

Tropical Coral Reef Fisheries: Reviewing Local Management Schemes

Jessica Lyon King's College London



Coral reefs are one of the most threatened ecosystems worldwide. Both human activities at a local and community scale as well as global climate change are negatively impacting reef health and fishing populations.

Top-down and bottom up management approaches have been utilised to try protecting coral reefs and improve livelihoods of marine resource dependent communities.

This review explores local management marine areas and management techniques, specifically temporary fishing closures and summarises the main factors that influence the success and failure of these projects.

1. Introduction

Tropical coral reefs are biodiversity hotspots, vital in supporting marine life. Their topographic complexity provides a variation of habitats and resources to sustain a wide diversity of fish populations; with over 25% of all known marine species having an association with coral reefs (Coker *et al.*, 2013). They have intrinsic value and are admired globally with many people fascinated by the ecosystem, tuning into documentaries such as Blue Planet 2 which received over 14 million viewers (BBC, 2018), and travelling miles to visit the underwater habitats as recreational divers. The touristic value alone of coral reefs has been estimated at \$36 billion per year (Spalding *et al.*, 2017). For others, coral reefs are more than an admiration but a dependency. Over 500 million people dependent on the ecosystem services coral reefs provide (Harvey *et al.*, 2018; NOAA, 2019). The Millennium Ecosystem Assessment highlighted the importance of biodiversity in supporting

ecosystem services, of which coral reef provides many (Millennium Ecosystem Assessment, 2005) (Figure 1).

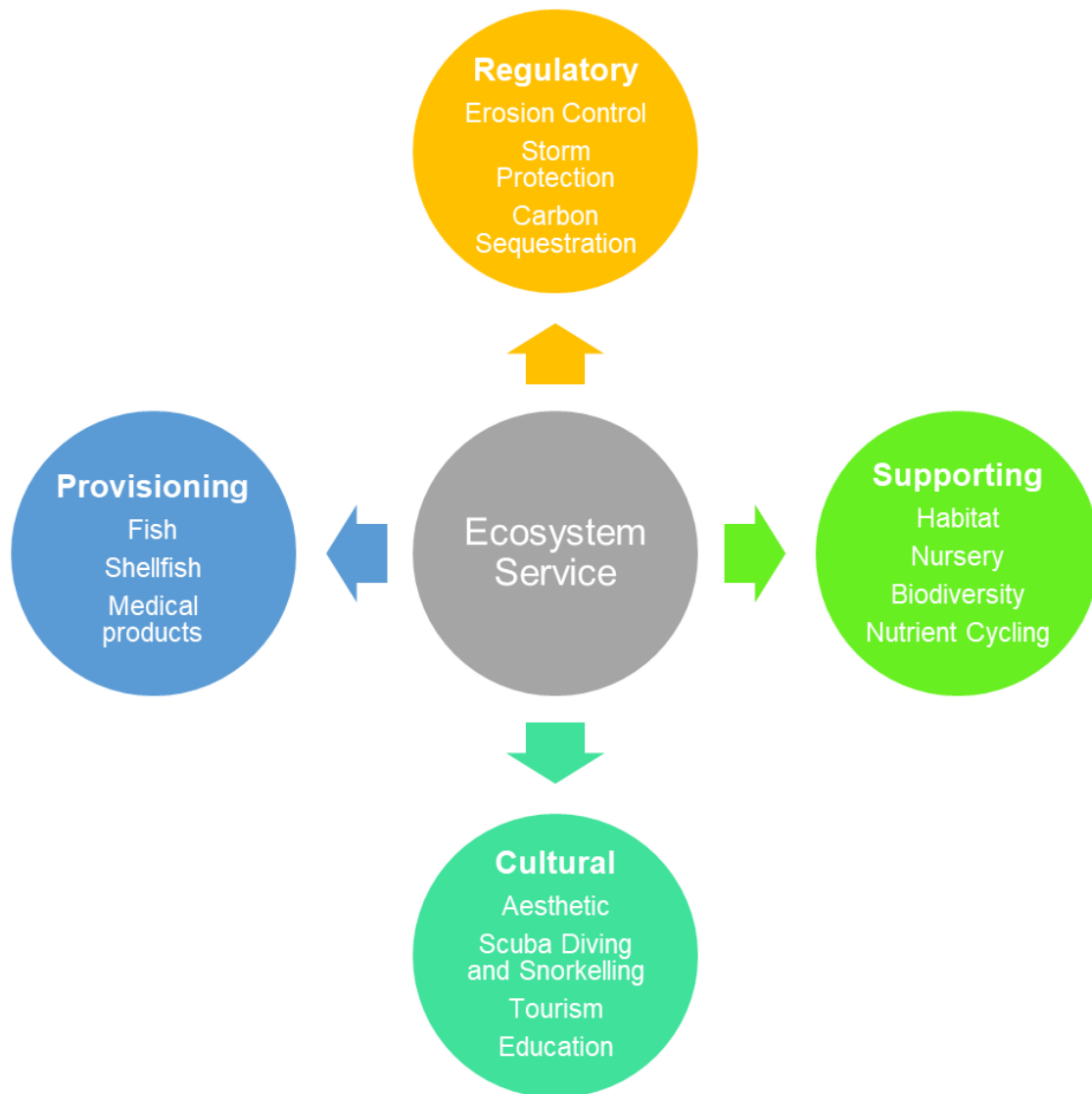


Figure 1. Ecosystem services as highlighted by the Millennium Ecosystem Assessment and examples from coral reef ecosystems. Regulatory services include benefits obtained from the regulation of ecosystem processes, supporting include services necessary to produce all other services, provisioning includes products obtained from ecosystem and cultural include nonmaterial benefits. (Adapted from Millennium Ecosystem Assessment, 2005)

Unfortunately, these ecosystems are among one of the most threatened ecosystems globally. The threats to coral reefs come under two main umbrellas: human activity and climate change (Figure 2.) Both threats have impacts on the health of the coral reef ecosystem and the fish populations that they support. Management of these systems is therefore imperative. Schemes have included techniques such as reducing fishing effort,

catch management controls, catch quotas, fishing gear restrictions, improved coastal management and marine protected areas. These management schemes can be proven effective at reducing the effect of human activity on the quality of the reef and its fisheries. Local management techniques are unlikely able to shake the global effects of climate change however they can help improve coral reef health and resilience as well as support

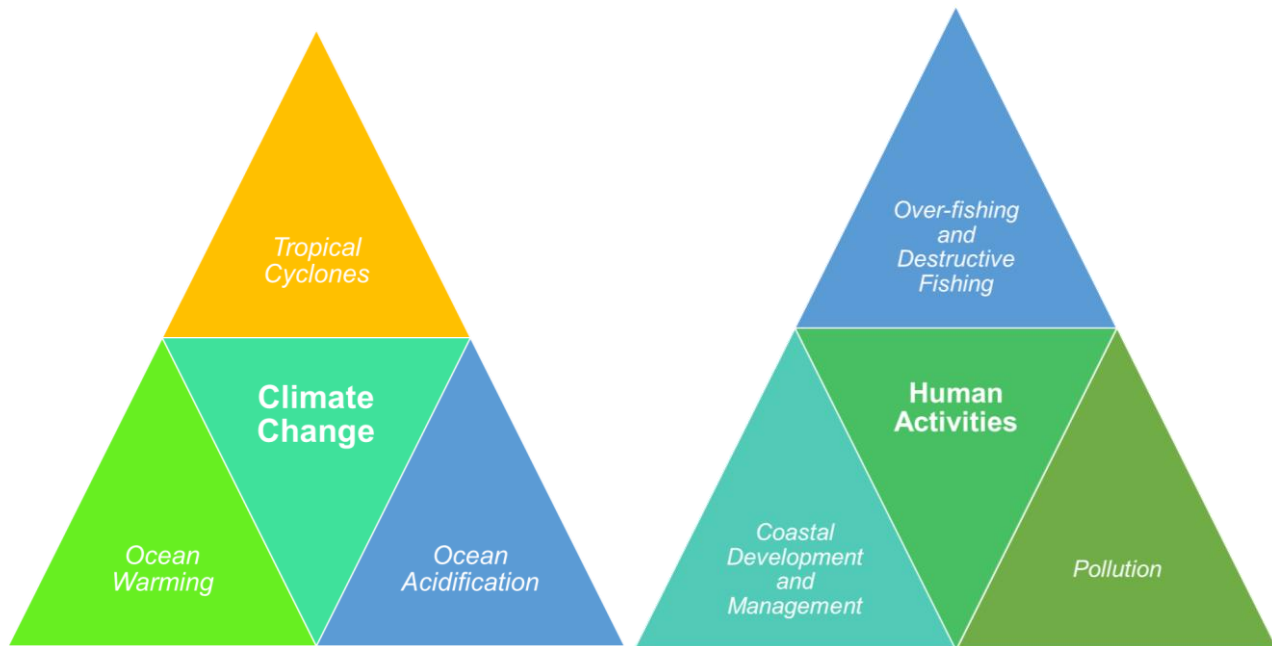


Figure 2. Threats to coral reef ecosystem from “Climate Change” and “Human Activity”

healthy sustainable fish stocks that communities are dependent on. In order to address the global issue of climate change on coral reefs, large scale policy and emissions reductions need to be employed such as the Kyoto Protocol and Paris Agreement (UNFCCC, 2019)

The Sustainable Development Goals (SDGs) developed by the United Nations Development Programme highlight targets that need to be met in order to end poverty and protect the planet; “Goal 14” concerns life below water. In order to reach these targets not only are international and national governments needed to be addressed but also local communities who will most be affected by the management and resource availability. It is therefore important that local management techniques are discussed and assessed inline with these goals and the protection of tropical coral reef environments. The difference between a top-down conservation approach which involves a centralised, governmental intervention approach vs a bottom-up, local community engagement approach have been

debated in the literature. It is often suggested that a combination of both are necessary to meet conservation targets (Table 1.)

Table 1. Examples of Top Down and Bottom Up management approaches to marine conservation and their pros and cons

Examples		Pros	Cons
Top Down	MPAs and VLMPAs (Very Large Marine Protected Areas)	○ Large Area ○ Conserves lots of biodiversity ○ Protects breeding and nursery grounds ○ Beneficial for large range and migratory species ○ Large scale MPA networks	○ Difficult to oversee ○ Difficult to set obvious defined boundaries ○ Lots of potential for illegal activity ○ Often low levels of protection / restriction ○ Conflicts with fishermen and resource use ○ Often set arbitrarily to meet targets
	Global Targets (IPCC, SDGs, IUCN 10% MPA)	○ Global Scale participation ○ Targets sets a tangible goal ○ Wide reach ○ Spread a message	○ Often arbitrary ○ Little repercussions ○ Absolves a level of responsibility ○ Alienates local communities and management
	Regional Policy (Gear Restrictions, Poaching Laws)	○ Prevents extreme destructive practices ○ Protects endangered species ○ Promotes more sustainable attitude	○ Alienates local communities ○ Creates black markets
Bottom Up	LMMAs (Locally Managed Marine Areas)	○ Increase compliance ○ Self-sustained ○ Improves local livelihoods	○ Smaller MPAs ○ Sometimes not placed effectively ○ Compromises with community may affect conservation effort
	Sustainable Livelihood Projects	○ Reduces pressure on reef ○ Supports community ○ Reduces poverty	○ Can't always obtain same level of income ○ People reluctant to change

2. Marine Protected Areas

Marine protected areas are one of the most widely used tools in marine conservation however their definition, management and design can vary greatly dependent on location.

The IUCN defined an MPA as - *"Any area of littoral or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment"*.

Though the most widely used marine management tool, MPAs have often been criticised due to the broad term leading to generality and obscure objectives (Jones, 2002). Other terms such as buffer zone, no-take zone, marine reserve and marine parks have been used as an attempt to refine their definition but can sometimes cause greater confusion.

A 2018 review of MPAs indicated that stakeholder engagement was the main attributing factor in their success and their failure (Giakoumi et al., 2018). It also indicated that clear objectives, strong scientific engagement and clearly delineated MPA boundaries improved the success (Giakoumi et al., 2018) whereas those that lacked legal compliance, identification of the key stakeholders and effective MPA size increased likelihood of failure (Giakoumi et al., 2018)

3. Locally Managed Marine Areas (LMMAs)

Though MPAs are often managed with a top-down approach, in recent years a move to community led and locally managed marine protected areas has been established. A bottom-up approach aims to increase local engagement and compliance, provide sustainable livelihoods, whilst also protecting environments. This is specifically apparent across the Indo-Pacific region where local communities are taking responsibility for the management of inshore marine resources often through a calibration with governments or NGOs (Rocliffe et al., 2014). In the Pacific, more than 500 communities in 15 countries manage 12,000 km² of coastal resources, 1,000 km² of which is under no-take protection zone (Rocliffe et al., 2014). Areas under part or full community control are referred to as "locally managed marine areas".

"A Locally Managed Marine Area (LMMA) is an area of nearshore waters and its associated coastal and marine resources that is largely or wholly managed at a local level

by the coastal communities, land-owning groups, partner organizations, and/or collaborative government representatives who reside or are based in the immediate area” (The LMMA Network, 2016)

There are trade-offs associated with the management on an LMMA depending on the objectives of the project e.g biodiversity protection may clash with increasing fishery yield. The main objective may also be dependent on the stakeholder (Jupiter et al., 2014). Whilst the local community often site improving fishing yield and ensuring sustainability of the fishery, associated agencies may be more interested in the biodiversity conservation (Jupiter et al., 2014). As research shows that clear objectives determine MPA success and the LMMA longevity and perception, it is vital for the local communities and partners to understand the explicit and implicit objectives (Jupiter et al., 2014).

The Locally Managed Marine Area Network

The LMMA Network was established in 2000 as a group of practitioners primarily across the Indo-Pacific that includes community members, land-owning groups, traditional leaders, elected decision-makers, conservation staff, university scientists and researchers and donors (The LMMA Network, 2016). The network established with the aim of improving locally managed projects by sharing resources and information, protecting biodiversity, promoting LMMA approach and help to develop policy at the local, regional and international scale (The LMMA Network, 2016).

The LMMA network has had success in Indonesia by using their framework to enhance local knowledge and management techniques. Hatta Island, located in the Banda Islands upholds a traditional management practice known as “sea sasisen” where marine areas are closed temporarily to allow fishery stocks to replenish (The LMMA Network, 2016). Due to limited procedure regarding the sasisen and the open harvest season stocks declined, and the community became concerned. In conjunction with the LMMA fishery management regulations and no-take zones were established as well as a customary regulation on natural resource management (The LMMA Network, 2016). The management procedures were integrated at several levels and the customary regulations were formally endorsed in a traditional local ceremony (The LMMA Network, 2016).

. Objectives of LMMA often include the following:

- Increase long-term fishery sustainability
- Increase short-term fishery yield
- Protect biodiversity and Ecosystem
- Improve biomass and breeding populations
- Improve economy and livelihood

The objectives of the LMMA also determine which are the most effective management tools to apply. A review of LMMA objectives and management tools concluded the effectiveness of each practice in reaching the objectives Table 2. (Jupiter et al., 2014)

Table 2. Results of a 2014 review of LMMA objectives and the effectiveness of associated management tools in reaching the objectives. Level of effectiveness ranges from poor, intermediate, good, very good (Adapted from Jupiter et al., 2014)

Objective/ Management	Permanent Closures	Periodically- harvested closures	Species restrictions	Gear restrictions	Access restrictions	Alternative livelihoods
Increase long-term sustainable yield	<i>Very Good</i>	<i>Poor - Good</i>	<i>Poor - Good</i>	<i>Poor - Good</i>	<i>Poor - Good</i>	<i>Poor - Intermediate</i>
Increase efficiency of harvests short-term yield	<i>Poor</i>	<i>Very Good</i>	<i>Poor</i>	<i>Poor</i>	<i>Poor</i>	<i>N/A</i>
Maintain biodiversity and Ecosystem function	<i>Very Good</i>	<i>Poor - Good</i>	<i>Intermediate</i>	<i>Intermediate</i>	<i>Poor - Good</i>	<i>Poor - Intermediate</i>
Maintain biomass & breeding populations	<i>Very Good</i>	<i>Poor - Good</i>	<i>Intermediate – Very Good</i>	<i>Intermediate - Good</i>	<i>Poor - Good</i>	<i>Poor - Intermediate</i>
Enhance economy & livelihoods	<i>Good</i>	<i>Poor - Good</i>	<i>Poor</i>	<i>Poor</i>	<i>Poor</i>	<i>Poor - Good</i>

4. Temporary Fishing Closures

Temporary fishing closures have been deployed by many indigenous communities across the Indo-Pacific and are referred to using local terminology; such as the previously mentioned “sasisen” or “sasi laut” in Indonesia (Gnanalingam and Hepburn, 2015). The

type of closure can vary between non-permanent set time periods referred to as temporary closures, rotational closures and areas predominately closed and then allowed a temporary opening for a harvest period; periodic harvesting (Gnanalingam and Hepburn, 2015). Traditionally temporary closures have often been deployed for cultural and traditional reasons such as respect for a death, protecting sacred areas and to assert control (Gnanalingam and Hepburn, 2015) rather than an attempt to manage resources sustainably.

As a marine management tool, temporary closures primary function is to build stocks within the closed area that are directly exploited periodically and secondarily aim to provide some improvement of fishery stocks via spillover and larval export (Cohen and Foale, 2013). Benefits of temporary closures in comparison to permanent no-take zones include reduced enforcement, simpler administration and logistics and maintaining community access to marine resources that they are dependent on (Gnanalingam and Hepburn, 2015). Periodic and temporary closures are often well-received within local communities due to similarities with traditional practice and the ability to maintain a level of resource accessibility (McLeod *et al.*, 2009; Cohen and Foale, 2013).

The success of the area in replenishing stocks is mechanism, site, time period and species specific (McLeod *et al.*, 2009; Cohen and Foale, 2013). Reviews suggest that the design of the closures is highly variable, can be fixed or dynamic and are usually driven by communities that have tenure to the area rather than the scientific basis supplied by partnering NGOs or government (Cohen and Foale, 2013).

5. Factors Affecting Success

Species life history and Length of Closure

Periodic closures may be more suited to short-lived and fast-growing species as they can recover quicker following closures (Cohen and Foale, 2013). In theory it is harder for slow growing, longer lived species which are often commercially important fish, to replenish with periodic closure management due to slower rates of population increase (Cohen and Foale, 2013). Sedentary species and short-lived larvae can be well protected and result in population increase in small reserve whereas larger home ranges and long-lived larvae less likely to be protected (Cohen and Foale, 2013).

Location and habitat

Fertilisation, larval dispersal and recruitment can depend on conditions at the locations specifically oceanography and habitat conditions as well as the densities of source recruitment and settlement sites (Cohen and Foale, 2013). Temporary closures can improve coral reef health by reducing damage to coral and therefore increasing support of residing fish populations. For areas where algal dominance is occurring increased herbivory due to periodic closures may improve coral reef health and ecosystem resilience (Cohen and Foale, 2013).

Vulnerability of Population

Heavily fished stocks and populations with reduced mature adults can be slow to replenish due to allee effect (Cohen and Foale, 2013). This suggests that implementing a longer closure/ no -take period prior to implementing a periodic closure may allow populations to recover and improve the ability for fish populations to be maintained under a periodic closure scheme.

Timing of Harvest Period

Fish susceptibility to harvesting varies depending on different life stages. Local fisherman have good local knowledge on the optimal time to fish and often this influences when open harvest times are chosen (Cohen and Foale, 2013). Timings may be chosen due to improved environmental conditions making it easier to fish. However, harvest periods that result in high catchability will also result in over-harvesting and depletion of stocks. Timing closure to protect spawning stocks is important in allowing the populations to replenish (Cohen and Foale, 2013).

Intensity of Fishing during Harvest

Opening of an area to fishing after closure may result in intense 'pulse-fishing' that can cause a long-term damage to stocks (Jupiter et al., 2012; Cohen and Foale, 2013). For the

scheme to be successful harvesting must not exceed the replenishment occurring during closure. Fishing pressure may also be shifted from the closure ground to a nearby area which will have knock on negative effects.

6. Case Studies

Kakarotan, Sangihe-Talaud Archipelago, North Sulawesi, Indonesia (Cinner et al., 2006)

Kakarotan island is a small coral cay with a population of 730 people that showed positive results to periodic closure schemes for both long- and short-lived species (Cinner et al., 2006). Closure management involved periodic reef closure of 1 in 9 reef areas for a period then opened to harvest in a traditional ceremony (Cinner et al., 2006). A ban on all fishing activity was placed for 6 months in sites selected by community leaders. Biomass and average size of fish was shown to be greater inside periodic closure zones compared to open area access areas of both long- and short-lived species benefited from closure (Cinner et al., 2006). Success of this management was attributed to: exclusive tenure over marine resources, large amount of traditional ecological knowledge, social customs supported closures, low human population size and a low dependence on fisheries (Cinner et al., 2006).

The Cakaulevu tabu, Kia Island, Macuata Province, Fiji (Jupiter et al., 2012)

In 2005, the high Chief of Macuata province established a community-managed marine network of 9 MPAs with assistance from conservation partners (Jupiter et al., 2012). In September 2008 they reopened the fishing grounds for a period of 5 weeks harvesting (Jupiter et al., 2012). The harvest resulted in a heavily intensive fishing period which removed nearly all positive benefit from the establishment of the MPA network (Jupiter et al., 2012) (Figure 3.). The biggest losses occurred on large-bodied fish (Jupiter et al., 2012). During the harvest an increase in number of small herbivores species was observed possibly due to removal of large species and reduction in territorial aggression (Jupiter et al., 2012). Though numbers increased, mean biomass significantly declined and abundance of turf algae increased indicating reduced herbivorous grazing (Jupiter et al., 2012). Also during the harvest period, increases in fish abundance and biomass was observed in the control, open fishing area, suggesting a “bail-out” behavioural response from fish within the MPAs (Jupiter et al., 2012).

A year after the harvest, fish biomass did not recover and biomass of piscivores was nearly absent (Jupiter et al., 2012). This highlights the long-term impact of the harvest period and indicates a continuation of fishing despite claims of the reinstated ban. The study suggested that improved control measures such as gear, catch, opening and access restrictions as well as improved management and proper establishment of objectives is necessary to improve these type of schemes (Jupiter et al., 2012).

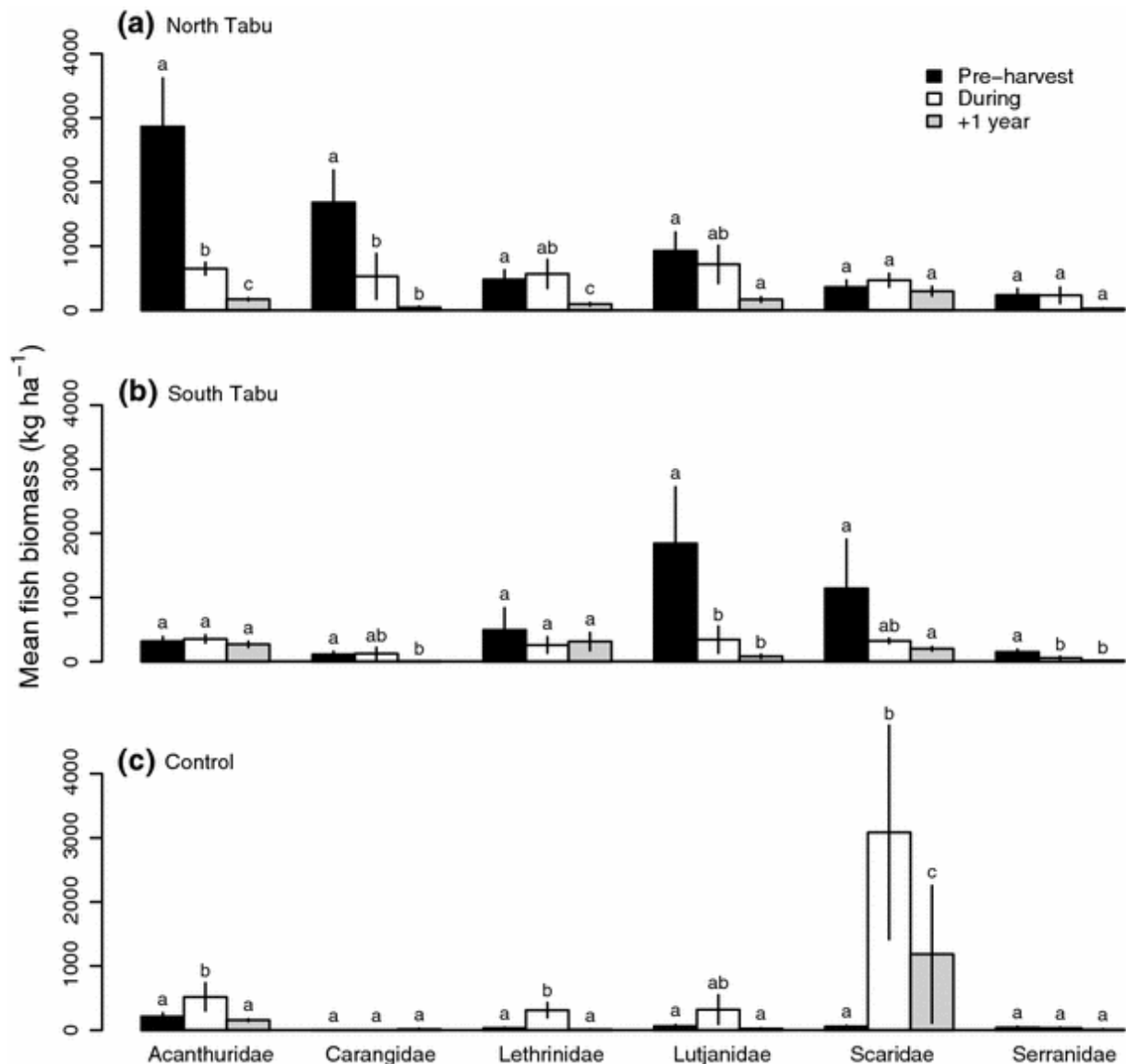


Figure 3. Mean biomass of fish families in temporary closure areas (a and b) and control open access area (c), before (black bars) during (white bars) and 1 year after (grey bars) the 5 week harvest opening of marine protected areas. Different letters indicate significant difference. (Taken from Jupiter et al., 2012)

7. Summary

- Coral reef ecosystems are at threat from local scale human activity and global scale climate change. This directly impacts marine resource dependent communities who are reliant on the ecosystem services coral reefs provide.
- Top-Down management approaches are important to conserve large marine areas and to tackle global greenhouse gas emissions which negatively impact coral reef systems through ocean warming and ocean acidification. Bottom-Up management approaches are necessary to tackle local pressures and to improve fishing stocks for communities that are reliant on them.
- LMMAs can improve local reef systems and fisheries if key stakeholders are identified, engaged and involved in the management process. Clear objectives for the LMMA need to be defined in order to improve success. LMMA Network can improve success of projects by sharing knowledge and resources.
- Temporary fishing closures have been used historically in the Indo-Pacific as a traditional marine management technique and can be enhanced with partner engagement and scientific knowledge.
- Success of temporary fishing closures is very site, species and design specific. It is unlikely to improve coral reef health and fishery stocks when used in isolation but can be a good compromise with local communities when used in association with other management techniques.
- Communities that have lower fishery dependency, lower fishing intensity and healthier fish populations perform better with temporary closure management plans. Therefore, it would be beneficial to establish these conditions prior to opening to harvesting.

References

- BBC (2018). *Blue Planet II tops 2017 TV ratings*. [online] BBC News. Available at: <https://www.bbc.co.uk/news/entertainment-arts-42641146> [Accessed 1 Apr. 2019].
- Cinner, J., Marnane, M., McClanahan, T. and Almany, G. (2006). Periodic Closures as Adaptive Coral Reef Management in the Indo-Pacific. *Ecology and Society*, 11(1).
- Cohen, P. and Foale, S. (2013). Sustaining small-scale fisheries with periodically harvested marine reserves. *Marine Policy*, 37, pp.278-287.

- Coker, D., Wilson, S. and Pratchett, M. (2013). Importance of live coral habitat for reef fishes. *Rev Fish Biol Fisheries*, 24(1), pp.89-126.
- Giakoumi, S., McGowan, J., Mills, M., Beger, M., Bustamante, R., Charles, A., Christie, P., Fox, M., Garcia-Borboroglu, P., Gelcich, S., Guidetti, P., Mackelworth, P., Maina, J., McCook, L., Micheli, F., Morgan, L., Mumby, P., Reyes, L., White, A., Grorud-Colvert, K. and Possingham, H. (2018). Revisiting “Success” and “Failure” of Marine Protected Areas: A Conservation Scientist Perspective. *Frontiers in Marine Science*, 5.
- Gnanalingam, G. and Hepburn, C. (2015). Flexibility in temporary fisheries closure legislation is required to maximise success. *Marine Policy*, 61, pp.39-45.
- Harvey, B., Nash, K., Blanchard, J. and Edwards, D. (2018). Ecosystem-based management of coral reefs under climate change. *Ecology and Evolution*, 8(12), pp.6354-6368.
- Jupiter, S., Cohen, P., Weeks, R., Tawake, A. and Govan, H. (2014). Locally-managed marine areas: multiple objectives and diverse strategies. *Pacific Conservation Biology*, 20(2), p.165.
- Jupiter, S., Weeks, R., Jenkins, A., Egli, D. and Cakacaka, A. (2012). Effects of a single intensive harvest event on fish populations inside a customary marine closure. *Coral Reefs*, 31(2), pp.321-334.
- McLeod, E., Szuster, B. and Salm, R. (2009). Sasiand Marine Conservation in Raja Ampat, Indonesia. *Coastal Management*, 37(6), pp.656-676.
- Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being*. Washington, DC: Island Press.
- NOAA (2019). *Coral Reefs*. [online] Coast.noaa.gov. Available at: <https://coast.noaa.gov/states/fast-facts/coral-reefs.html> [Accessed 1 Apr. 2019].
- Roccliffe, S., Peabody, S., Samoilys, M. and Hawkins, J. (2014). Towards A Network of Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. *PLoS ONE*, 9(7), p.e103000.
- Spalding, M., Burke, L., Wood, S., Ashpole, J., Hutchison, J. and zu Ermgassen, P. (2017). Mapping the global value and distribution of coral reef tourism. *Marine Policy*, 82, pp.104-113.
- The LMMA Network. (2016). *Home*. [online] Available at: <http://lmmanetwork.org/> [Accessed 1 Apr. 2019].

UNDP (2019). *Goal 14: Life below water | UNDP*. [online] UNDP. Available at: <https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-14-life-below-water.html> [Accessed 1 Apr. 2019].

UNFCCC (2019). *Timeline - UNFCCC -- 25 Years of Effort and Achievement*. [online] Unfccc.int. Available at: <http://unfccc.int/timeline/> [Accessed 1 Apr. 2019].