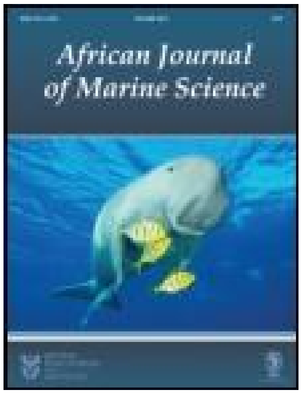


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# Diversity and coverage of seagrass ecosystems in south-west Madagascar

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# Diversity and coverage of seagrass ecosystems in south-west Madagascar

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**Seagrass meadows provide important nursery and feeding grounds for many commercially valuable fish species. Here, we address the paucity of published information on the status of seagrasses in Madagascar by documenting the results from ecological surveys of 11 seagrass beds in Velondriake, a locally managed marine area (LMMA) in south-west Madagascar. The diversity and coverage of meadows was highest in the north of the LMMA with up to 51% coverage, and lowest in the south (26%). Overall, eight seagrass species were recorded: *Cymodocea rotundata*, *C. serrulata*, *Halodule uninervis*, *Halophila ovalis*, *H. stipulacea*, *Syringodium isoetifolium*, *Thalassia hemprichii* and *Thalassodendron ciliatum*. We discuss the natural and anthropogenic factors that may account for the observed low diversity of seagrasses in southern Velondriake, including overfishing, beach-seining, cyclones, siltation and mangrove deforestation. Based on these baseline surveys, as well as discussions with local communities, it is recommended that measures should be taken to reinforce efforts to ban beach-seines and that the role of seagrasses as carbon sinks and potential sustainable financing options through blue carbon initiatives should be investigated through further, more detailed surveys.**

**Keywords:** beach-seine, blue carbon, community management, LMMA, locally managed marine areas

## Introduction

Seagrasses are aquatic flowering plants found mainly in shallow nearshore salt water. They thrive in sheltered areas where currents are slow and there is little wave action, mostly in tropical regions and usually between mangroves and coral reefs (Short et al. 2011). Seagrasses are just as important economically and ecologically as coral reefs, although they generally have lower species diversity, and have increasingly been assessed as conservation priorities for management (Unsworth and Cullen 2010). Seagrass meadows act as a nursery and as feeding grounds and refuge areas for many commercially valuable fish species, including snappers and parrotfish (Heck and Thoman 1984). Shellfish found within seagrass beds provide a considerable source of protein for many coastal-living people within the Indo-Pacific (de la Torre-Castro and Rönnbäck 2004).

Seagrass meadows also provide critical ecological services. Seagrass leaves attenuate wave energy, reducing coastal erosion, while their dense network of roots stabilises the seabed, reducing sedimentation and water turbidity (Hemminga and Duarte 2000). In addition, seagrass meadows trap sediment carried out to sea by rivers, preventing it from smothering coral reefs, which require clean and clear water for favourable growth (Hemminga and Duarte 2000). Seagrass meadows are also increasingly being highlighted as important global carbon sinks (Laffoley and Grimsditch 2009), and future conservation goals may include sustainable financing mechanisms based on their potential to sequester carbon. Blue carbon is defined as carbon stored and sequestered in, and released from, coastal ecosystems, and blue carbon projects are becoming increasingly common worldwide (Herr et al. 2011).

Despite their importance, the world's seagrass meadows are shrinking at an unprecedented rate. Between 1990 and 2006, meadows disappeared at a rate of 7% of their total global area per year, and the annual loss from 1980 was 110 $km^2$ (Waycott et al. 2009). Seagrass meadows are particularly prone to overfishing, because they are shallow and sheltered and can be fished even in poor weather conditions (Unsworth and Cullen 2010). Overfishing and removal of certain fish species triggers population explosions of sea urchins and epiphytes, both of which damage and destroy seagrass (Rose 1999, Heck and Valentine 2007, Moksnes et al. 2008, Eklof et al. 2009). Certain fishing methods are physically damaging to the plants (Duarte 2002), such as beach-seining, in which weighted fishing nets are dragged across the seabed, causing seagrass to uproot. Such damage has been shown to result in lower overall catch rates of coral reef fish (McClanahan and Mangi 2001). At low tide, seagrass meadows attract shellfish and octopus collectors, who trample the plants underfoot.

In all, 13 species of seagrass are found along the coast of the Western Indian Ocean (WIO), but knowledge of factors that influence their distribution and composition along this coast, and particularly that of Madagascar, is very scarce (Gullström et al. 2002). Throughout the WIO, seagrass research is overshadowed by coral reef and mangrove studies (Gullström et al. 2002). For example, in Kenya, where marine research is generally more advanced than in most other WIO nations on account of the long-term government involvement and presence of large non-governmental organisations (NGOs), seagrass-specific studies represent just 4% of published research output (*n* = 10) whereas there have been over 200 published articles related to coral reefs in the past 20 years (Muthiga and Kawaka 2010).

The area of coverage and the extent of loss of seagrass in Madagascar have to date not been adequately assessed (Green and Short 2003). However, in south-west Madagascar, research carried out in 2008 near the town of Toliara identified *Halodule uninervis* as the most abundant species in the area (LePoint et al. 2008). The upper littoral □one of the seagrass meadow, which is located 20 km south of Toliara, consisted of monospecific stands of *H. uninervis* and *Halophila ovalis*, whereas the mid-intertidal □one was a mix of *H. uninervis*, *Thalassia hemprichii* and *Cymodocea rotundata*. In the deeper waters of the subtidal □one, *Syringodium isoetifolium* dominated, whereas the deepest □ones consisted mainly of *Cymodocea serrulata* and *Thalassodendron ciliatum*. An in-depth literature survey both of publications and reports available online, and paper reports available at libraries of universities and government institutions in Madagascar, suggests that there are currently no published studies related to the seagrass meadows that lie north of Toliara, which are believed to be less degraded.

Few seagrass meadows in the WIO, and even fewer in Madagascar, have been mapped, even at low spatial resolution, making it very difficult for managers to incorporate them into marine conservation initiatives (Unsworth and Cullen 2010). To fill this gap in knowledge, we undertook surveys of 11 seagrass meadows in the locally managed marine area (LMMA) of Velondriake (Figure 1). The aim of this study was to provide baseline information on the diversity and coverage of seagrass beds in this region.

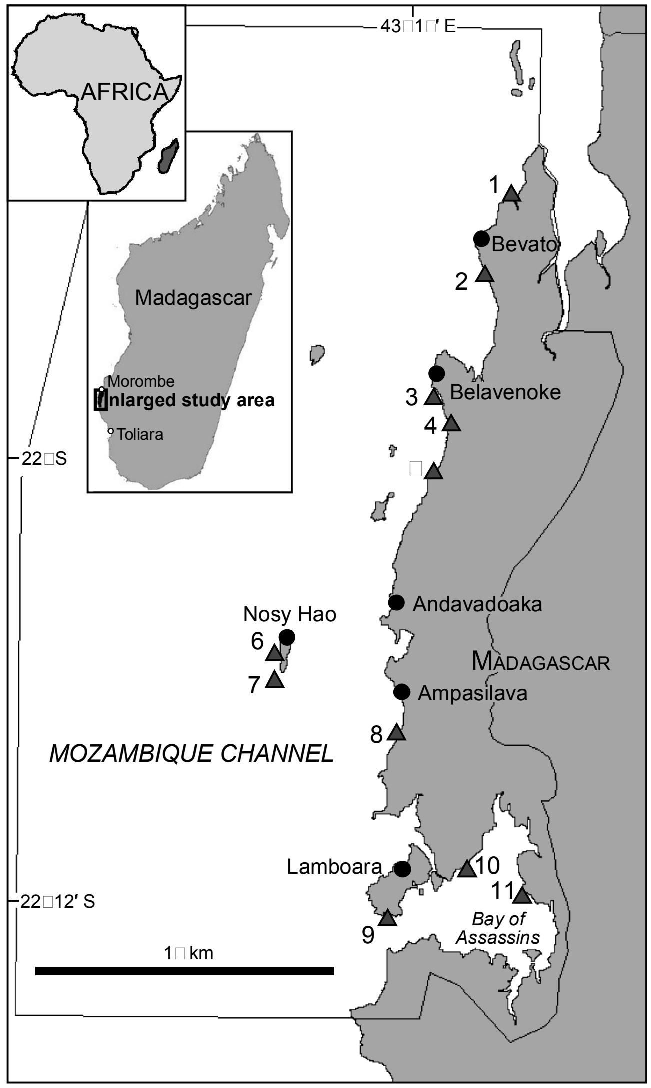
## Material and methods

### *Study sites*

The research sites are located in the approximately 1 000 km² Velondriake LMMA in south-west Madagascar (Harris 2011). Velondriake is divided into three management regions, encompassing northern, central and southern areas, and surveys were conducted at sites close to villages in all three regions. The central region has been the most effectively managed to date as this is the central point of the LMMA management committee. The region is the base of the support by the NGOs that provide assistance to the management committee. The incidence of beach-seining is lowest in the central region due to better law enforcement and stronger leadership there and beach-seine fishers from inland tribes are most prevalent in the northern area (Andriamalala 2010). Most of the inhabitants of the LMMA are traditional fishers belonging to the Ve□o tribe, who fish from pirogues or by walking on reef flats and seagrass meadows at low tide. The main targets are finfish (e.g. Serranidae, Scaridae, Scombridae and Lutjanidae), octopus *Octopus cyanea*, squid *Loligo* spp. and lobsters *Palinurus* spp. (Gough et al. 2009).

### *Survey methods*

A survey team including staff from Blue Ventures, an NGO based in the region, and trained local assistants surveyed 11 seagrass sites throughout the Velondriake LMMA (Figure 1). Seagrass sites were selected for ecological surveys within the LMMA area based on informal discussions with local fishers to ensure a representative cross-section of sites (popular fishing sites, etc.). Current usage of selected sites and a brief geophysical description was also recorded.




**igure 1:** Map of survey sites in the Velondriake LMMA. Survey sites are numbered 1□11 and correspond to site names as follows□ 1 □ Lobaho, 2 □ Ampasy, 3 □ Betalatala, 4 □ Andamalama, □ □ Anakao, 6 □ West Nosy Hao, 7 □ South-west Nosy Hao, 8 □ Beambariake, 9 □ Andavakalanoro, 10 □ Ampengoke, 11 □ Ampasimara. Thin black line indicates extent of the LMMA boundary

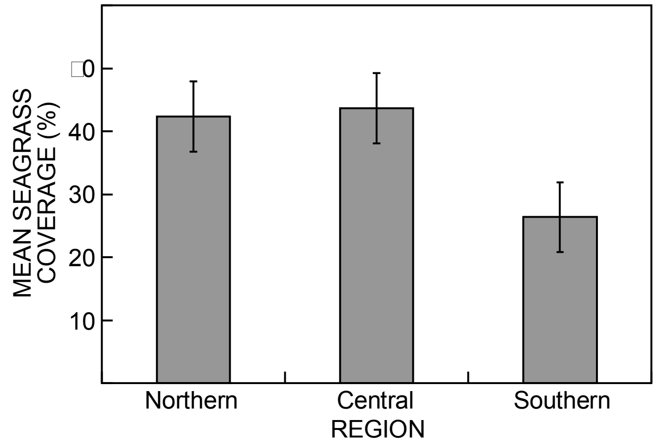
Ecological data were collected to provide information on the diversity and coverage of seagrasses at the 11 selected survey sites along three □0 m-long transects laid parallel to the coast at each site. Data were collected following the methods developed by SeagrassNet (Short et al. 2006). The three transects were laid at varying depths and spaced at intervals across the extent of the seagrass meadow in an attempt to encompass a representative sample of the character of the bed. Twelve 1 m² quadrats were placed at random intervals along each transect, generating 36 quadrat replicates per site. Within each quadrat, the seagrass species present were identified and recorded using field photo-identification cards. The total percentage surface coverage of all species in the quadrat, and the surface coverage of individual species, were visually estimated using the SeagrassNet percentage cover photo-guide. A visual assessment of dominant sediment type at each site was also recorded.

## esults

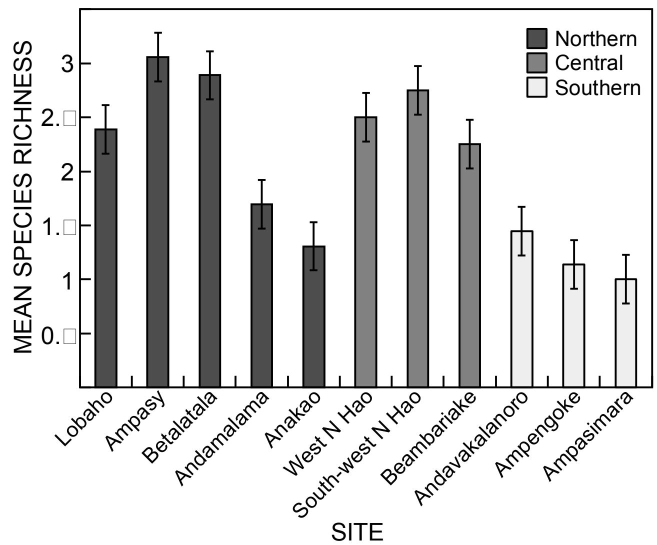
In all, eight species of seagrass were found at the 11 study sites within the Velondriake LMMA□*Cymodocea rotundata*, *C. serrulata*, *Halodule uninervis*, *Halophila ovalis*, *H. stipulacea*, *Syringodium isoetifolium*, *Thalassia hemprichii* and *Thalassodendron ciliatum*. The meadows with the highest overall seagrass coverage were located in the northern and central regions of the LMMA (42% and 44% respectively) compared to a mean coverage of 26% at the southern sites (Figure 2), and there was a strong relationship between region and percentage cover ($r$□= 0.69). The mean cover across all sites in Velondriake was 37% (SE 3.3).

Overall, mean species richness decreased from north to south (Figure 3, $r$□= 0.44). The most diverse meadows were located in the northern region, where sites contained a mean of 6.3 species, compared to □.0 species in the centre and 2.3 in the south (Table 1).

Species composition varied across the sites. *Syringodium isoetifolium* was abundant at the northern and central sites, but were entirely absent in the south of the LMMA, whereas the percentage coverage of two species *T. ciliatum* and *C. serrulata* declined from north to south. In contrast, the percentage coverage of *T. hemprichii* was higher at southern sites than in the north (Figure 4).




**igure 2:** Mean percentage cover of seagrass at sites in the northern ($n$ □ □), central ($n$ □ 3) and southern ($n$ □ 3) regions of the Velondriake LMMA. Error bars denote SE




**igure :** Mean species richness (number of species) at each site from north to south in the three regions of the Velondriake LMMA. Error bars denote SE

## Discussion

This survey documents, for the first time, the highly diverse nature of the seagrass meadows of the Velondriake LMMA. Eight of the 13 species of seagrass found in the WIO region (Gullström et al. 2002) were found in the LMMA. In addition to being more diverse, seagrass meadows in the north of the LMMA showed greater coverage than those in the south. Of the 11 sites, eight had seagrass coverage of over 30%, which is considered to be □low' (Chansang and Poovachiranon 1994). Two sites had over □0% coverage, which is comparable to that found in Wakatobi Marine National Park in Sulawesi, Indonesia, a region considered to have □high' coverage (Unsworth et al. 2008). Even at best, however, the seagrass coverage across all sites does not approach that found in a permanently submerged lagoon in Mombasa Marine National Park in Kenya, where the coverage was estimated at 83.6% (Alcoverro and Mariani 2002). The observed variation in seagrass species richness and cover can be explained by a number of factors, including natural variation in substrate, the differential impacts of cyclones, use of destructive fishing practices, overfishing, and mangrove degradation. Although we did not specifically investigate any of these factors, the information gathered from personal observations and from the community members provided important baseline data on the seagrass condition in the different areas.

Community members in Lamboara and Nosy Hao attributed the poor condition of the local seagrass meadows to the strong cyclones in 200□. Cyclones generate high-energy waves that physically damage seagrass meadows, uproot plants and stir up sediments, which increases turbidity and limits photosynthesis (Preen et al. 199□, Fourqurean and Rutten 2004). It is expected that cyclones would negatively impact all seagrass meadows in Velondriake□however, it is likely that the degree of impact would be influenced by water depth and the shape of the coastline. Thus, some sites may be more vulnerable to damage from strong waves and swell during cyclones and tropical storms than others.

Overfishing and destructive fishing techniques, particularly beach-seining, may also play a role in the low cover and diversity of seagrass meadows in the south of the LMMA. Beach-seining is illegal inside Velondriake

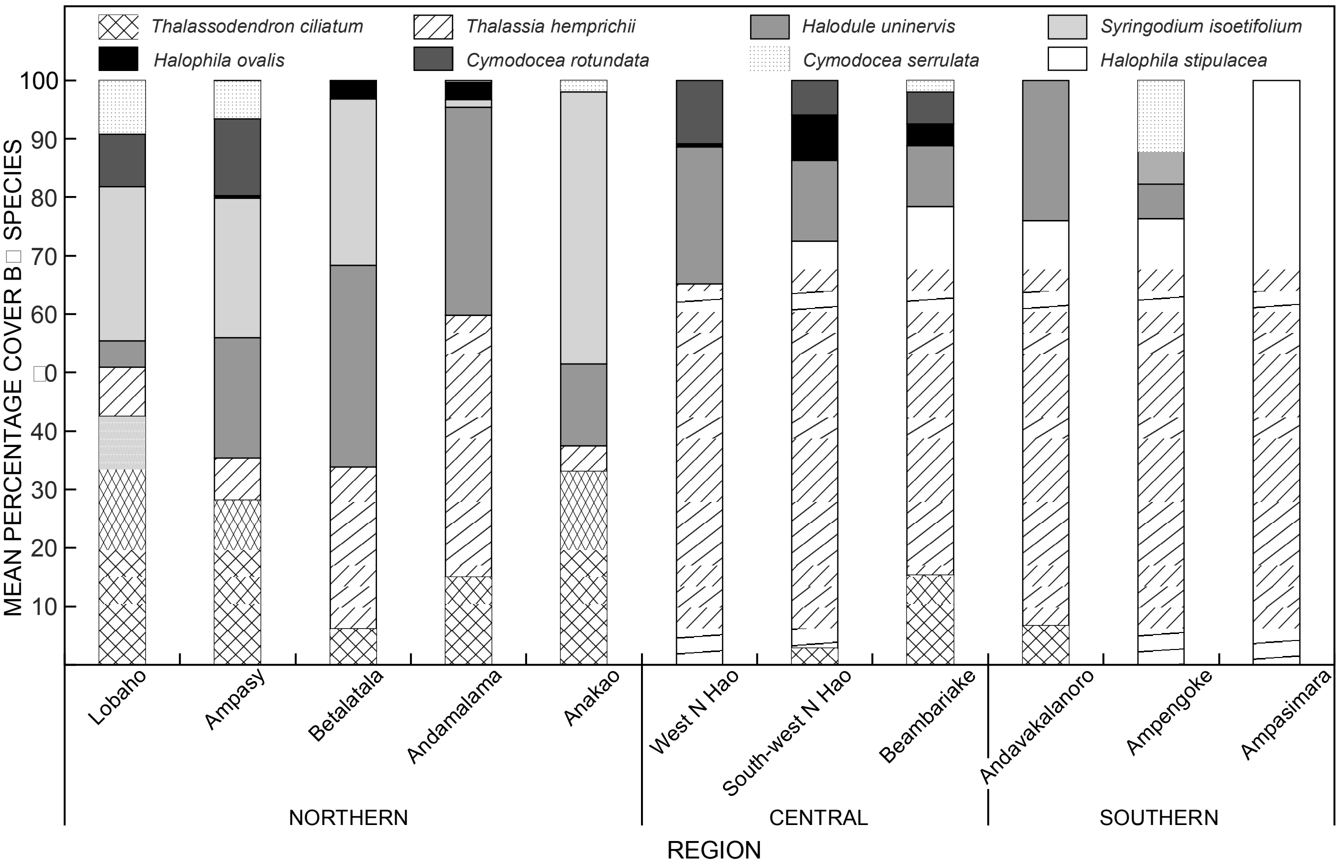
**Table 1:** Summary of individual site characteristics generated from ecological survey data and informal discussion with fishers and village elders

| Site | Region | Main associated village | Total seagrass cover (%) | Species richness | Dominant species | Sub-strate | Geophysical description | Use history |
|---|---|---|---|---|---|---|---|---|
| 1 Lobaho | Northern | Bevato | 39 | 6 | *Syringodium isoetifolium* | Fine sand | Located at entrance to mangrove forest. Subtidal | Popular gleaning site for sea cucumbers |
| 2 Ampasy | Northern | Bevato | 44 | 8 | *Syringodium isoetifolium* | Fine sand | Runs parallel to the coast south of Bevato along the eastern edge of the fringing reef. Intertidal | Popular with beach-seiners |
| 3 Betalatala | Northern | Belavenoke | 39 | 6 | *Halodule uninervis* | Sand | Subtidal | Northern end fished for sea cucumbers (Dec□ Mar)□southern end popular all year for fish and octopus |
| 4 Andamalama | Northern | Belavenoke | 46 | 6 | *Thalassia hemprichii* | Sand | Littered with large rocks, patchy seagrass. Subtidal | Popular fishing site for dive fishing and gleaning |
| □ Anakao | Northern | Belavenoke | 28 | 6 | *Thalassodendron ciliatum* | Sand | West □ sandbar□ east □ beach□ north □ large rock□ south □ large rock. Predominantly intertidal | No data |
| 6 West Nosy Hao | Central | Nosy Hao | □0 | □ | *Thalassia hemprichii* | Sand | Mostly intertidal | Popular fishing site |
| 7 South-west Nosy Hao | Central | Nosy Hao | 30 | □ | *Thalassia hemprichii* | Coarse sand | Coarse sand littered with dead coral. Subtidal | No data |
| 8 Beambariake | Central | Ampasilava | □1 | 6 | *Thalassia hemprichii* | Sand□ silt | Subtidal | Transit route for pirogues□ previously a popular fishing site |
| 9 Andavakalanoro | Southern | Lamboara | 29 | 2 | *Thalassia hemprichii* | Silt | Intertidal | Not a popular site |
| 10 Ampengoke | Southern | Lamboara | 14 | 4 | *Thalassia hemprichii* | Silt | Intertidal | Popular fishing site |
| 11 Ampasimara | Southern | Lamboara | 20 | 1 | *Thalassia hemprichii* | Silt | Patchy seagrass coverage. Subtidal | Popular fishing site. Beach-seining observed |



(Andriamalala and Gardner 2010), but itinerant fishers from Morombe, a town to the north of the LMMA, were seen employing this gear at northern sites during the survey period, and it is possible that they use the same techniques in the southern regions. Community members also indicated reduced motivation to conserve the seagrass meadows when they saw intruders exploit them, despite relying on the meadows themselves for fish and octopus. Community members living near the southern sites of Ampasimara and Ampengoke reported that the practice of beach-seining was common locally and considered it as the cause of degradation in the meadows. Whereas official reports of beach-seining activity indicate that it is much more prevalent in the northern region, unreported beach-seining at the southern sites could explain why the relative coverage of seagrass meadows declines from north to south in the LMMA. In particular, *T. ciliatum* is a large species of seagrass that easily becomes entangled in nets and is often cut back by fishers (de la Torre Castro 2006).

It is important to note, however, that beach-seining is generally declining in the LMMA□when Velondriake was created in 2006, fishers from 21 villages inside the LMMA




**igure :** Mean species contribution to total seagrass coverage at sites in the Velondriake LMMA, from north to south



reported using this method of fishing, whereas currently only four villages continue to do so (Andriamalala 2010). A social marketing campaign, which was initiated in 2010 with the specific goal of eradicating beach-seining, continues to reduce the number of active beach-seine fishers within Velondriake. Also, a campaign in Morombe in 2011 sought to stop the migrant beach-seine fishers from entering Velondriake (Blue Ventures Conservation, unpublished data).

Overfishing may also account for the low diversity and coverage of seagrass at the southern sites. The Bay of Assassins has a higher density of villages than any of the other regions in the LMMA and therefore fishing pressure on its seagrass meadows is likely to be highest in this region. Overfishing reduces the number of large herbivorous fish that normally eat the epiphytes that grow on seagrass leaves. Epiphyte blooms on seagrass limit sunlight from reaching the plants and thus reduce photosynthesis rates and result in an overall reduction in seagrass coverage (Unsworth and Cullen 2010). Herbivory by sea urchins *Tripneustes gratilla* has a considerable impact on the species composition of tropical seagrass meadows (Vonk et al. 2008), reducing the abundance of certain species (in particular *T. ciliatum* and *S. isoetifolium*), but increasing the relative abundance of other species such as *T. hemprichii*. Overfishing removes the predators of seagrass-consuming sea urchins, causing their populations to increase dramatically. This has been found to reduce seagrass coverage significantly in East Africa (de la Torre-Castro 2006).

Collection of shellfish in seagrass meadows may also contribute to the lower percentage cover and diversity of seagrass meadows in the south. At low tide, shellfish collectors dig up the meadows and trample plants□shellfish collection like this is noted as a major cause of seagrass loss in parts of East Africa (Eckrich and Holmquist 2000, Bandeira and Gell 2003).

Seagrass meadows may be poorer in quality in the south on account of localised logging of mangrove forests. Mangroves normally trap sediment carried by rivers before it can smother other marine ecosystems, such as seagrass meadows and coral reefs, attenuating the light that is needed for photosynthesis. In the south of Velondriake, mangroves have been logged more heavily than in the north (Ravaorainorotsihoarana 2008), and excessive siltation can reduce both the coverage (Duarte et al. 1997) and the diversity of seagrass meadows.

Overall, the seagrass meadows of Velondriake are in a variable condition. Some, particularly in the north, seem to be relatively healthy in terms of species diversity and percentage cover. Given the potential role of seagrass areas as carbon sinks in climate change mitigation programmes (Crooks et al. 2011), further surveys should be conducted on the seagrass beds of Velondriake to assess their density and potential for income generation, through future blue carbon projects. We also suggest that measures such as the social marketing campaign initiated in 2010 should be implemented to reinforce efforts to ban beach-seining.

The use of beach-seine nets and resulting overfishing is a critical threat to the seagrasses of the Velondriake LMMA. Beach-seine nets can catch up to 70% juvenile fish in Kenya (Mangi and Roberts 2006), leading to declines in long-term fishery sustainability and declines in catch rates (McClanahan and Mangi 2001). In addition, it has been shown in other areas in the WIO that the use of nets can create long-term conflicts when competing with other more traditional and less-damaging fishing gears (de la Torre-Castro and Lindstrom 2010, de la Torre-Castro 2012). This highlights the need to continue to actively enforce community bans on the use of beach-seining nets and to ensure that community leaders are sufficiently motivated to do this.

The threats that seagrass meadows face are growing□ the coastal population in Velondriake is predicted to grow by 2□% by 202□ (Blue Ventures Conservation, unpublished data), and the pressures of overfishing and pollution will inevitably take their toll on the region's meadows, unless precautionary steps are taken soon to safeguard them.

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## eferences

Alcoverro T, Mariani S. 2002. Effects of sea urchin gra□ing on seagrass (*Thalassodendron ciliatum*) beds of a Kenyan lagoon. *Marine Ecology Progress Series* 226□2□□□263.

Andriamalala G. 2010. Velondriake locally managed marine area. □Ve□o aho' Campaign final report. MSc thesis, University of Texas, USA.

Andriamalala G, Gardner C. 2010. L'utilisation du dina comme outil de gouvernance des ressources naturelles□le□ons tires de Velondriake, sud-ouest de Madagascar. *Tropical Conservation Science* 3□447□472.

Bandeira SO, Gell F. 2003. The seagrasses of Mo□ambique and southeastern Africa. In□Green EP, Short FT (eds), *World atlas of seagrasses*. Prepared by the UNEP World Monitoring Conservation Centre. Berkeley□University of California Press. pp 93□100.

Chansang H, Poovachiranon S. 1994. The distribution and species composition of seagrass beds along the Andaman coast of Thailand. *Phuket Marine Biological Center Research Bulletin* □9□ 43□□2.

Crooks S, Herr D, Tamelander □, Laffoley D, Vandever □. 2011. *Mitigating climate change through restoration and management of coastal wetlands and near-shore marine ecosystems: challenges and opportunities*. Environment Department Paper 121. Washington, DC□World Bank.

de la Torre Castro M. 2006. Humans and seagrasses in East Africa. PhD thesis, Stockholm University, Sweden.

de la Torre-Castro M. 2012. Governance for sustainability□insights from marine resource use in a tropical setting in the Western Indian Ocean (WIO). *Coastal Management* 40□612□633.

de la Torre-Castro M, Lindström L. 2010. Fishing institutions□ addressing regulative, normative and cultural-cognitive elements to enhance fisheries management. *Marine Policy* 34□77□84.

de la Torre Castro M, Rönnbäck P. 2004. Links between seagrass processing. *Ocean and Coastal Management* 47□361□387.

Duarte C. 2002. The future of seagrass meadows. *Environmental Conservation* 29□192□206.

Duarte C, Terrados □, Agawin NSR, Fortes MD, Bach S, Kenworthy W□. 1997. Response of a mixed Philippine seagrass meadow to experimental burial. *Marine Ecology Progress Series* 147□ 28□□294.

Eckrich CE, Holmquist □G. 2000. Trampling in a seagrass assemblage□direct effects, response of associated fauna, and the role of substrate characteristics. *Marine Ecology Progress Series* 201□199□209.

Eklof □S, Frocklin S, Lindvall A, Stadlinger N, Kimathi A, Uku □N, McClanahan TR. 2009. How effective are MPAs□ Predation control and □spill-in effects' in seagrass-coral reef lagoons under contrasting fishery management. *Marine Ecology Progress Series* 384□83□96.

Fourqurean □W, Rutten LM. 2004. The impact of Hurricane Georges on soft-bottom, back reef communities□site- and species-specific effects in south Florida seagrass beds. *Bulletin of Marine Science* 7□□239□2□7.

Gough C, Thomas T, Humber F, Harris A, Cripps G, Peabody S. 2009. Ve□o fishing□an introduction to the methods used by fishers in Andavadoaka, Southwest Madagascar. Blue Ventures Conservation Report. Available at http□□blueventures.org□images□ downloads□research□Fisheries□Report□final□web.pdf □accessed 1 □uly 2012□.

Green EP, Short FT. 2003. *World atlas of seagrasses*. Prepared by the UNEP World Conservation Monitoring Centre. Berkeley□ University of California Press.

Gullström M, de la Torre Castro M, Bandeira SO, Björk M, Dahlberg M, Kautsky N, Rönnbäk P, □hman MC. 2002. Seagrass ecosystems in the Western Indian Ocean. *Ambio* 31□ □88□□96.

Harris AR. 2011 Out of sight but no longer out of mind□a climate of change for marine conservation in Madagascar. *Madgascar Conservation and Development* 6□7□14.

Heck KL, Thoman TA. 1984. The nursery role of seagrass meadows in the upper and lower reaches of the Chesapeake Bay. *Estuaries* 7□70□92.

Heck KL, Valentine □F. 2007. The primacy of top-down effects in shallow benthic ecosystems. *Estuaries and Coasts* 30□371□381.

Hemminga MA, Duarte CM. 2000. *Seagrass ecology: an introduction*. Cambridge□Cambridge University Press.

Herr D, Pidgeon E, Laffoley D (eds). 2011. Blue carbon policy framework□based on the first workshop of the international blue carbon policy working group. Gland, Swit□erland□IUCN and Arlington, USA□Conservation International.

Laffoley D, Grimsditch G (eds). 2009. *The management of natural coastal carbon sinks*. Gland, Swit□erland□IUCN.

LePoint G, Frederich B, Gobert S, Parmentier E. 2008. Isotopic ratios and elemental contents as indicators of seagrass processing and sewage influence in a tropical macrotidal ecosystem (Madagascar, Mo□ambique Channel). *Scientia Marina* 71□109□117.

Mangi SC, Roberts CM. 2006. □uantifying the environmental impacts of artisanal fishing gear on Kenya's coral reef ecosystems. *Marine Pollution Bulletin* □2□1646□1660.

McClanahan TR, Mangi S. 2001. The effect of a closed area and beach seine exclusion on coral reef fish catches. *Fisheries Management and Ecology* 8□107□121.

Moksnes PO, Gullstrom M, Tryman K, Baden S. 2008. Trophic cascades in a temperate seagrass community. *Oikos* 117□763□777.

Muthiga NA, Kawaka □. 2010. *Progress towards conservation science for marine protected areas in Kenya: an annotated bibliography*. WIOMSA Book Series 4. Nairobi, Kenya.

Paynter CK, Cortes □, Engels M. 2001. Biomass, productivity and density of the seagrass *Thalassia testudinum* at three sites in Cahuita National Park, Costa Rica. *Revista de Biología Tropical (San Jose) 49, Suppl*. 2□26□□272.

Preen AR, Lee Long W□, Coles RG. 199□. Flood and cyclone related loss, and partial recovery, of more than 1000 km$^2$ of seagrass in Hervey Bay, □ueensland, Australia. *Aquatic Botany* □2□3□17.

Ravaorainorotsihoarana LA. 2008. The mangroves of the Velondriake LMMA, southwest Madagascar. Blue Ventures Conservation Report. Available at research□ blueventures.org □accessed on 3 □uly 2012□

Rose CD. 1999. Overgra□ing of a large seagrass bed by the sea urchin *Lytechinus variegatus* in Outer Florida Bay. *Marine Ecology Progress Series* 190□211□222.

Short FT, McKen□ie L□, Coles RG, Vidler KP, Gaecklem □L. 2006. *SeagrassNet manual for scientific monitoring of seagrass habitat, Worldwide edition*. USA□University of Hampshire Publication.

Short FT, Polidoro B, Livingstone SR, Carpenter KE, Bandeira S, Bujang □S, Calumpong HP, Carruthers T□B, Coles RG, Dennison WC, Erftemeijer PLA, Fortes MD, Freeman AS, □agtap TG, Kamal AHM, Kendrick GA, Kenworthy W□, La Nafie □A, Nasution IM, Orth R□, Prathep A, Sanciangco □C, van Tussenbroek B, Vergara SG, Waycott M, □ieman □C. 2011. Extinction risk assessment of the world’s seagrass species. *Biological Conservation* 144□1961□1971.

Unsworth R, Cullen LC. 2010. Recognising the necessity for Indo-Pacific seagrass conservation. *Conservation Letters* 3□ 63□73.

Unsworth RKF, Salinas De Leon P, Garrard S, □ompa □, Smith D□, Bell □□. 2008. High connectivity of Indo-Pacific seagrass fish assemblages with mangrove and coral reef habitats. *Marine Ecology Progress Series* 3□3□213□224.

Vonk □A, Pijnappels MH□, Stapel □. 2008. *In situ* quantification of *Tripneustes gratilla* gra□ing and its effects on three co-occurring tropical seagrass species. *Marine Ecology Progress Series* 360□ 107□114.

Waycott M, Duarte CM, Carruthers T, Orth R□, Dennison WC, Olyarnik S, Calladine A, Fourqurean □W, Heck KL, Hughes AR, Kendrick GA, Kenworthy W□, Short FT, William SL. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences of the USA* 106□12377□12381.



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