Seaweed Mariculture in Bazaruto Archipelago

Environmental, economic and social considerations

Photos: Eucheuma spp. farms in Belo-sur-mer, Madagascar

Prepared by Isabelle Giddy[1], Endangered Wildlife Trust, July 2016

[1]Isabelle Giddy – isabelleg@ewt.org.za

Contents

Executive Summary 3
The development of seaweed mariculture 4
Seaweed mariculture in developing countries 5
Socio-economic impacts 6
Environmental impacts 7
    Non-native species introduction for cultivation 7
    Seagrass ecosystem function and biodiversity 8
    Dugongs 9
The potential for seaweed mariculture in the Bazaruto Archipelago National Park 9
    Environmental Considerations 9
    Social Considerations 9
    Technical Considerations 10
    Monitoring and environmental management plan 10
    Before beginning the project 10
    During the project 11
Recommendations 11
Acknowledgements 11
References 12

Executive Summary

Over the last four decades red seaweed (*Kappaphycus alvarezii/Eucheuma)* mariculture has grown into a global industry, providing business opportunities for coastal communities where often there are limited livelihood options. The farming of seaweed is a relatively low impact activity in comparison to other forms of aquaculture as there is no need for the introduction of fertilisers and pesticides. However, it is important to recognise that there are, nevertheless, complex environmental, social and economic repercussions. It is essential to keep these in mind and to develop mitigation strategies that address these risks when considering introducing seaweed mariculture as an alternative/additional livelihood. In the case of the Bazaruto Archipelago National Park, the introduction of seaweed aquaculture is not recommended as the environmental risks outweigh the benefits.

The development of seaweed mariculture

The industrially important red seaweed generas, *Kappaphycus alvarezii/Eucheuma* , were selected from wild populations in the Philippines in the early 1970s (Doty, 1973, 1978; Parker 1974) and commercial cultivation was developed by Dr. Maxwell Doty (University of Hawaii Botany Department, Parker 1974) in collaboration with what was Marine Colloids corporations (now FMC Health and Nutrition). Valued as a source of carrageenan (commonly used as a stabilising, emulsifying, and thickening agent in food, cosmetics and pharmaceuticals), it has subsequently been introduced in over 20 countries across the world over the past thirty years by a variety of government, non-government and private agencies (Ask et al., 2001).

The *Eucheuma spp.* mariculture industry has been growing rapidly over the last decade. By the end of 2014, approximately 9 million wet tons of *Eucheuma* spp. were being produced annually worldwide (FAO (2016), see Figure 1), with the most production coming from Indonesia, the Philippines, Zanzibar, Malaysia, Kiribati and Madagascar. By extrapolation, if we assume that 1.3tons of seaweed requires 1 hectare of space this equates to approximately 70 000 hectares of shallow intertidal coast currently being used for seaweed mariculture.

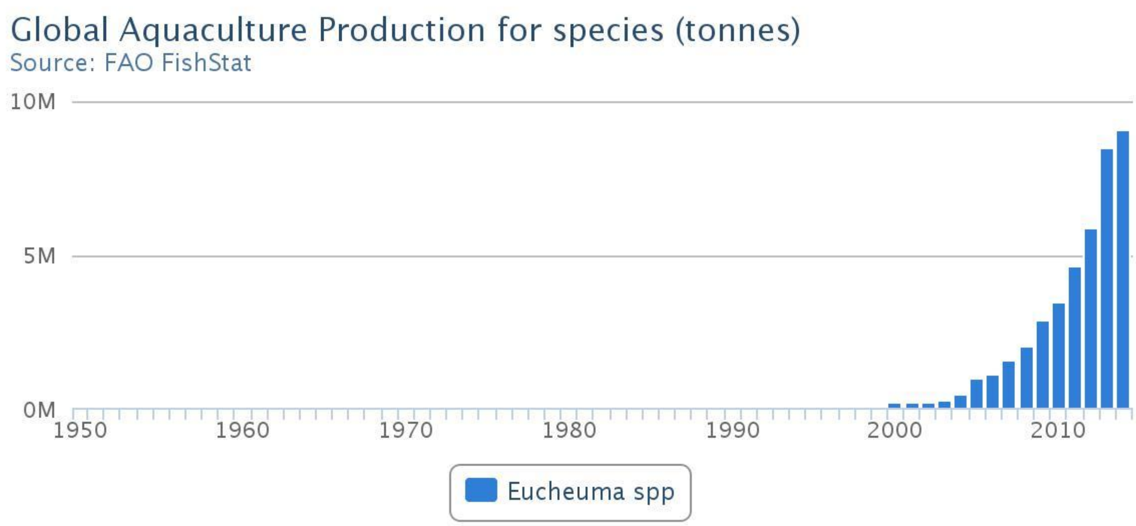

Figure 1: Global Aquaculture Production of Eucheuma spp (FAO, 2016)

Traditionally, seaweed has been grown using a method referred to as the "Off-bottom method" where cuttings of seaweed are tied at 20-30cm intervals along a line suspended about 0.5m off the bottom, secured by weighted stakes at either end. Additional parallel lines are added about 1m apart. Other methods include weighted rafts and longlines which can be placed in deeper water. Plants are grown to about 1kg wet weight over a period of 45 days, at which stage they are harvested. During the growing time, farm maintenance is focused around the weeding out of epiphytes, cleaning the seaweed of silt and dirt, replacing poorly growing seedstocks with fast growing ones, replacing lost plants, removing other species of seaweeds that compete with *Eucheuma spp.*, repairing the farm support system and removing benthic grazers/predators. During harvesting, 100g cuttings from the harvested seaweed are re-attached to the lines and the rest is dried, sold, baled and sent for extraction (see Figure 2). For a detailed manual on seaweed farming see Ask (2001).

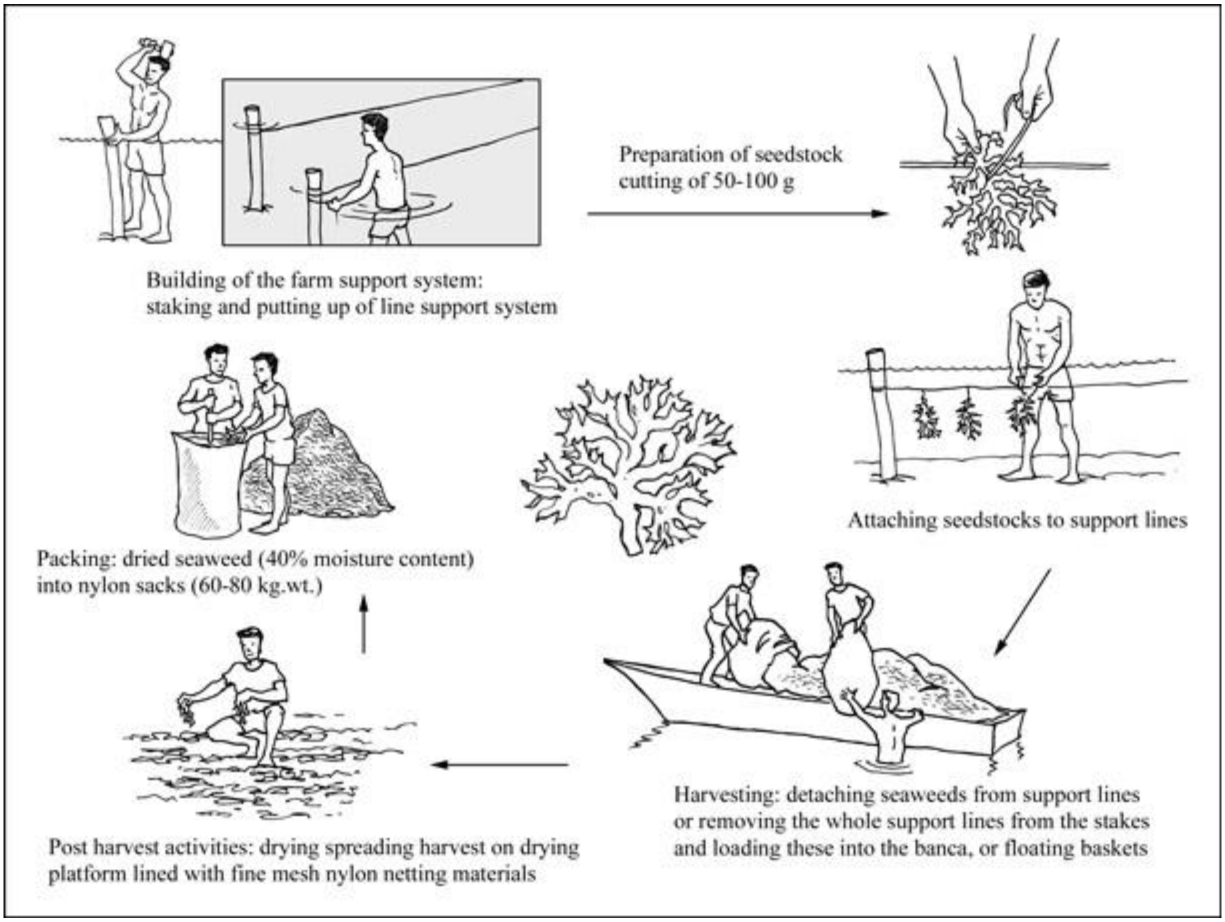

Figure 2: Eucheuma mariculture production circle (FAO, 2016)

Seaweed mariculture is often considered the most environmentally friendly form of aquaculture as it requires little or no input of fertilisers, intuitively does not cause any major physical alterations of the environment (Johnstone and Olafsson, 1995; Bryceson, 2002), and can be used to mitigate eutrophication and pollution (e.g. Haglund and Lindstrom, 1995, Rai et al, 2000). The lack of obvious environmental impacts and the relatively simple and cheap equipment needed to farm seaweed, described by Ask, (1999), has lead the promotion of seaweed mariculture as an alternative livelihood in developing countries (Ask et al., 2001; Sievanan et al., 2005).

Seaweed mariculture in developing countries

The first seaweed farm was established in 1969 in the Southern Philippines province of Tawi Tawi (Trono, 1990) by a collaboration of American based Marine Colloids Corporation and Dr. Doty from the University of Hawai'i. The industry was quickly successful in the Philippines, mainly due to the low cost of labour, the flexibility that small family run farms had and the low capital and technological requirements for entry into the business. From the Philippines, the industry spread to Indonesia, achieving similar successes. Today, Indonesia and the Philippines are the world's largest producers of *Eucheuma spp.* Farmed *Eucheuma spp.* was then introduced in Zanzibar, Tanzania in the early 1990s, making them the third biggest producer, however remaining far behind the production levels of Indonesia and Philippines. In a 2009 comparison, Indonesia produced 85 000 tons (dry weight), the Philippines 61 000 tons and Tanzania, 10 000 tons (Valderrama, 2012). Within the Western Indian Ocean (WIO) Tanzania has remained the leading producer. In 2012, the *Eucheuma spp.* producers (Tanzania, Madagascar, Mozambique, Mauritius, Kenya) together produced 16 000 tons dry weight equivalent to $4.2 million, 95% of which came from Tanzania (Msuya et al., 2013). The productivity has remained low due to outbreaks of ice-ice, epiphytes, high water temperatures, low farm gate prices and farmers leaving for better prospects (Eklöf et a., 2012).

In Mozambique, *Eucheuma spp.* was introduced in Murrebue Village (1998), Pemba (2002) and Nampula (2006) with the assistance of FMC Health and Nutrition (Bryceson and Massinga, 2002). This venture involved 2000 farmers, of which 80% were woman. The production in 2003 was 500 tons and by 2004, this had reduced to 140 tons. All farming had ended by 2009 due to inconsistent production and logistical challenges (Ribeiro, 2007).

Socio-economic impacts

There are countless case studies that show that the introduction of seaweed farming to rural coastal communities has improved the living standards of households (e.g. Ask et al., 2003), leading to the conclusion that the socio-economic impacts of seaweed farming have been, on the whole, positive. This is due to a number of reasons. Seaweed farming favours small-scale family operations over corporate farms, generates substantial employment relative to other forms of aquaculture and provides livelihood opportunities for coastal communities where there are a reduced number of economic alternatives. FAO (2012) review on carrageenan seaweed farming highlights how villages that have traditionally lived below the poverty line before seaweed farming have succeeding in substantial improvements to their standards of living due to the additional cash income. This has allowed families to send their children to school, improve their homes, diversify their diets and purchase more goods. Moreover, because of the nature of seaweed farming, this income-earning activity that can be undertaken without neglecting traditional household obligations, allowing for the participation of females and thereby contributing to improving gender equality.

However, it is important to note that the need for low cost production of raw seaweed places coastal communities in situations where they can easily be exploited. In fact, FMS Health and Nutrition, often selects its sites in areas where people are so poor that they will accept any income.

"As a potential seaweed supplier trying to find the best village to work in, you should be delighted to find a village populated by consumers with no or little livelihood options. In this case we call cottonii and spinosum farming the livelihood of last resort. Today we find the most productive and consistent farmers from villages like these…. In these places it is too arid to farm or the soil is unsuitable and the reefs have been destroyed and fish stocks decimated …. Your ultimate goal is to make seaweed farming become a way of life for the villagers. This happens after five or so years. At this stage people don't think too much about price, they just farm because they have always farmed. Their children will follow them into that career." – Ask, FMC Health and Nutrition (See Bryceson, 2002)

Such examples as described above, coupled with the low farm gate prices that keep farmers from expanding, places the industry at risk of locking farmers in a low income state (Eklöf et al., 2012).

Environmental impacts

While seaweed mariculture is often regarded as an environmentally sustainable, elaborated by Ask et al., (1999), there are few empirical studies that back up the statements of the negligent/positive impacts of seaweed mariculture (for a detailed assessment see Zemke-White and Smith, 2006). Of the few that have been carried out, a number of negative impacts have been highlighted.

Non-native species introduction for cultivation

Eucheuma spp, has been introduced to 19 tropical countries (Zemke-white and Smith, 2006) for cultivation. It is commonly assumed that the vegetative nature of *Eucheuma spp.* renders it incapable of surviving outside of farming environments. While general observations from farmers tend to back this up, and by nature, the seaweed is generally kept in check by harvesters, there is no empirical evidence of that *Eucheuma spp.* cannot become invasive. Amidst the paucity of literature on the long term effects of *Eucheuma spp.*, there are studies that reveal its invasive nature.

In Hawai'i, *Eucheuma spp.* was introduced in the 1970s. After two years, Russell (1983) concluded that *Eucheuma spp.* was non-competitive in Hawai'i, primarily occupying barren sand covered channels in the reef that didn't support native algae and coral species. However, 22 years later, Rodgers and Cox (1999) determined that the algae had spread 5.7km from 1974-1996. Conklin and Smith (2005) further found evidence that the algae was overgrowing coral patches and had established itself on hard strata. Similar results have been found in both India (Chandrasekaren et al., 2008) and Venezuela (Barrios et al., 2007).

More recently, in a study of abandoned *Eucheuma spp.* farms in Panama, Sellers et al. (2015) found that non-native *Eucheuma spp.* had spread into adjacent seagrass beds, mangroves and coral patches with a density greater than 30% and appeared to be smothering seagrass, corals and sponges.

Seagrass ecosystem function and biodiversity

Seagrasses are flowering plants (angiosperms) adapted to complete their entire lifecycle in marine waters. The structure of the plant (stems, leaves, rhizomes and roots), provides habitats for a number of phyla (Williams and Heck, 2001) such as crustaceans, molluscs, echinoderms and fish. They are important nursery grounds for juveniles (Heck et al., 2003; Chittaro et al., 2005). Seagrasses also form a large portion of the diets of certain turtle species and the vulnerable Dugong (IUCN, 2001). These interactions are summarised in Figure 3.

Seagrasses and macroalgae (seaweed) often compete for limiting resources like light (Holmquist, 1997; Irlandi et al., 2004) and nutrients (Dumay et al., 2002). This competition is expected to apply when seaweed farms are placed in seagrass meadows, as is often the case (e.g. Zanzibar, Philippines).

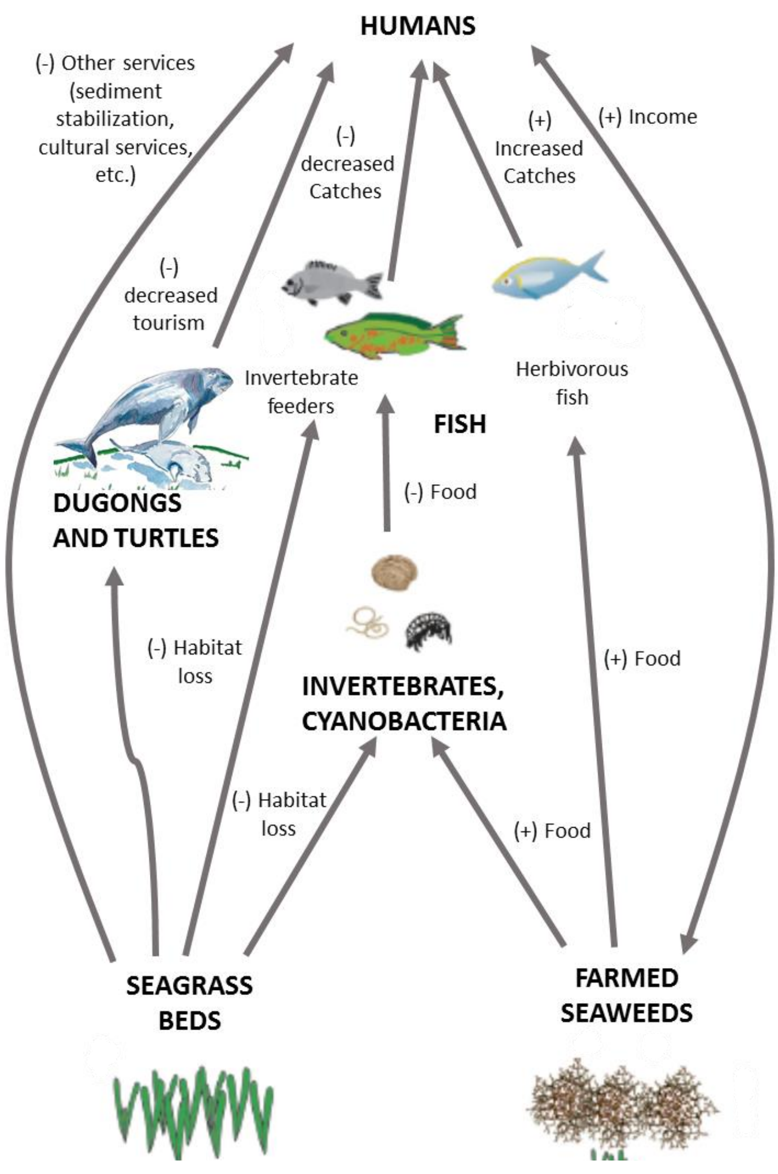

Figure 3: Seagrass, seaweed and ecosystem interactions, adapted from Eklöf et al., 2012)

While studies are limited, results from a studies in Tanzania (Eklöf et al., 2005; Lyimo et al.,2008) showed that seaweed farming over seagrass beds affects both biodiversity and ecosystem function (e.g. provision of shelter, food). Seagrass beds underneath seaweed farms has less seagrass (shoot density, biomass, cover and canopy height) and native macroalgae, finer sediment, lower sediment organic matter connect and a reduced abundance and biomass of macrofauna. Interviews with farmers explain that when a seaweed plot is started, the seagrass underneath the algae starts to decrease in cover, and sometimes even disappears after a few months (de la Torre-Castro and Ronnback, 2004).

Besides seaweed directly influencing seagrass beds through light and nutrient competition, mechanical abrasion by the algae fronds, trampling and deliberate removal of shoots by farmers (de la Torre-Castro and Ronnback, 2004) may all also reduce shoot density. The FAO guideline (FAO, 1988) for *Eucheuma spp.* farming actually advised farmers to remove all seagrass, and predatory macrofauna (e.g. echinoderms) from the site selected. Furthermore, the excretion of hydrogen peroxide and halogenated toxic substances by the algae (Mtolera et al., 1995, 1996) could also stress seagrasses.

Dugongs

The IUCN rated vulnerable Dugong (*Dugong dugon)* (IUCN, 2001) finds its habitat in many areas that are selected for seaweed cultivation (e.g. Philippines, Madagascar, Mozambique), often in shallow areas above seagrass beds. The loss of seagrass beds due to competition for light and nutrients, removal and trampling (detailed above) pose a threat to dugongs by threatening their source of food. Furthermore, a recent study describing the mortality of a Dugong in a seaweed farm rope (Poonian and Lopez, 2016) highlights the potential for increased Dugong mortalities due to rope entanglement in seaweed farms as the industry continues to grow.

The potential for seaweed mariculture in the Bazaruto Archipelago National Park

Seaweed mariculture can be successful in improving the quality of life of rural coastal families where livelihood opportunities are limited, as well as increasing gender equality as it is characteristically a female dominated occupation. However, for the sustainable and successful implementation of seaweed mariculture in the Bazaruto Archipelago National Park a number of considerations need to be taken into account.

Environmental Considerations

For the successful commercial production of Eucheuma *spp*. sites should be selected that fulfil a set of specific environmental conditions (adapted from Smart fish, 2012 and Ask, 2001).

- Sea water temperature should ideally be between 20° and 32°C.
- Avoid sites where salinity is outside of the range of 23-38 PSU. Sites should also be chosen away from fresh water sources (river mouths) and considerations should be taken for slower growth rates during rainy season.
- Sites should not be shallower than 0.75m at spring low tide
- While seaweeds require a certain amount of current to bring in nutrients, seaweeds are vulnerable to high turbidity
- Measures should be taken to prevent grazing by herbivorous fish
- Algal parasites (such as Epiphytic Filamentous Algae, EFA) need to be kept under control
- Sudden changes in temperature and salinity expose seaweed to ice-ice. Measures should be taken to avoid rapid changes in these variables (e.g. placing the seaweed in deeper water).
- There should be space for future expansion

Social Considerations

Before introducing seaweed farming into a community the social, economic and cultural systems in the community should be taken into account (Adapted from Ask, 2001)

- There should not be conflicts between existing practices and seaweed mariculture and if there are conflicts (e.g. conflicts about areas of use) there should be a strategy in place to manage these conflicts.
- Successful farming is also reliant on hard work and time spent caring for the seaweed. One should establish whether villagers are willing to work hard on this project.
- Can the current price of commercial eucheumoids on the world market and the farm-gate price+supplier operating costs+other supplier costs+profit margin compete?
- Is the farm-gate price accepted by the community? Many farmers in Tanzaniz have desisted due to low income and other higher-income occupations (e.g. tourism).
- Is there governmental support of the project and is the country stable for investors?

Technical Considerations

Adapted from Smartfish (2012)

- Cottonii is much more vulnerable to environmental factors than is the case with Spinosum, and therefore it is harder to farm it successfully. For example, in Tanzania, farmers have struggled to grow Cottonii resulting in low income and subsequently a lack of motivation to farm;
- From a technical perspective, seaweed that is under environmental stress may at best stop growing, and at worst, display what is in effect a negative growth rate as plant biomass is lost;
- Cottonii sells at a price at least double that of Spinosum;
- The sector of course depends on both producers and buyers, but for the latter a financial break-even production is reached at 300mt/yr for Cottonii and 500mt/year for Spinosum;
- To reach financial break-even requires three years at least;
- International buyers are not interested in exporters that cannot provide a least 1,000mt dry-weight per year;
- Evidence suggests that a private-sector investor has only about a 25% of succeeding in the seaweed farming business;
- As there is currently no processing plant currently in Mozambique, finances and arrangements for packaging and export will need to be made

Monitoring and environmental management plan

If seaweed mariculture were to be introduced in Bazaruto Archipelago National Park a number of steps should be taken in order to ensure the least possible environmental impact.

Before beginning the project

1. Baseline conditions should be determined for use as a critical reference point. This should cover the state of seagrasses, invertebrate biodiversity, fish stocks and corals.
2. Any introduced seaweed species should go through standard quarantine procedures.

3. Minimum conditions of farms, standards and protocols of maintenance should be agreed upon by all participants in the project. This should include site selection away from seagrass beds and gear design (e.g. floating tubular net rafts) to prevent incidental dugong mortality.
4. Strong technical supervision for farmers is secured.
5. A contingency plan designed and funding secured for cases where the seaweed is seen to be having negative environmental impacts
6. Agreement and funding secured for the removal of all seaweed from the site if seaweed farming is stopped.

During the project

1. Baseline habitats should be monitoring throughout the project construction and operations
2. Compliance to the minimum conditions and standards checked throughout the project
3. Environmental impacts should be assessed and mitigation measures reassessed annually

Recommendations

Considering the objectives of introducing alternative livelihoods in the Bazaruto Archipelago are to decrease fishing pressure, encourage fishers to use sustainable fishing gear (as opposed to gill nets) and improve the conservation of seagrass and dugongs, it is not recommended that seaweed mariculture be introduced into the Bazaruto Archipelago National Park. As highlighted throughout this report, seaweed mariculture does in fact have negative environmental impacts, specifically to seagrass beds and coral reefs. Furthermore, cases of dugong mortalities through entanglement in seaweed farm gear have been reported in the Philippines. Recent studies (Hill et al., 2011) have also shown that the introduction of seaweed farming does little to mitigate the effects of fisheries overexploitation, finding that more commonly is the income from seaweed farming used as an additional income, perhaps even being invested into improving fishing gear, increasing effort and therefore fishing pressure. Nevertheless, seaweed mariculture does have potential as a successful development tool if implemented with environmental and social considerations. There is a need for a seaweed mariculture sustainable practices guidelines to be further researched, agreed upon by international stakeholders and disseminated throughout the seaweed mariculture industry so as to ensure that the expansion of this industry is promoted within a sustainable framework on all levels.

Acknowledgements

We would like to thank the Global Environment Facility (GEF) for funding the research of this report.

References

Ask E.L., L.E.A, Batibasaga and S. Mario. 2003. Developing the cottonii (*Kappaphycus alvarezii*) cultivation industry in the Fiji Islands. In Chapman ARO, Anderson RJ, Vreeland VJ, Davison IR (eds.), Proceedings of XVIIth International Seaweed Symposium, Oxford University Press, pp. 81–85.

Ask, E.L. 1999. Cottonii and Spinosum Cultivation Handbook. Food Ingredients Division, FMC.

Ask, E.L. 2001. Creating sustainable commercial *Eucheuma* cultivation industry: the importance and necessity of human factor. Proceedings, 17th International Seaweed Symposium, Chapman ARO, Anderson RJ, Vreeland VJ, Davison IR (eds), Cape Town, 13–18

Ask, E.L. 2003. Creating a sustainable commercial *Eucheuma* cultivation industry: The importance and necessity of the human factor. In Chapman ARO, Anderson RJ, Vreeland VJ, Davison IR (eds.), Proceedings of XVIIth International Seaweed Symposium, Oxford University Press, pp. 13–18.

Barrios J, J. Bolaños, R. López. 2007. Blanqueamiento de arrecifes coralinos por la invasión de *Kappaphycus alvarezii* (Rhodophyta) en Isla Cubagua, estado Nueva Esparta,Venezuela. Boletín del Instituto Oceanográfico de Venezuela, 46: 147–152

Bryceson, I. 2002. Coastal aquaculture developments in Tanzania: sustainable and non-sustainable experiences. Western Indian Ocean Journal of Marine Science. 1:1–10

Bryceson, I and A. Massinga. 2002. Coastal resources and management systems influenced by conflict and migration: Mecuti, Mozambique. Ambio., 31(7-8):512-517

Chandrasekaran, S., N. Arun Nagendran, D. Pandiaraja, N. Krishnankutty, B. Kamalakannan. 2008. Bioinvasion of *Kappaphycus alvarezii* on corals in the Gulf of Mannar, India. Current Science. 94: 1167–1172

Chittaro, P. M, P. Usseglio and P.F. Sale. 2005. Variation in fish density, assemblage composition and relative rates of predation among mangrove, seagrass and coral reef habitats. Environmental Biology of Fishes. 72(2): 175-187

Conklin, E.J., and J.E. Smith. 2005. Abundance and spread of the invasive red algae, *Kappaphycus* spp., in Kane'ohe Bay, Hawai'i and an experimental assessment of management options. Biological Invasions

de la Torre-Castro M., and P. Ronnback. 2004. Links between humans and seagrasses—an example from tropical East African Ocean Coast Management. 47:361–387

Doty, M.S. 1973. Farming the red seaweed, *Eucheuma*, for carrageenans. Micronesia. 9:59–73

Doty, M.S. 1978. *Eucheuma*—current marine agronomy. In: Krauss RW (ed) The marine plant biomass of the Pacific Northwest coast. Oregon State University Press, Corvallis, OR, pp 203–214

Dumay O, C. Fernandez and G. Pergent. 2002. Primary production and vegetative cycle in *Posidonia oceanica* when in competition with the green algae *Caulerpa axifolia* and *Caulerpa racemosa*. Journal of the Marine Biological Association. UK 82:379–387

Eklof J.S., F.E. Msuya, T. J. Lyimo and A.S. Buriyo. 2012. Seaweed Farming in Chwaka Bay: A Sustainble Alternative in Aquaculture? In: People, Nature and Research in Chwaka Bay, Zanzibar, Tanzania, se la Torre-Castro, M, and T,J, Lyim (eds). Pp 213-233. ISBN: 978-9987-9559-1-6. Zanzibar Town: WIOMSA

Eklof, J.S., M. de la Torre-Castro, N. Kautsky and N.S. Jiddawi, 2005. Differences in macrofaunal and seagrass assemblages in seagrass beds with and without seaweed farms Estaurine, Coastal and Shelf Science 63(3): 385-96

Eklof, J.S., R. Henriksson and N. Kautsky. 2006. Effects of tropical open-water seaweed farming on seagrass ecosystem structure and function. Marine Ecology Progress Series. 325:73-84

FAO. 1988. Euchuema spp. In Manual of running water fish culture. ASEAN/SF/88/Manual No. 2. http://www.fao.org/3/contents/483b81b4-9699-56ef-a70b-416f973d73ea/AC416E00.htm

FAO. 2016. Eucheuma spp. Cultured aquatic species information programme. http://www.fao.org/fishery/culturedspecies/Eucheuma_spp/en

Haglund K. and J. Lindstrom. 1995. The potential use of macroalgae for removal of nutrients from sewage water in East Africa. Ambio. 24:510–512

Heck Jnr, K.L., G. Hays and R.J. Orth. 2003. Critical evaluation of the nursery role hypothesis for seagrass meadows, Marine ecology progress series, vol. 253, pp. 123-136.

Hill, N., J.M. Rowcliffe, H.J. Koldewey, E.J. Milner-Gulland. 2011. The Interaction between Seaweed Farming as an Alternative Occupation and Fisher Numbers in the Central Philippines. Conservation Biology. 26: 324–334. doi: 10.1111/j.1523-1739.2011.01796.x PMID: 22098395

Holmquist, J.G. 1997. Disturbance and gap formation in a marine benthic mosaic: influence of shifting macroalgal patches on seagrass structure and mobile invertebrates. Mar Ecol Prog Ser 158:121–130

Irlandi, E.A., B.A. Orlando and P.D. Biber. 2004. Drift algae-epiphyteseagrass interactions in a subtropical *Thalassia testudinum* meadow. Marine Ecology Progress Series. 279:81–91

IUCN. 2001. Red List Categories and Criteria. www.iucnredlist.org

Johnstone R. and E. Ólafsson. 1995. Some environmental aspects of open water algal cultivation: Zanzibar, Tanzania. Ambio. 24:465–469

Msuya, F.E. 2013. Social and economic dimensions of carrageenan seaweed farming in the United Republic of Tanzania. *In* D. Valderrama, J. Cai, N. Hishmunda and N. Ridle, eds. Social and economic dimensions of carrageenan seaweed farming. Pp 115-146. Fisheries and Aqucaulture Techinical Paper No. 580. Rome, FAO. 204 pp

Mtolera, M.S.P. 2003. Effects of seagrass cover and mineral content on *Kappaphycus* and *Eucheuma* productivity in Zanzibar. Western Indian Ocean Journal of Marine Science. 2:163–170

Mtolera, M.S.P., J. Collén, M. Pedersen and A.K. Semesi. 1995. Destructive hydrogen peroxide production in *Eucheuma denticulatum* (Rhodophyta) during stress caused by elevated pH, high light intensities and competition with other species. European Journal of Phycology. 30:289–297

Parker, H.S. 1974. The culture of the red algal genus *Eucheuma* in the Philippines. Aquaculture 3:425–439

Poonin, C. and D.D. Lopez. 2016. Small-scale Mariculture: A Potentially Significant Threat to Dugongs (*Dugong dugon*) Through Incidental Entanglement. Aquatic Mammals. 42(1): 56-59

Rai, L.C., H.D. Kumar, F.H. Mohn and C.J. Soeder. 2000. Services of algae to the environment. Journal of Microbial Biotechnology. 10:119–136

Ribeiro, F. 2007. Inventory of Small-Scale Mariculture in Mozambique. WIOMSA SUCCESS Program. [online]. Updated 10 April 2008. [Cited 16 July 2016] http://www.wiomariculture.org/pubs/Mariculture%20inventoty%20Mazambique.pdf

Rodgers, S. K. and Cox, E. F., 1999. Rate of spread of introduced rhodophytes *Kappaphycus alvarezii*, *Kappaphycus striatum* and *Gracilaria salicornia* and their current distributions in Kane'ohe Bay, O'ahu, Hawai'i. Pacific Science. 53**:** 232-241.

Russell, D. J. 1983. Ecology of the imported red seaweed *Eucheuma striatum* Schmitz on Coconut Island, Oahu, Hawai'i. Pacific Science. 37 (2)**:** 87-108.

Sievanen, L., B. Crawford, R. Pollnac and C. Lowe. 2005. Weeding through assumptions of livelihood approaches in ICM: seaweed farming in the Philippines and Indonesia. Ocean Coast Management. 48:297–313

Smartfish (2012). The Farming of Seaweeds. Implementation of a Regional Fisheries Strategy For The Eastern-Southern Africa and India Ocean Region. REPORT/RAPPORT : SF/2012/28

Trono, G.C. 1990. Seaweed resources in the developing countries of Asia: production and socioeconomic implications. Pages 1-8 in I.J. Dogma, G.C. Trono and R.A. Tabbada (editors). Culture and Use of Algae in Southeast Asia:

Proceedings of a Symposium on Culture and Utilization of Algae in Southeast Asia. Southeast Asia Fisheries Development Center. Tigbauan, Iloilo, Philippines.

Williams, S.L., Heck Jr., K.L., 2001. Seagrass communities. In: Bertness, M.D., Gaines, S., Hay, M.E. (Eds.), Marine Community Ecology, Sinauer, Sunderland, pp. 317–337.

Zemke-White, W. L. and M. Ohno. 1999. World seaweed utilization: an end of century summary. Journal of Applied Phycology, 11**:** 369-376.

Zemke-White, W.L. and J.E. Smith. 2006. Environmental impacts of seaweed farming in the tropics. In: Critchley AT, Ohno M, Largo DB (eds) World seaweed resources — an authorative reference system. ETI BioInformatics, Wokingham, DVD-Rom