An Integrated Assessment of anthropogenic and climatic interactions with seagrass habitats in the Seychelles.

Preliminary expedition report

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1. Background

One of the inner granitic islands of the Seychelles archipelago, Mahé (152 km^2) is the largest island (Figure 1) and has 93% of the total population. The Seychelles are economically dependent largely on their marine resources primarily through tourism. However, land reclaimation, dredging, untreated sewerage outlets resulting from urban expansion, and soil run-off due to deforestation, are threatening many of the shallow coastal environments.

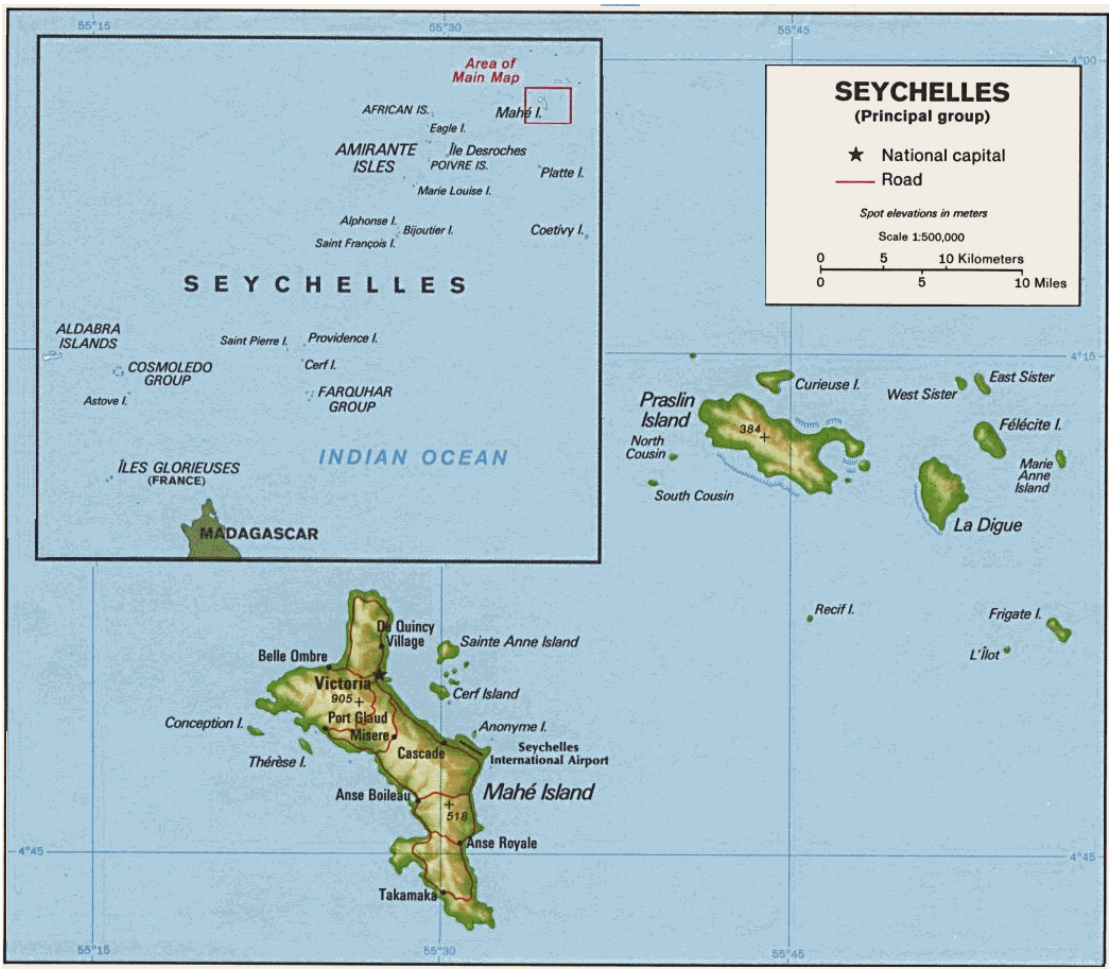

Figure 1. The islands comprising the Republic of the Seychelles.

Although recent projects under the 'Shoals of Capricorn' programme have focused on mangrove and coral communities, relatively little work has been conducted on seagrass habitats in this region. Several studies have mapped and desicribed the extent of seagrass meadows around Mahe (Figure 2), little work has focused on the dynamics operating within these ecosystems or the biodiversity of the infauna with in the seagrass meadows of the innner islands. As these coastal marine ecosystems span the interface between land and sea they are easily accessible and thus vulnerable to disturbance. If chronic, these impacts may have long term effects on ecosystem stability.

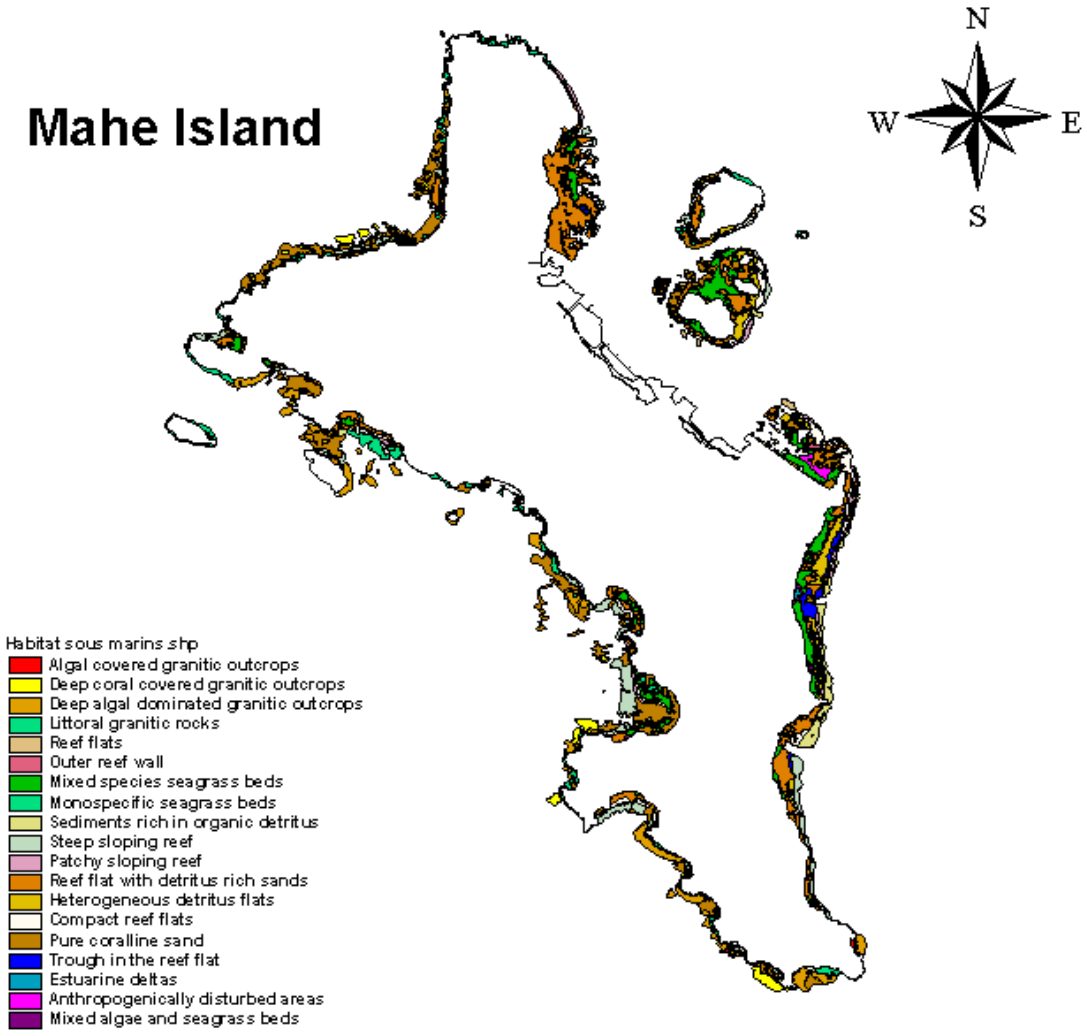

Figure 2. Coastal shallow marine habitat map of Mahe (courtesy, Seychelles Ministry of Land and Habitats).

Seagrass ecosystems are a critical component of the coastal zone due to the following:

a. They provide a important nursery and breeding habitat for commercial fish and invertebrate species,
b. They provide a critical role in sediment stabilization and reduce nutrient loading from terrestrial run-off thereby improving water clarity in support of coral ecosystems,
c. Extensive seagrass meadows attenuate wave action in support of low-energy mangrove ecosystems and in reducing beach erosion.

The proximity of seagrass meadows to shore means that they receive terrestrial pollutants and silt from rivers, sediment from coastal erosion, and are often destroyed by development, such as reclamation. These stresses on the marine environment, are likely to intensify with the rapidly growing population of the Seychelles. An understanding of how seagrass communities respond to the stress associated with these activities is crucial for mitigating the impacts that threaten their existence. Marine Park Area (MPA) designation potentially provides some guard against

seagrass ecosystem degradation, however, no studies to date have evaluated the protection afforded by management of such conservation areas.

Research completed by the expedition has:

1. determined the extent of seagrass habitats encompassed within two marine park boundaries in comparison to those of Mahé Island;
2. measured above- and below-ground biomass, leaf area and physical variables (temperature, salinity, depth, turbidity and water quality) of selected sites;
3. undertaken a species diversity assessment of the benthic macroinvertebrates in seagrass ecosystems at selected sites and identify factors responsible for any differences in community structure observed;
4. evaluated the impact of terrestrial pollutants on seagrass composition, stand density and leaf area at one site;
5. qualitatively assessed the level of protection afforded to seagrass habitats by MPA status;
6. provided a baseline level of information regarding the seagrass beds around Mahé, against which future changes can be monitored.

These research aims were investigated by examining the seagrass beds in two protected sites (Ste Anne and Baie Ternay National Marine Parks) and one non-protected site (Anse aux Pins) on Mahé Island. Anse aux Pins was chosen both as a control and as an anthropogenically impacted study site for two reasons: (a) it is the second most densely populated area on Mahe and bordered by one of the most extensive seagrass beds surrounding Mahe, and (b) an area of pronounced disturbance in front of a freshwater sewerage outfall was identified as one of the sample sites within the extensive Anse aux Pins meadow. The study site assessments have been undertaken at three spatial scales, encompassing regional (using aerial photography), surface, and subsurface level variations in habitat.

2. Methods

2.1. Fieldwork (biodiversity assessment):

To cover a large area of seagrass habitat in a relatively short time period to evaluate the benthic community analysis, swim transect methods were employed. Replicated quadrats were taken along each swim transect to encompass a greater degree of the spatial variation within each study site than would be possible with a single large quadrat. Five 50m transects were sampled at each site. For each transect a weighted transect line was deployed from a boat running perpendicular to shore, marked at each end with floating buoys. Five stations were established at ten metre intervals along each transect line. At each station a quadrat area of 4 m by 4 m was sampled by marking out 1m by 1m quadrants, systematically beginning at the bottom left hand corner of the transect line. This data was later pooled over the four quadrants. A GPS (Global Positioning System) position reading was taken at the beginning and end of each transect for later relocation. Mask and snorkel were used to undertake all sampling. Sediments were categorized according to a five-class visual assessment scheme. All visible surface benthic fauna were identified and enumerated. In addition, holes on the surface of the sediment created by burrowing crustaceans and the exhalent openings of razor clam shells (***Pinna muricata***) were also counted. Although these last two features are part of the infaunal components of the seagrass beds, their low densities could not be accurately quantified by the infauna sampling method described below and so were included in these transect counts.

Coring devices were used to determine the biodiversity of infaunal communities (collected from below the sediment surface). At each study site, ten subjectively assigned stations were randomly positioned to encompass as much habitat heterogeneity as possible. At each station, three replicate cores were taken from within a square metre making a total of 30 core samples per site. Core samples were taken using a 110mm diameter PVC corer sunk into the beds to a depth of 20 cm. A GPS location was recorded at each station for future reference, along with a depth measurement that was later standardized to the depth at mean low tide of chart datum. At each station, sediment type was recorded as for the transect sampling method. Each core was washed in the field through a 1mm mesh sieve, then labelled and bagged for later laboratory analysis of infauna count.

2.2. Fieldwork (terrestrial impacts study):

Shoot density and leaf area of seagrass were selected as the most appropriate variables to measure in consideration of the objectives of this part of the study. Sampling design consisted of 13 perpendicular transects in the vicinity of the sewerage outfall. Each transect was 120 meters long, all transects were spaced 20 meters apart. There were 6 transects spaced evenly up to 120 meters north of the effluent, 6 spaced evenly up to 120 meters south of the effluent, and one extending from the mouth of the effluent towards the sea in an easterly direction. Samples were taken along each transect at seven stations separated 20 meters apart from each other, starting at 0 meters from shore and ending at 120 meters from shore. In order to analyze any effect from the effluent on the seagrass community and composition, the sampling regime was devised in this grid formation, so that each station would be equidistant from surrounding stations. This allows an analysis of the effect of distance from the

effluent on the density and leaf area at each station through post-sampling interpolated analysis of the data. At each station, a 110 mm diameter PVC corer was used to retrieve the shoots per station. These were then placed in plastic bags, labeled and transported to the laboratory to separate species and to count shoots densities. Additionally, 5-10 shoots per species were sub-sampled and collected in the vicinity of the core. These were also placed in bags, labeled and transported to the lab for measuring leaf area. A series of water quality measurements were also taken across the study area and later analysed for nitrate concentration, phosphate concentration, conductivity, and total suspended solid concentration. Sediment type was recorded at each station, as was depth, temperature and salinity. Turbidity measurements were made with a Secchii disk at each station in three transects: the transect immediately in front of the effluent and the most northerly and southerly transects.

3. Results and conclusions

3.1. Seagrass species and biodiversity assessments

The primary assessment of the composition at each site revealed that the beds at both Anse aux Pins and the Ste. Anne (Cerf channel) sites were predominantly a mixture of three sympatric species, ***Thalassia hemprichii*** (Figure 3), ***Syringodium isoetifolium*** (Figure 4) and ***Cymnodocea serrulata***. Although densities of the mixed community were high at both sites, Anse aux Pins appeared to have a higher degree of patchiness.

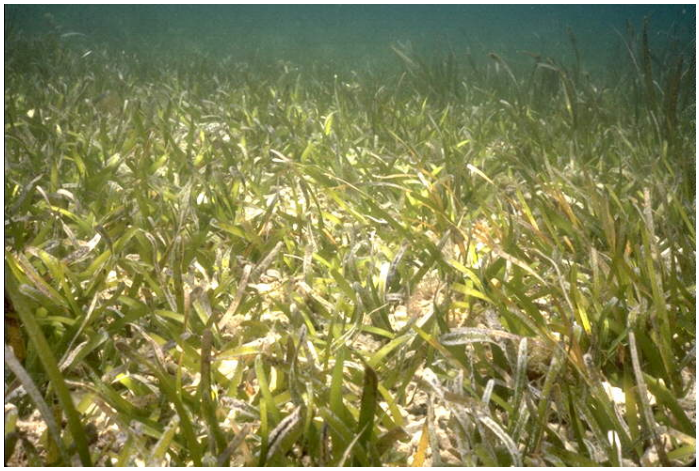

Figure 3. ***Thalassia hemprichii*** **Meadow**

Figure 4. ***Syringodium isoetifolium*** **Meadow**

(pictures courtesy of http://www.botany.hawaii.edu/seagrass/)

The seagrass community at Baie Ternay is dominated by ***Thalassia hemprichii***. Other green algal species (including ***Caulerpa racemosa, C. sertularoides*** and ***Codium*** spp.) were also abundant and resulted in a multispecific community. A comparison of the shoot densities of the different seagrass species indicates some variation between the sites (Table 1). Large standard deviations from the mean seagrass densities

indicated that there was also a substantial amount of variation in seagrass density within each site, which correlated to a high degree of natural clumping or spatial heterogeneity within the beds. This was noticeable in areas where bioturbation produced large bare patches of sediment, increasing the patchiness of the beds. This effect appeared to be reduced at Baie Ternay.

Seagrass species	**Baie Ternay** Mean shoot density (m^2) with s.d. (n=30)	**Cerf Channel** Mean shoot density (m^2) with s.d. (n=30)	**Anse aux Pins** Mean shoot density (m^2) with s.d. (n=30)
Thallasia hemprichii	656 ± 426	275 ± 472	554 ± 462
Syringodium isoetifolium	291 ± 890	887 ± 898	873 ± 1168
Cymnodocea serrulata	189 ± 339	803 ± 563	522 ± 549
Halodule uninervis	35 ± 192	63 ± 199	-
Halophilia ovalis	42 ± 180	-	-

Table 1. Densities of the five seagrass species by site.

Although ***Thallasia hemprichii, Syringodium isoetifolium*** and ***Cymnodocea serrulata*** were regularly found growing together, all five seagrass species did not occur sympatrically within any of the quadrats. ***Halophilia ovalis*** was also encountered in littoral margins at both Baie Ternay and Cerf Island, but was not found an Anse aux Pins. It was only found within 20 m from shore in the most sheltered areas of Baie Ternay and Cerf Island, although it was found in considerably rougher water elsewhere around Mahé. ***Halodule uninervis*** was located at Anse aux Pins, however, it was not recorded in sufficient quantities to determine the density.

A total of 58 infaunal invertebrates were found during the research surveys. This level of diversity is similar to, although slightly lower, than that observed in other tropical seagrass ecosystems of corresponding latitude. The species richness of both the seagrass and infaunal community did not differ significantly between the three principal study sites. Yet, differences found in the dominance and abundance of the infaunal components of the beds indicate some variation in the overall community structure of each site. Based on invertebrate abundance, seagrass beds at Baie Ternay on the western side of Mahé had a distinct infaunal macroinvertebrate community composition compared to beds located on the eastern coast. This is likely to be only a locally important distinction determined mainly by differences in the physical characteristics of the beds.

3.2. The impacts of the outfall

The results from the surveys undertaken at Anse aux Pins demonstrated that: (a) seagrass community composition differed between anthropogenically- and freshwater-impacted areas and undisturbed sites, (b) shoot density varied between these sites but was species specific, and (c) leaf area was lower for all species in disturbed areas. The factors responsible for variability in the seagrass beds in Anse aux Pins were a result of both natural and human disturbances. Fluvial sediment deposition, together with the seasonal monsoon winds, and the erosive actions of a built seawall interacted to alter the sediment regime in the area and redistribute it along the coastline. The resultant impacts were turbid waters and shallow, silty conditions close to the shoreline, conditions that are inhospitable to seagrass communities. Where seagrass can survive, the community composition appeared to be in a state of 'moderate' disturbance when compared with the unaffected sites, due to the higher number of recorded seagrass species with widely variable ecological characteristics. The most conspicuous variations in species distributions between the disturbed and non-disturbed sites were found among the two species of seagrass having extreme degrees of tolerance: **S*yringodium isoetifolium***, the species proven to be most sensitive to siltation, and ***Halodule uninervis***, the species most resilient to severe conditions. These extremes suggest that there may be potential for developing a dose-response relationship of seagrass to the degree of turbidity that can be tolerated within a seagrass ecosystem. This could be useful for predicting and evaluating environmental impacts on an area.

3.3. Discussion

The importance of baselines for monitoring is highlighted by natural variation in the distribution of some benthic organisms within the seagrass ecosystems. In this study, the starfish, ***Protoreaster linckii*** was located only within the Ste. Anne Marine Park. However, Taylor and Lewis (1970) in a general study of seagrass ecosystems around Mahé did not record this species as present. Conversely, Ebert in 1976 recorded populations of both ***P. linckii*** and another locally rare starfish ***Pentaceraster horridus*** from within the Marine Park boundaries. Based on just these two previous studies the conclusions reached about the location of this starfish within the protected area change considerably. The presence of ***P. linckii*** within the Cerf Island beds over an extended period suggests that a long lifespan and low levels of recruitment are a more appropriate explanation of its anomalous distribution than protection from human harvesting pressure.

In contrast, the occurrence of the gastropods, ***Cypraea moneta, Cypraea tigris*** and ***Strombus spp***. within the Baie Ternay National Marine Park may have considerable implications. These species all have shells that are valuable in the tourist souvenir trade. Historical evidence suggests that these species were at one time common around Mahé before overharvesting reduced their abundance. Their present distribution seems limited to seagrass beds within a MPA, which suggests that protection from harvesting is playing some role in maintaining the populations. Other research based on sound scientific baselines has demonstrated that protected areas can have a significant effect on gastropod population. Therefore, while the site-specific differences in community structure do not superficially appear to be related to the protected status of the beds, the MPA areas do contain a number of key species and

may offer some protection to them, and others against harvesting. These suggestions are tentative and, now that a baseline has been set for these areas, future changes of abundance can be monitored.

Results also indicated that sedimentation resulting from the Anse aux Pins sewerage outfall appeared to be the dominant factor in suppressing seagrass growth in large areas around the river mouth. The high degree of sedimentation appears to be the result of human and natural factors acting together to alter the coastal environment. The presence of a sea wall typically increases erosion. However, in this situation, the seagrass communities were only negatively affected by the erosive forces of the sea wall north of the mouth of the effluent. This effect was due to the combined impacts of sedimentation due to silt carried downstream by the river, the forces of the northeast monsoon, and the erosive capacity of the seawall. These observations have important implications for coastal planning by demonstrating the need to consider the multiplicity of complex factors acting within the coastal zone such as monsoonal winds(which are seasonal), sea defence structures, and land use along watersheds feeding into the coastal zone.

Representativeness is one of the fundamental principles of Marine Protected Area (MPA) design. Thirty-one percent of the Mahés seagrass ecosystems are located within Marine National Parks. These protected areas encompass both of the local community types determined by this study and are representative of the overall ecosystem, although the regionally rare seagrass species ***Enhalus acoroides*** was not located in the MPAs surveyed. A lack of prior baseline monitoring of the seagrass beds in these MPAs meant that it was not possible to accurately quantify the effects of protection. However, the presence of some historically harvested gastropods within MPA areas may indicate potential benefits of protection. These results stress the need to empirically apply principles such as representation and the importance of baseline monitoring.

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