Biophysical principles for designing resilient networks of marine protected areas to integrate fisheries, biodiversity and climate change objectives in the Coral Triangle

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EXECUTIVE SUMMARY

Introduction

The Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) and its six member countries (CT6) have committed to establishing a Coral Triangle Marine Protected Area System, applying an ecosystem approach to fisheries management, and applying climate change adaptation measures. Developing a robust and practical set of principles to underpin establishment of marine protected area networks that contribute meaningfully to food security, biodiversity conservation and climate change resilience is an important part of contributing to that challenge.

Fisheries are one of the most important ecosystem services benefiting the communities of the Coral Triangle (CT). Overfishing and loss of key habitats is severely undermining the long term sustainability and food security of the region. This trend, if allowed to continue unabated, will result in escalating hardship and economic instability. It will also impact the globally significant marine biodiversity of the region and reduce resilience to climate change and other external impacts. Developing improved methods for applying marine protected areas to contribute to food security and livelihoods is a key challenge for all concerned with managing the fisheries and biodiversity of the CT.

The USAID funded Coral Triangle Support Partnership (CTSP) is a five-year project to provide technical support to the CT6 in achieving their goals. The CTSP is the part of USAID's support to the CTI, along with the US National Oceanic and Atmospheric Administration (NOAA), the US Department of State, and additional contract support through a Program Integrator. One of the primary objectives of the Regional CTI Plan of Action (RPOA) is the establishment of a regional Coral Triangle Marine Protected Area System (CTMPAS) that protects "each major near-shore habitat type within the Coral Triangle Region (e.g. coral reefs, seagrass beds, mangroves, beaches, coastal forests, wetland areas and marine/offshore habitat)". This objective is mirrored in each CT country's National Plan of Action (NPOA). In line with the RPOA and NPOAs, CTSP's support for the CTMPAS focuses upon the nearshore habitats of the CT.

Biophysical principles are presented in this report to help nearshore marine protected area networks achieve fisheries sustainability, biodiversity conservation and ecosystem resilience in the face of climate change. These principles can be considered rules-of-thumb to help guide decision making. In the past, such principles and associated rules-of-thumb have focused on only one or two of these objectives – not all three simultaneously.

Effective management of marine resources that achieves resilience and sustainable production requires careful application of a wide range of tools and methods, which includes marine protected areas. Management interventions are likely to be most effective if they are applied as part of an ecosystem-based approach. Marine protected areas, in their various forms can, if well designed and effectively implemented, play a significant role in achieving sustainable use at multiple scales.

The principles developed in this report are designed to contribute to a larger process that includes implementing networks of marine protected areas in ways that complement human uses and values and align with local legal, political and institutional requirements. All of these factors play into an overarching requirement: to achieve fisheries or any other benefits, management actions must be complied with. It is beyond the scope of this report to set out essential political, governance and socio-economic principles to guide marine protected area network design processes; its purpose is to identify biophysical principles. Realistic implementation of any marine protected area network would require that these biophysical principles be coupled with well-developed guidelines dealing with the local human contextual factors.

Marine protected areas, in this report, are defined as any clearly-delineated, managed marine area that contributes to protection of natural resources in some manner. They include, but are not limited to: no-take areas; community-based protected areas; area-based restrictions upon gear, species, size, and take of a particular sex of species or access.

Networks of marine protected areas, for the purposes of this report, refer to a collection of individual marine protected areas that are ecologically connected. For the same amount of spatial coverage, networks of marine protected areas can potentially deliver most of the benefits of individual marine protected areas but with, potentially, less cost due to greater flexibility and diversity in size, shape, distribution and location options. Because of their flexibility in design and application, marine protected area networks are particularly suited to addressing multiple objectives within various contexts.

Theoretically, multiple local or sub-national networks within adjacent ecosystems, ecoregions or seascapes can be scaled up into regional networks by ensuring adjacent networks are ecologically connected as per the principles herein. Such scaling-up has already been planned for parts of the CT (e.g. Sulu-Sulawesi Marine Ecoregion, Lesser Sunda Marine Ecoregion, Bird's Head Seascape and others). An early objective for each country is to contribute at least one well-designed and effectively managed marine protected area network that contributes to an overall CT marine protected area system. These principles will help with these and future scaling up efforts.

In developing biophysical principles to guide the design of networks of marine protected areas, many information gaps were found regarding, for example, the ideal design, the CT ecosystems, and how the socio-political, economic and natural environments currently operate and will change. These uncertainties are not unique to the CT but apply globally. Thus, the principles are designed to embrace this uncertainty including the spreading of risk. Their implementation requires refinement through use of local knowledge (for example target species life histories and habitat use), community uses and values. It also requires an adaptive management system, which managers can use to improve protection as more information becomes available.

Biophysical Principles for Designing Resilient Networks of Marine Protected Areas to Integrate Fisheries, Biodiversity and Climate Change Objectives in the Coral Triangle

Biophysical principles for designing resilient networks of marine protected areas to integrate fisheries, biodiversity and climate change objectives in the CT are provided in the table below. The main rationale for each principle is also provided. These principles each contribute to five broad categories that relate to resilient marine protected area network design: 1) risk spreading; 2) protecting critical areas; 3) incorporating connectivity; 4) threat reduction; and 5) sustainable use.

Many of the principles traditionally proposed as necessary to provide adequate protection of biodiversity are also applicable to the design of marine protected areas to enhance resilience in the face of climate change and to support sustainable fisheries. This is because, although a good deal of previous work on design principles focused on fisheries species, the results apply to unfished species as well. The main differences between principles for the different goals of sustainable fisheries, biodiversity conservation and climate change resilience are that:

- For fisheries goals, individual marine protected areas should be smaller to allow for spillover, to maintain access to more areas yet protect examples of all habitats, to enable flexibility to fishers needs;
- For fisheries goals, marine protected area shapes should allow for more spillover of, especially, adult fished species, but also larval and juvenile fished species;
- For biodiversity goals, some special, unique, isolated etc. sites that contain species and ecosystem functions not commonly found elsewhere are more important to include;
- For biodiversity and climate change goals, no-take areas are more important, as the more holistic conservation benefits far outweigh those of other types of protection;
- For biodiversity and climate change goals, longer-term protection is more important because this will allow the full range of species and ecosystem functions to be restored and maintained in an ongoing manner;
- For climate change goals, climate change "resistant" sites should be prioritized;
- For climate change goals, emphasis should be placed on building connectivity among source *refugia* and susceptible sink reefs to enhance recovery; and
- For climate change goals, emphasis should be placed on including at least three widely separated replicates of all major habitat types into networks to spread risk.

Currently, nowhere in the CT has enough information (or resources to obtain the information) to enable comprehensive implementation of all the principles presented in the table below. Everywhere in the CT there will be enough information to implement some of the principles. The more sparse the information, the more important is the application of the principles regarding prohibition of destructive activities, minimum amount of protection (representing each habitat where known) and replication (refer to principles 1 through 3 below). Even where information is sparse, application of these three principles increases the likelihood of protecting the entire range of known and unknown species, habitats and processes of importance and of insuring against the impact of unpredictable disturbances including large scale catastrophes. In addition, recommendations about minimum size requirements, spacing of marine protected areas and critical habitats, where known, are also often implementable with lower levels of information (principles 4, 7 and 8 below).

Besides limits in knowledge, there are often socio-economic, cultural, political and other reasons that prevent full application of all the principles. When required to compromise, the authors' experience suggests, in the absence of local knowledge to guide decisions, prioritize the principles in the order in the table.

Threat reduction	**Principle 1. Prohibit destructive activities throughout the managed area.** Prohibit as many destructive activities as possible, for example, blast fishing, poison fishing, spearfishing on scuba, bottom trawling, long-lining, gill netting, coral mining, fishing on hookah, night spearing (refer also to Principle no. 6 below). **Rationale**. Coastal habitats and their values are vulnerable to destructive activities which can decrease the health and productivity of the ecosystem and consequently, all species (including targeted fish species) living within it. Destructive activities also decrease ecosystem resilience to other impacts.
Connectivity	**Principle 2. Represent 30 percent (or at least 20 percent) of each habitat within no-take areas.** Represent the range of types of coral reefs, seagrass, mudflats, algal beds, soft seabed communities, rocky shores, coastal forests, beaches, mangroves, other wetlands and other habitats in no-take areas. If the only protection offered is no-take areas, then the proportion of no-take areas needs to be higher (40 percent); if additional effective protection is offered (e.g. input/ output controls[1], other spatial controls) then apply 30 percent (or at least 20 percent) no-take areas[2]. **Rationale.** Protection of all fish habitats, all plants and animals and of entire ecosystem health, integrity and resilience can be achieved only if adequate examples of every habitat are included in no-take areas. To ensure achievement of fisheries objectives in areas where fishing has been intense, and of biodiversity conservation and ecosystem resilience where any local stressors have (or have had) impacts, no-take areas should encompass at least 30 percent of the management area. Lesser levels (but not less than 10 percent) can apply in areas with historically low fishing pressure. If aiming to protect species with lower reproductive output or delayed maturation (e.g. sharks or some groupers) more area will be required.

[1] For example, adequate and effective restrictions on type and quantity of gear, effort, and capacity; limits on catch or landings; limits on sizes; limiting catch of a given sex, or animals in a particular stage of the breeding cycle; regulating discards; daily bag or possession limits.

[2] While this percentage of no-take area coverage is a goal to strive for, the reality in the CT countries is that dense populations of resource users make it difficult to achieve. Thus, opportunistic placement of no-take areas is often the default approach which provides varying percentages of area within no-take areas. While not ideal, working within and around the local context for interventions that are feasible and acceptable is often the bottom-line.

Risk spreading	**Principle 3. Replicate protection of habitats.** Include at least three widely-separated replicates of every habitat within a protected area network, ideally, in no-take areas. (See also Principle 8 on spacing) **Rationale**. Replication of protection minimizes risk that all examples of a habitat will be adversely impacted by the same disturbance. If some protected habitat areas survive an impact, then they can act as a source of larvae for recovery of other areas. Replication also helps enhance representation of biological heterogeneity within habitats that are less understood.
Critical areas	**Principle 4. Ensure that no-take areas include critical habitats.** Include important aggregation sites (e.g. spawning, feeding, breeding grounds), juvenile fish habitat areas, and larval sources. **Rationale.** When animals aggregate they are particularly vulnerable and, often, the reasons they aggregate are crucial to the maintenance of the population. Therefore the main sites where animals aggregate must be protected to help maintain and restore natural balances of populations in communities.
Sustainable use	**Principle 5. No-take areas, prohibitions on destructive fishing gear, other fishing gear and access limits should be in place for the long-term, preferably permanently.** **Rationale.** Long-term protection allows the entire range of species and habitats to recover and maintain natural ecosystem health and associated fishery benefits. Some benefits can be realized in the shorter term (1 to 5 years), especially if fishing pressure has not been heavy. However, 20 to 40 years protection allows heavily fished species and longer-lived targeted predator species (e.g. shark, other coral reef predators) the opportunity to grow to maturity and thereby increase in biomass and then contribute more, and more robust, eggs to stock recruitment and regeneration. This time period also allows for maintaining these ecosystem and fishery productivity benefits. In heavily fished situations, shorter term protection may fail to achieve fisheries, biodiversity and ecosystem resilience objectives. Necessary duration of protection may also be influenced by the life history characteristics of the species of interest. If no-take status reverts to open access in heavily fished areas, the benefits of improved ecosystem function and increased biomass of fishery species can be quickly lost. Thus, no-take areas should be maintained as long as possible. Seasonal closures have an inherent (i.e. seasonal) temporal timeframe, and other temporal closures will be applied for reasons that will have their own temporal requirements.
Connectivity	**Principle 6. Create a multiple use marine protected area that is as large as possible.**[3] Include as much as possible of the coastal ecosystem within a legal, or otherwise formalized, multiple-use management boundary. **Rationale**. To apply an ecosystem approach to fisheries management, to maximise the range of biodiversity and habitats protected, to mitigate against any risks, including climate change impacts, the best advice is to include all of the ecosystem within a multiple-use marine protected area. The different levels and types of protection offered within a multiple-use area can offer synergistic benefits, as seen within ecosystem based fisheries management.

[3] This may also be known as a marine managed area or a multiple use marine park.

Connectivity

Principle 7. Apply minimum and a variety of sizes to protected areas within the network.

7.a. For no-take areas: If no additional effective protection is in place (e.g. no fisheries input/output controls for wide ranging species: refer to Principle 2), a mixture of small (a minimum of 0.4 km^2 or 40 ha) and large (e.g. 4 to 20 km across) no-take areas is required to achieve biodiversity, climate change and fisheries objectives. If there is additional protection for wider ranging species, then networks of small no-take areas can achieve most objectives, particularly regarding fisheries management (subject to implementing Principle 2). Ideal sizes to use will depend on movement patterns of the species of key importance in any situation.

7.b. For temporal closures of any kind: should be, at minimum, the entire area of site plus a 100 m buffer (or 40 ha minimum if these details are unknown).

Rationale for 7(a) and 7(b): To help build resilience into fisheries as well as ecosystem health, and to contribute meaningfully to biodiversity protection, the minimum recommended size for all goals is larger (e.g. 10 to 20 km across) than for fisheries alone (e.g. 0.1-0.2 km^2 or 10 to 20 ha). For resilience and biodiversity conservation, larger areas should be protected. Some consider ~4 to 6 km or more to be the minimum diameter to be viable in terms of containing larval dispersal distances of most species (as well as adult movement); but others have found smaller effective dispersal distances. Of course, using networks of protected areas is one way to increase connectivity between sites without matching the size of each site with adult and larval movement patterns. The recommended minimum size here assumes: a network of no-take areas; and the application of principle 2 across those no-take areas.

Where larval dispersal patterns and/or adult movement patterns of particular target species are known, this information can inform decisions about ideal sizes of protected areas. Mackerel and other near-shore pelagic species, for example, will need much larger marine protected areas, as their ocean neighborhoods are larger.

7.c. For zones with gear restrictions: as large an area as possible, up to the entire marine managed area and all areas where gear interferes with threatened species.

7.d. For zones with access restrictions: as appropriate throughout the marine managed area.

Rationale for 7(c) and 7(d). Gear and access restrictions can be used, in addition to no-take areas (long-term and temporal), to minimize impacts upon habitats and species.

Connectivity

Principle 8. Separate no-take areas by 1 to 20 km apart (with a mode of ~1 to 10 km).
Apply a variety of spacing of individual no-take areas throughout the entire management area. Inshore no-take areas should be located closer together (≥1 km apart) than offshore no-take areas (~20 km apart).

Principle 8. cont. Spacing of other long-term protected areas either not applicable OR same as for no-take areas.
Other types of protected areas (e.g. spatial gear or access restrictions) might be quite large in extent throughout the management area (see Principle 7), so it might not be logical to have specified "distances" between them.

Risk spreading	However, if other permanent protected areas are isolated "islands" of protection, then the same spacing rules should apply as to no-take areas. **Rationale**. Connectivity between protected areas is important for maintaining diversity, fish stocks, and especially important for maintaining ecosystem resilience. Adult movement is generally at a smaller scale than larval movement. Recent studies are showing huge variability in larval dispersal distances and lower dispersal distances than previously thought (e.g. 100 m to 1 km to 30 km). Mackerel and other nearshore pelagic species may need marine protected areas spaced further apart as their ocean neighborhoods are larger. Because the CT is the center of marine biodiversity and has multi-species coastal fisheries, there are likely, commensurate diversity in adult movement ranges and larval dispersal distances in species of interest. For these reasons, varying the spacing of no-take areas between 1 to 20 km apart is useful. Spacing at the higher end of the range (20 km apart) helps with risk spreading and capturing the range of biodiversity. If spacing is less than 20 km, these benefits may still occur. See also principle 3, replication. Where local knowledge exists on connectivity of locally important species, it should be used to inform this principle on spacing.
Sustainable use	**Principle 9. Include an additional 15 percent in shorter-term no-take protection within the network.** For example, seasonal, rotational or other temporally variable zones. **Rationale**. Shorter term spatial management tools should be applied in addition to the minimum level of no-take protected areas; these can help address particular fisheries needs where targeted stocks need to be restored or recovered. Rotational closures, seasonal closures and most other temporal closures can be beneficial for fisheries (e.g. protecting critical areas at critical times if not included in long-term no-take areas; allowing limited fisheries access at culturally important times). However, they are usually less useful for conserving biodiversity or building resilience where part of the aim is to build and maintain healthy, natural communities and sustain ecosystem services. These areas may also function as a partial insurance factor[4] by enhancing overall ecosystem resilience against catastrophes such as cyclones, oil spills.
Sustainable use	**Principle 10. Have a mixture of protected area boundaries: both within habitats and at habitat edges.** The relative mix of boundary locations will depend upon management priorities, local knowledge and the geography and resources of a site. **Rationale**. To build resilience to external impacts, it is best to retain the integrity of any protected area as much as possible by locating boundaries at habitat edges to limit adult spillover. However, to encourage fisheries benefits, some boundaries should be located in the middle of fish habitats.

[4] Partial because the best available science refers to no-take areas.

Sustainable use	**Principle 11. Have protected areas in more square or circular shapes.** Use square or circular shapes subject to considerations of compliance (including use of landmarks). **Rationale.** These shapes allow for limited adult spillover which helps maintain the integrity of the protected areas and, therefore, the sustainability of their contribution to fisheries, biodiversity and ecosystem resilience.
Threat reduction	**Principle 12. Minimize external threats.** All else being equal, choose areas for protection that have been, and are likely to continue to be, subject to lower levels of damaging impacts (e.g. areas with higher water quality; no mining; no shipping activity; areas where fishing is likely to be regulated and managed and existing, functional protected areas). **Rationale.** To optimize protection of areas that are less likely to be exposed to local threats and most likely to recover, it is wise to avoid areas that have been or are likely to be damaged from threats including damaging human uses. From a resilience point of view, these areas are also more likely to be in better condition. Therefore they will be more resilient to external threats such as climate change and contribute more and more quickly to overall ecosystem health and fisheries productivity. It takes time for marine protected areas to improve ecosystem health. It is usually advantageous to include existing functional marine protected areas within a new network.
Critical areas	**Principle 13. Include resilient sites in the network.** Protected areas should include areas that are most likely to survive climate change impacts as indicated by either previous survival or conditions that make them more likely to resist, recover or migrate from impacts. **Rationale.** Areas with historically variable sea surface temperature and ocean carbonate chemistry (e.g. aragonite saturation levels) levels appear likely to withstand changes in those parameters similar to areas known to have withstood such environmental changes in the past. Networks should also include coastal habitats (e.g. mangroves which have adjacent, low-lying inland areas that they can expand into as sea level rises).
Critical areas	**Principle 14. Include special or unique sites in the network.** Protected areas should include sites that are important for: rare or threatened species (e.g. turtle nesting sites); rare or threatened habitats; being highly biodiverse and especially those at risk; endemic species or habitats and also isolated sites. **Rationale.** Inclusion of these sites within no-take or other protected areas can help ensure all examples of the biodiversity and processes of the ecosystem are protected. Being comprehensive in this way increases the chance that all the crucial parts of the system are also able to contribute to ecosystem health and resilience.

Connectivity	**Principle 15. Locate more protection upstream of currents**. If currents are known and consistent, then a greater number of the protected areas, especially no-take areas, should be located towards the upstream end of the management area. If currents are not known, or not constant, then this principle does not apply and protection should be distributed evenly throughout the management boundaries (subject to the principles 7 and 8 on size and spacing). **Rationale.** Protected areas, especially no-take areas, could become a source of larvae contributing disproportionately more to population recruitment. To the degree that currents influence larval dispersal, they will influence genetic connectivity and population recruitment more in locations downstream of protected areas. In this way, one can maximize the likely population "return" per unit area protected and optimize the return to natural population levels which are genetically connected. Information about specific target species larval movements can also inform this principle.

Application of the principles provided in this report will only work if those implementing the marine protected area network have clear, locally relevant, management objectives and align those objectives with the appropriate principles. As the report shows, each set of management objectives require slightly different principles, and local needs may identify different priorities than those indicated above. Local knowledge is crucial to inform prioritization, application and adjustment of these principles.

There is no single method or approach that is able to manage the wide range of pressures and threats to sustainable use. Solutions rest in flexible adoption of integrated management built on sound governance frameworks which are responsive to local needs and aspirations.

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