nursery ground for many organisms including economically important fish and shellfish (Terrados 2006, Heck et al. 2003). The importance of the seagrass ecosystems needs to be brought to the public.

The current conservation methods are not enough to completely protect seagrass beds but they are a step in the right direction. A lot of improvements still need to be made but the increase in research projects, scientific papers and directives (Habitat directive, WFD) is a promising site.

References

Christensen PB, Almela ED, Diekmann O (2004) Can transplanting accelerate the recovery of seagrasses? In: Borum J, Duarte CM, Krause-Jensen D and Greve TM (eds.), European seagrasses: an introduction to monitoring and management, pp 77–82.

Costanza R, et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253–260.

den Hartog C and Kuo J (2006) Taxonomy and Biogeography of Seagrasses. In: Larkum AWD, Orth RJ

and Duarte CM (eds.), Seagrasses: Biology, Ecology and Conservation, pp. 1–23.
Duarte CM, Alvarez E, Grau A and Krause-Jensen D (2004) Which monitoring strategy should be chosen? In: Borum J, Duarte CM, Krause-Jensen D and Greve TM (eds.), European seagrasses: an introduction to monitoring and management, pp 41–44.
Duarte CM and Cebrián J (1996) The fate of marine autotrophic production. Limnol. Oceanogr. 41, 1758–1766.
Duarte CM and Chiscano CL (1999) Seagrass biomass and production: a reassessment. Aquatic botany 65: 159–174.
Duarte CM, Marbà N and Santos R (2004) What may cause loss of seagrasses? In: Borum J, Duarte CM, Krause-Jensen D and Greve TM (eds.), European seagrasses: an introduction to monitoring and management, pp. 24–32.
Fonseca MS, Kenworthy WJ and Thayer GW (1998) Guidelines for the Conservation and Restoration of Seagrasses in the United Staes and Adjacent Waters. NOAA Coastal Ocean Office, Silver Spring, MD
Giesen WBJT, Van Katwijk MM, den Hartog C (1990) Eelgrass condition and turbidity in the Dutch Wadden Sea. Aquatic Botany 37: 71-85
Hardin G (1968) The tragedy of the commons. Science 163: 1243–1248.
Heck KL, Hays C and Orth RJ (2003). A critical evaluation of the nursery role hypothesis for seagrass meadows. Marine Ecology Progress Series 253: 123–136.
Hemminga M, Duarte CM (2000) Seagrass Ecology. Cambridge Univ. Press, Cambridge. ISBN 0521661846.
Jackson JBC, et al (2001) Historical over fishing and the recent collapse of coastal ecosystems. Science 293: 629–638.
Kenneth AM, Short FT (2006) Zostera: Biology, Ecology and Management. In: Larkum AWD, Orth RJ and Duarte CM (eds.), Seagrasses: Biology, Ecology and Conservation, pp. 361–386.
Kenworthy WJ (2000) The role of sexual reproduction in maintaining populations of *Halophila decipiens:* Implications for the biodiversity and conservation of tropical seagrass ecosystems. Pacific Conservation Biology 5: 260–268.
Kenworthy WJ, et al. (2004) Seagrass Conservation Biology: An Interdisciplinary Science for Protection of the Seagrass Biome. In: Larkum AWD, Orth RJ and Duarte CM (eds.), Seagrasses: Biology, Ecology and Conservation, pp. 595–623.
Orth RJ, et al. (2006) Seagrass recovery in Delmarva coastal bays, USA. Aquatic Botany 84: 26–36
Orth RJ, et al (2006) A global crisis for seagrass ecosystems. Bioscience 56: 987–996.
Philippart CJM, Dijkema KS (1995) Wax and wane of *Zostera noltii* Hornem. in the Dutch Wadden Sea. Aquatic Botany 49: 255-268
Plus M, Deslous-Paoli JM and Degault F (2003) Seagrass (*Zostera marina* L) bed recolonisation after anoxia-induced full mortality. Aquatic Botany 77: 121–134
Procaccini G, Olsen JL, Reusch BH (2007) Contribution of genetics and genomics to seagrass biology and conservation. Journal of experimental marine biology and ecology 350, pp. 234–259.
Rasmussen E (1977) The wasting disease of eelgrass (*Zostera marina*) and its effects on environmental factors and fauna. In: McRoy CP and Helfferich C (eds) Seagrass ecosystems. Marcel Dekker, New York, p 1–51
Terrados J and Borum J (2004) Why are seagrasses important? – Goods and services provided by seagrass meadows. In: Borum J, Duarte CM, Krause-Jensen D and Greve TM (eds.), European seagrasses: an introduction to monitoring and management, pp. 8–10.
Van der Heide TJ, et al. (2009) Predicting habitat suitability in temperate seagrass ecosystems. Limnol. Oceanogr. 54: 2018–2024.
van Katwijk MM, et al. (2009) Vulnerability to eutrophication of a semi-annual life history: A lesson learnt from an extinct eelgrass (Zostera marina) population. Biol. Conserv. doi:10.1016/j.biocon.2009.08.014 (in press).
Waycott M, et al. (2006) Seagrass evolution, ecology and conservation: a genetic perspective. In: Larkum AWD, Orth RJ and Duarte CM (eds.), Seagrasses: Biology, Ecology and Conservation, pp. 25–50.
Williams SL, (2001) Reduced genetic diversity in eelgrass transplantations affects both individual and population fitness. Ecological Applications 11: 1472–1488.

Websites

Het Ministerie van landbouw, natuur en voedselkwaliteit. Natura 2000/Vogel- en Habitat richtlijn : http://www.minlnv.nl/portal/page?_pageid=116,1640949&_dad=portal&_schema=PORTAL&p_document_id=110237&p_node_id=2182500&p_mode=BROWSE

TMAP handbook seagrass. TMAP monitoring handbook (2008): http://www.harbasins.org/fileadmin/inhoud/pdf/Final_Products/WP1/1.4/TMAP_Handbook_Seagrass__08-03-28_.pdf

SeagrassWatch: http://www.seagrasswatch.org/home.html

SeagrassNet:
http://www.seagrassnet.org/

Seagrass Recovery:
http://www.seagrassrecovery.com/