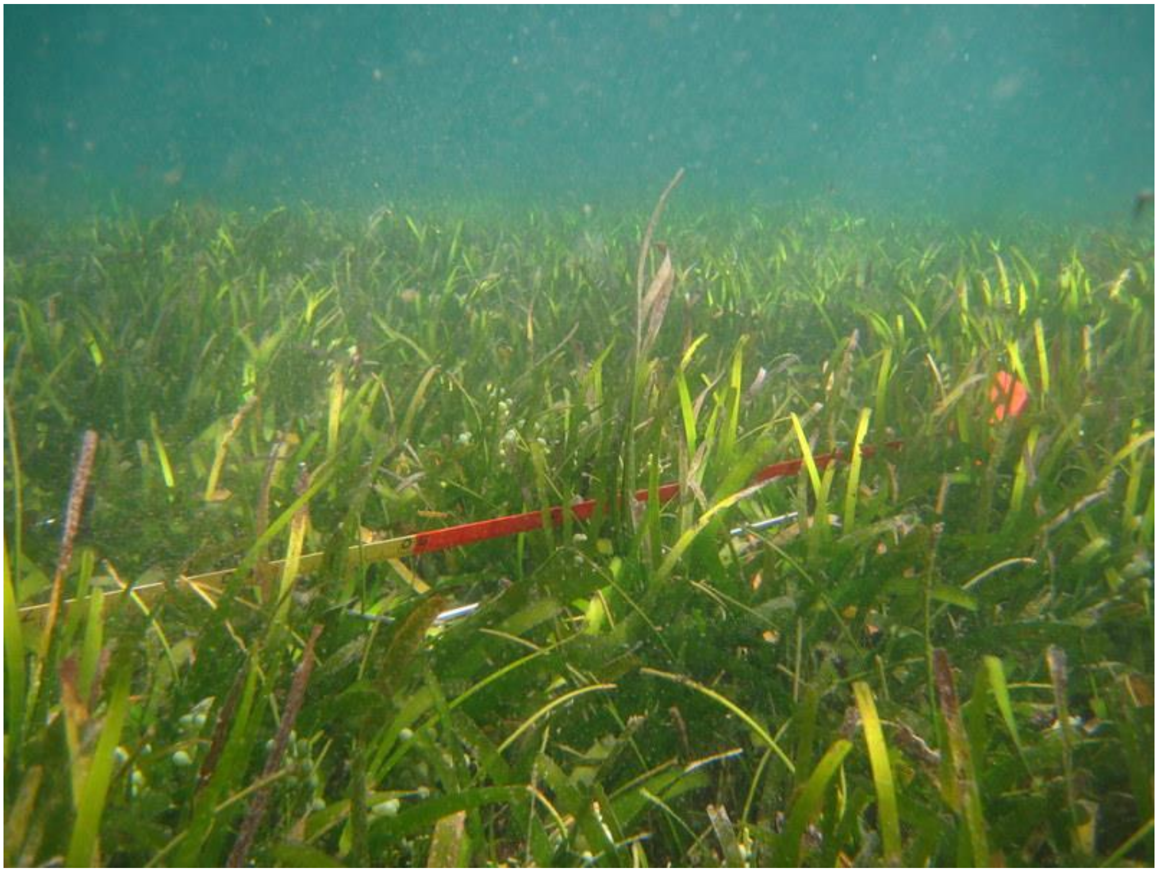
Gaining insight on MPA health through long-term seagrass monitoring in Palau



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Introduction

Without careful management the protection of natural resources can fail to the detriment of the resource and the communities that rely on them. Monitoring of natural resources is a key component to adaptive management and allows managers to see how their protected status is affecting the ecological community, to identify positive or negative ecological trends that can only be seen on longer time scales, and to determine how management can be improved to meet local stakeholders' objectives. This report outlines the methods and results of one monitoring effort in the seagrass meadows of The Republic of Palau, where monitoring found negative trends that might have otherwise gone unnoticed.

Seagrass meadows are a dynamic ecosystem that occupy a small and ever changing portion of land at the confluence of terrestrial and marine systems (Duarte et al. 2000). There are 60 seagrass species found worldwide, with the highest diversity of these plants found in the Indo-Pacific region (Short et al. 2007). Seagrasses are flowering plants that spend their entire life cycle in shallow salt and estuarine water (Björk et al. n.d.). They reproduce both vegetatively and sexually, and in addition to flowers they produce leaves, stems, rhizomes and roots (Björk et al. n.d.). Seagrass beds, while often overlooked by managers and conservationists alike, play a pivotal role in the health of marine communities (Orth et al. n.d.).

The close spatial and trophic ties between seagrass beds with both mangroves and coral reefs make healthy seagrass beds essential to the success of these other tropical marine habitats (Hemminga & Duarte 2000). Additionally, their position at the border of land and sea make seagrass habitats highly susceptible to anthropogenic effects and degradation (Duarte et al. 2000). This crucial location, however, also allows for these systems to act as an early form of detection of larger ecosystem-wide changes and help managers prevent system wide degradation and disturbances (Freeman et al. 2008). Because of this ability to indicate overall system health, seagrass management and study is essential to the sustainability of healthy coastal habitats (Freeman et al. 2008).

Based on area, seagrass meadows are some of the most productive communities on the planet (Duarte et al. 2000), and the ecosystem services they provide rank among the highest in the world (Björk et al. n.d.). These services include high value fishing and harvesting products, nurseries and habitat for fish and other herbivores, fuel for the detritus food web, carbon sequestration, sediment and nutrient filtration and stabilization (Björk et al. n.d.), and wave energy dissipation (Freeman et al. 2008). The removal of these services can have grave implication on the marine community at large. For examples, loss of seagrass habitat often leads to decreased fish and invertebrate populations as well as higher sedimentation rates on reefs, which can ultimately kill coral communities (Duarte et al. 2000). Additionally, a collapsed marine system can threaten the livelihood of communities that depend on tourism, and commercial and subsistence fishing or harvesting for their economic and cultural wellbeing.

Increasingly rapid development of coastal areas has a dramatic impact on near shore marine habitats such as reefs, mangroves, and seagrass (Freeman et al. 2008). Seagrasses are currently in decline worldwide mainly due to anthropogenic causes (Duarte et al. 2000) including commercial dredging (Neckles et al. n.d.), over harvesting and fishing (Bujang et al. 2006), removal of herbivores (Jakobsen et al. 2006), mounting storm intensity due to climate change (Short et al. 2006) and degradation of water quality (Freeman et al. 2008). This final threat, degradation of water quality, causes the most significant damage to healthy seagrass communities as it limits light availability and inhibits plant growth (Short & Wyllie-Echevrria 1996; Freeman et al. 2008). Loss of water quality is caused by poor forestry practices (Terrados et al. 1998), coastal development (Freeman et al. 2008), dredging (Erftemeijer & Lewis 2006), and eutrophication (Short et al. 2006; Vermaat et al. 1997); all of which are related to increased sedimentation. Over time, this reduction in growth potential can lead to the degradation and loss of important ecosystem services provided by seagrass beds (Freeman et al. 2008).

The Republic of Palau has a long history of Marine Protected Areas (MPA) that aim to ensure continued harvest and tourism based on diverse marine resources. In 2011, the Palau International Coral Reef Center (PICRC) began conducting seagrass monitoring surveys for three main purposes: 1) to gage the effectiveness of these MPAs, 2) to better understand the state of seagrass meadows around the islands of Palau, and 3) to asses threats to fish populations associated with seagrass habitats. From 2011 to 2013, PICRC conducted surveys of fish, invertebrates and seagrass cover and found a decreasing trend in fish density and biomass, invertebrate density, and seagrass cover. Armed with this new information managers must now begin the difficult task of determining what is leading to this decline in seagrass, fish and invertebrate communities in Palau.

Materials and Methods

Site selection
PICRC chose monitoring sites in four states – Airai, Ngchesar, Peleliu and Koror – as each state had an existing seagrass MPA. Within each state a site was established within the MPA boundary as well as a control site outside of the MPA boundaries. MPA sites were selected based on accessibility and habitat composition, while control sites were paired with MPAs based on similar habitat composition. Finally, three stations were established haphazardly at each site by choosing points that appear to be a good representation of the overall seagrass community in that area.

Fish Monitoring
Fish monitoring was conducted three times a year from 2011 to 2013 at all three stations in the four MPA and Control sites. Field technicians chose a direction to measure from the station point that provided the most consistent habitat, and the direction was noted and used on future monitoring visits to consistently measure the station transect. At each station three transects running 25 meters (m) were measured. Once the first transect was completed a second and third transect of the same 25m length was measured along the same line and in the same direction as the first.

To collect fish data, a field technician swam along the belt transect and counted fish within 2.5m either side of the tape; therefore, each transect measured 25m x 5m or 125m^2. Technicians counted fish within this boundary, identified them to the species level and gave a visual size estimation of the fish in 5cm increments.

Invertebrate monitoring

At the beginning of the project in 2011 and again at the end in 2013, marine macro invertebrates were also sampled. Transects were the same for invertebrate sampling as for fish sampling and technicians followed a similar process for invertebrate data collection. They again swam the 25m transect and recorded all invertebrates within 1m of either side of the tape; meaning each transect measured 25m x 2m or 50m². Technicians counted, identified to the species level and measured each invertebrate using a ruler.

Seagrass Monitoring

Similar to invertebrate data, seagrass data was collected at the beginning of the project in 2011 and again in 2013. Transects were set up following the same guide lines as for fish and invertebrate sampling. A technician swam along a 25m transect and stopped every 5m to place a 0.5m² quadrant on the substrate below them. They started at the zero meter mark, and ended at the 20m mark, measuring five locations in total for each transect. Within each quadrat, the technician identified all seagrass present within the quadrant to the species level and gave a visual estimation of the percent cover for each species.

Data Analyses

After surveying was completed, data was entered and analyzed using Excel and Primer with PERMANOVA software. Fish and invertebrate density and fish biomass were analyzed using mixed effects ANOVA. Differences were tested amongst states (4 levels, fixed), status (2, fixed), and year (2 or 3, fixed), and stations (5) were random and nested in the interaction of the main effects. Data was not normally distributed so was analyzed using 999 permutation. Fish and invertebrate density data did not conform to homogeneity of variances before or after transformations, therefore the α was increased to 0.01 to avoid a type II error (Underwood 1997). Fish Biomass data conformed to homogeneity of variances after transformation by log (x+1).

Results

Fish Density and Biomass

A sigificantly higher number of fish were present within MPAs compared to their reference sites in all states ($p = 0.002$). Overall, there was an average of 11 fish per $125m^{-2}$ in the MPAs, and 7 fish per $125m^{-2}$ in the control sites (Figure 1). However, despite higher fish density in the MPAs, fish density decreased in both MPAs and reference sites from 2011 to 2013. A significant interaction was found amoung states • years (p=0.007).In general pairwise comparisons demonstratedsignificantreductions in fish density between 2011 and 2013 in all states.Additionally, significant negative interactions were found between the year 2011 and 2013 in all states except Peleliu.

Similar to fish abundance, fish biomass was significantly higher within MPAs compared to control sites in all states (p=0.001). Over the three year period, MPAs had an average of 5822 g • $125m^{-2}$ while control siteshad just 1009 g •$125m^{-2}$ (Figure 2). The general trend however, was negative at all sites, showing a loss of biomass from 2011 to 2013. A significant interaction was found between states (p=0.001) and there was a significant effect found within years (p=0.001). Generally, pairwise comparison showed significant reductions in biomassover time in all states. Additionally, significantly negative interections were found between the year 2011 and 2013 and 2012 and 2013. Overall loss of biomass can be attributed to large decreases in *Siganus fuscescens,* which saw an average of 79.5% biomass loss at all sites, and *Lethrinus harak,* which lost an average of 56% biomass. Additionally, at Peleliu and Koror sites *Hipposcarus logiceps* decresed by an average of 85% and in the Koror MPA an average of 96% of *Siganus argenteus* was lost from 2011 to 2013.

Invertebrate Density

Higher invertebrate dansities were found in Ngchesar and Koror MPAs compared to paired control sites (Figure 3). Conversly, the Airai and Peleliu sites showed higher average densities of invertebrates outside MPAs. The only resultsreporting a p value below 0.05 was the interaction of State • status however it was found to be not significant as it did not conform to homogeneity of variances before or after transformations, and the p value of 0.015 did not meet α increase of 0.01.Pairwise tests did show significantly positive interactions between MPA and control status at Koror (p=0.036) and Ngchesar (p=0.02) with higher densities found in MPAs. When looking at overall trends the date showed a decrease in invertebrate density from 2011 to 2013 in all states.

Seagrass coverage

The average percent cover of seagrass was higher at MPAs in Airai and Koror when compared to control sites (Figure 4). The overall trend, however, showed a decrease in percent cover in all states from 2011 to 2013. Additionally, there was a loss of species diversity over this same time period at the Airai control site, all sites in Koror state, the Ngchesar control site and the Peleliu MPA.

Discussion

The seagrass beds of Palau are showing a clear negative trend in fish density and biomass, invertebrate density and seagrass percent cover. One potential driver of this decline are the high sedimentation rates found in Palau. As mentioned before, sedimentation can have dramatic negative effects on seagrass communities (Freeman et al. 2008), and the steep topography, large annual rainfall, and easily erodible soil in Palau, amplified by increases in land-use (Koshiba et al. 2013) makes this a potential cause of the current seagrass degradation. In addition to examining sedimentation, surveying fishers regarding their harvesting practices could provide valuable traditional ecological knowledge (TEK) about what is driving declines in the seagrass community. Ultimately, managers need to focus on boosting resilience within the seagrass habitat by reducing human impact, collecting baseline data and monitoring for change, and raising awareness of the values and threats of seagrass systems (Björk et al. n.d.). By working to build resilience, managers can help these dynamic systems deal with the increasing anthropogenic changes they face (Björk et al. n.d.)and protect the essential ecosystem services they provide.

As seen in this report, MPA monitoring over time is crucial for managers to gain a clear and complete understanding of ecosystem health by examining the interacting direct and indirect anthropogenic effects on these ecosystems. In the case of seagrass MPAs in Palau, a simple one year survey comparing MPAs and control sites would have shown higher density, biomass and percent cover in MPAs and might have lead managers to assume that the MPAs were effective and in good health. On a larger time scale, however, monitoring clearly shows that something is impacting the seagrass MPAs in Palau. With global climate change becoming more noticeable and devastating, and other anthropogenic degradation taking their tolls, effective and informed management decisions are now more crucial than ever to seagrass habitats (Björk et al. n.d.). The monitoring that PICRC has conducted offers a model of research that can provide valuable information for managers to use as they face increasingly difficult decisions about local resources (Björk et al. n.d.). Additionally, monitoring data can help fill in many of the missing pieces in global ecological knowledge and give scientists and managers a more complete prospective of the global status of seagrass (Green & Short 2003; Short et al. 2007) and other crucial marine communities.

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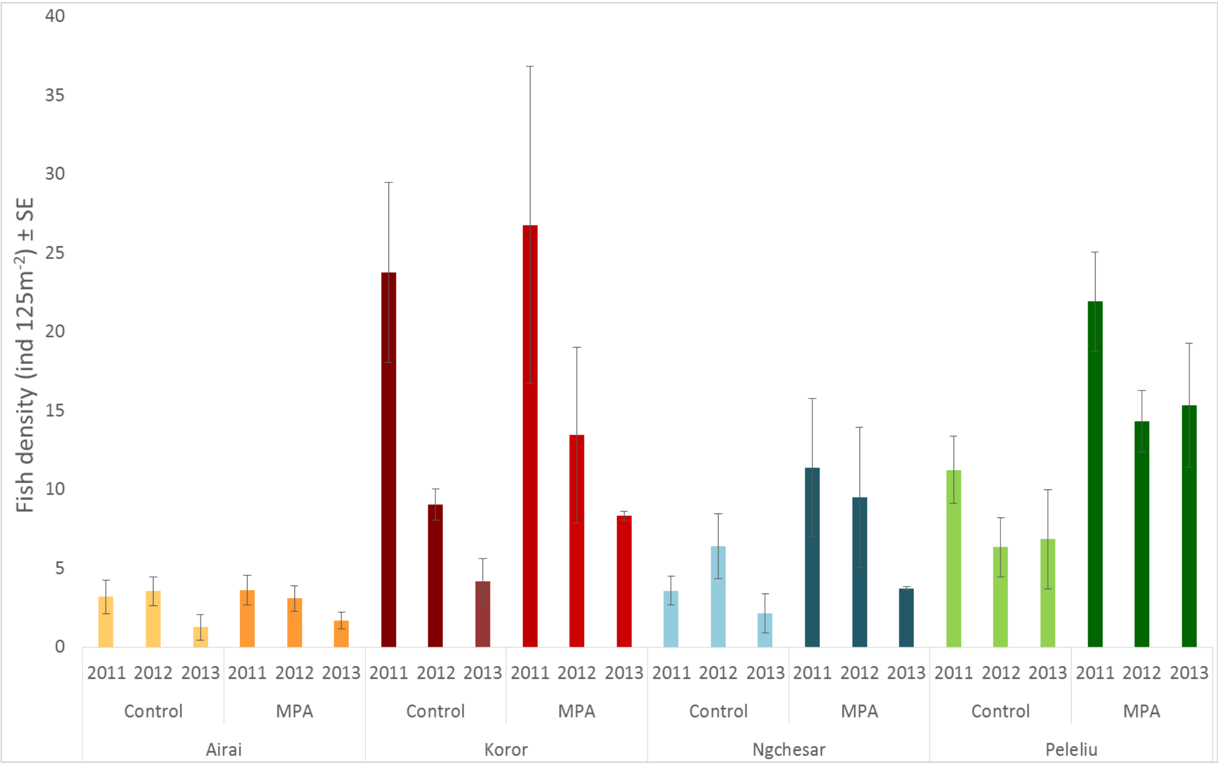

Figure 1.Fish density (Ind •125m^{-2}) by state, site status and year.

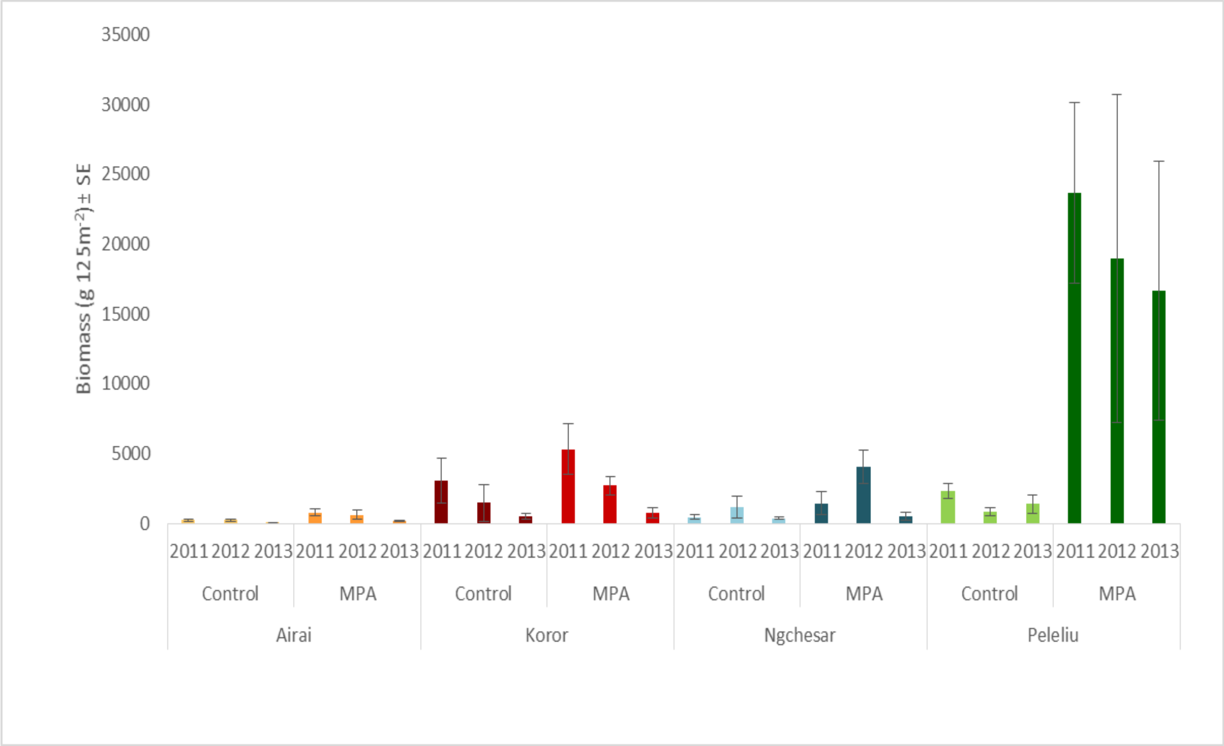

Figure 2.Fish Biomass (g • 125m^{-2}) by state, site status and year.

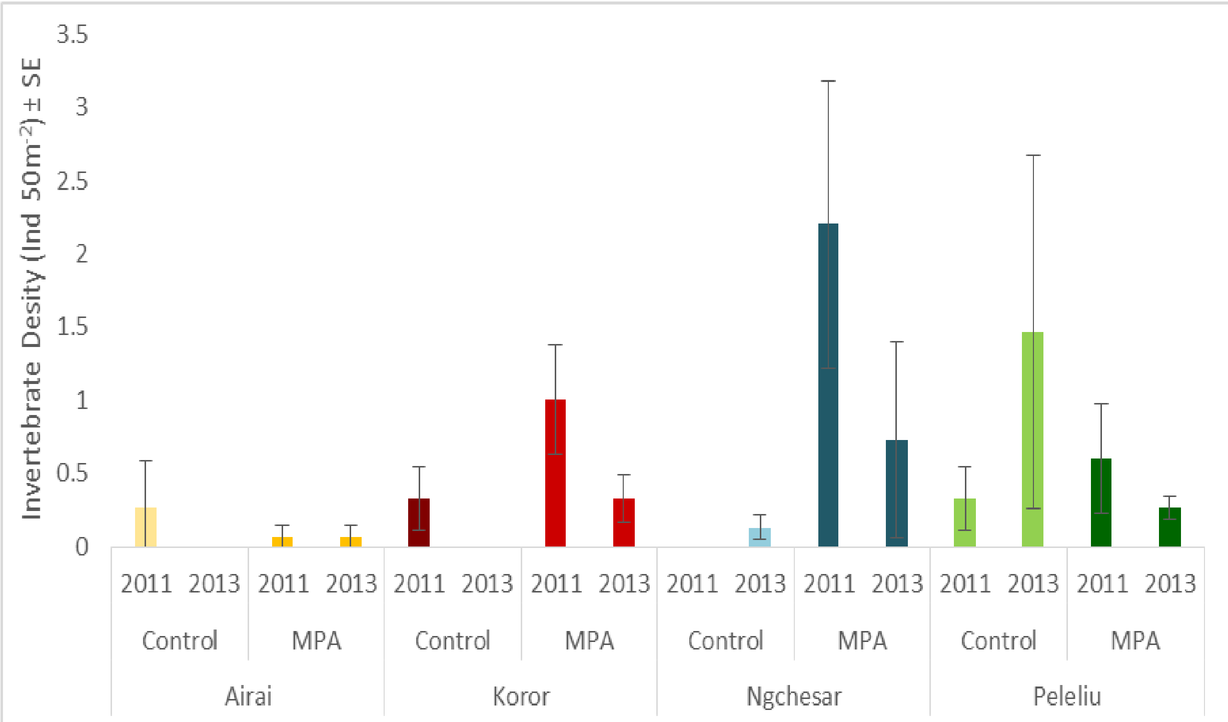

Figure 3. Invertebrate density (Ind • $50m^{-2}$) by State, site status and year.

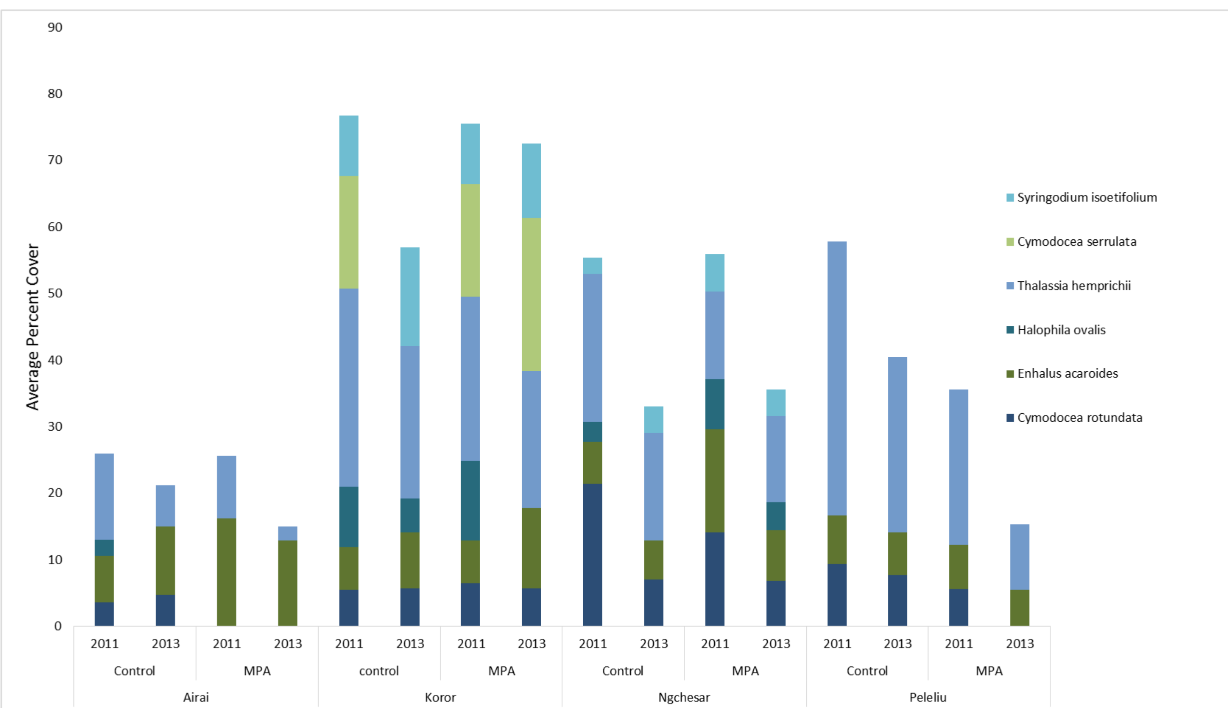

Figure 4.*Seagrass percent cover by state, site status, year and species.*

Work Cited

Björk, M. et al., *Managing Seagrasses for Resilience to Climate Change*,

Bujang, J., Harah, Z. & Arshad, A., 2006. Distribution and significance of seagrass ecosystems in Malaysia. *Aquatic Ecosystem Health and Management*, 9(2), pp.203–214.

Duarte, C.M. et al., 2000. Á Seagrass ecosystems : their global status and prospects. *Aquatic Ecosystems*.

Erftemeijer, P. & Lewis, R., 2006. Environmental impacts of dredging on seagrass: A review. *Marine Pollution Bulletin*, 52, pp.1553–1572.

Freeman, A.S. et al., 2008. Author ' s personal copy Seagrass on the edge : Land-use practices threaten coastal seagrass communities in Sabah , Malaysia. *Biological Conservation*, 141(12), pp.2993–3005.

Green, E. & Short, F., 2003. *World Atlas of Seagrass*, Los Angelas: University of California Press.

Hemminga, M. & Duarte, C.M., 2000. *Seagrass Ecology*, Cambridge: Cambridge University Press.

Jakobsen, F. et al., 2006. Sabah shoreline management plan (Borneo, Malaysia): ecosystems and pollution. *Ocean and Costal Management*, 20, pp.84–102.

Koshiba, S. et al., 2013. Palau's taro fields and mangroves protect the coral reefs by trapping eroded fine sediments. *Wetlands Ecology Management*, 21, pp.157–164.

Neckles, H.A. et al., Disturbance of eelgrass zostera marina by commercial mussel mytilus edulis harvesting in Maine: dragging impacts and habitat recovery. *Marine Ecology Progress Series2005*, 285, pp.57–73.

Orth, R. et al., A global crisis for seagrass ecosystems. *Bioscience*, (56), pp.987–996.

Short, F. et al., 2007. Global seagrass distribution and diversity: a bioregional model. *Journal of Experimental marine Biology and Ecology*, 350(1-2), pp.3–20.

Short, F.T. et al., 2006. SeagrassNet monitoring across the Americas : case studies of seagrass decline. , 27, pp.277–289.

Short, F.T. & Wyllie-Echevrria, S., 1996. Natural and human-induced disturbance of seagrass. *Environmental Conservation*, 23(1), pp.17–27.

Terrados, J. et al., 1998. Changes in community structure and biomass of seagrass communities along gradients of siltation in SE Asia. *Estuarine, Coastal and Shelf Science*, 46(5), pp.757–768.

Underwood, A.J., 1997. *Experiments in ecology: their logical design and interpretation using analysis of variance.*, Cambridge University Press.

Vermaat, J. et al., 1997. The capacity of seagrass to survive increaded turbidity and siltation: The significance of growth form and light use. *Ambio*, 26, pp.499–504.