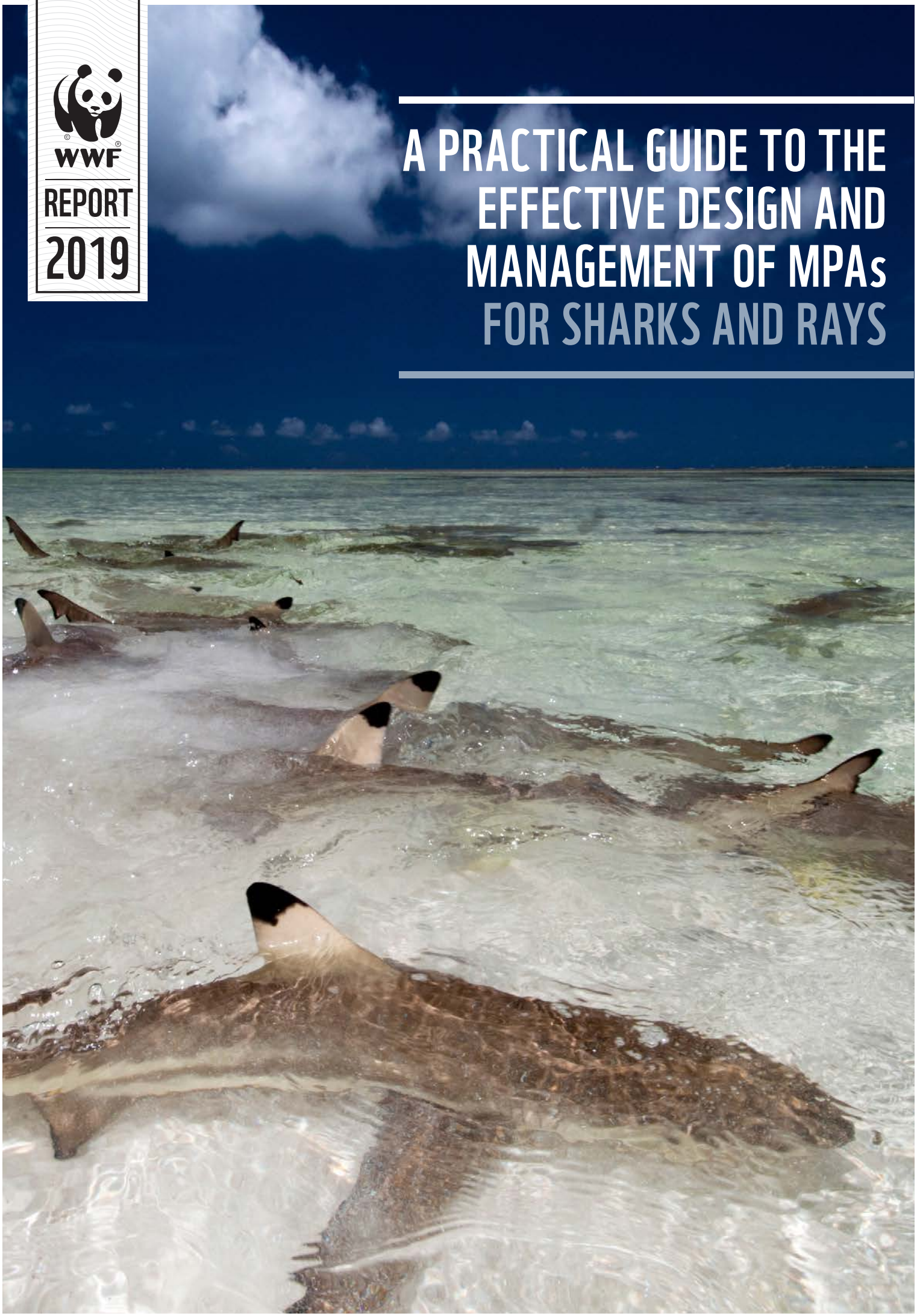
WWF

REPORT

2019

A PRACTICAL GUIDE TO THE EFFECTIVE DESIGN AND MANAGEMENT OF MPAs FOR SHARKS AND RAYS



This project has been a collaboration between the Centre for Sustainable Tropical Fisheries and Aquaculture (CSTFA) at James Cook University, Australia, and WWF.

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www.panda.org
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CONTENTS

ABOUT
ABOUT THIS GUIDE 5

SECTION 1
EXISTING MPAS 6

SECTION 2
EFFECTIVE MPA MANAGEMENT 12

SECTION 3
SPATIAL FISHERIES MEASURES 16

SECTION 4
DEFINING GOALS AND OBJECTIVES FOR SHARK AND RAY MPAS 20

SECTION 5
KEY INFORMATION REQUIRED FOR PLANNING SHARK AND RAY MPAS 24

SECTION 6
DESIGNING SHARK AND RAY MPAS 32

SECTION 7
MONITORING AND EVALUATION 40

INDEX
INFORMATION, ACKNOWLEDGEMENTS AND REFERENCES 44

ABOUT THIS GUIDE

Shark and ray numbers are declining globally, and a quarter of all species are believed to be threatened with extinction.[1] Marine protected areas (MPAs) can potentially play a key role in protecting and conserving shark and ray populations – but for MPAs to be effective their planning, design and management need to reflect the unique characteristics of these species.

MPAs for sharks and rays need clear goals, objectives and conservation targets. They must incorporate the considerable scientific knowledge on shark and ray movement, biology and habitat use alongside socioeconomic and cultural considerations; and they must be well managed and enforced in the long term.

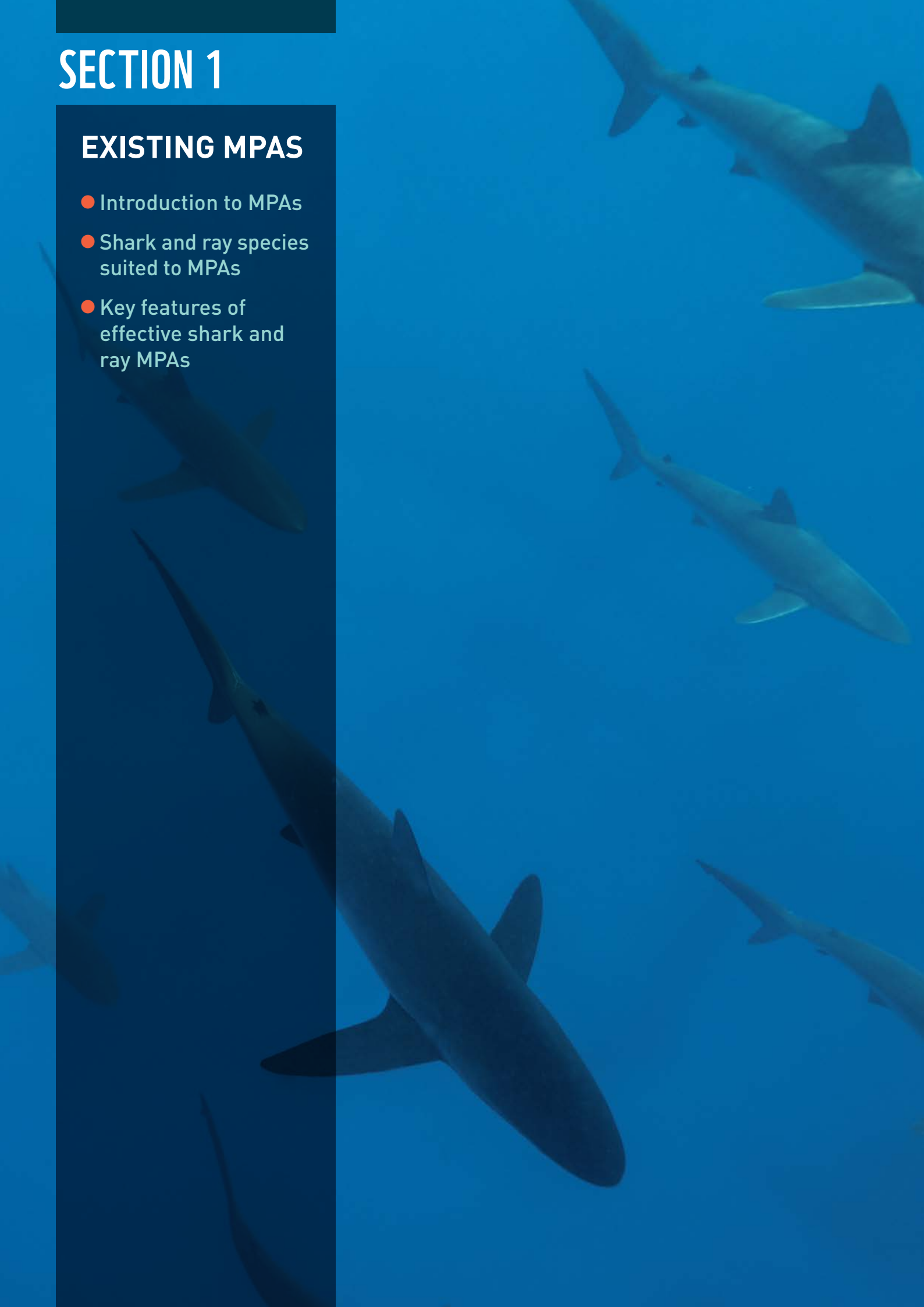
This Guide has been produced to provide practical, science-based advice on how to maximize the effectiveness of both new and existing shark and ray MPAs, to ensure these animals are protected now and far into the future. While it will be of interest to anyone wanting to know more about the subject, it's particularly aimed at:

- Authorities responsible for marine habitat and species protection
- National fisheries managers
- Regional fisheries management organizations (RFMOs)
- NGOs and other conservation practitioners
- Shark and ray tourism operators.

SECTION 1

EXISTING MPAS

- Introduction to MPAs
- Shark and ray species suited to MPAs
- Key features of effective shark and ray MPAs



EXISTING MPAS

SHARKS AND RAYS IN CRISIS

Sharks and rays are facing a global crisis. Many species are in decline due to overfishing,[2] while populations are also being impacted by habitat degradation and loss.[3] To compound these pressures, sharks and rays tend to be slow to recover when their numbers fall: they typically grow slowly, mature at a late age, and have few young.

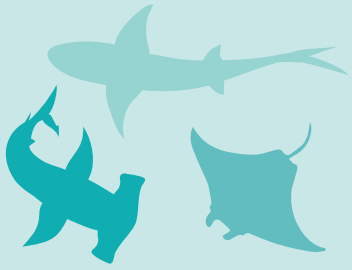
The conservation of sharks and rays is urgent and crucial. Many species play vital roles in the marine ecosystem, and their loss would cause major long-term issues for the environment.[4] They're also important for food security, and they generate income in many countries through fishing and tourism.[5]

INTRODUCTION: SPATIAL MANAGEMENT AND MPAS

Support is growing for the use of spatial management to protect sharks and rays. Its purpose is to protect sharks and rays from major threats, such as overfishing and habitat loss, as well as to reduce the level of these impacts.

Marine protected areas (MPAs) are the main tool used in spatial management. They come in many forms – from large, zoned multiple-use areas to small no-take marine reserves – all aiming to restrict activities that affect marine life within a defined area, thereby benefiting biodiversity and improving ecosystem resilience.[6] MPA governance varies widely, from government control to local management.

Some MPAs have been implemented specifically for shark and ray conservation – in this Guide, we refer to them as 'shark and ray MPAs'. These usually incorporate a ban on shark and ray fishing and retention of shark and ray products, and sometimes a ban on all trade of shark and ray products, all within a clearly defined area. They may also include seasonally closed areas, spatial fishery closures, and fishing gear restrictions.



38 IN 2018, SOME 38 EXISTING SHARK AND RAY MPAS COVERED A TOTAL AREA OF ABOUT

21 21 MILLION KM², OR

6% 6% OF THE OCEAN SURFACE

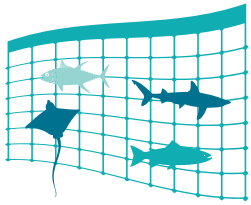
The majority of these shark and ray MPAs encompass countries' entire exclusive economic zones (EEZs), and are sometimes referred to as 'shark sanctuaries'. Their large size helps ensure they have the potential to protect not only inshore coastal species but also the highly mobile sharks and rays that range into open waters offshore.

Most shark and ray MPAs have only been in place since 2009: as they're relatively new, monitoring, evaluation and adaptive management are particularly important.

There are also many general MPAs that have been implemented to protect a broad range of marine species and habitats. Although they aren't designed solely for sharks and rays, they do provide protection when they're large enough and in the right areas to cover key movements, critical habitats or life stages, such as nursery areas or breeding grounds.[7]

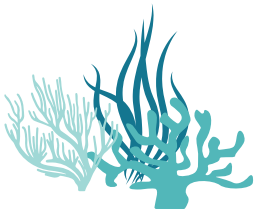
EFFECTIVE SHARK AND RAY MPAS

EFFECTIVE MPAS



PROTECT SPECIES FROM KEY THREATS

REDUCE MORTALITY



PROTECT CRITICAL HABITATS

POSITIVE CONSERVATION OUTCOMES

Scalloped hammerhead sharks, Galapagos Islands

The effectiveness of MPAs for sharks and rays depends on the overlap between their area of spatial protection and the animals' movements and critical habitats. These vary widely by species, meaning MPAs are more effective for some types of shark and ray than others – research suggests those that use reef habitats for part or all of their lives tend to benefit the most.

These reef-dwelling species include:

- Grey reef shark
- Whitetip reef shark
- Tiger shark
- Blacktip reef shark
- Scalloped hammerhead
- Nurse shark
- Silvertip shark
- Sharptooth lemon shark
- Galapagos shark
- Blacktip shark
- Caribbean reef shark
- Giant manta rays
- Reef manta rays

However, since most scientific studies have focused on MPAs around reefs there may be an element of bias in these findings. Other species can also benefit:

- Small-bodied shark species that spend their lives in inshore coastal habitats, such as the sharpnose shark and blacknose shark, can be protected by inshore MPAs.[8] Aside from reefs, inshore habitats important for sharks and rays include mangroves, seagrass beds and sand flats.[9]
- Inshore MPAs can also protect sawfishes which inhabit shallow, coastal areas including estuarine and freshwater habitats.[10]
- Wide-ranging species that predictably use an open water area can benefit from appropriately placed offshore MPAs. These can protect habitat hotspots or migratory corridors, such as the corridor between the Galapagos Marine Reserve and the Cocos Island National Park used by a variety of species including silky sharks and scalloped hammerheads.[11]

ONLINE RESOURCE

For interactive information on how different shark and ray species' movement distances and distribution overlap with existing MPAs, visit ***https://rossdwyer.shinyapps.io/sharkray_mpa/***.

The table below shows some examples of shark and ray species that have responded well to MPA protection, and the benefits and factors involved in each case (other species may also benefit in each MPA, but the data quoted relates to specific studies).

GENERAL MPA	YEAR DESIGNATED	SIZE (KM^2)	SPECIES BENEFITED	EVALUATION METHOD	BENEFIT	FACTOR FOR BENEFIT
COCOS ISLAND NATIONAL PARK, COSTA RICA[12]	1978	1,997	Scalloped hammerhead, tiger shark, Galapagos shark, blacktip shark, whale shark	UVC-diver observers over 21 years, telemetry	Occurrence increased over time in MPA, seasonally resident	Reef-associated site fidelity, tiger shark long-term residents, stop-over for scalloped hammerheads and whale sharks
GLOVERS REEF MARINE RESERVE, BELIZE[13]	1997	328	Caribbean reef shark, nurse shark	Telemetry & fishery-independent longline survey	Stable population over time, frequently occurring within MPA	No-take zone surrounded by area with regulated fishing, habitat connectivity
KOMODO NATIONAL PARK, INDONESIA[14]	1980	1,520	Reef manta ray	Telemetry & visual observation	Predictable feeding and cleaning aggregation sites in MPA	Aggregation site fidelity in protected area
MORETON BAY MARINE NATIONAL PARK, AUSTRALIA[15]	2016	3,205	Giant guitarfish	Telemetry	Sub-adults seasonally prevalent	No-take zone in critical seagrass habitat

Table 1: *General MPA benefits to sharks and rays*

Reef edge areas can offer particular conservation benefits for shark and ray species

BEHAVIOUR FACTORS

The main shark and ray behaviours which determine the selection of effective MPA areas include:

- **Residency and site fidelity (remaining in a particular area)** Caribbean reef sharks are long-term residents of Glovers Reef Marine Reserve, Belize.[16] Juvenile sharptooth lemon sharks remain within Mangrove Bay, Ningaloo Marine Park, Australia.[17] Juvenile pigeye sharks spend several years in Cleveland Bay, Great Barrier Reef Marine Park, Australia.[18]
- **Philopatry (repeatedly returning to a particular area)** Nurse sharks seasonally return to breed in the Dry Tortugas National Park, Florida, USA.[19]
- **Critical habitat (important for a particular species, such as breeding, nursery and feeding grounds)** New-born and juvenile scalloped hammerheads occur seasonally in the Rewa River MPA, Fiji.[20] Reef manta rays form regular feeding aggregations in Komodo Marine Park, Indonesia.[21] Whale sharks aggregate in their hundreds every summer to feed in the Yucatan Peninsula Whale Shark Biosphere Reserve, Mexico.[22]

MPAS OFFER VARYING LEVELS OF PROTECTION TO INSHORE REEF SPECIES AND ALSO TO WIDE-RANGING SPECIES THAT REGULARLY AND PREDICTABLY USE A PARTICULAR AREA

KEY FEATURES OF EFFECTIVE SHARK AND RAY MPAS

- **Isolated** – separated from fished areas by habitat boundaries such as depth. The area doesn't have to be remote – it could comprise reefs separated by deep water that reef sharks and rays do not frequently cross.[23]
- **Old age** – long-term protection. Time is needed for benefits to accrue. This is particularly important for many shark and ray species, which are long-lived, mature late and have few young – as such, their populations are slow to rebuild.
- **No-take or reduced fishing pressure** – decreased shark and ray mortality helps reduce population decline and can help depleted populations rebuild.
- **High-value habitat** – nursery areas (for both juvenile feeding and protection from predators),[24] breeding areas and feeding areas for a variety of life stages are particularly valuable habitats.

Individual reefs separated by deep water. Great Barrier Reef, Australia. Satellite image courtesy of NASA

MPAs operate most effectively when they combine spatial protection and complementary fisheries management measures to reduce mortality.

SEE SECTION 4

MPA SIZE

If well designed, all sizes of MPAs can be effective for sharks and rays:

- **Large shark and ray MPAs** (>100–100,000km^2)[25] offer protection of a wide range of habitat types used by many shark species at different life stages; protect pelagic sharks whose home ranges extend beyond coastal areas of most MPAs; and encompass a mosaic of ecologically connected habitats beneficial for wide-ranging sharks.

- **Small shark and ray MPAs** (<100km^2) can effectively protect critical breeding, feeding and nursery areas. These MPAs can be very small and still effective, particularly when they're designed with a species-specific goal. A good example is the Dry Tortugas Courtship and Mating Ground in the US, where breeding nurse sharks are protected in an area of <1km^2.[26]

REDUCING MORTALITY FROM FISHING

While targeted fishing for sharks and rays is banned in most shark and ray MPAs, in some they are still caught as non-targeted take where large- and small-scale fishing occurs. This fishing for other species is often an important economic activity for the countries concerned. An essential aim in all MPAs should be to reduce non-targeted take mortality so species can be maintained at or recover to sustainable levels[27] – the ultimate protection will only be achieved when there is absolutely no human-caused shark mortality within an MPA. In some shark and ray MPAs restrictions on fishing gear have been introduced to reduce non-targeted take mortality. One example is a ban on wire leaders on tuna longlines – these are harder for sharks to bite through than monofilament leaders, and generally mean higher shark catch rates. The ban reduces the number of sharks retained on the line and brought to the boat.

NON-TARGETED TAKE

Sharks and rays may be captured while fishing for other species. They are not being targeted but are still caught, becoming 'non-targeted take' or 'bycatch'. Even if they're required to be released the animals may be dead when brought to the fishing boat, or die soon after release – non-targeted take mortality is a serious threat to many shark and ray populations worldwide.

© Hélène Petit / WWF

Even within MPAs, non-targeted take mortality is a serious threat to sharks and rays

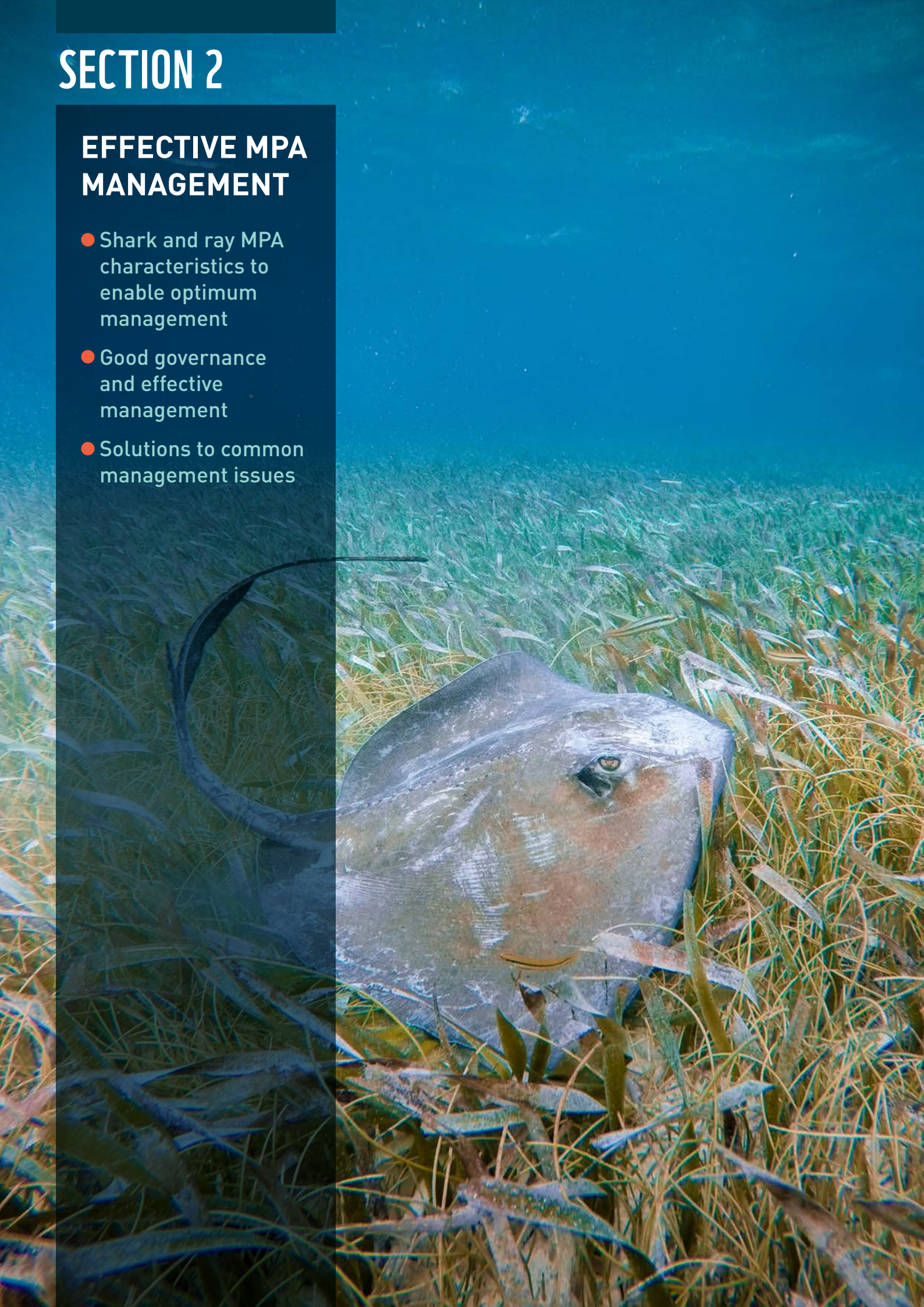
SECTION 5

Socioeconomic and cultural factors need to be included for effective shark and ray MPAs. Stakeholder engagement, adequate compliance and enforcement resources, and appropriate governance are crucial for effectiveness.

SECTION 2

EFFECTIVE MPA MANAGEMENT

- Shark and ray MPA characteristics to enable optimum management
- Good governance and effective management
- Solutions to common management issues



EFFECTIVE MPA MANAGEMENT

An effective shark and ray MPA will have these essential characteristics:[28]

- Well-defined goals and objectives
- Suitable size, location and design to deliver goals
- Management plan to reach goals
- Clearly defined, fairly agreed and legislated boundaries
- Support from key local stakeholders, particularly fishers
- Resources and capacity for implementation.

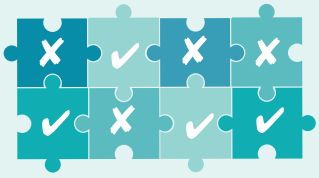
This requires good governance and effective management, usually best achieved through a combination of top-down and bottom-up approaches with community involvement.[29]

GOOD GOVERNANCE[30]

- Clearly defined, legitimate, equitable and functional governance arrangements, including the political will to implement the MPA. Transparent decision-making processes and clear responsibilities for implementation
- Fairly represents and addresses the needs of society, rights-holders and stakeholders.

EFFECTIVE MANAGEMENT[31]

- A management plan or equivalent, with a periodic review and amendment process for updating objectives, conservation targets and management
- Adaptive management framework that allows performance monitoring and flexible governance, with capacity to incorporate improvements and maximize effectiveness
- Functioning legislative and institutional frameworks
- Permitted extractive activities (if any) well managed and regulated
- Adequate financial resources and capacity, including personnel
- Effective and appropriate compliance investment
- Communications strategy to inform stakeholders, build trust and ownership, increase participation.



MANAGEMENT ISSUES AND SOLUTIONS

Every shark and ray MPA is unique, but key management issues are common across the board. The most frequent are discussed below.

INSUFFICIENT RESOURCES

When a shark and ray MPA is designated, particularly at a large scale, it is essential that enough resources are committed for effective management. If not, there's a risk that it will simply be a 'paper park' that fails to properly restrict access and exploitation, or reduce threats.[32] Financial resources and technical capacity are both needed for management, monitoring and enforcement.[33]

Many shark and ray MPAs are in developing countries,[34] and external assistance may be required with resources and capacity-building, both initially and on an ongoing basis. This assistance needs to be coordinated with local communities and MPA users, to ensure the support of key local stakeholders, particularly fishers. Buy-in from these groups and others such as tourism operators can also strengthen monitoring and enforcement, especially in remote areas.

*Caribbean reef shark (*Carcharhinus perezi*) with hook. Roatan, Bay Islands, Honduras.*

INADEQUATE ENFORCEMENT

This is a major issue in some existing shark and ray MPAs, with illegal fishing reported in the Marshall Islands, Palau and Honduras.[35] Surveillance is often restricted to patrol boats and fisheries staff, and logistics can mean that response times to reported illegal activities are slow.

However, improving technology and decreasing costs for remote surveillance – eg using satellite data and drones[36] – could prove useful for enforcement, particularly in large shark and ray MPAs.

SEE SECTION 5

POOR PLANNING

Despite a prohibition on such activities, inadequate planning has led to continued trade in shark products and sometimes targeted capture within some shark and ray MPAs. In the Maldives shark and ray MPA, cross-institutional arrangements weren't in place when the ban on shark fishing and trade was abruptly announced, and legislative conflicts meant that trade of shark products was not regulated. There was no formal stakeholder consultation, and little provision for alternative livelihoods for the shark fishers. As a result, and with a lack of education and awareness, many fishers continued shark fishing after the ban.[37]

Cross-institutional alignment, stakeholder engagement, education, communication and awareness are all essential in planning effective MPAs. Consideration of alternative income sources and livelihoods is important to engage public support.[38] Sometimes shark tourism has the potential to generate an alternative non-consumptive revenue stream for the local economy – but not all fishers can easily adapt to such a major change in their way of life, and their needs must be carefully considered and managed.[39]

FISHING MORTALITY

The most effective way of reducing shark and ray mortality is for MPAs to have strictly enforced no-take areas – however, it's not always practical or socioeconomically and culturally acceptable to completely prohibit fishing, particularly across large areas and in developing countries that depend on marine resources for economic and food security.[40] A spatial ban on target shark fishing and trade in shark products is a more tolerable solution in such locations, and should still reduce mortality levels.

It's also feasible to work with the fishing industry and regulators to change fishing practices and gears within MPAs to reduce shark and ray bycatch: this has been an ongoing process in tuna fisheries in the Pacific and other regions,[41] although it's essential that results are monitored to determine how far the threat has been reduced.[42]

Measures and methods which can reduce shark and ray bycatch mortality include:[43]

- A ban on wire leaders on tuna longlines and other line fishing gears
- Use of circle hooks instead of J-hooks
- Trials of permanent magnets, rare earth metals and other electrical measures to reduce shark and ray attraction to baited hooks
- Trials of LED lights on gill-nets (see https://sharks.panda.org/stories-from-the-field/seeing-the-light-in-reducing-wildlife-bycatch)
- Best-practice at-vessel handling and release methods
- Management/retrieval of abandoned fishing gear
- Fish aggregation device (FAD) design to eliminate shark entanglement
- Changed night/day setting depending on species behaviour.

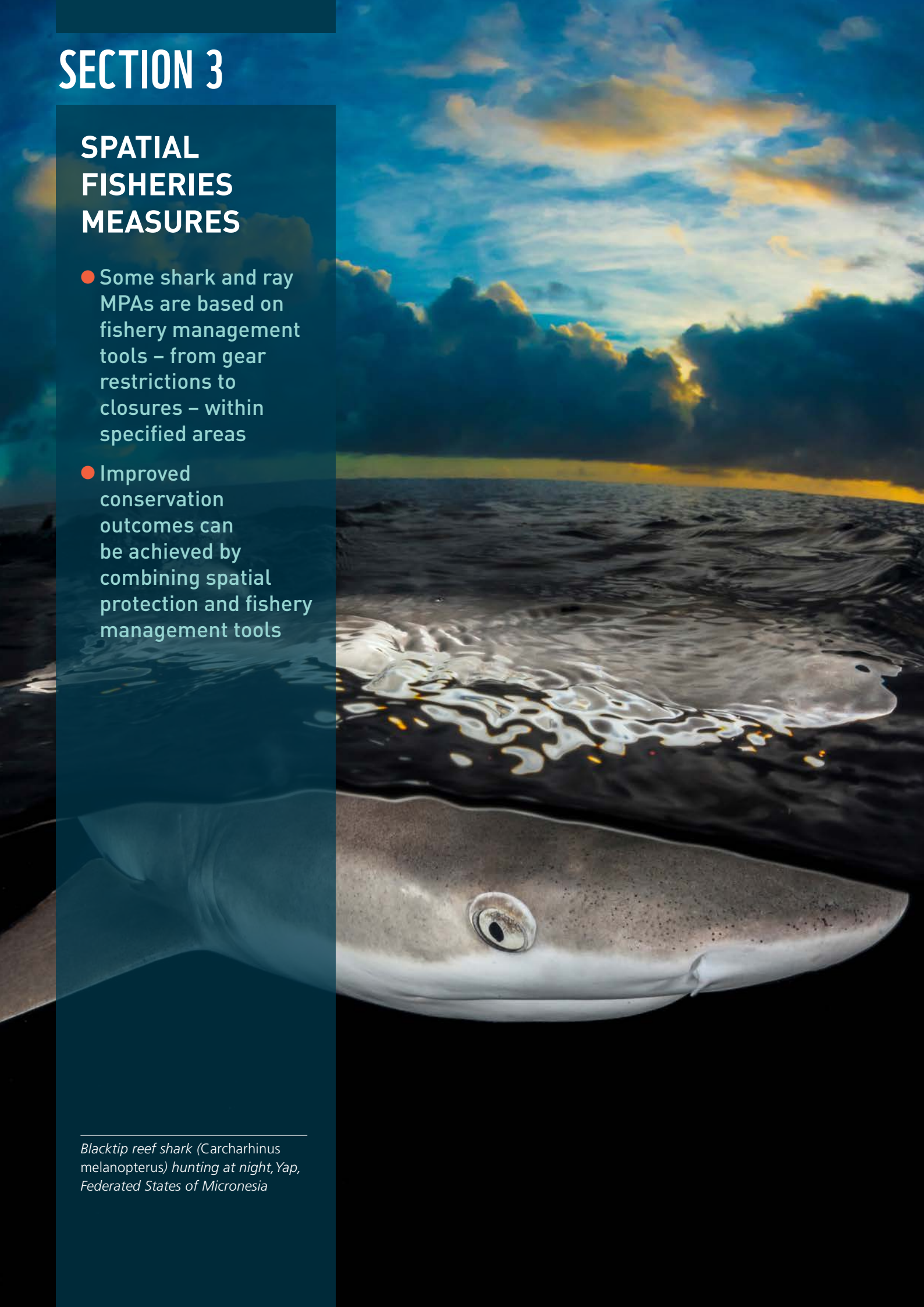
SHARK AND RAY MOVEMENT BEYOND MPA

Shark and ray MPAs can't always completely protect species from the threat of fishing mortality, because animals often move beyond the MPA boundaries.[44] Greater protection and reduction of fishing mortality requires complementary strategies such as ecosystem-based management approaches or fisheries management outside the MPA.[45]

SECTION 3

SPATIAL FISHERIES MEASURES

- Some shark and ray MPAs are based on fishery management tools – from gear restrictions to closures – within specified areas
- Improved conservation outcomes can be achieved by combining spatial protection and fishery management tools



*Blacktip reef shark (*Carcharhinus melanopterus*) hunting at night, Yap, Federated States of Micronesia*

SPATIAL FISHERIES MEASURES

Spatial protection alone may not be enough to reduce shark mortality to levels which allow population rebuilding, so additional regulation and reduction of fishing effort can enhance conservation outcomes.[46] Fisheries management and spatial protection are certainly not mutually exclusive.

Some large-scale MPAS – such as Australia's Great Barrier Reef Marine Park – integrate a range of fisheries management measures. Multiple zones ranging from no-take to general use exist alongside fisheries effort controls, gear restrictions and size and catch limits to manage and conserve biodiversity (including sharks and rays) across a large area.[47] Such planning needs to be carried out in cooperation with relevant stakeholders including the fishing industry, regulatory agencies and RFMOs.

Fishery management measures applied in a spatially defined area haven't traditionally been viewed as a type of MPA, but this is changing. The 'other effective area-based conservation measures' acknowledged in the Aichi Biodiversity Target 11 have a new definition which now includes 'area-based fisheries management measures'.[48]

IUCN DEFINITION: MARINE PROTECTED AREA

"A clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values."

Although the IUCN's widely adopted definition requires an MPA's primary objective to be conservation, this excludes other types of spatial protection which can also contribute but which have different primary aims – such as area-based fisheries management measures and areas designated under marine spatial planning processes.

GEAR RESTRICTIONS

Fishing gear restrictions in a spatially defined area can provide conservation benefits to sharks and rays, but today MPAs are largely based only on spatial protection.

In some regions spatial gear restrictions may be more socially acceptable than complete spatial closures, for example among small-scale fishers whose traditional fishing grounds are coming under pressure with increased fishing effort and reduced catches.

Similarly, gear restrictions within shark and ray MPAs can reduce bycatch mortality while commercial fishing continues. Many Pacific island countries with large shark and ray MPAs depend economically on commercial tuna fishing, so are in no position to ban it – but by, for example, banning wire leaders on tuna longlines, shark and ray bycatch mortality is reduced. This gear restriction is in force in the Marshall Islands, Cook Islands and the Federated States of Micronesia.[49]

*Silvertip shark (*Carcharhinus albimarginatus*), Chuuk, Federated States of Micronesia*

SUCCESSFUL GEAR RESTRICTIONS

© Jürgen Freund / WWF

Whaler sharks (Carcharhinids) benefit from fisheries management measures in a number of tropical MPAS: their biomass has been found to increase in response to restrictions on all fishing gear except for hook and line.[50]

© Brian J. Skerry / WWF

Towed bottom-fishing gear has been prohibited in a 340km^2 area on the south coast of the UK since 1978. Both the spotted skate and smalleyed skate have heavier individuals within the restricted gear area, the benefits of the refuge resulting from its coverage of suitable habitat combined with the limited movement of the rays.[51]

© Simon Buxton / WWF

A permanent spatial ban on shark longline and dropline gear is in place in Western Australia. This was implemented in 1993 to protect breeding stocks of large whaler shark species, the sandbar shark and dusky shark.[52] Both are important to fisheries, but the gear closure area provides them with a spatial breeding refuge.[53]

SPATIAL FISHERY CLOSURES

Fixed area seasonal fishery closures have been suggested to conserve some varied species of sharks and rays:

- A three-year seasonal spatial closure was modelled as an effective way of ensuring recovery of a thornback skate population threatened by high bycatch levels, while minimizing loss of fishery yield.[54]
- Seasonal fishery closures in fixed areas have been proposed to protect the Endangered speartooth shark in northern Australia. This species migrates seasonally, so the proposed closures aim to protect its most frequently used seasonal habitats while maximizing open areas for fisheries.[55]
- Some pelagic species taken as bycatch in tuna fisheries – such as silky sharks, shortfin mako, blue shark and great hammerhead – have been shown to occupy predictable areas, or 'habitat hotspots'.[56] Spatial, seasonal fishery closures in these hotspots could lessen bycatch, although targeted take would likely be reduced too – hence to date no spatial closures are known to have been introduced by any

tuna RFMOs. However, with silky sharks there are areas of persistent high non-targeted take of small sharks that are spatially distinct from high tuna catch areas. These areas could be appropriate for seasonal protection, reducing non-targeted pelagic shark take with the least loss of targeted tuna catch.

- A spatial closure to trawl fishing was proposed in Costa Rica to a depth of 100m in an area where fishing grounds overlap with habitat for threatened sharks and rays. It could be reasonably enforced through the use of the Automatic Identification System (AIS) vessel tracking system, which is a cost-effective solution.[57] This later led to a more widespread ban on trawling in Costa Rica.

SUCCESSFUL SPATIAL CLOSURES

© Boris Pamikova / Shutterstock

© Rudolf Svenson / WWF

Since 2007, a network of spatial closures has been designated within a fishery in eastern and southern Australia. This is enabling the recovery of two gulper shark species – Harrisson's dogfish and southern dogfish – both of which were significantly depleted by fishing. The closures, implemented through legislation, encompass the species' movement within their home ranges. Biomass declines have halted, although recovery is likely to take decades due to the species' longevity and low productivity.[58]

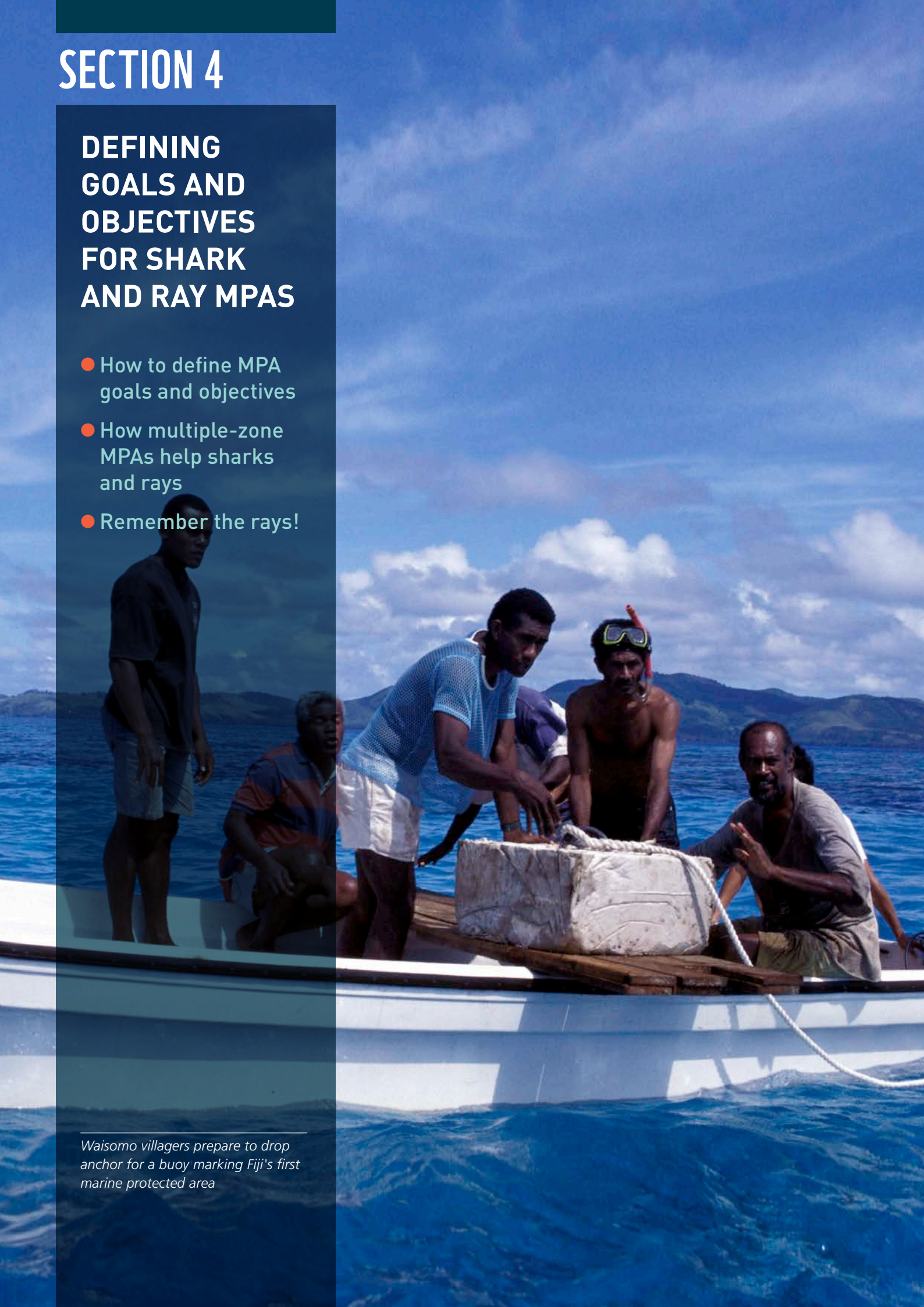
© Brent Stirton / Getty Images / WWF-UK

Documenting MPAs and WWF projects in Tanzania, East Africa

SECTION 4

DEFINING GOALS AND OBJECTIVES FOR SHARK AND RAY MPAS

- How to define MPA goals and objectives
- How multiple-zone MPAs help sharks and rays
- Remember the rays!



Waisomo villagers prepare to drop anchor for a buoy marking Fiji's first marine protected area

DEFINING GOALS AND OBJECTIVES FOR SHARK AND RAY MPAS

There are a range of reasons for protecting sharks and rays, and these will influence the nature of the protection that's put in place. Broadly speaking, MPA objectives can be grouped into three main categories:[59]

ECOLOGICAL

Protect biodiversity, habitats and threatened species

ECONOMIC

Safeguard human livelihoods and fishery sustainability

SOCIAL AND CULTURAL

Promote tourism, education and research

Clearly defining and stating goals and objectives is an essential first step in creating and managing an MPA. This enables focused design, assessment of effectiveness, and determination of success.

EFFECTIVENESS

The ability and capacity of an MPA to accomplish its goals

SUCCESS

The accomplishment of an MPA's goals

REALISTIC OBJECTIVES: KEY QUESTIONS

The objectives must be realistic to be effective – and the resources needed to achieve them must be available. This means being clear on some basic questions:

- What shark and ray species need to be protected? Are they inshore coastal species, or offshore open-water species?
- Which fisheries in the area catch sharks and rays? Do people rely on them for income or food? Do other human activities (e.g. oil and gas extraction) affect sharks and rays?
- Which spatial and fisheries measures most effectively minimize threats? Can other relevant activities be regulated? Is inshore or offshore protection more appropriate?
- What resources are available?

COMMON AIMS

The central conservation purpose of spatial management is to maintain viable populations of sharks and rays in their natural surroundings.[60] A variety of goals and objectives can address this overall aim in shark and ray MPAs:

- Assess and protect from **key threats** – overfishing, habitat loss and climate change
- Restore and recover **depleted populations** – reduce shark mortality, protect critical habitat
- Conserve critical **habitats, migration corridors** and critical **life stages**
- Conserve **threatened species** or subsets of species
- Protect **biodiversity and ecosystem health**, benefiting multiple species
- Protect **biodiversity hotspots**, prioritizing areas with high concentrations of endemic species threatened by habitat loss[61]
- Protect **evolutionary distinctness**, prioritizing irreplaceable species with few close relatives[62]
- Ensure **sustainability** of sharks and rays caught in targeted fisheries and/or as non-targeted take
- **Reduce mortality** – to enable recovery to sustainable levels
- Improve **socioeconomic benefits** – capitalize on shark and ray contribution to cultural, economic and tourism values.

All these objectives can be enacted at a local, regional and national level. Some contribute directly to higher-level shark and ray policies and conventions, including:

- International and National Plans of Action
- The Memorandum of Understanding on Conservation of Migratory Sharks
- The Convention on Biological Diversity (Aichi Targets 11 and 12)
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

MPA GOALS

One key question is whether the MPA aims to protect all sharks and rays in its spatial area, or to focus on a particular threatened species:

SINGLE SPECIES

May be more relevant for highly threatened species such as sawfish. Species-based conservation targets are more likely to ensure critical species-specific habitat requirements are addressed.[63]

MULTIPLE SPECIES

Shark and ray community species may respond differently to the same threat depending on their life history traits, such as the size of their home range or the speed of recovery once protected.[64] Effective protection of multiple species may increase the conservation contribution of an MPA.[65]

To decide on the most appropriate approach, identify the shark and ray species and life stages that are to be conserved, along with the critical habitat(s) required by the species in question. Then use this information to determine optimal locations where an MPA could be placed to achieve conservation goals.

GOALS AND OBJECTIVES

> **"Protect sharks and the ecosystem they support...shelter over 100 Western Pacific shark and ray species threatened or near threatened with extinction...maintain integrity of our marine ecosystem."**
>
> Palau shark and ray MPA

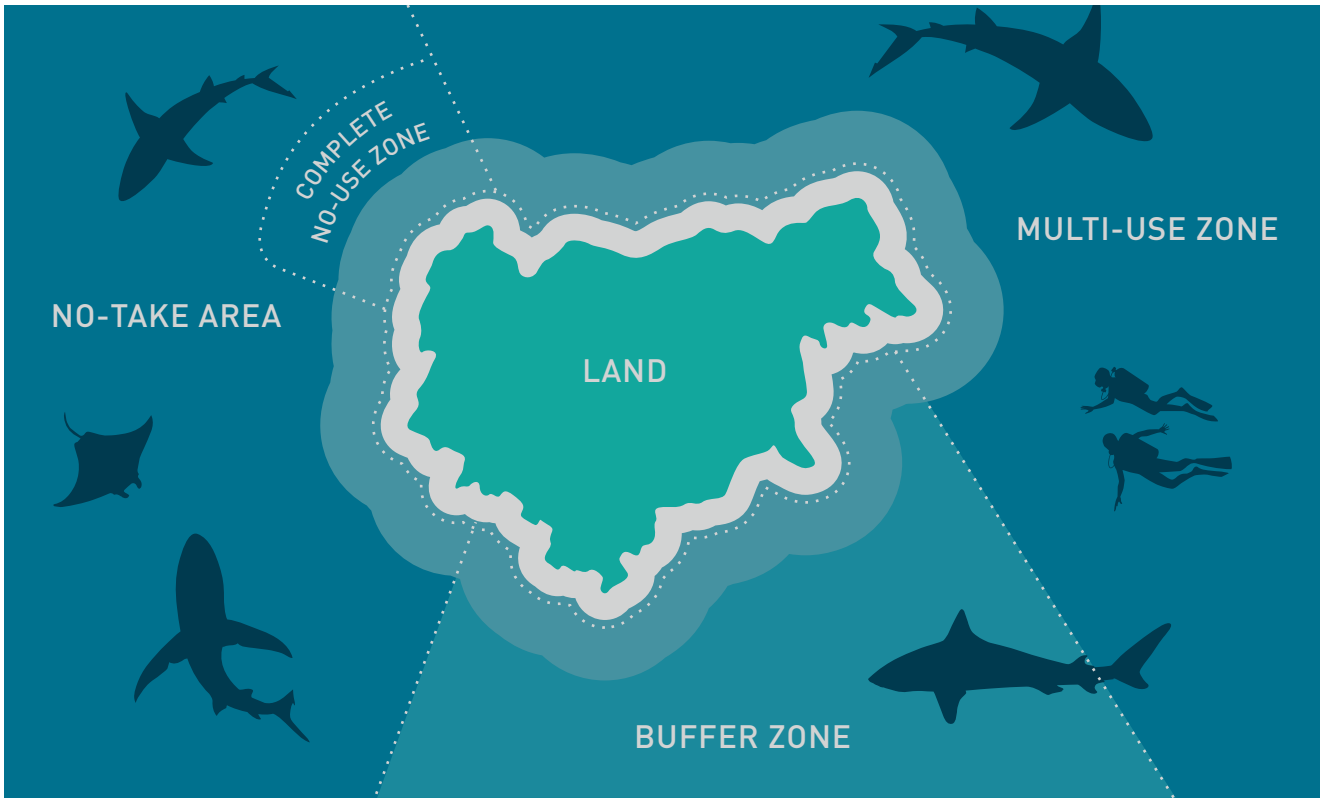
> **"A refuge for the protection and conservation of marine mammals and sharks... Appropriate measures will be taken to ensure protection of sharks and their habitats from the negative impacts of human activities, whether direct or indirect, actual or potential."**
>
> Dutch Caribbean shark and ray MPA

CASE STUDY: GLOVERS REEF MARINE RESERVE

The Glovers Reef Marine Reserve (GRMR) in Belize is a good example of an effective general MPA which has achieved success for sharks in line with its clearly stated goals. The Caribbean reef shark is one of the species targeted for conservation in the GRMR's management plan,[66] and long-term monitoring over 13 years indicates that populations have remained stable with no apparent changes in population size or structure.[67] A high proportion of the sharks are resident, and all life stages are present across a range of habitats. Caribbean reef sharks are more abundant within the GRMR than in fished reefs outside its boundaries.

The MPA's success is attributed to a combination of its large size, remote location, old age, active enforcement regime, and a multi-zoned approach where a large no-take zone with diverse and connected habitats is surrounded by larger zones with regulated fishing that includes gear restrictions.[68] Research and monitoring along with community participation also contribute to the MPA's effectiveness.

MULTIPLE ZONED MPA



MULTIPLE ZONES

The multiple zone approach incorporates multiple objectives into a single MPA. A good example is Australia's Great Barrier Reef Marine Park, which encompasses a wide range of aims across different areas, from strict biodiversity protection to sustainable resource management.[69] The zones – based on four of the six IUCN protected area management categories – are like different types of MPAs with varying levels of protection, which work together to form a network within one larger MPA.

The multiple zone MPA approach offers protection to mobile shark species by reducing their exposure to fisheries, while its protection of a wider range of habitat types contributes to conservation of different shark species and life stages.[70]

IUCN PROTECTED AREA MANAGEMENT CATEGORIES

1. Strict nature reserve and wilderness area
II. National park
III. Natural monument or feature
IV. Habitat/species management area
V. Protected landscape or seascape
VI. Protected areas with sustainable use of natural resources[71]

RAYS

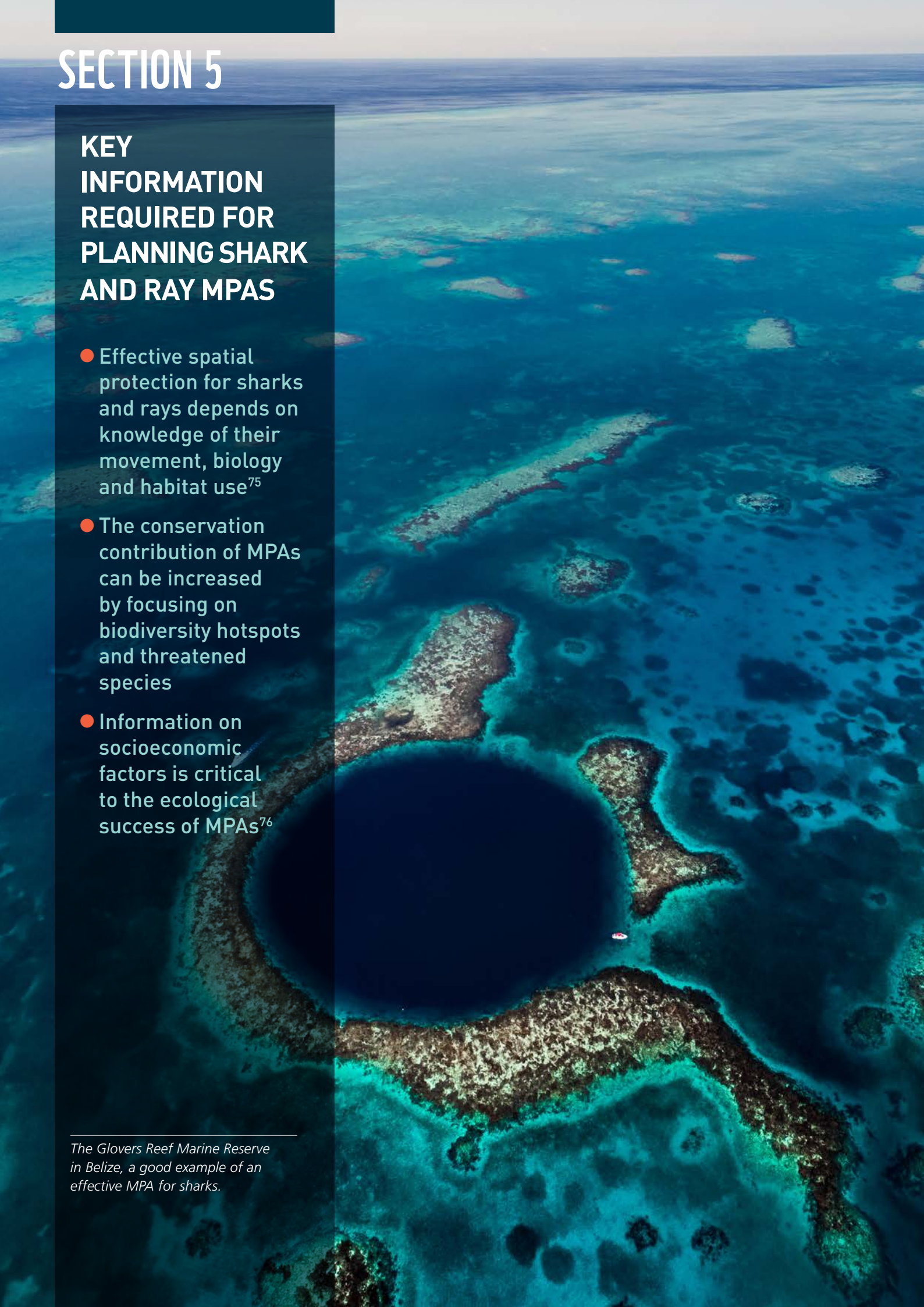
Rays receive less attention than sharks, yet they're currently more threatened. The most threatened species include sawfishes, wedgefishes, stingrays and guitarfishes.[72] Some of the large shark and ray MPAs include ray protection in their regulations, including in the Dutch Caribbean, the British Virgin Islands, the Cook Islands, New Caledonia and the Maldives.[73] Rays are not, however, included in the regulations of large MPAs in the Bahamas, Honduras and the Marshall Islands.

The first nationwide MPA created specifically for ray conservation was announced for Belize in October 2017.[74]

SECTION 5

KEY INFORMATION REQUIRED FOR PLANNING SHARK AND RAY MPAS

- Effective spatial protection for sharks and rays depends on knowledge of their movement, biology and habitat use[75]
- The conservation contribution of MPAs can be increased by focusing on biodiversity hotspots and threatened species
- Information on socioeconomic factors is critical to the ecological success of MPAs[76]



The Glovers Reef Marine Reserve in Belize, a good example of an effective MPA for sharks.

SPATIAL PROTECTION

MOVEMENT

Movement of sharks and rays is the main type of information needed when considering spatial protection – knowledge of movement patterns and life stages will determine where an MPA should be located, and how large an area it should cover, in order to best protect mobile species from fishing and other threats.[77]

In recent decades acoustic and satellite telemetry, as well as conventional tagging, have provided a large amount of information on a wide variety of shark and ray species' movements, some specifically in relation to MPAs.[78] There's a growing understanding of:

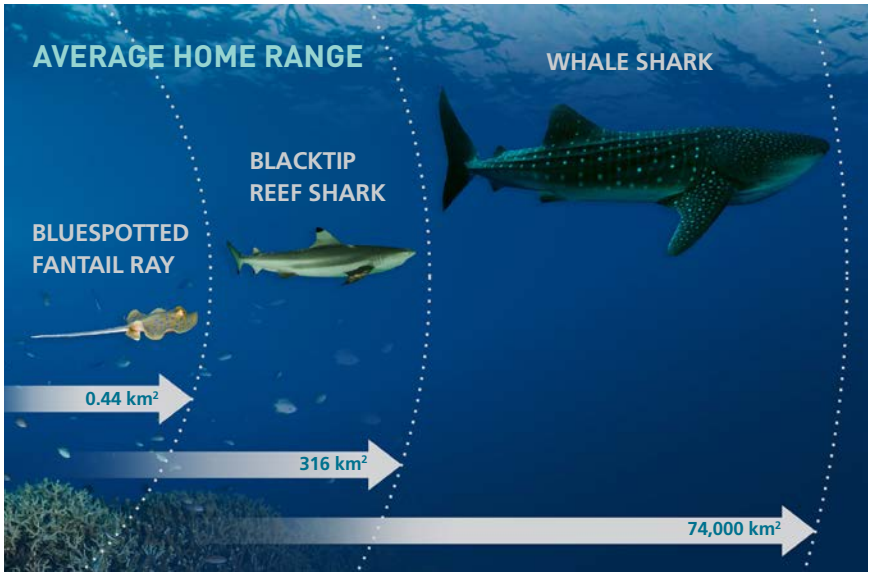
- The type, scale and timing of movement patterns
- Home range size
- Site fidelity
- Connectivity
- Critical habitat requirements.

For futher infrmation see *Rapid Assessment Toolkit for Sharks and Rays*

Much of this is available via internet searches on a shark or ray species and movement – and even if information on a particular species or group of species is not available, data from similar species or groups could be used as a proxy source.[79]

- A good starting point is www.shark-references.com
- Detailed species-specific movement data is available at https://rossdwyer.shinyapps.io/sharkray_mpa

If the area proposed for protection is larger than the area for which tagging or telemetry information is available, movement data models can project additional spatial planning information on habitat selectivity, species distribution and individual movements. These models use environmental characteristics from the habitats of tagged animals to find other similar areas of potential species occurrence.[80]



Source: V. Udyawer unpublished data Australian Institute of Marine Science

Different species have home ranges of different sizes

For example:

- Large-scale migration telemetry data was used in a habitat selectivity model to confirm that a network of MPAs on Australia's west coast provides important habitat and protection to whale sharks. The data also revealed other large areas of suitable habitat in the wider region that could become priority areas for whale shark conservation in future.[81]
- A species-distribution model was used to project the probability of the presence of Critically Endangered angelsharks in the coastal waters of the Canary Islands, providing key information for the design of effective spatial protected areas.[82]

BIOLOGY AND ECOLOGY

The biology and ecology of sharks and rays partly drive their movement patterns. Key aspects include reproduction, feeding and migration – these are linked to site fidelity, repeated use of critical habitats, and ecological connectivity between habitats.

CRITICAL HABITAT

MPAs are often criticized as being too small to provide effective protection to highly mobile, wide-ranging shark and ray species. However, protection of shark and ray habitats critical to life history (breeding, nursery and feeding areas; migratory routes) contributes to the conservation of some species and populations.[84]

Knowledge of migratory movements should be incorporated into existing and future MPAs for a wide variety of species, including the whale shark.

Many shark species segregate by size and sex, with mature females, juveniles and new-borns residing in different habitats at times.[85] Juveniles and new-borns show site fidelity to shallow, inshore habitats, which provide them with feeding grounds and shelter from predators.[86] Some general MPAs around the world have shown that they can offer significant protection to these young animals, for species including grey reef shark,[87] pigeye shark,[88] grey smoothhound,[89] lemon shark,[90] sharptooth lemon shark,[91] Caribbean reef shark, blacktip shark, spinner shark, milk shark, nurse shark and southern stingray.[92]

Some shark and ray species repeatedly return to the same areas, often for breeding. This breeding site fidelity has been used in a number of cases as the basis for shark conservation:

- **Dry Tortugas, Florida** – seasonal closures to protect nurse sharks[93]
- **Western Australia** – spatial gear closures to protect whaler sharks[94]
- **Western Australia** – spatial fishery closures to protect southern dogfish and whiskery sharks.[95]

Other species that show breeding site fidelity include the blacktip reef shark,[96] bull shark,[97] grey nurse shark,[98] Port Jackson shark,[99] lemon shark[100] and smooth stingrays.[101]

Site fidelity – for juveniles and adults alike – is also related to the availability of prey. This can cause aggregations of animals (whale sharks and manta rays are known to aggregate for feeding) which may make species more vulnerable to fishing mortality.[102] Spatial protection can be used to reduce mortality where these aggregations are predictable – the Whale Shark Biosphere Reserve on Mexico's Yucatan Peninsula, for example, was designated specifically to protect whale sharks aggregating to feed.[103] Since the designation, another feeding aggregation area has been discovered further east along the peninsula:[104] adaptive management would provide a mechanism to act on this new information.

LIMITED MOVEMENT

Some species – particularly smaller skates and rays, and some smaller sharks – show limited movement throughout their lives. Information on the presence of these types of species in an area can show if spatial protection of their habitat will be effective. Examples of these species include:

- The nervous shark – inhabits nearshore, shallow waters[105]
- The epaulette shark and Pacific angelshark (and others) – prefer complex bottom habitats[106]
- The deepwater Kermadac spiny dogfish – protected in the Kermadac Islands Marine Reserve, which encompasses most of its known distribution.[107]

MIGRATORY ROUTES

Migratory routes are important habitats for a range of sharks and rays. Increasing information is available on the migratory movements of a wide variety of species,[108] including:

- Whale sharks[109]
- Deepwater leafscale gulper sharks [110]
- Bull sharks[111]
- White sharks[112]
- Reef manta rays[113]
- Silky sharks[114]
- Scalloped hammerheads.[115]

These and other studies recommend that knowledge of migratory movements should be incorporated into existing and future MPAs to increase protection, particularly for threatened species.[116]

ECOLOGICAL AND HABITAT CONNECTIVITY

Movement of sharks and rays between habitats can be essential for activities such as feeding and breeding. It can be challenging to provide protection to wide-ranging adult sharks and rays and species that don't show site fidelity, but it is still possible in some cases to include ecological connectivity of habitats in spatial design to improve population viability and conservation outcomes.[117]

Sometimes this movement occurs on a scale that enables protection of the adults. For example:

- Silvertip shark and large male grey reef shark protection could include closely spaced reef habitats (<20km).[118]
- Nurse shark and Caribbean reef sharks use diverse habitats on reef systems such as lagoons, channels and reefs: by providing spatially protected connectivity between them, the risk of exposure to fisheries is reduced.[119]
- Silky sharks and scalloped hammerheads migrating between the Galapagos Marine Reserve and the Cocos Island National Park could be protected by a migratory corridor MPA.[120]

ONLINE RESOURCE

MigraVia

For more than a decade, MigraVia has been generating information on the movement of migratory species in the Eastern Pacific. You can find out more at ***http://migramar.org/hi/en/migravia-2/***

MPA NETWORKS

A network of ecologically connected MPAs can enable habitat connectivity – and reduce exposure to fisheries – across a wide area.

OCEANIC MPAS

Many shark and ray MPAs include open ocean areas where highly mobile species such as the oceanic whitetip shark occur: if oceanic MPAs are established and their regulations are respected, then such species will be protected. The proposed Galapagos-Cocos migratory corridor (see above) would essentially be an oceanic MPA.

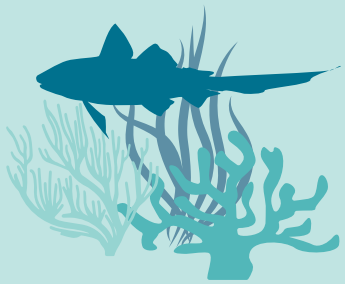
Some pelagic sharks – eg shortfin mako, blue shark, great hammerhead – occupy habitat hotspots which vary according to seasonally shifting ocean temperatures and primary productivity. Dynamic spatial and temporal closures may be more appropriate than fixed measures to protect them, leaving room for greater management flexibility.

In the case of the tuna industry, where non-targeted sharks and rays are also taken, although dynamic closures may have economic consequences for the target species industry, they would deliver a conservation benefit to shark and rays. Dynamic spatial closures of this kind have been successfully implemented to limit the catch of non-target species in an Australian longline tuna fishery.[121]

Many shark and ray MPAs include open ocean areas

CONSERVATION CONTRIBUTION

A biodiversity hotspot is often defined as an area with a high concentration of endemic species threatened by habitat loss;[122] although it can also signify an area of general species richness (not solely endemic) where habitat loss may not be an issue.



ENDEMIC SPECIES

only exist in one geographical area

Aichi Target 11 of the Convention on Biological Diversity aims to preserve areas of importance for taxonomic biodiversity.[123] In the case of sharks and rays, with more than 1,100 species globally, a prioritization of biodiversity hotspots is needed.

There are biodiversity hotspots for sharks and rays in nearly all waters of the countries where they're fished most intensively.[124] Finding out the number of species in an area, and whether they're endemic or threatened, helps inform how an MPA can make a contribution to biodiversity protection.

THREATENED SPECIES

The IUCN Red List of Threatened Species (🔗 www.iucnredlist.org) identifies which shark and ray species face the highest risk of extinction – in most cases this matches the species most threatened by overfishing.

The most threatened sharks and rays tend to be large-bodied, shallow-water species that are most accessible to fisheries. The most threatened family of all is the sawfishes, with other mainly inshore families of large rays also highly threatened – wedgefishes, guitarfishes, sleeper rays and stingrays. Angel sharks and thresher sharks are also at great risk.[125] If these families can be included in the design of an MPA, its conservation contribution will be increased.

EVOLUTIONARY DISTINCTIVENESS

There's a general consensus that all elements of biodiversity should be conserved, including evolutionary information.[126] The 'evolutionary distinctiveness' (ED) concept is that species on the longest evolutionary branches represent a greater degree of evolution, are more distinct, and have few close relatives: their loss would mean a disproportionately large loss of evolutionary information than in the case of more recently evolved species with many close relatives. With this in mind, ED may be useful to consider when setting MPA conservation priorities.[127]

EDGE SPECIES

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The Edge of Existence programme (🔗 **www.edgeofexistence.org**) lists the top 50 shark and ray species with the highest ED and most threatened conservation status. The highest ranked EDGE shark and ray species are 🔗 **sawfishes, angelsharks** and **guitarfishes.**

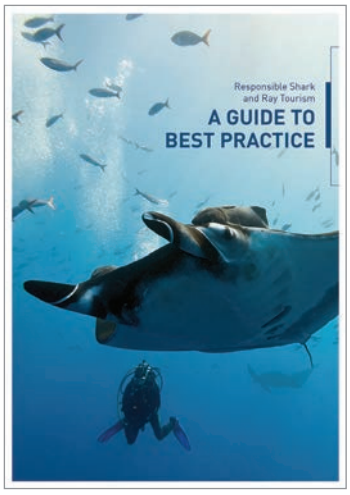
To maximize the conservation contribution of an MPA, it's usually best to focus on a combination of these hotspot biodiversity metrics – endemics, species richness and ED. A recent study[128] examines these metrics to identify 21 countries across five hotspot regions as prime locations for shark and ray conservation. The regions are:

- Southwest Pacific Ocean
- Northwest Pacific Ocean
- Southwest Indian Ocean
- Western Africa
- Southwest Atlantic Ocean.

SOCIOECONOMIC FACTORS

- **People must be included in conservation plans**
- **Build up social capital and equity**
- **Sharks and rays may contribute to food security and income**
- **MPAs need to balance protection with economic and subsistence needs**

WORKING WITH COMMUNITIES



WWF has produced a detailed guide to shark and ray tourism, which includes guidance on building strong relationships with local communities. The guide is available for free at sharks.panda.org/tools-publications/tourism-guide

STAKEHOLDER ENGAGEMENT

To achieve effective conservation outcomes in an MPA, the social and economic needs of the people it affects must be taken into account.[129]

Community stakeholders should be engaged from the initial planning stages and through the design and management process, since the MPA will regulate and modify their behaviour.[130] It's particularly important to understand how local people view the MPA – unless they perceive benefits, their support is less likely.[131]

Within communities there may also be different perceptions, depending on the roles and skills of the people concerned: for example, some fishers may not feel able to adapt to the loss of a fishing way of life, and may feel marginalized from the tourist activities replacing their traditional living.[132] Social inequity of this kind can cause conflict,[133] and needs to be avoided – it's essential to engage with all stakeholders to build social licence (trust, respect, support).

If a proposed MPA will reduce income or food security in the local community, alternative income sources, livelihood options and fair compensation should all be considered. So too should people's capacity for resilience – their ability to cope with and adapt to external change. This is likely to vary between individuals and demographic groups.[134]

Socioeconomic and cultural considerations in MPA planning are likely to vary between developed and developing countries. In a few of the large shark and ray MPAs – specifically Palau, the Marshall Islands and the British Virgin Islands – the needs of local communities have been considered and incorporated into the regulations, which allow for subsistence shark fishing.[135]

In developing countries, community governance of MPAs is common. It's particularly important to explore how to build social capital with communities, especially trust and transparency in local leadership; and long-term support and positive outcomes will likely depend on an equitable distribution of MPA benefits.[136] Local and traditional knowledge may assist in design and planning of a shark and ray MPA, particularly if data is lacking.

Socioeconomic data on communities affected by MPAs is crucial. It can be spatial – such as tenure area, subsistence and artisanal fishing grounds; or non-spatial – such as education, livelihood options, material assets, and perception of MPAs. Information on all of these areas was gathered to create multiple use MPAs in Raja Ampat, Indonesia, which were later incorporated into the Raja Ampat Shark Sanctuary.[137] Stakeholders were given the opportunity to review the draft zoning plans to produce final plans: these both satisfied guidelines for resilient MPA design, and were supported by the community and government.[138]

Stakeholder partnerships within shark and ray MPAs are useful to promote good fishing practices, to gather catch and release information, and to increase the value of sustainable catches through certification. Direct stakeholder engagement can also play a critical role in adaptive management, particularly in light of the increasing effects of climate change.

WHO HOLDS A STAKE IN AN MPA?

Stakeholders can include many groups with a vested interest in an MPA – including local community groups and traditional owners, the fishing industry, environmental NGOs, ethical investment funds, financial institutions, governments and others.

STAKEHOLDER AWARENESS AND COMMUNITY EDUCATION

Raising awareness of the value of protecting sharks and rays – and the role of MPAs in doing so – should be an integral part of MPA planning and management. In addition, stakeholders need to understand the structure of the MPA's design and governance, and how it will impact them and their community. Complex spatial planning processes may also need to be explained. Ongoing education and outreach is essential to provide communities with the information they require on the MPA process, as well as updates on monitoring and adaptive management changes.[139]

COMPLIANCE AND ENFORCEMENT

The ecological success of MPAs depends heavily on people complying with their regulations.[140] Stronger monitoring and enforcement are known to improve MPA effectiveness, but these can be challenging and expensive, particularly in larger MPAs.[141]

Technology can help. Access to satellite data, vessel monitoring systems (VMS) or automatic identification systems (AIS) can all improve surveillance capacity. Some initiatives that use VMS and AIS, such as Global Fishing Watch, provide information in almost real time.[142]

The ability to enforce regulations will depend on considerations like the number and capacity of patrol boats, fisheries and MPA staff: assessing and prioritizing these resources efficiently is important.[143]

In some circumstances, promoting voluntary compliance may reduce the need for strict enforcement. This involves focusing on people's behaviour, perceptions and motivations; all of which can be influenced by social and personal norms. Understanding these norms can reveal routes towards behaviour change: for example, it may be possible to involve trusted members of a fishing community who'll apply positive social pressure on their peers to comply; or to build up a sense of stewardship in maintaining shark and ray resources for the community.[145]

Introducing positive incentives to change people's perceptions may also achieve compliance more cost-effectively than monitoring and enforcement.[146] Understanding how to apply these incentives can be valuable, whether that involves users participating in management decisions, promotion and education about the benefits and regulations of MPAs, or the promotion of traditional knowledge.[147] Communities can also be engaged to assist with monitoring and enforcement through education and outreach, and with the development of community-derived regulations.[148]

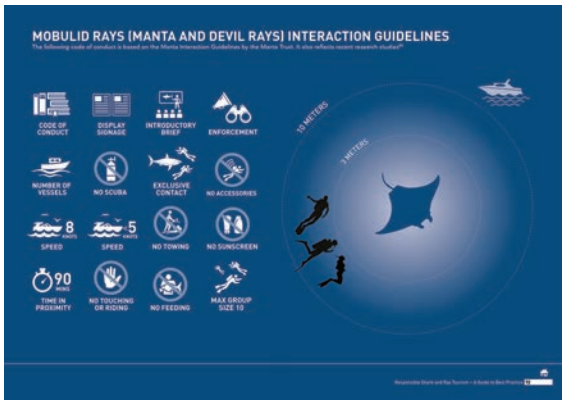
Compliance in MPAs is stronger when engaged and empowered fishers and local communities work together with administrators, researchers and NGOs in a co-management scheme. In areas where tourism operations regularly occur, these too can assist in monitoring. In some cases – such as at Fiji's Shark Reef and at Monad Shoal in the Philippines – tourism operators have some limited enforcement powers, reducing the burden on local authorities.

GOVERNANCE

> **"[Governance is defined as] who makes decisions and how those decisions are made. Governance also describes who has the influence, authority and accountability with respect to the rights of all legitimate parties."[149]**

It's very important to consider the most appropriate type of governance for shark and ray MPAs – and one of the main lessons of the last decade is that there's no single best or right approach.[150] Each MPA site has a unique blend of historical, socio-political and socioeconomic factors along with specific ecological goals, so a tailored approach to governance is always required.[151]

The large shark and ray MPAs encompassing entire Exclusive Economic Zones (EEZs) are all governed at the national level, with regulations enacted as declarations, amendments to fisheries acts, or independent laws.[152] Conversely, smaller shark and ray MPAs have more diverse governance frameworks: some of the more ecologically effective are based on private co-management within the community (eg the Raja Ampat Shark Sanctuary, Indonesia) or co-management between government sectors (eg the Dry Tortugas, Florida, USA).[153]



SHARK AND RAY TOURISM

If well managed, shark and ray tourism can generate an alternative income that directly benefits the local economy and supports conservation.[154] However, it may not directly benefit sharks and rays unless it is conducted sustainably, and confers protection to sharks and rays which would otherwise be overfished or threatened in some other way. The potential impacts of tourism on the shark and ray species should also be considered.[155]

WWF has produced a detailed guide on responsible shark and ray tourism, which you can download for free at
https://sharks.panda.org/tools-publications/tourism-guide

CASE STUDY: RAJA AMPAT

© Luky Pradita / Shutterstock

The government of Raja Ampat created the first shark sanctuary in the Coral Triangle

Raja Ampat Shark Sanctuary in Indonesia has been noted as an ecological and socioeconomic success. The abundance of grey reef sharks and blacktip sharks was significantly higher in two privately managed no-take zones (NTZs). The two NTZs are relatively small at 425km^2 and 403km^2, and the data was collected after two and seven years of protection respectively using baited remote underwater video systems (BRUVS).

The success of the no-take spatial management was not thought to be due to zone size, depth or reef habitat complexity, but was instead attributed to the governance structure. This was a partnership between the private sector and local communities, where the communities received lease payments and employment in return for protecting the zone, which ensured effective enforcement.[156]

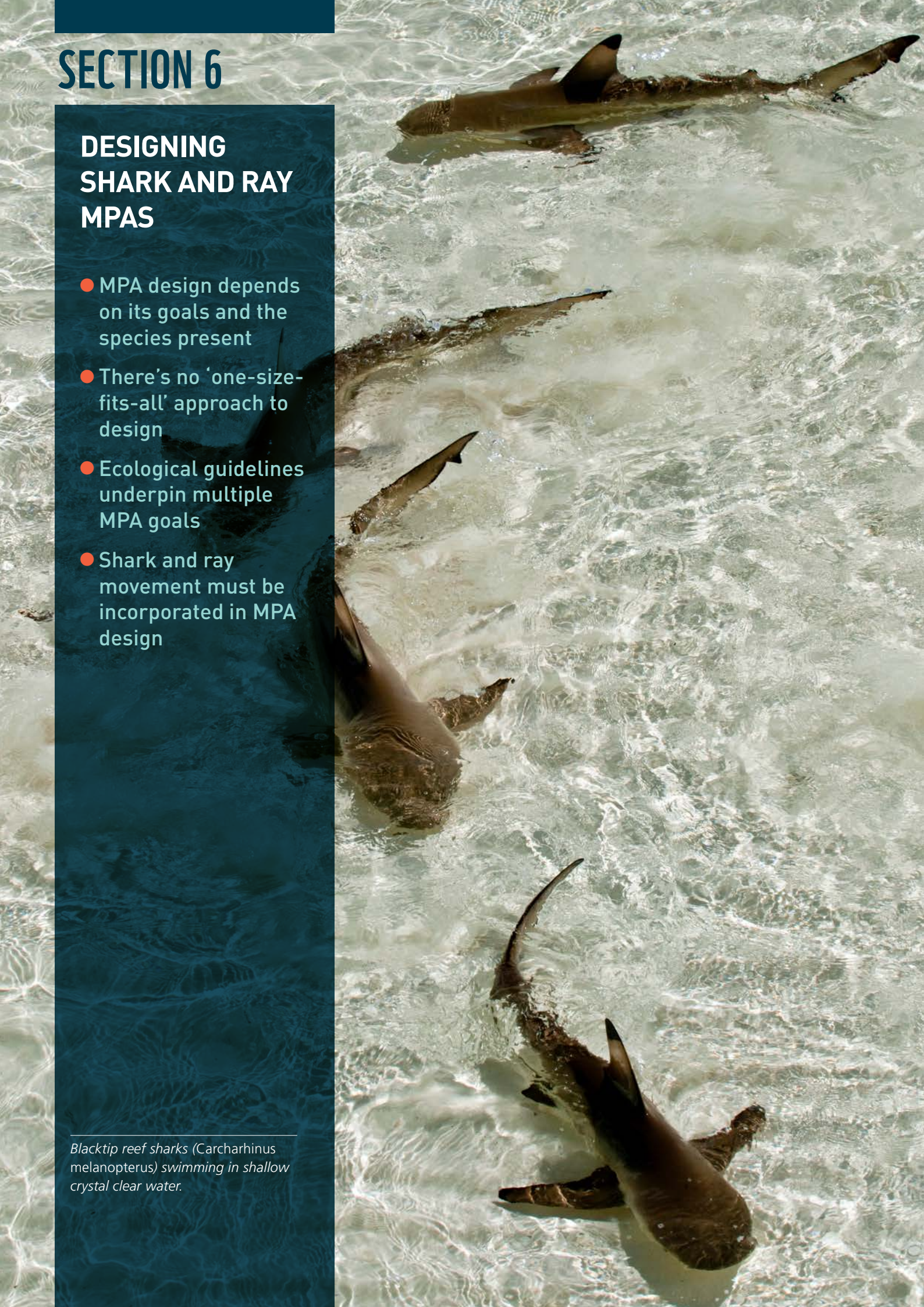
MISSING INFORMATION

The key information discussed in this chapter may not all be available: it's intended as a wish-list that can be used to identify knowledge gaps and prioritize future work. Depending on circumstances it may also be possible to apply information relating to similar marine areas, species and countries with similar resources in making plans for spatial protection.

SECTION 6

DESIGNING SHARK AND RAY MPAS

- MPA design depends on its goals and the species present
- There's no 'one-size-fits-all' approach to design
- Ecological guidelines underpin multiple MPA goals
- Shark and ray movement must be incorporated in MPA design

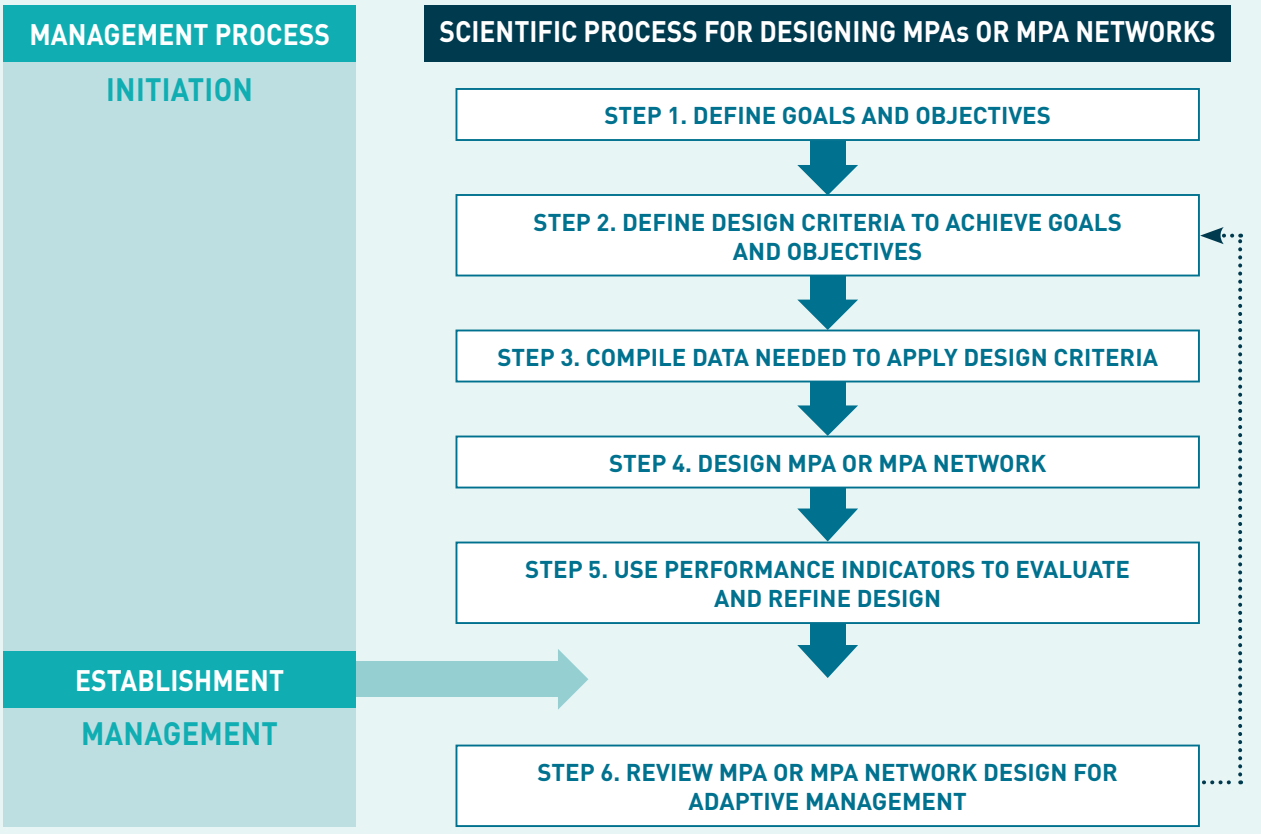


*Blacktip reef sharks (*Carcharhinus melanopterus*) swimming in shallow crystal clear water.*

DESIGNING SHARK AND RAY MPAS

Designing a shark and ray MPA should be a systematic, structured and strategic process with clearly defined conservation goals, informed by the most relevant science.[157] An illustration of such a process is shown below.

STEPS IN DESIGNING AND ESTABLISHING MPAS[158]



Note that this framework includes an adaptive management model – this provides flexibility to adjust the MPA over time to maximize its effectiveness and success. As an example, in the Seychelles telemetry revealed that moving the upper boundary of an MPA from the beach at high tide to the reef edge at low tide increased the coverage of reef shark movements by about a third, extending the MPA to cover extensive lagoon and reef habitats favoured by reef sharks.[159] In response, the government adopted the measure.

NO ONE DESIGN FITS ALL

The design of a shark and ray MPA depends on its goals and the species present. It might be designed for one or more purposes:

- Single species protection – highly threatened
- Commercially important species – fisheries
- Multiple species – biodiversity
- Tourism – socioeconomic

An adapted set of general ecological guidelines for designing marine MPAs (below) is relevant for sharks and rays. Design guidelines for MPAs aimed specifically at tourists are detailed in the *WWF Responsible Shark and Ray Tourism Best Practice Guide*, available for free at https://sharks.panda.org/tools-publications/tourism-guide

ECOLOGICAL PRINCIPLES FOR DESIGNING SHARK AND RAY MPAS	
REPRESENT HABITATS	Protect at least 20% of each major habitat[1] used by sharks and rays in MPAs.
REPLICATE HABITATS (SPREAD THE RISK)	Protect at least three examples of each major habitat type used by sharks and rays in MPAs. Spread them out to reduce the chances they will all be affected by the same disturbance.[2]
REHABILITATE HABITATS AND RECOVER SPECIES	Effectively manage threats[3] and facilitate population recovery of focal species[4] by habitat protection and fisheries management measures such as spatial fishery closures in MPAs.
PROTECT CRITICAL, SPECIAL AND UNIQUE AREAS	Protect critical areas or habitats[5] in the life history of sharks and rays[4] in MPAs. Protect critical areas or habitats[5] for threatened or protected species.[4] Protect special and unique natural phenomena[6] in MPAs. Protect areas that are important at the national, international or global scale for conservation or management of focal species.
INCORPORATE CONNECTIVITY: OCEANOGRAPHY	Consider variations in oceanography,[7] substrate and bathymetry that affect the spread of biological and non-biological material.
INCORPORATE CONNECTIVITY: MOVEMENT OF ADULTS AND JUVENILES	MPAs must be large enough to sustain adults and juveniles of shark and ray species within their boundaries. Where possible, include whole ecological units[8] in MPAs. If not, choose bigger versus smaller areas. Where a habitat feature does not dictate shape, use compact shapes[9] for MPAs rather than elongated ones to minimize edge effects and maximize protection. Ensure MPAs are large enough to contain all habitats[1] used by focal species during their life history;[10] or establish networks of MPAs that are close enough to allow for movements of focal species among protected habitats.[11]
ALLOW TIME FOR RECOVERY	Establish MPAs for the long term (20-40 years), preferably permanently, and monitor changes over time.
PROTECT HEALTHY AREAS AND AVOID LOCAL THREATS	Protect areas where habitats and populations of focal species are in good condition with low levels of threat.[12] If possible, avoid areas where habitats and populations of focal species are in poor condition due to local threats. Reduce threats as much as possible.
ADAPT TO CHANGES IN CLIMATE AND OCEAN CHEMISTRY	Protect ecologically important sites that are sensitive to changes in climate and ocean chemistry[13] in NTZs. Protect sites that are likely to be more resilient or resistant to global environmental change[13] (refugia) in MPAs. Increase protection of key species that play important functional roles in ecosystem resilience (e.g. apex predators). Consider how climate and ocean change will affect the life history of focal species, and the implications for refining the design criteria above. Address uncertainty by spreading the risk (see above); and increasing the coverage of habitats, critical areas and species most vulnerable to changes in climate and ocean chemistry.

Explanatory notes: **1.** Coral reefs, rocky reefs, mangroves, seagrass beds, sand flats, migratory corridors **2.** Major storms, coral bleaching **3.** Overfishing, habitat loss, climate change **4.** Including key fisheries species; threatened and protected species and/or migratory species; high trophic level species important for maintaining ecosystem function **5.** Nursery, breeding and feeding areas and migratory corridors **6.** Areas with very high biodiversity, high endemism, unique marine communities or high productivity (e.g. unique pelagic habitats such as upwelling, fronts, eddies) **7.** Salinity, currents, temperature **8.** Such as reefs or seamounts **9.** Such as squares or circles **10.** For home ranges, nursery, breeding and feeding areas **11.** Through ontogenetic (change from juvenile to adult) habitat shifts and migrations **12.** For example adjacent to effectively managed terrestrial protected areas **13.** Such as rising sea temperatures, rising sea levels etc. *Source: Modified from Green et al., 2014; Green et al., in prep.*

CLIMATE CHANGE

Climate change is an increasingly important factor to consider – it may affect habitats, or change water temperature and ocean currents, directly impacting the distribution of sharks and rays. Approaches are being developed to incorporate climate projections into MPA design using conservation planning software tools like Marxan (see below) and spatial meta-analysis of climate impact models.[160]

NO ONE SIZE FITS ALL

There are shark and ray MPAs ranging from <1km^2 to <360,000km^2 in size – and all of them can play important roles.

Size should be informed by the goals of the MPA and the home ranges of the main (focal) species. It will also depend on available resources, socioeconomic factors, and other management measures in place.

Areas of high fishing pressure and no fisheries management measures outside the MPA may be better suited to networks of large and small MPAs to achieve both biodiversity and fishery goals.

It's important to consider what proportion of their time sharks and rays spend outside MPA boundaries, along with the probability of capture.[161] How severe are mortality risks outside the MPA? Can they be effectively managed to reduce the mortality threat to focal species?

As an example, longline fisheries are a threat to tiger sharks outside some Caribbean shark MPAs: even if the animals are effectively protected within the MPAs, most of their movement occurs outside the boundaries.[162] This means their level of protection depends on the size, area and management approach in the fisheries concerned, such as whether there are gear restrictions in place (eg a ban on wire leaders).

SHARK AND RAY MPA NETWORKS

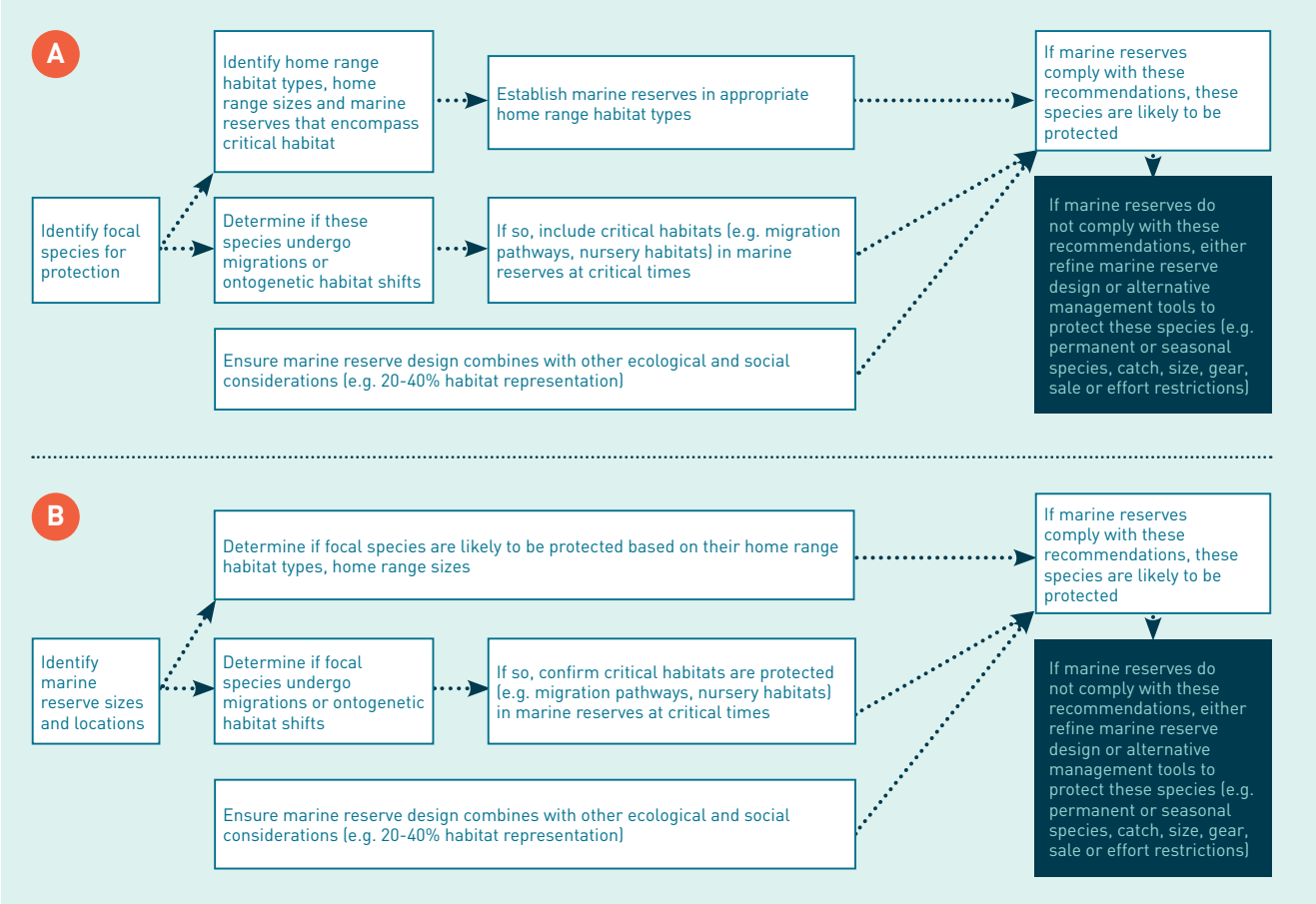
A network of separate, relatively isolated and small shark and ray MPAs may be more logistically feasible and socially acceptable than a single large shark and ray MPA; while still providing ecological connectivity and conservation benefits for mobile species.

- In Australia, an extensive network of 26 separate MPAs along the east coast is mostly designated for grey nurse shark conservation.[163]
- In Indonesia, a network of shark and ray MPAs may achieve better conservation outcomes than a single large MPA, as it could enable displaced shark fishers to access other sustainable livelihood options, such as a different style of fishing in their local area (e.g. sustainable small-scale fishing for reef fish instead of sharks), rather than simply shifting shark-fishing effort to other unmanaged areas.[164]

INCORPORATING SHARK AND RAY MOVEMENT DATA INTO DESIGN

Information on shark and ray movement can be used to help MPA design in two major ways:[165]

- To help determine MPA location and size once the focal species for protection are identified
- To identify the MPA area and work out which species occurring there would be protected.



Protocol for using connectivity information for marine reserve network design and adaptive management using either (A) focal species for protection or (B) marine reserve sizes and locations as starting points. Focal species may be high-priority species for fisheries, tourism or conservation. Source Green et al., 2015

There's now a large body of research and data on shark and ray movement, which can make an important contribution to the design of effective shark and ray MPAs – particularly if introduced early in the planning stage. Systematic conservation planning software such as C-Plan, Zonation and Marxan can incorporate complex movement data into the process.[166]

MARXAN

Marxan is the most widely used design software, as it integrates well with geographic information systems (GIS) and can include different kinds of data. It has been used in the design of several MPAs globally, including the re-zoning of the Great Barrier Reef Marine Park, Australia.[167]

Marxan aims to find the optimal spatial location and design of protected areas to deliver conservation goals while minimizing the social and economic cost of the closures. As discussed previously, including socioeconomic considerations is an important factor in making an MPA design effective and successful.

There are a range of spatial management design options which can be generated depending on the conservation objective (e.g. 50% critical habitat protection) and the acceptable cost of that protection to current or future users of area resources.[168]

Conservation data includes biological or geographical characteristics to be protected such as breeding areas, preferred habitat and depth ranges, and their conservation targets (these targets are usually expressed as a percentage of the total characteristic available). Movement information is one of the main types of data used in Marxan to work out preferred and critical habitat.[169]

- Movement information from speartooth sharks in northern Australia identified critical resident areas and migration corridors, and was used with Marxan to develop seasonally varied spatial closures. This proved to be the best strategy for protecting the most commonly used seasonal habitats, while maximizing open areas for fisheries.[170]

Marzone is another systematic conservation planning software that can incorporate socioeconomic data with biological design criteria – it was used, for example, to develop zoning plans for the Raja Ampat Shark MPA network.[171] Such an approach increases the likelihood of ecological success, as stakeholders are more engaged and community support is more likely.

ONLINE RESOURCE

A global database on systematic conservation planning with more examples of its use and application is available at ***http://database.conservationplanning.org***

SOCIOECONOMIC DESIGN FACTORS

Detailed guidelines including socioeconomic considerations for large shark and ray MPAs have been produced by a group of experienced large-scale MPA managers.[172]

Large-scale MPAs can face some unique social, cultural and economic challenges, due to their size, socio-political complexities and varying cultural perspectives. When multiple rights-holders, cultural rights, distinct communities and agencies are involved, the process of ensuring equitable alternative sustainable livelihood options, food security and fair compensation can be complex.[173]

Local, national and regional economics may all need to be considered in large-scale site design, as it may influence market-level demand, supply and international trade.[174] Including them at the planning phase increases the chance that the MPA will ultimately be effective for long-term conservation.

GOVERNANCE

One of the most favoured MPA governance structures is to combine top-down government control with decentralized bottom-up, community-based approaches, with the latter being especially important early in the planning and design process.[175] This strategy combines the benefits of strong legislative control with an empowered, supportive local community.[176]

It's more difficult to incorporate appropriate legal frameworks when an MPA crosses borders. While most shark and ray MPAs are in a single EEZ, large, migratory species could benefit from protection of migratory corridors and habitat hotspots across multiple jurisdictions and on the high seas.[177]

The Memorandum of Understanding on the Conservation of Migratory Sharks has a stated objective in Annex 3 (Objective C, Activity 9.1) "to designate and manage conservation areas, sanctuaries or temporary exclusion zones along migration corridors and in areas of critical habitat."[178] This gives signatories a plan and means to work collaboratively towards providing protection on the high seas for some migratory species.[179]

The UN is facilitating discussions on how to simplify the process of creating MPAs on the high seas, also known as areas beyond national jurisdiction (ABNJs).[180] Bilateral agreements are another option: Costa Rica and Ecuador, for example, are working on an agreement to protect seamounts connecting the Galapagos Marine Reserve with the Cocos Island National Park, providing a migratory corridor for sharks.[181]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CASE STUDIES: WHAT DOES GOOD SHARK AND RAY

GOAL: BIODIVERSITY – PROTECT MULTIPLE SHARK AND RAY SPECIES

TUBBATAHA REEFS NATURAL PARK (TRNP), PHILIPPINES

Established in 1988 with an area of ~1,000km^2, TRNP has a goal of protecting high biodiversity, high quality reef and deepsea habitats, and threatened marine species.[184] Remote and relatively undisturbed, the park has a no-take policy throughout its area, with multiple use access zones. It is legally protected through national protected areas legislation, with clear delegation to the area management authority, and has regular enforcement patrols and radar monitoring of vessel activity. Due to the logistical challenges of managing such a remote area, there's a 10-nautical-mile buffer zone around the TRNP.

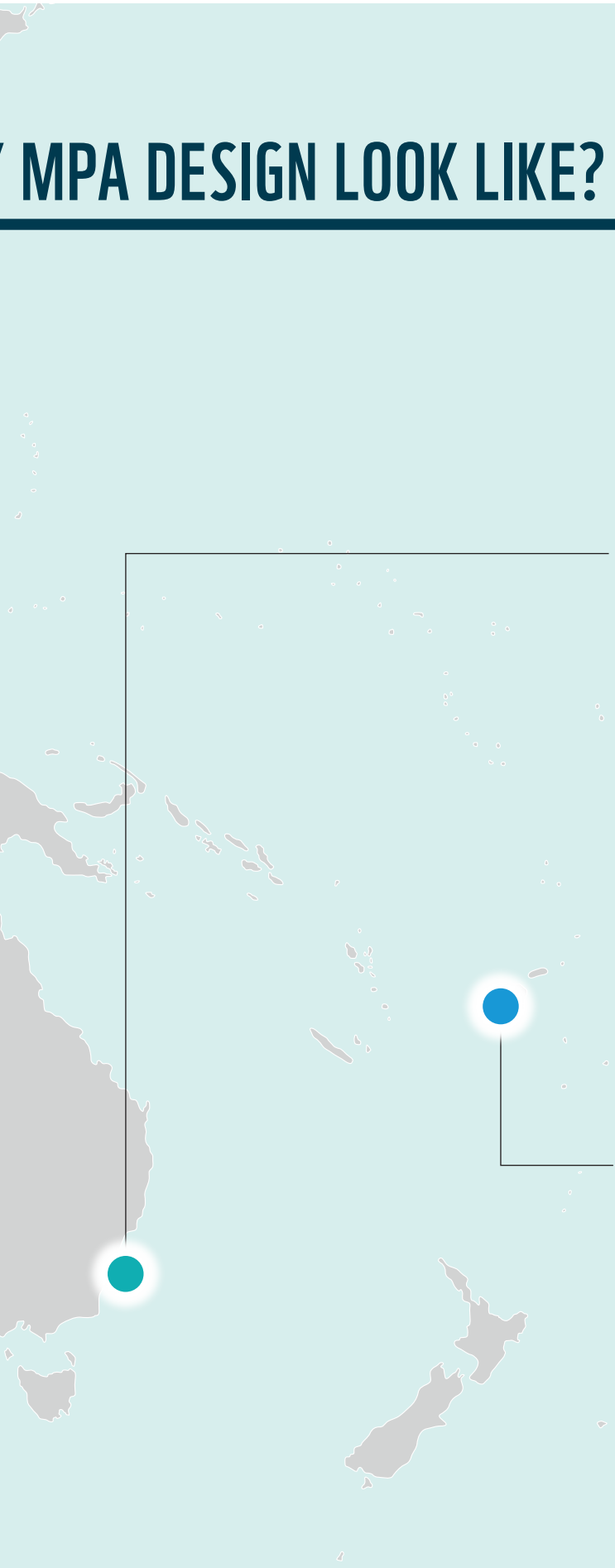
Research using underwater visual census (UVC) and baited remote underwater video systems (BRUVS) has shown that TRNP has one of the highest densities of whitetip reef sharks and grey reef sharks in the world.[185]

ROWLEY SHOALS MARINE PARK (RSMP), AUSTRALIA

Established in 1990 with an area of 7,137km^2, RSMP aims for long-term protection of marine biodiversity and ecological integrity, recognizing the high abundance of sharks within its borders. It has a clearly articulated goal, strategy and management plan, and is relatively well enforced.[182]

The RSMP is large, remote, old, and contains a mix of no-take zones and zones with highly regulated fishing. More than 20 years after its implementation, the RSMP has protected a range of species from overfishing. Sharks within its borders are twice as diverse and abundant, 20% longer, and have 13 times greater biomass than those in another remote reef in the region with long-term targeted shark fishing.[183]

' MPA DESIGN LOOK LIKE?



GOAL: PROTECT THREATENED SHARK SPECIES

EASTERN AUSTRALIA

A network of spatial fishery closures was implemented in 2007 to enable recovery of two gulper shark species, Harrisson's dogfish and southern dogfish. As a fisheries management tool these closures aren't strictly permanent, but are temporarily legislated for periods of up to five years. Fishing is prohibited within the closed areas, which were designed to encompass the species' movement within their home range; and some operational measures were also adopted outside the closed areas, including non-retention of gulper sharks and regulated handling practices to improve their survival when returned to the sea.[186] Both species have benefited, with declines in biomass halted.[187]

GOAL: SOCIOECONOMIC/ TOURISM

SHARK REEF MARINE RESERVE (SRMR), FIJI

At just 0.09km^2, the SRMR was officially recognized in 2004 and designated as a marine reserve in 2014.[188] Its purpose was to attract shark tourism, and local stakeholders have since received significant economic benefits.

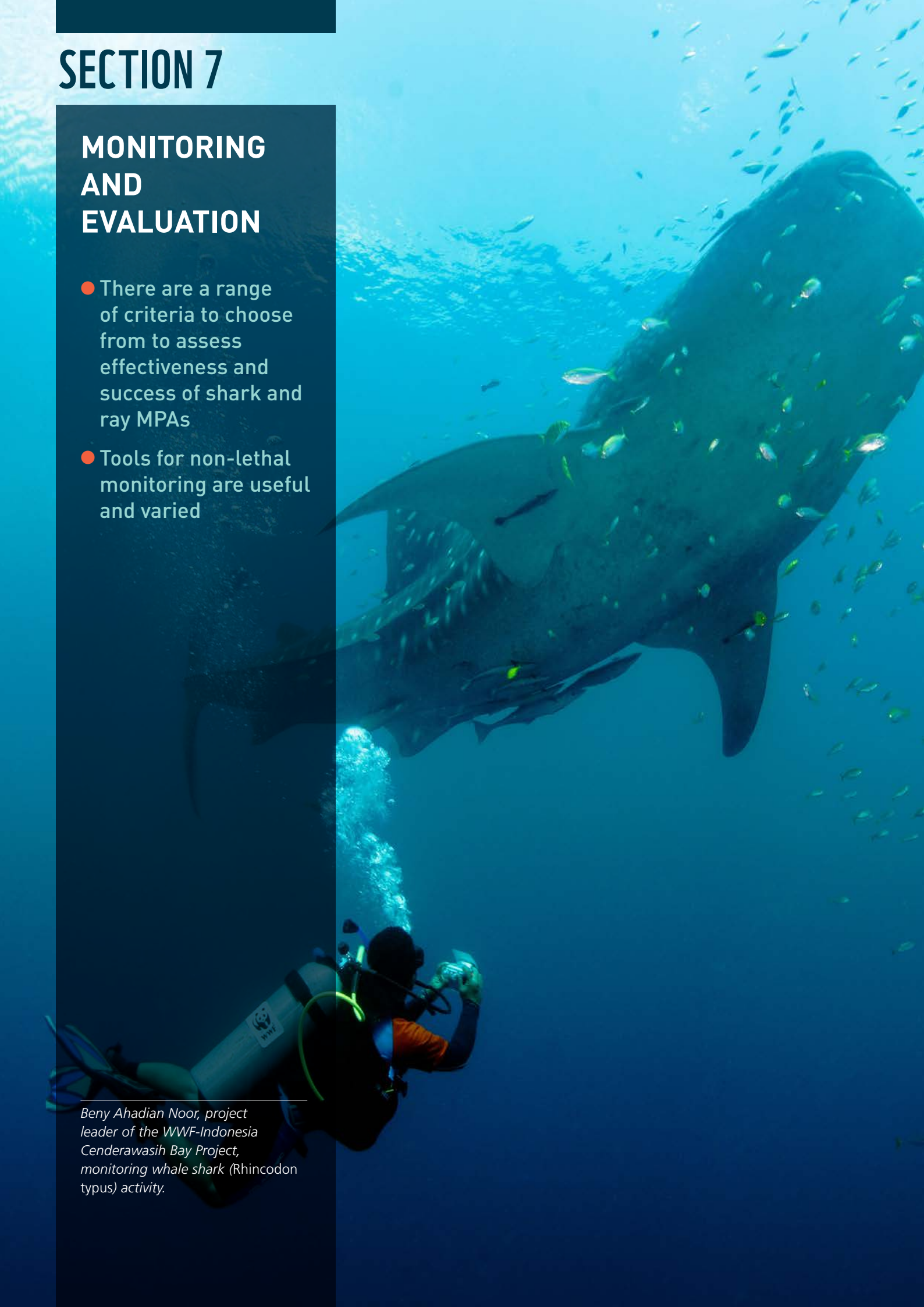
The SRMR is privately governed, and a levy is paid direct to local communities as compensation for not fishing within it. Locals have been actively engaged in the implementation and development of the SRMR, including being employed by the private operator and empowered as fish wardens to enforce the no-take zone. The reserve is well managed, enforced and attracts considerable numbers of divers to dive with sharks.[189]

The SRMR was not established with the goal of ecological protection, although long-term monitoring of shark populations has been conducted since 2003 through UVC. Provisioning (shark feeding by tourist operators) has led to a gradual shift in the shark community composition, although no long-term changes to the dominant bull sharks' site fidelity or movement have been observed.[190]

SECTION 7

MONITORING AND EVALUATION

- There are a range of criteria to choose from to assess effectiveness and success of shark and ray MPAs
- Tools for non-lethal monitoring are useful and varied



*Beny Ahadian Noor, project leader of the WWF-Indonesia Cenderawasih Bay Project, monitoring whale shark (*Rhincodon typus*) activity.*

MONITORING AND EVALUATION

Monitoring and evaluation of the effectiveness and success of a shark and ray MPA is best done with measurable criteria against clearly stated goals, objectives and targets.[191] It should include regular assessments of the condition of the MPA.[192]

Ultimately, the process should determine the effect of the shark and ray protection relative to what the outcomes would have been without an MPA.[193]

Monitoring and evaluation begins with collection of baseline data on species:

- Diversity and abundance
- Distribution
- Size structure
- Movement and life history
- Mortality.

Some of this information may be available from existing knowledge and studies, and some may need to be gathered in the field.

Data on habitat quality is useful too, to enable monitoring of any degradation in conditions. If possible, data on environmental factors relating to climate change – eg sea temperature, salinity and acidity – should also be collected.[194]

CRITERIA FOR MONITORING AND EVALUATION

The most common method for monitoring the effectiveness of a shark and ray MPA is to compare criteria within it to those in similar geographic areas, before and after implementation. Monitoring is an ongoing process, and it's important to consider what methods and frequency will be most effective in addressing the MPA goals.

Detailed evaluation of the effectiveness or success will depend on the specific goals of the MPA, but commonly used criteria are:

- Abundance
- Average body size
- Biomass.

More complex and less commonly used criteria for populations within the MPA include:

- Adequate reproductive potential
- Recruitment success.

A statistically rigorous approach is best for monitoring and evaluation, like before-and-after-impact control which takes into account factors such as MPA age, size and habitat structure, and fishing pressure.[195]

Alternatively, biological effectiveness and success can be evaluated by comparing data collected in the field with model predictions for criteria such as biomass, fishery yield and trophic level responses.[196]

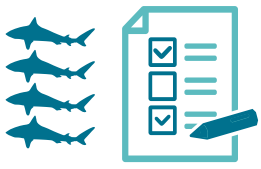
A third approach is to use model simulations to test and predict future outcomes. This is useful for highly mobile species and in large shark and ray MPAs where collection of field data requires considerable time and resources. Simulation models based on individuals can now incorporate complex and dynamic movement data, while population and fishing fleet models help to evaluate MPA effectiveness.[197]

Other monitoring and evaluation criteria that can be applied include:

- Reduced mortality
- Conservation status
- Conservation likelihood.

REDUCED MORTALITY

Reducing mortality from the key threat of overfishing is a critical aspect of shark and ray conservation.[198] The effectiveness of these efforts can be evaluated by measuring the reduction in shark and ray mortality after MPA implementation and over the long term. This criterion relates to more than just target shark and ray fisheries – it should also measure the impacts of non-targeted take mortality from fishing for other species within MPA boundaries.[199] It's also important to estimate the levels of illegal catches of sharks and rays that could be contributing to fishing mortality.[200]



CONSERVATION STATUS

The IUCN Red List of Threatened Species conservation status of sharks and rays is another useful criterion, particularly on a regional or national level. The status of the species within an MPA over time can

be compared to areas outside, and used as a measure of success.

CONSERVATION LIKELIHOOD

Conservation likelihood is a composite index of governance, economics, welfare and human pressure factors that determines how far conservation actions are likely to be successful in a given country.[201] The index uses national measures, so is most useful in measuring the success of large shark and ray MPAs that encompass entire EEZs. The index – and its changes over time – could be compared within and outside these large MPAs.

SOCIOECONOMICS

The socioeconomic effectiveness and success of a shark and ray MPA can be evaluated through criteria including:[202]

- Level of stakeholder participation
- Degree of compliance
- Community perception of success
- Conflict resolution
- Economic benefits.

Nevertheless, it can be challenging to include socioeconomic criteria in scientific analyses. A range of guidelines and tools have been developed which integrate socioeconomic and ecological factors, all of which aim to evaluate the success of MPA management plans. Examples include:[203]

- IUCN guidelines
- Management Effectiveness Tracking Tool
- Management Effectiveness Assessment Tool
- Marine Reserve Evaluation Application

ASSIGN RESPONSIBILITY

It's important to assign clear responsibility for monitoring and evaluation. Will it be done by the national government? Regional government? Local communities? Consider the resources needed, where they'll come from, and who'll be in charge of managing them.

NON-LETHAL MONITORING

Traditional monitoring often involves lethal sampling, such as fishing to capture sharks and rays for identification and size measurements – however, this is unlikely to be appropriate in an MPA.

Alternative non-lethal approaches include:

- Telemetry
- Genetics
- Environmental DNA
- Stable isotope analyses
- Baited remote underwater video systems (BRUVS)
- Underwater visual census (UVC)

WWF's *Rapid Assessment Toolkit for Sharks and Rays* gives practical guidance for using these non-lethal monitoring methods, including information on the type of data each collects, the costs involved, and the required level of expertise. The Toolkit can be used to determine which method – or combination of methods – is best suited to provide information on the species present in a shark and ray MPA.

TELEMETRY AND TAGGING

This is the most commonly used and widely applied method for evaluating the effectiveness of MPAs. Tracking the spatial and temporal movements of tagged individual animals inside and outside an MPA shows how far the protected area overlaps with shark and ray movement patterns.[204]

GENETICS

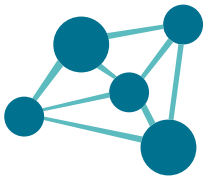
Genetics is used to understand movement over long time periods. Many sharks and rays have long life spans that are beyond the scope of a few years of telemetric study: instead, genetic and genomic analysis can

be used to determine the extent of movement, reproductive mixing and connectivity between populations over large areas and timescales.[205]

ENVIRONMENTAL DNA (EDNA)

This new technique involves the analysis of DNA from water samples, and is a rapid and cost-effective approach to spatial surveys and monitoring of species. It accurately identifies individual shark and ray species, and can efficiently sample them across large spatial and temporal scales. It can also simultaneously identify several species from a single sample, to assess species diversity in an area.[206]

eDNA metabarcoding of water samples from the Caribbean and Pacific Ocean showed that shark diversity was greater within the Bahamas shark and ray MPA than in other unprotected Caribbean areas, and that within New Caledonian waters shark and ray diversity was highest in remote and pristine regions.[207]



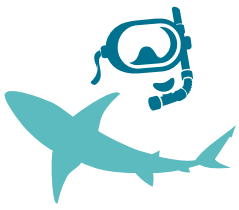
STABLE ISOTOPE ANALYSIS (SIA)

This technique uses a sample of tissue from a shark or ray to determine its prey – not just what it ate recently, but the types of prey eaten over the last six to twelve months[208]. It can reveal novel insights into habitat use and hence is useful for spatial monitoring. For example, while grey reef sharks are observed on many reef slopes in the Pacific; SIA revealed their prey is mostly from adjacent open ocean waters, not from the reef slope.[209]

BRUVS

Baited remote underwater video systems (BRUVS) are used to determine shark and ray species and their sizes in a given area, and to estimate relative abundance between different areas. Since they depend on visual counts from videos of species attracted to a bait they're best in clear waters, and are most useful for monitoring shallow reef species. Stereo BRUVS – with two cameras in place – can be used to measure size.

A global-scale study of shark diversity using BRUVS – FinPrint – is providing open-access data on shark and ray species and abundance from reefs within and outside MPAs around the world. Everyone is free to examine and use this data to build knowledge of shark and ray species in their areas.[210]



UVC

Underwater visual census (UVC) is a simple method of swimming transects to identify shark and ray species in an area. It can be used to assess the diversity, abundance and size of shark and ray populations within and outside MPAs.[211] For larger areas, a manta tow – where a snorkeller is towed behind a small boat – may be useful. Remote operated vehicles with cameras can also be used to move along transects.

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MORE INFORMATION

You can find more information and practical guidance on general MPAs in the following sources, which are also useful for all aspects of shark and ray MPA planning, design and management:

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ACKNOWLEDGEMENTS

A Practical Guide to Effective Design and Management of MPAs for Sharks and Rays **represents the views of the authors to reflect the current state of scientific knowledge related to shark and ray MPAS. It does not necessarily reflect the views of all contributors and reviewers, nor James Cook University and WWF.**

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