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Towards a climate resilient multispecies finfish management plan for Belize

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Notes

Reference to "dollar" and "$" indicate United States dollars, unless otherwise stated.
Reference to "BZD" indicates Belize dollar.
Reference to "hp" refers to the horsepower of fishing vessels.

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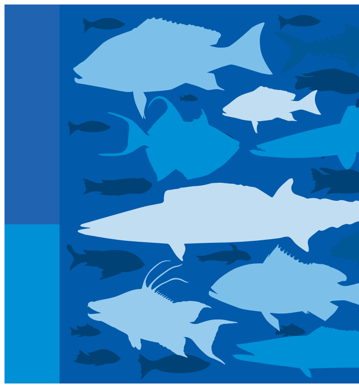

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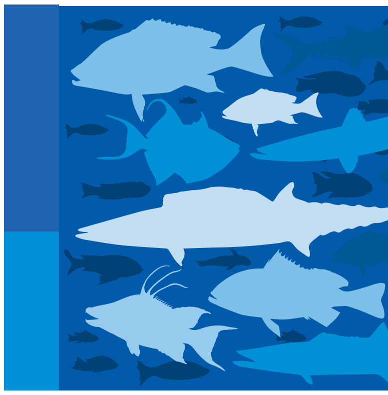
Abbreviations and acronyms

AMF	adaptive management framework
CPUE	catch per unit effort
DOALOS	Division for Ocean Affairs and the Law of the Sea of the Office of Legal Affairs of the United Nations
EDF	Environmental Defense Fund
F_{MSY}	fishing mortality rate that results in maximum sustainable yield
FAO	Food and Agriculture Organization of the United Nations
HCR	harvest control rule
IUU	illegal, unreported and unregulated fishing
L_{opt}	optimal length of harvest
LBAR	mean length
LRP	limit reference point
MAA	Managed Access Area
MCCAP	Marine Conservation and Climate Adaptation Project
MPA	marine protected area
MPA-DR	MPA-density ratio
MSY	maximum sustainable yield
NFPSAP	National Fisheries Policy, Strategy & Action Plan
NGO	non-governmental organization
NTZ	no-take zone
OETS	Oceans Economy and Trade Strategy
PSA	productivity susceptibility analysis
SMART	Spatial Monitoring and Reporting Tool
SPAGs	spawning aggregation sites
TAC	total allowable catch
TRP	target reference point
UNCTAD	United Nations Conference on Trade and Development



Executive summary

This document details a proposal for a national adaptive multispecies finfish management plan for Belize. The plan's development and implementation are initiatives of the Belize Fisheries Department, in compliance with the provisions of the Fisheries Resources Act of 2020[1] and in accordance with the National Fisheries Policy, Strategy & Action Plan (NFPSAP) of Belize and the OETS.

The proposed plan was developed with support from UNCTAD, DOALOS and EDF, and with input and expertise from dozens of stakeholders and international experts who participated in discussions and workshops.

Healthy finfish populations are important to the food security and livelihoods of thousands of Belizeans. Through an adaptive and integrated multispecies management approach, the proposed finfish management plan aims to ensure healthy ecosystems and sustainable use of fishery resources, even as climate change imposes unprecedented impacts. The management plan is based on three prioritized ecological and socioeconomic objectives:

1. sustainability and resilience of food security
2. sustainable economic growth and improved livelihoods
3. abundant finfish populations to support healthy ecosystems.

Thus a successfully implemented finfish management plan will contribute directly to the achievement of Sustainable Development Goal (SDG) 14 and will also support the achievement of SDGs 2, 12, 13 and 17. It responds to international conventions, agreements and guidelines, including the United Nations Convention on the Law of the Sea (UNCLOS), the United Nations Fish Stocks Agreement, the United Nations Ocean Conference 2017 Call for Action, the Code of Conduct for Responsible Fisheries of the Food and Agriculture Organization of the United Nations (FAO), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Biological Diversity (CBD), the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (the SSF Guidelines) and several regional agreements.

The management plan proposal builds upon the existing governance and management framework for the coastal fisheries of Belize, including the Managed Access secure fishing rights programme that was adopted countrywide in 2016. The proposed plan applies an adaptive management framework (AMF), an 11-step decision-making framework already in use for the queen conch and spiny lobster fisheries. The AMF guides the implementation of, or adjustment to, harvest controls based on regular fishery monitoring and a set of pre-determined harvest control rules (HCRs).

For the complex, multispecies finfish fishery, the AMF is augmented with a "fish baskets" approach that simplifies monitoring and decision-making by grouping managed species into baskets. Stakeholders who participated in the plan's development identified 47 finfish target species to include in the plan and grouped these species into 13 baskets based on fishery and species characteristics. Fishery stakeholders also recommended harvest control measures, such as size limits, gear restrictions and closed seasons, that may be appropriate and effective for each basket should additional controls be necessary to achieve fishery goals.

[1] See https://www.nationalassembly.gov.bz/wp-content/uploads/2020/03/Act-No.-7-of-2020-Fisheries-Resources-Act.pdf (accessed 14 November 2021).

The AMF relies on fishery-dependent and fishery-independent data to assess fishery performance, using a set of performance indicators defined by fishery stakeholders: fishery-dependent estimate of average length, previous season total landings, and fishery-independent abundance estimates. Stakeholders designated reference points for each performance indicator, which define when management responses should be applied (i.e., to reduce fishing pressure or to relax harvest controls). The AMF integrates more than a dozen existing data streams and calls for a standardized national data collection system with protocols for fishery-independent and fishery dependent monitoring.

The proposed plan describes the governance and management structure for the multispecies finfish fishery. The Belize Fisheries Department is the only government institution mandated with management responsibility for the finfish fishery. The primary responsibility of the Department is to ensure the sound management, conservation and sustainable use of the finfish resource. The Fisheries Department maintains co-management agreements with three non-governmental organizations (NGOs) which provide support in the monitoring, control and surveillance of fishing activities within their specific marine reserve. The multispecies finfish fishery regulations are enforced by the Conservation and Compliance Unit (CCU), marine reserve personnel, co-management partners and the Belize National Coast Guard (BNCG). Penalties for non-compliance may include fines, suspension or cancellation of a fishing license, or imprisonment.

Under the Fisheries Resources Act of 2020, fishery regulations or amendments to the management plan may be proposed by the Fisheries Administrator with guidance from the Capture Fisheries Unit and in consultation with the Fisheries Council and fishery stakeholders. They may then be submitted to the minister responsible for fisheries for approval (presently the Minister of Blue Economy and Civil Aviation).

Stakeholder input is a key component of decision-making for the multispecies finfish fishery, and the Fisheries Department holds consultations regularly with stakeholders, including fishers, tourism sector representatives, the general public, NGOs, conservation groups and others, on various matters that affect the fishing industry. Inputs and recommendations from the fishing community are taken into consideration in the fisheries management and decision-making process.

The adaptive, participatory, and science-based approach to managing multispecies finfish fisheries in Belize, as articulated in this proposed finfish management plan, is essential for ensuring healthy ecosystems and sustainable, climate-resilient fisheries that support the livelihoods and food security of fishery-dependent communities.

1. INTRODUCTION

1.1 Description of the fishery

The Mesoamerican Reef (MAR) is the world's second largest barrier reef system, spanning 700 miles from the tip of Mexico's Yucatán Peninsula to the Bay Islands of Honduras. Within the MAR lies the Belize Barrier Reef, the longest barrier reef in the northern and western hemispheres, situated along the coast of Belize. The Belize Barrier Reef and the broader MAR system are highly biodiverse and home to many species that are both important sources of food and essential to two major economic sectors in the region: fisheries and tourism (McField and Kramer, 2005; Garcia-Salgado et al., 2008; Muhling et al., 2013). The MAR and the people whose livelihoods depend on it have benefitted from decades of governmental, institutional, and private philanthropic investment focused on the establishment of nearly 50 marine protected areas (MPAs) (McField et al., 2020).

As is the case in many if not most other geographic contexts, however, MPAs alone cannot sufficiently protect the MAR ecosystem, due to their limited spatial scale and the pervasiveness of certain fishing activities. While 7.61 per cent of the territorial sea of Belize and an additional 6.28 per cent of the country's exclusive economic zone (EEZ) are under no-take status (due to the recent expansion of Sapodilla Cayes Marine Reserve) (Belize Fisheries Department, personal communication, 2021), there is a risk of overfishing in unprotected areas in the absence of a well-implemented, well-enforced, science-based FMP. In addition, some degree of illegal fishing undoubtedly occurs within MPA boundaries (Cox et al., 2017). Apart from global climate impacts that threaten all reefs (ICRI, 2013; IPCC, 2014), overfishing is considered the largest anthropogenic threat to reef biodiversity, environmental conservation and the provision of ecosystem services critical to food security, productivity and income generation in the region. As climate change continues to drive warming waters, sea level rise and intensified storms, sustainable management of the finfish fisheries of Belize will be essential for ensuring the resilience of coastal ecosystems and the communities that depend on them for their livelihoods and food security.

High-value lobster and conch fisheries in the region are often prioritized for management, but a significantly greater contribution to coral reef health could be made through the effective management of mixed-species finfish fisheries within the MAR system. This is because most significant ecological cascades in reef systems that result in reef degradation are closely related to the depletion of finfishes (Hughes, 1994; Mumby et al., 2006, 2007; Hughes et al., 2007; Edwards et al., 2013; Ruppert et al., 2013). However, a major barrier to the effective management of finfish in the region – one that has yet to be reliably overcome – is the sheer number of species for which management must account. Even the most up-to-date, data-limited stock assessment approaches are unlikely to be maintained on a species-by-species basis in such a complex and species-rich setting.

Approximately one third of the MAR falls within the territorial sea and management of Belize and actions taken in Belize will continue to play an important role in determining its future state (McField et al., 2015). Belize maintains a network of MPAs and Managed Access Areas (MAAs – areas in which access and fishing activity are closely monitored and controlled) (Figure 1); employs a relatively extensive data collection programme and administers a framework for the assignment of secure fishing rights within MAAs.

In addition, the Managed Access secure fishing rights program (Managed Access Program) in Belize was adopted countrywide in 2016, along with a new, systematic approach to use the best available information – and actively improve the adequacy of information for management – in goal-setting and performance tracking. The new approach is called "the Adaptive Management Framework" (Government of Belize, 2015). Recently, Belize implemented a management plan in the conch fishery based on an AMF that uses fishery performance indicators tied to reference points and predetermined HCRs (McDonald et al., 2017). The spiny lobster fishery is undergoing a similar process, as stakeholders develop an AMF to improve understanding and management of the lobster fishery (Belize Fisheries Department, 2017a, 2017b; McDonald et al., 2017). Draft fishery management plans (FMPs) have now been completed for both (EDF, personal communication, 2021). Thus, there is a strong foundation for expanding the AMF through managed access to address the mixed finfish assemblages of Belize.

Healthy finfish populations are critically important to Belize. Finfish are an important local food source and have traditionally been of local economic importance for Belizeans and tourists, supporting dive tourism and ecotourism, especially in major coastal communities. Finfish are also culturally significant; during holidays they are an important cultural staple, and command high prices. However, a significant challenge remains: harvesting enough finfish to maintain local livelihoods and food security – for which reef-based finfish are especially important – while keeping enough finfish in the water to avoid the serial depletion of vulnerable stocks and preserving ecological function and balance essential to coral reef health in the face of numerous stressors, including climate warming and associated threats.

Currently, management measures related to finfish include species protection, gear restrictions, size limits and seasonal and spatial closures. All persons engaged in commercial fishing should be holders of valid commercial fishing licenses. While licenses are currently not species-specific, the Fisheries Resources Act of 2020 (Part IV, section 10(3)[c])[2] authorizes the Minister to issue licenses for designated commercial fisheries (i.e., lobster, conch and finfish) and non-commercial fisheries.[3] The Fisheries Department plans to implement these licensing designations in the coming years in order to ensure fishing effort can be effectively managed across different target species and uses of fishery resources. In addition, each fisher is required to select up to two fishing areas (MAAs). Since 1982, all fisheries in Belize have been managed through an extensive network of reserves (i.e., MPAs), with imbedded replenishment zones (i.e., no-take areas) (Gibson et al., 2004; Babcock et al., 2015; Karr et al., 2017). These include 13 spawning aggregation sites (SPAGs), in which almost all fishing is banned, with the exception of one where fishing for mutton snappers is allowed via a special license (Burns and Tewfik, 2016), and several national parks (e.g., Laughing Bird Caye) and wildlife sanctuaries (e.g., Swallow Caye) that have protected marine elements (Gibson et al., 2004; Cox et al., 2017; Figure 1). Complementing the SPAGs are MPAs designated as replenishment zones where no fishing is allowed.

Fishing activity for finfish species varies by gear type. Gear used to catch finfish includes beach trap, fish pot, handline, set line, tow line, fly fishing, longline, rod and reel, electric reel, sling, and spear gun while free diving (Ylitalo-Ward, 2016). Handline fishing is used for subsistence fishing, but the handline catch may also be sold locally at landing sites and fish markets. Fishers target snappers, jacks, groupers, grunts and other fish. There are no gear registration requirements or regulations for handlines. Longline fishing targets large pelagic species and sharks. No registration is needed for this type of equipment. Gill nets are banned from the waters of Belize (Government of Belize, 2020). The fishing fleet is composed of 8 to 12 m wooden sailboats, which are equipped with sails and outboard engines (15–40 hp) and carry 6 to 10 fishers for fishing trips that last 6 to 12 days. Each sailboat carries 8 to 10 wooden canoes, which are used by individual fishers to search and harvest finfish, conchs and lobster. The fishing fleet also includes 6–8.5 m skiffs (made of fiberglass or wood) equipped with outboard engines (25–60 hp) and a crew of three fishers; fishing trips last 1 to 2 days (Ylitalo-Ward, 2016).

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[2] See https://www.nationalassembly.gov.bz/wp-content/uploads/2020/03/Act-No.-7-of-2020-Fisheries-Resources-Act.pdf (accessed 3 December 2021).

[3] While the authority to manage commercial and non-commercial fishery resources (including sport fisheries) is a mandate of the Fisheries Department, the licensing regime for sport fisheries is under the jurisdiction of Belize's Coastal Zone Management Authority and Institute (CZMAI).

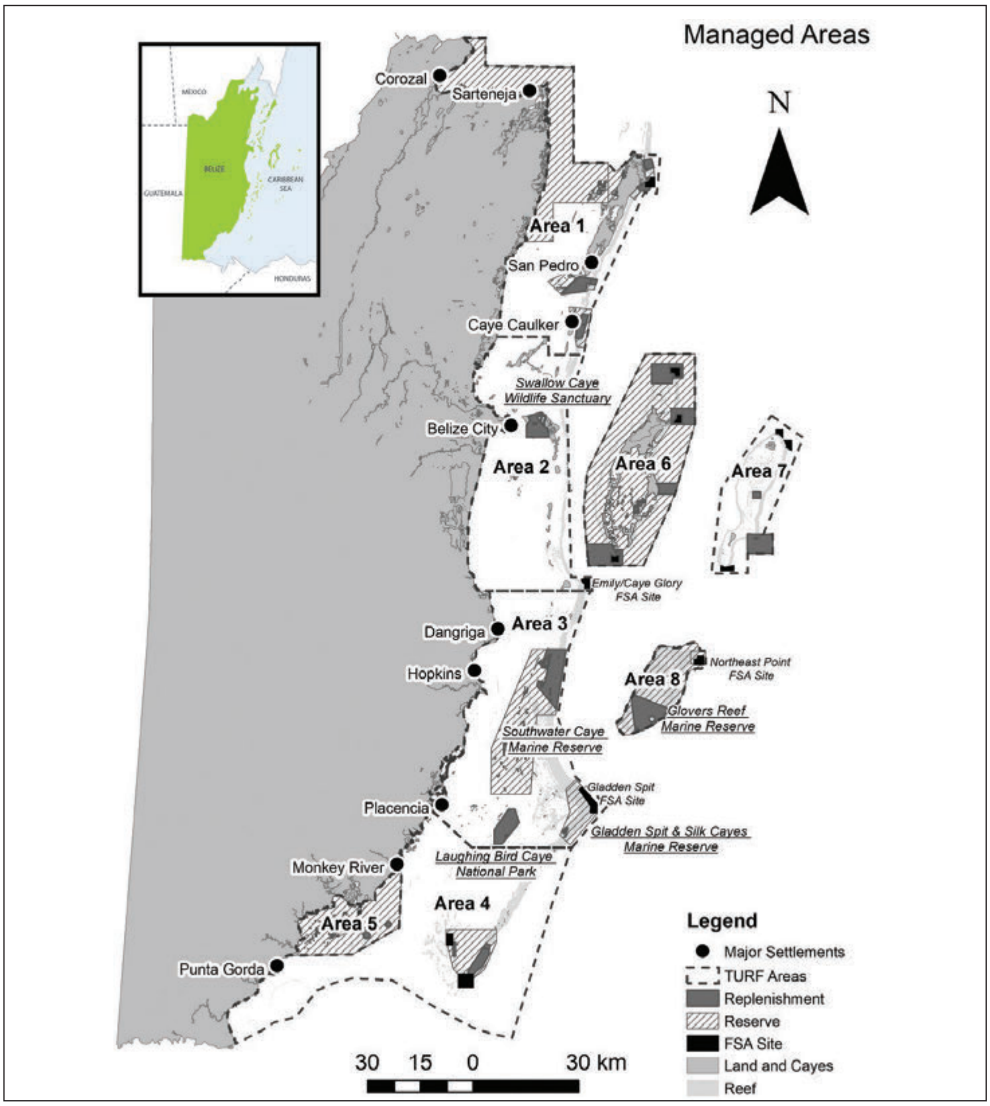


Figure 1. Map of Managed Access Program fishing areas, including territorial use rights for fisheries (TURF) zones, i.e., MMAs, marine reserves and associated replenishment zones, fish SPAGs and wildlife sanctuaries.

Source: Tewfik et al., 2020a.

The finfish fishery is dominated by men, but as of January 2017, there were 47 women registered by the Fisheries Department, of whom 85 per cent were crew members. There are limited data on the number of women processors, vendors and fish scalers. Surveys of women in fisheries indicate that many of them (62 per cent) are unwilling to form or join fisher organizations (MCCAP & WCS, 2017).

Southern fishing grounds are principal fishing areas for finfish. Snapper species and groupers such as red hind ("jimmy hind") (*Epinephelus guttatus*) are targeted in the outer barrier reef slope at spawning aggregation peak times, while species such as silk snappers (*Lutjanus vivanus*), mackerel (*Scomberomorus* spp.) and jewfish (*Epinephelus itajara*) are targeted closer to the coast. In 1998, yellowtail snapper (*Ocyurus chrysurus*), mutton snapper (*Lutjanus analis*), lane snapper (*Lutjanus synagris*), cero mackerel (*Scomberomorus regalis*) and crevalle jack (*Caranx hippos*) were within the top landed finfish in southern Belize (Heyman and Graham, 2000). In 2011, approximately 26 main fishing grounds were identified according to the volume of fish harvested. They included the area south of Punta Gorda, Sapodilla Cayes Marine Reserve, and areas northward towards Ranguana Caye and other boundaries of Gladden Spit and Silk Cayes Marine Reserve (CZMAI, 2014). Today, these fishing areas are MAAs under the national Managed Access Program. According to the Belize Fisheries Department annual report (2018), there are eight MAAs (with a ninth area optional for deep sea fishing). MAA 3 has the most registered fishers, while MAA 5 has the least (Table 1).

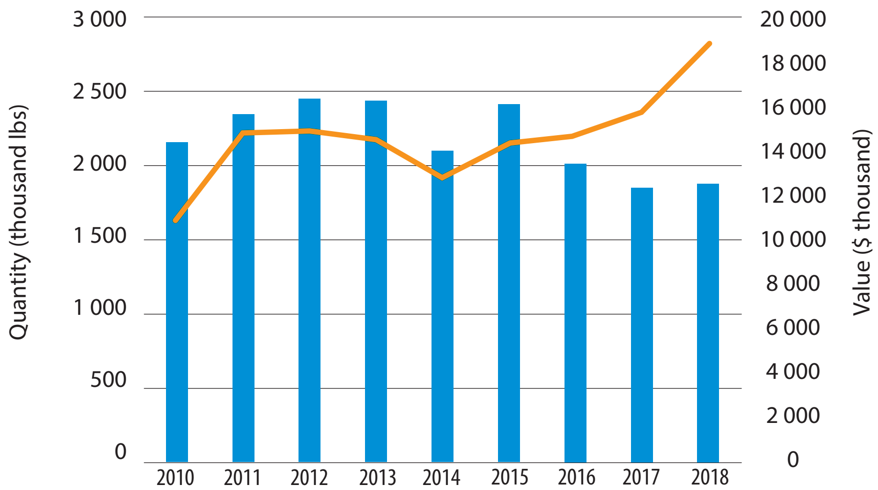
Table 1. Estimated number of fishers in each Managed Access Area

Managed Access Area	Number of fishers
1	481
2	829
3	1 048
4	558
5	106
6	850
7	516
8	176

Source: Author's compilation, 2021.

Between 2010 and 2019, capture fisheries in Belize were relatively stable (Figure 2), with the total value of wild caught fisheries exports estimated to be BZD 42,390,000. Finfish exports were valued at BZD 265,110 and totalled 85,120 lbs in 2018 (Belize Fisheries Department, 2018a). Finfish have primarily been exported by the Jamaica-based company Rainforest Seafoods.[4] As shown in Figure 3, Jamaica is the main importer of Belizean finfish, specifically for whole fish (*Lutjanus* spp. and several other finfish species; Figure 4, Annex 1). Finfish are also sold in domestic markets, with sales closely linked to the tourism sector, as fishers supply hotels and restaurants in their communities. The OETS outlines key trade issues, including a decrease in exports over the past five years, increased fishing pressure on spiny lobster and queen conch, and the need to identify additional and niche markets for marine and seafood products from Belize (UNCTAD, 2020). Strategies to address these trade issues, while not directly addressed by this management plan, are essential complementary activities to achieve finfish fishery goals. These strategies include, for example, supporting increased exports of finfish products, implementation of sanitary and phytosanitary measures at fish markets and landing sites, and the application of technological tools and certification programmes to increase market access (UNCTAD, 2020).

Figure 2. Total national exports in capture fisheries, 2010–2018



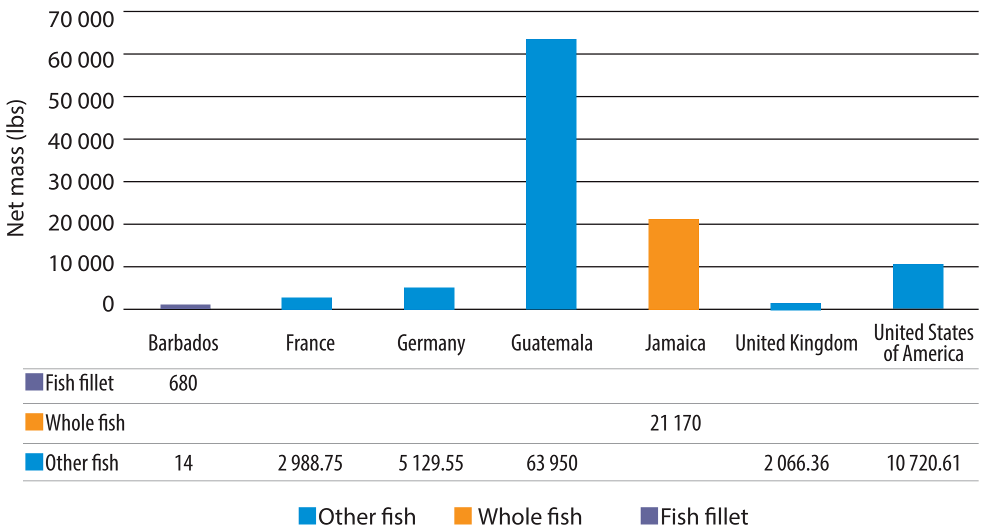
	2010	2011	2012	2013	2014	2015	2016	2017	2018
Quantity (thousand lbs)	2 150	2 335	2 434	2 430	2 084	2 397	2 004	1 843	1 864
Value ($ thousand)	10 894	14 727	14 804	14 447	12 632	14 241	14 647	15 617	18 627

Data source: Statistical Institute of Belize (SIB), 2019. *Figure source*: UNCTAD, 2020.

Notes: aggregated – spiny lobster, queen conch, finfish, fish fillet, ornamental fish and crab. Values were extracted from the export breakdown provided by the SIB. Quantity and values reported exclude the shrimp and aquaculture sector.

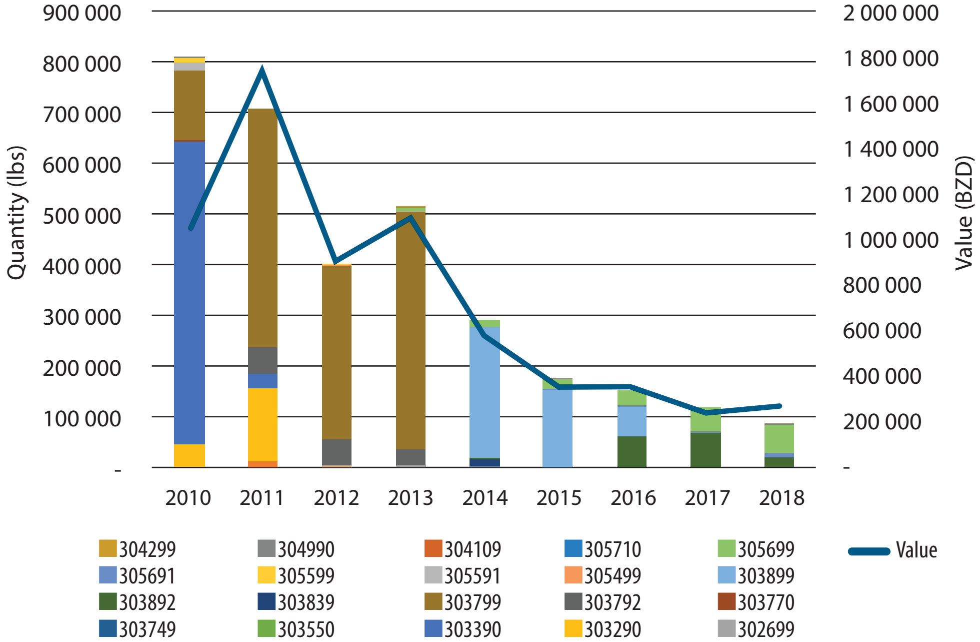
[4] See https://rainforestcaribbean.com/ (accessed 2 December 2021).

Figure 3. Finfish importers in Belize in 2018



Data source: Belize Fisheries Department, 2018b. *Figure source*: UNCTAD, 2020.

Figure 4. Finfish export breakdown, 2010–2018



Source: UNCTAD, 2020.

Note: Finfish categories do not include farmed species such as tilapia. The HS codes in the legend have undergone two revisions within the time frame reported and therefore grouping and categories may change. See list of HS codes for finfish in Annex 1.

1.2 Description of the resource

Ecosystem health assessments of the MAR have been conducted periodically since 2008. According to the 2020 MAR report card (McField et al., 2020), the Reef Health Index (RHI) ranked Belize as "Good" (3.0). The Southern Barrier Complex, the Central Barrier Complex, and the Lighthouse Reef received good health status for Belize. The Southern Barrier Complex, a sub-area which includes the lagoon and reef southward of Placencia, as well as Laughing Bird Caye National Park, Gladden

Spit and Silk Caye Marine Reserve, and Sapodilla Cayes Marine Reserve, have the best regional value for commercial fish (Table 2).

Table 2. Estimated Reef Health Index scores and commercial fish density in each subregion of Belize

MAA	RHI subregion	Reef Health Index	Commercial fish g/100 m²
1	Northern Barrier Complex	Poor/2.3	493
2	Central Barrier Complex	Fair/3.0	845
3			
4	Southern Barrier Complex	Fair/3.3	1 575
5			
6	Turneffe	Poor/2.5	505
7	Lighthouse Reef	Fair/3.0	614
8	Glovers Reef	Fair/2.8	465

Source: McField et al., 2020.

Fishery-dependent monitoring within MPAs is focused on key conservation targets, which can be a combination of ecosystem, species and species assemblages. These are identified through the development of management plans for each MPA via a conservation action planning process. Commercial species (conch, lobster and finfish) and non-commercial species were identified as conservation targets across all marine reserves. Thus, managers and co-managers have invested resources in monitoring the status of these species. On an annual basis, staff of the MPAs conduct commercial species monitoring using the Mesoamerican Barrier Reef System (MBRS) protocol to determine abundance and density of reef fish species. Monitoring of spawning aggregations is done from December to June using underwater visual census surveys. Catch data are collected from fishers aboard their fishing vessels and at key landing sites in various communities and fish markets.

Ongoing data collection efforts are essential for understanding and quantifying local fishing activity, fisheries production and exports. One mechanism to increase understanding of finfish landings is the Spatial Monitoring and Reporting Tool (SMART) data collection system (Tewfik et al., 2020b) (additional finfish data collection efforts are described in Section 5). Data analyses of the SMART fish landings from February 2017 and June 2019 (17,369 finfish or 77 per cent of the observations) identified more than 100 species of fish. The top 30 species represented 92 per cent of total abundance. They come from 36 families (11 for the top 30 species) and were landed from seven MAAs (Figure 5). The snappers (Lutjanidae) dominated landings (44 per cent), followed by mojarras (Gerridae), while traditionally used groupers (Serranidae) (2 per cent) ranked very low. Traditionally landed larger species – cubera snapper (ranked 30th), black grouper (ranked 45th) and Nassau grouper (ranked 64th) – were low ranking in total abundance and mostly immature. Most communities (Belize City, Caye Caulker, Placencia and Punta Gorda) were dominated by landings made by lines, while both Corozal and Dangriga appeared to rely heavily on gillne*ts* (46 per cent and 47 per cent respectively) (Figure 6).

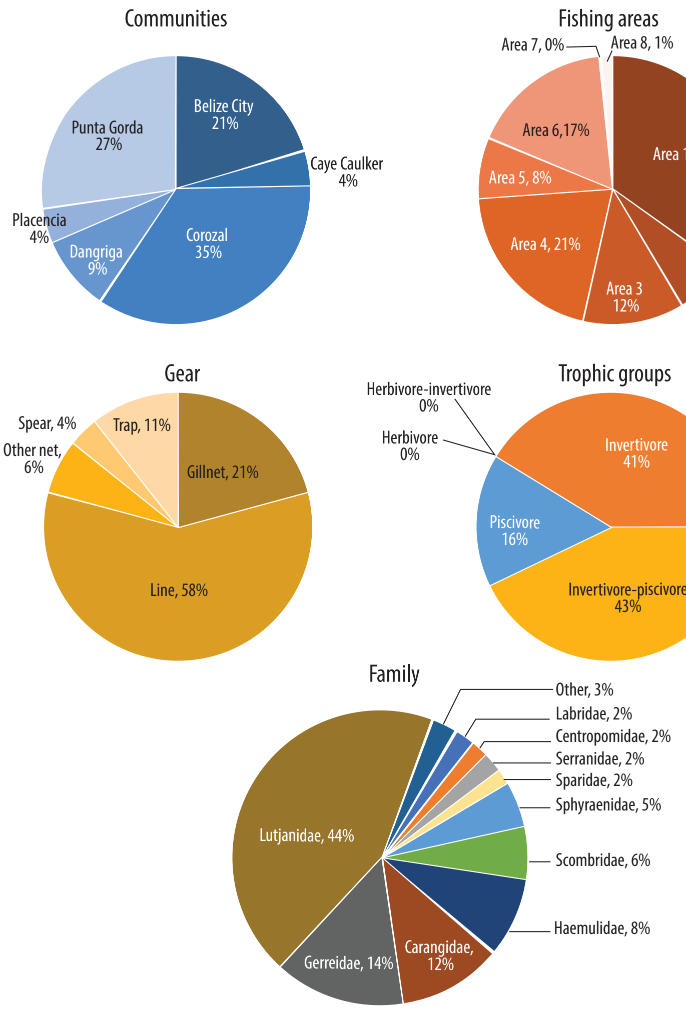


Figure 5. Overview of fish landings collected by Spatial Monitoring and Reporting Tool data collection system (February 2017 and June 2019)

Source: Tewfik et al., 2020b.

Note: 17,369 finfish or 77 per cent of the observations represented. Observations are presented by community, fishing area, gear, trophic groups and family. Zeros represent values of less than one but not zero.

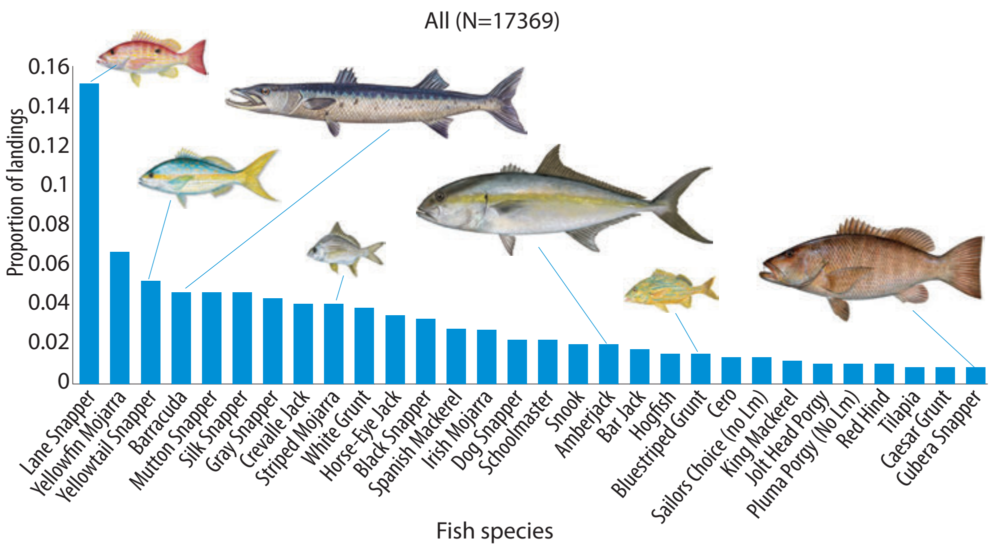


Figure 6. Proportion of Spatial Monitoring and Reporting Tool landings of the top 30 species across all community sites representing 91.8 per cent of abundance for scale fish landings

Source: Tewfik et al., 2020b.

Note: Highest, lowest and representative species highlighted.

Several fishery regulations have been put in place across Belize to protect exploited finfish species. These include: a ban on the use of SCUBA to collect any seafood; prohibitions on gears such as spear guns, nets, longlines, fish traps, and beach traps within marine reserves; closed seasons for the critically endangered Nassau grouper (*Epinephelus striatus*; 1 December to 31 March); size limits for Nassau grouper (50 to 76 cm total length), as well as a complete ban on the harvest of scarids (parrotfish) and acanthurids (tang/surgeonfish/doctorfish). Nassau grouper must be landed whole; all fish landed as fillets must include a skin patch (5 × 2.5 cm) for species identification to prevent circumvention of this rule. Permit (*Trachinotus falcatus*), tarpon (*Megalops atlanticus*), and bonefish (*Albula vulpes*) may not be landed but are important for recreational catch-and-release fishing associated livelihoods. Shark fishing is allowed via a special license during open season from 1 November to 31 May[5] of the following year. However, nurse sharks (*Ginglymostoma cirratum*) and whale sharks (*Rhincodon typus*) are completely protected. The Belize Fisheries Department currently has no regulations regarding total allowable catch (TAC) of finfish.

As a key element of the implementation of the Fisheries Resources Act of 2020, Belize will introduce its first science-based multispecies fishery management system aimed at producing good yields while concurrently protecting coral reef ecosystem integrity. The FMP will be based on 47 managed species (Annex 2), as identified by multistakeholder workshops held in March 2020 and June/July 2021.[6] The development and implementation of the management plan will be conducted in compliance with the provisions of the Fisheries Resources Act of 2020, including but not limited to the specifications set forth for fisheries management plans in Section 10. Science-based management is expected to improve the performance of the country's fisheries against ecological and socioeconomic goals, as it has in many other fisheries, and serve as a model for the management of other fisheries in the MAR and throughout the tropics.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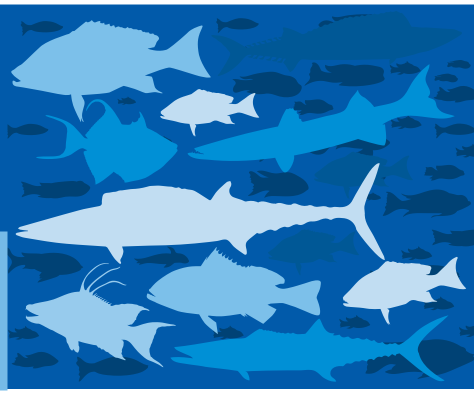
5 The closed season for shark fishing was recently extended through Statutory Instrument 128 of 2021.

6 The March 2020 workshop was led jointly by Belize Fisheries Department and Turneffe Atoll Sustainability Association (TASA) with support from EDF. The June/July 2021 hybrid workshop was a joint activity of UNCTAD, DOALOS, the Belize Ministry of Blue Economy and Civil Aviation, Belize Fisheries Department, the Directorate General for Foreign Trade and EDF. Additional information is available at https://unctad.org/meeting/workshop-adaptive-multispecies-finfish-management-belize (accessed 2 December 2021).

2. POLICIES AND LEGISLATION



2.1 National policies relevant to finfish management

The management of a fishery should initially be guided by its fishery policy, which articulates goals and objectives that indicate precisely what the fishery is expected to achieve. According to FAO (1997), fisheries policy and planning require information related to the importance of fisheries in terms of economics, employment and food production. The finfish fishery of Belize has been regulated by the implementation of a few statutory instruments that focus on the species-specific closed season, size limit, gear restriction, banning, and spatial closure of SPAGs. Prior to 2018, there existed no formal national policy or management plan that articulated the goal and objective for the sustainable management of the finfish fishery. However, a NFPSAP was developed in 2019 and endorsed by the Government of Belize.[7] The NFPSAP consists of five policy priority areas and ten policy statements and is now the guiding framework for the Fisheries Department to fulfil its mandate. It is consistent with and complementary to other national policies and international and regional commitments and agreements related to the fisheries sector. Overarching principles that guide the NFPSAP are as follows:

- Fisheries and mariculture development are a critical pillar of the Belizean economy.
- Fisheries are deeply rooted in the culture and social fabric of Belize.
- The development of the fisheries sector must be founded on relevant research, scientific advice and expertise, and be guided by best practice standards that are sensitive to gender and vulnerable groups.
- Equitable access to and use of fisheries resources is only possible with active private sector participation and community stewardship.
- The ecosystem approach and the precautionary principle govern all fisheries management interventions.
- An appropriately structured and relevant fisheries governance regime that is built on transparency and accountability is indispensable for the sustainability of the fisheries of Belize.

The mission of the NFPSAP is to achieve sustainable fisheries management and development through improved governance, research, private sector participation, community stewardship and effective enforcement and compliance. Thus, it outlines five policy priority areas which are as follows:

- Policy priority area 1: conservation and management of fish and ecosystems
- Policy priority area 2: research and development of the fisheries sector
- Policy priority area 3: enforcement and compliance
- Policy priority area 4: capacity building and knowledge management
- Policy priority area 5: fisheries governance.

[7] A copy of the NFPSAP is available upon request from Belize Fisheries Department.

Each priority area has respective policies (Table 3) that encompass adaptive management, the ecosystem approach, climate change, blue economy and the involvement of women in fisheries as key pillars. It is responsive to the development challenges and opportunities faced by the fisheries sector, and in particular the need to improve the sustainable production of fish for food security and income generation. This is aligned with the social, biological and economic objectives for the management of the multispecies finfish fishery.

Table 3. Policy priorities of the National Fisheries Policy, Strategy and Action Plan

Priority area	Policies
Conservation and management of fish and ecosystems	(1) Fisheries priority areas and aquatic reserves must be identified, designated and managed to better bridge the gap between biodiversity conservation and food security. (2) Management plans and regimes are critical tools for optimizing the effectiveness of fisheries priority areas and aquatic reserves.
Research and development of the fisheries sector	(1) Management research, fisheries research and bioprospecting are foundational pillars of the fisheries sector. (2) Development of the fisheries value chain and blue economy is critical for the economic development of Belize.
Enforcement and compliance	(1) Effective enforcement and compliance rely on community stewardship of the sector and socially acceptable protocols and norms. (2) Fisheries enforcement efforts must be context suitable and involve the most relevant and best available tools and technology.
Capacity building and knowledge management	(1) Capacity building and knowledge management are indispensable for optimum performance and the achievement of fisheries management goals.
Fisheries governance	(1) The Fisheries Department must be structured and strengthened to ensure effective implementation of the Fisheries Act, oversee the development of the sector, and ensure compliance with international commitments. (2) Fisheries governance in support of sector development and diversification is not possible without assertive and effective private sector and civil society participation. (3) Fisheries governance best practice must embrace and make effective obligations and commitments acquired under international and regional agreements.

Source: ID&M, 2019.

The policy priorities align with the OETS, an action plan developed in consultation with UNCTAD, DOALOS and the Government of Belize to realize the full potential of the oceans economy sectors.[8] The intended outcomes of the plan's implementation include (UNCTAD, 2020):

1. increased capacity of stakeholders in ocean-based economic sectors by creating an enabling environment for research and development
2. economic resilience through the diversification of fisheries and seafood production by identifying opportunities for market access
3. overall sustainable economic growth in ocean-based economic sectors, thus improving livelihoods of those involved directly in the oceans economy
4. production of high-quality marine products through value-added options
5. enhanced synergies with ongoing projects, national plans, strategies and policies of Belize.

The multispecies finfish management plan is a key action that contributes to the objectives of the NFPSAP and the OETS. The implementation of the strategies and actions of priority area 2 (Research and development of the fisheries sector) should contribute to the improved management of the finfish fishery of Belize (Grant, 2019). Policy priority area 2 supports management research, fisheries research and bioprospecting with the strategic objectives to:

[8] See https://unctad.org/system/files/official-document/ditctedinf2020d5_en.pdf (accessed 2 December 2021).

- conduct research on a systematic basis to inform management decision-making in support of species diversification
- the identification of new economic opportunities
- improvements in management and the overall sustainable management of fisheries resources.

This includes the development of species-specific management plans for finfish and the development of an action plan for the identification, feasibility assessment and sustainable exploitation of deep-slope species and pelagic species in the EEZ.

2.2 Specific management measures for the finfish fishery

This finfish FMP provides a framework by which management measures may be defined for 47 finfish species based on the AMF (as detailed in Section 7).[9] New management measures may complement current management measures in order to meet the objectives defined herein. Current regulations pertaining to finfish include:

- Nassau grouper (*Epinephelus striatus*):
  - closed season – 1 December to 31 March inclusive of any year
  - no person should have Nassau grouper less than 20 inches in total length or greater than 30 inches in total length
  - shall be landed whole
- Prohibition for all scheduled species under the Fisheries Resources Act of 2020 (Part XIX, section 88(1)),[10] including the following finfish:
  - parrotfish (Scaridae, all species)
  - surgeon fish (Family: Acanthuridae, all species)
  - angel fish (Family: Pomacanthidae, all species)
  - triggerfishes (Family: Balistidae, all species)
  - whale shark (*Rhincodon typus*).
  - nurse shark (*Ginglymostoma cirratum*)
  - sawfish (*Pristis perotteti* and *Pristis pectinate*)
  - rays (all species of rays of the superorder Batoidea)
- Fish fillet:
  - all fish fillet must have a skin patch of 1 inch by 2 inches
- Sportfishing:
  - must not have in possession tarpon, bonefish and permit (catch and release only).

Gear such as spear guns, nets, longlines, fish traps and beach traps are not allowed in marine reserves. The use of SCUBA for fishing is prohibited. Fishers engaging in commercial fishing should hold valid licenses.

Fisheries regulations will continue to be enforced by the CCU of the Belize Fisheries Department at a countrywide level. The personnel who manage the MPAs and co-management partners are also authorized to enforce the fisheries regulations. The enforcement of regulations plays an important role in the management of the finfish fishery because it helps to ensure compliance by fishers and other stakeholders, and deters illegal fishing.

The ecosystem-based management (EBM) system applied in the finfish fishery consists of a network of eight marine reserves scattered along the coast of Belize; these provide protection, suitable ecosystems and feeding and reproductive grounds for juvenile and adult finfish. The management

9 Specific options for harvest control measures are proposed in Table 10.

10 See https://www.nationalassembly.gov.bz/wp-content/uploads/2020/03/Act-No.-7-of-2020-Fisheries-Resources-Act.pdf (accessed 3 December 2021).

of people and ecosystem services – core principles of EBM – is further strengthened through the application of a Managed Access Program, which has been introduced as a management tool in the marine reserve system and helps to control fishing effort in finfish fisheries. The overall goal is to ensure sound management, conservation and sustainable use of the fisheries resources.

2.3 Legal structure for management and monitoring, control and enforcement

The legal framework under which the management of the fishery is regulated is the Fisheries Resources Act of 2020. The Fisheries Act Chapter 210[11] was amended and became the Fisheries Resources Act, effective 1 February 2020. New regulations under the Fisheries Resources Act of 2020 have not been finalized and thus regulations under the Fisheries Act Chapter 210 remain valid. The Fisheries Resources Act of 2020 embraces the principles of the ecosystem approach to fisheries, uses a precautionary approach and requires FMPs which focus on biodiversity targets and the social and economic needs of fishing communities. The Fisheries Resources Act of 2020:

- establishes a/the Fisheries Council
- provides for the determination and thereafter the establishment of TAC for any fishery
- can determine management plan(s) for each fishery or category of fisheries
- makes determinations for fishery areas and reserves, including inland
- establishes co-management agreements by law
- outlines licensing policy for foreign and local fishing based on region and fishing type
- establishes regional cooperation and access agreements in fisheries
- establishes fisheries port measures
- provides for scientific research and mariculture operations
- provides for monitoring, control and surveillance by Fisheries Officers
- increases fines and penalties
- improves the process for evidence handling and administrative proceedings.

The Fisheries Resources Act of 2020 (Part XIV, sections 43 to 48) gives Fisheries Officers the following powers within Belize and its waters:

- power of entry and search
- provision for Officers to question persons and require them to produce documents as stipulated by Officers
- power of arrest
- power to give directions to a master of a vessel
- the power to use reasonable force and conduct seizures.

2.4 International conventions and agreements of relevance to the finfish fishery

This finfish management plan serves to advance the SDGs[12] in Belize, including but not limited to SDG14,[13] which calls for conservation and sustainable use of the oceans, seas and marine resources

[11] For more information on the Fisheries Act, Chapter 210, see http://www.ilo.org/dyn/natlex/docs/ELECTRONIC/91370/105936/F-1807763038/BLZ91370.pdf (accessed 3 December 2021).

[12] For a complete list of SDGs, see https://sdgs.un.org/goals (accessed 2 December 2021).

[13] For an overview of SDG14, see https://sdgs.un.org/goals/goal14 (accessed 2 December 2021).

for sustainable development. It contributes indirectly to SDGs 2, 12, 13 and 17: zero hunger; responsible consumption and production; climate action; and partnerships, respectively.

Fisheries management in Belize complies with international conventions, agreements and guidelines including:

- UNCLOS,[14] which serves as an overarching legal framework for sustainable fisheries under international law
- the 1995 United Nations Fish Stocks Agreement,[15] a detailed legal regime for the conservation and management of straddling and highly migratory fish stocks
- the United Nations Call for Action (Ocean Conference 2017), paragraph q[16]
- the 1995 FAO Code of Conduct for Responsible Fisheries[17]
- the 1973 CITES[18]
- the CBD[19]
- regional agreements such as those under the Western Central Atlantic Fishery Commission (WECAFC),[20] the Central American Integration System (SICA),[21] the Organization of the Fisheries and Aquaculture Sector of Central America (OSPESCA),[22] and the Caribbean Regional Fisheries Mechanism (CRFM)[23]
- the SSF Guidelines,[24] the first internationally agreed instrument dedicated entirely to the small-scale fisheries sector.

The Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (WCR) is the only legally binding regional environmental treaty for the WCR. The Convention, referred to as the Cartagena Convention, constitutes a legal commitment by countries to sustainably protect and manage their common coastal and marine resources individually and jointly. The Cartagena Convention and its protocols enhance not only protection but also development, as specifically noted in its provisions. For example, the Protocol for Specially Protected Areas and Wildlife (SPAW Protocol) promotes the use of the ecosystem approach to conservation. The Belize Fisheries Department has progressively established a coastal marine reserve network which, in combination with the recently introduced Managed Access Program in the MPAs seeks to sustainably manage important marine ecosystems and the organisms that inhabit them, while at the same time manage the fishing effort that is applied by commercial fisheries within these protected areas. Belize is considered a pioneer and leader in marine ecosystem conservation and fishery resource management and sustainable use in the Caribbean and Central American regions.

Furthermore, the Caribbean Community Common Fisheries Policy (CCCFP) states that participating parties should collect and compile catch and effort, biological, ecological, economic, social and aquaculture data. The CCCFP also states that participating parties should determine the potential of underutilized and unutilized fisheries.

14 For the complete UNCLOS, last updated in 2016, see https://www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm (accessed 2 December 2021).

15 For the UN Fish Stocks Agreement, see https://www.un.org/depts/los/convention_agreements/texts/fish_stocks_agreement/CONF164_37.htm (accessed 2 December 2021).

16 For more information, see https://oceanconference.un.org/callforaction (accessed 3 December 2021).

17 See www.fao.org/3/v9878e/V9878E.pdf (accessed 3 December 2021).

18 For more information on CITES, see https://cites.org/eng/disc/text.php (accessed 2 December 2021).

19 For more information on CBD, see https://www.cbd.int/ (accessed 2 December 2021).

20 https://www.fao.org/fishery/en/global-search?q=rfb%20wecafc&lang=en (accessed 3 December 2021).

21 https://www.sica.int/sica/vista_en.aspx (accessed 3 December 2021).

22 https://www.fao.org/fishery/en/global-search?q=rfb%20ospesca&lang=en (accessed 3 December 2021).

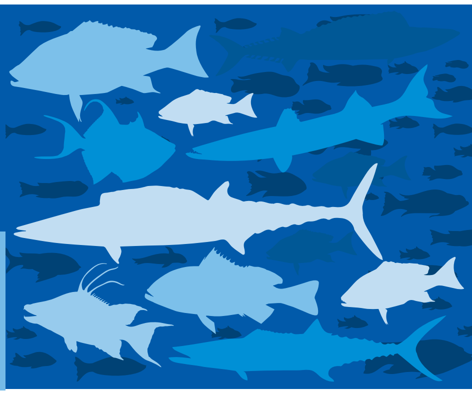
23 https://www.crfm.int/ (accessed 3 December 2021).

24 See www.fao.org/3/i4356en/I4356EN.pdf (accessed 3 December 2021).

The SSF Guidelines place a high priority on the realization of human rights and the need to attend to marginalized groups. Section 8 of the SSF Guidelines speaks to gender equality. A survey instrument focused on gender and gender equality in the fisheries sector was administered to 78 women in the fisheries value chain in Belize. While most respondents agreed with the SSF Guidelines on gender, many suggested that more should be done to ensure that women and men in the fishing industry have equal rights and opportunities. An action plan was developed to mainstream gender in the daily activities of government departments, NGOs and projects (MCCAP and WCS, 2017).

It is recommended that the overarching goals and objectives should be operationalized by developing management plans and strategies. Therefore, the fisheries policy should be translated into goals and the goals into objectives that indicate precisely what is expected to be achieved from the fishery. Consequently, there is an urgent need to operationalize the finfish fishery policy and management plan that would guide the optimum utilization of the fishery, while contributing to the implementation of the principles of the ecosystem approach to fisheries.

3. MULTISPECIES MANAGEMENT AND FISH BASKETS APPROACH



3.1 Description of multispecies management approach

This FMP applies a multispecies approach in recognition of the need for, and the ecological and socioeconomic benefits of, a holistic management strategy of commercial fisheries, non-commercial fisheries and mariculture, especially in the face of climate change. This management plan aims to support the needs of commercial and non-commercial fisheries, recognizing ongoing mariculture activities for several of the species managed by this plan. The Belize Fisheries Department is currently developing a National Mariculture Policy (ID&M, 2021),[25] which aims to position mariculture development in the Belizean economy to meet growing demand for mariculture products and as a source of community livelihood, through strengthened regulatory and institutional frameworks, market and capacity development, and the use of climate-smart technologies and best practices. It is expected that the mariculture policy and associated management actions will complement the management approaches and provisions set forth in this finfish management plan.

The Belize finfish fishery, like many fisheries around the world, is a multispecies fishery, meaning that multiple species are caught at the same time. While some species are targeted more than others, many species are caught together with the same gears and are thus caught at the same rate. This presents a challenge for sustainable management because some species are productive enough to withstand high catches while others are not. Low productivity species become overfished, reducing overall yield, markets for diverse species, and economic and ecological resilience. This is called "serial depletion". Low productivity species are often called "weak stocks" – they are the ones that are vulnerable to current levels of fishing effort and exploitation in multispecies fisheries.

Ideally, multispecies fisheries management should strive not only to produce good yields from single stocks, but also to avoid serial depletion and prevent adverse impacts of fishing on marine ecosystems. Historically, management of multispecies fisheries has often focused on only one or two target species (i.e., species that are economically or biologically important). This approach typically fails to protect weak stocks and generally provides inadequate ecosystem protection because ecosystem health depends on all species staying abundant enough to play their ecological roles, whether they are small grazers like damselfish or big predators like sharks (Hughes, 1994; Mumby et al., 2006, 2007; Hughes et al., 2007; Edwards et al., 2013; Ruppert et al., 2013). Management that focuses on protecting weak stocks has its own challenges. For example, managers typically must close an entire multispecies fishery when the allowable catch levels for weak stocks are exceeded. As a result, the fishing opportunities for target stocks are eliminated, resulting in poor economic yield. Additionally, this type of weak stock management requires high levels of technical capacity and data richness that are lacking in most of the world's fisheries. An effective multispecies approach balances the trade-offs between target species management and protections for weak stocks.

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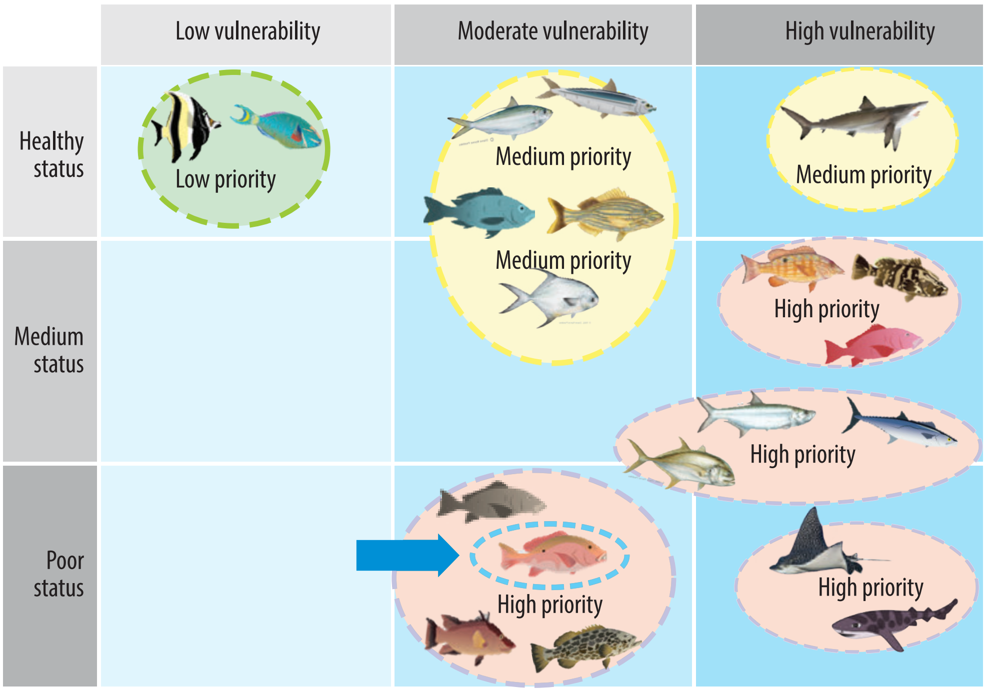
[25] The National Mariculture Policy, currently in draft form, addresses activities defined as "mariculture" under the Fisheries Resources Act of 2020 (Part II, section 2).

When data are limited and many species are caught together in the same gear type, common multispecies management strategies are not practical. To overcome these challenges, the Belize multispecies finfish fishery applies an AMF with a "fish baskets" approach, which groups species into management groupings (or "baskets") according to fishery and species characteristics (Karr et al., 2021). Stakeholders define fish baskets based on a rapid estimate of the vulnerability and depletion/health status of all the stocks in a multispecies fishery using data-limited methods. The species are then sorted by these two measures, creating initial baskets of groups of species with similar vulnerability[26] and health status[27] characteristics for management (see Figure 7 for an illustrative example). For example, one group would be made up of species that are highly vulnerable to fishing and are already depleted; another would be made of species that have low vulnerability to fishing and are healthy, and so on. These baskets would then need further refinement by stakeholders based on how the species are caught, risk tolerance of serial depletion, commercial value, etc.

Once stakeholders determine the appropriate fish baskets for the groups of species in their fishery, they can choose an indicator species with life history and/or vulnerability characteristics that are typical of the basket. The indicator species becomes the species that is assessed; the fishing mortality target is monitored and then applied to the rest of the species in the category. This greatly simplifies multispecies management. For example, the Belize multispecies finfish fishery that is focused on 47 species becomes a management plan focused on 13 fish baskets. It is anticipated that this management approach will reduce the risk of serial depletion (because fishing would be highly restricted or banned for vulnerable stocks that are already depleted) and ecosystem collapse (by maintaining a good mix of species at healthy levels within the ecosystem) while generating "pretty good yield"[28] (because catch rates could be higher on stocks that are not as vulnerable to overfishing and are at healthy abundance levels).

Figure 7. Theoretical prioritization of fish management baskets and an indicator species for a single basket



Source: EDF, 2021a.

26 Vulnerability estimates the relative risk or vulnerability of a stock to being overfished, based on the productivity of the species and the susceptibility of the stock to the fishery. Vulnerability is most often assessed using the productivity and susceptibility analysis model (Patrick et al., 2009) and which produces vulnerability scores for each species that are characterized as low, medium or high. For further guidance on vulnerability assessment see: http://fishe.edf.org/framework/step-4-stock-vulnerability-assessment.

27 The status of a stock determines whether target stocks are currently overfished and if so, by how much (EDF, 2021a).

28 Pretty good yield identifies a range of harvest policies that provide good yield while also producing other desired outputs, be they biological or economic (Hilborn, 2010).

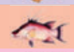
3.2 Fish baskets for finfish management in Belize

Fish baskets for Belize (Table 4; Figure 8) were developed based on stakeholder knowledge and monitoring data from MPA co-managers in two workshops – the first in March 2020 and the second in June/July 2021. In March 2020, the Belize Fisheries Department and representatives from Bacalar Chico Marine Reserve, the Port Honduras Marine Reserve, Glover's Reef Marine Reserve, Turneffe Atoll Marine Reserve, Gladden Spit and Silk Cayes Marine Reserve, South Water Caye Marine Reserve, the Corozal Bay Wildlife Sanctuary and the University of Belize's Environmental Research Institute identified 45 finfish targets to include in the multispecies management plan. Current finfish targets do not include sharks because sharks fished within the waters of Belize have a separate management plan. Both single species and multispecies fish baskets were identified. The multispecies fish baskets were organized into ecologically important groups of species, including reef species, deep-water species, spawning aggregations, micro-migratory, estuarine, pelagic and non-commercial. Two single species baskets were also identified, due to the current status and importance of the finfish: hogfish and Nassau grouper. Priority levels for each basket (low, moderate and high) were determined based on the status and vulnerability of the species in the basket (Figure 8).

The fish baskets were reviewed and revised in June/July 2021 in a workshop that included representatives from the Belize Fisheries Department, commercial fishers, Northern Fishermen Co-operative Society Limited, Rainforest Seafoods Limited, Fein Catch Seafood Limited, University of Belize, Turneffe Atoll Sustainability Association, Toledo Institute for Development and Environment, Hol Chan Marine Reserve, Sarteneja Alliance for Conservation and Development, Sapodilla Cayes Marine Reserve, Southern Environmental Association, Belize Audubon Society, The Nature Conservancy, Wildlife Conservation Society, EDF, CRFM, Belize Directorate General of Foreign Trade, UNCTAD, DOALOS and FAO. Modifications included additional species (for a total of 47), adjustments to species groupings, and changes to the indicator species based on stakeholders' knowledge of fishery and species characteristics. A list of species and characteristics used for determining fish baskets is provided in Annex 2.

Table 4. Fish baskets for the management of 47 finfish species in Belize

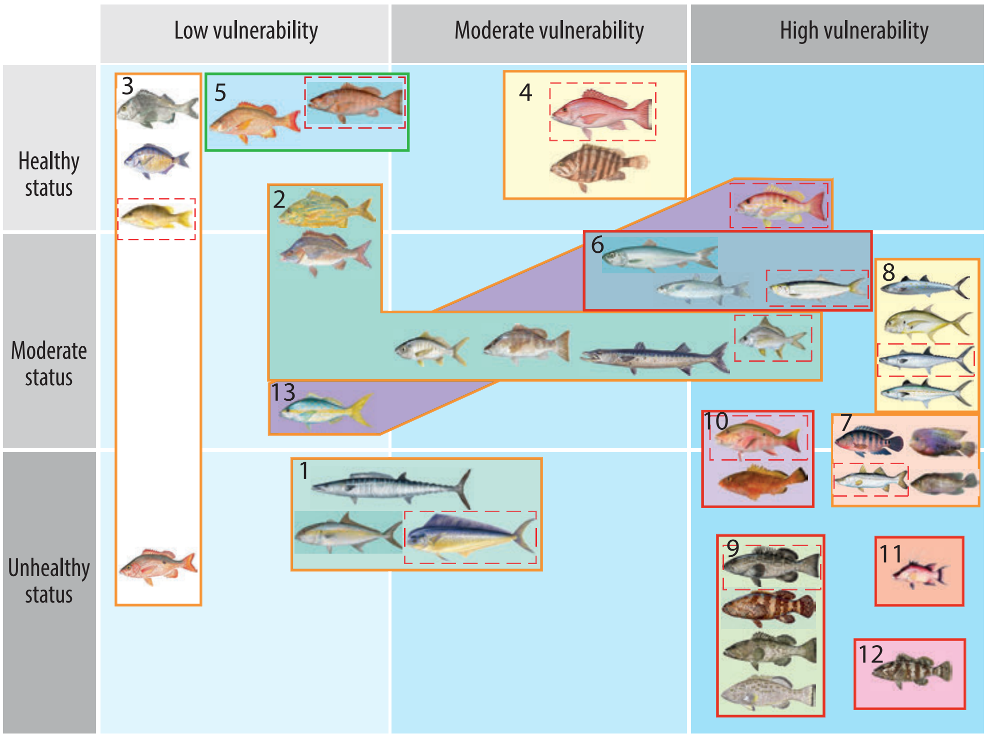
Species ID	Image	Group ID	Common name	Species name	Group identity	Priority
1			Dolphinfish	*Coryphaena hippurus*		
2			Wahoo	*Acanthocybium solandri*		
3			Marlin - white/stripe	*Kajikia albida/Kajikia audax*		
4		1	Swordfish	*Xiphias gladius*	pelagic/migratory/gear	Moderate
44			Yellowfin tuna	*Thunnus albacares*		
45			Cobia	*Rachycentron canadum*		
22			Great amberjack	*Seriola dumerili*		
5			White grunt	*Haemulon plumieri*		
6			Gray snapper	*Lutjanus griseus*		
7		2	Bluestriped grunt	*Haemulon sciurus*	beach traps	Moderate
8			Great barracuda	*Sphyraena barracuda*		
9			Mojarra (yellowfin)	*Gerres cinereus*		
10			Mojarra (Pompano)	*Diapterus auratus*		

Species ID	Image	Group ID	Common name	Species name	Group identity	Priority
12		**3**	**Schoolmaster**	***Lutjanus apodus***	opportunistic sling	Moderate
13			Mangrove/Mahogany snapper	*Lutjanus mahogoni*		
14			Sailor's choice	*Haemulon parra*		
15			Margate	*Haemulon album*		
16		**4**	Yellow-eyed snapper	*Lutjanus vivanus*	deep-slope fishery	Moderate
17			Deep water blackfin snapper	*Lutjanus buccanella*		
18			**Southern red snapper**	***Lutjanus purpureus***		
19			Queen snapper	*Etelis oculatus*		
20			Vermillion snapper	*Rhomboplites aurorubens*		
47			Misty grouper	*Hyporthodus mystacinus*		
21		**5**	**Cubera snapper**	***Lutjanus cyanopterus***	forereef/open/handline	Low
11			Dog snapper	*Lutjanus jocu*		
23		**6**	Mullet	*Muguil spp.*	bait for other fisheries	High
24			Sardine	*Sardinella spp.*		
25			**Sprat**	***Sprattus spp.***		
26		**7**	**Snook**	***Centropomus undecimalis***	habitat/traps/lines/nets	Moderate
27			Bay snook	*Petenia splendida*		
28			Crana	*Cichlosomas urophthalmus*		
29			Tuba	*Cichlasoma synspilum*		
46			Black-eye catfish (*baca*)	*Ictalurus furcatus*		
30		**8**	Spanish mackerel	*Scomberomorus maculatus*	pelagic/migratory/ gear-handline	Moderate
31			Crevalle	*Caranx hippos*		
32			**King mackerel**	***Scomberomorus cavalla***		
33			Cerro mackerel	*Scomberomorus regalis*		
34		**9**	**Black grouper**	***Mycteroperca bonaci***	Large groupers	High
35			Goliath grouper	*Epinephelus itajara*		
36			Tiger grouper	*Mycteroperca tigris*		
37			Yellowfin grouper	*Mycteroperca venenosa*		
38		**10**	**Mutton snapper**	***Lutjanus analis***	fished together, mutton needs to be managed	High
39			Red hind	*Epinephelus guttatus*		
40		**11**	**Hogfish**	***Lachnolaimus maximus***	needs to be rebuilt	High
41		**12**	**Nassau grouper**	***Epinephelus striatus***	special considerations	High
42		**13**	Yellowtail snapper	*Ocyurus chrysurus*	resilient and rebuild	Moderate
43			**Lane snapper**	***Lutjanus synagris***		

Source: Author's compilation, 2021.

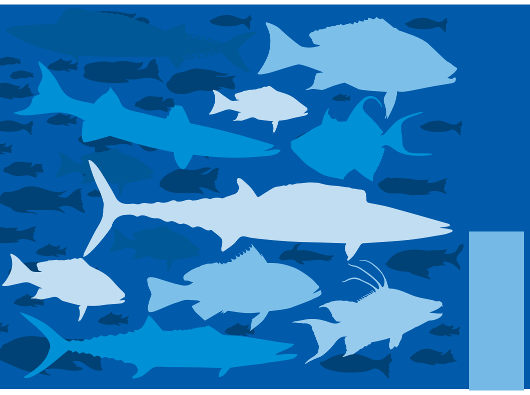
Note: Indicator species for each basket are underlined and in bold. Colours for each grouping are for visual distinction between fish baskets. The colours correspond to those in Figure 8.

Figure 8. Vulnerability and status diagram used by stakeholders to define the 13 fish baskets shown in coloured boxes.



Source: Author's compilation, 2021.

Note: Colours for each fish basket are for visual distinction and correspond to those in Table 4. The outlines around each fish basket correspond to the priority for the baskets (green = low priority, orange = moderate priority, red = high priority). Indicator species for each basket are outlined by red dashed boxes.



4. PROPOSED MANAGEMENT OBJECTIVES, INDICATORS AND REFERENCE POINTS

4.1 Management objectives

The Belize Fisheries Department and local stakeholders, including MAA managers and local and international NGOs, have identified several challenges that should be addressed by finfish management. In general, there has been an observed decline of abundance and size structure of snappers, groupers and jacks, which represent the most historically important commercial target species throughout the country. As these species have declined, fishers have been turning to other reef species such as angelfish, grunts and other grazers and excavators. These species are less desirable and valuable from a market perspective and play important ecological roles that could be jeopardized by increased fishing pressure. There are also conflicts between recreational and commercial finfish fishing that must be addressed, alongside a need to better monitor recreational catch.

Given the identified challenges, the Belize Fisheries Department outlined a triple bottom line set of social, economic and biological objectives for management of the country's finfish fisheries:

1. sustainability and resilience of food security
2. sustainable economic growth and improved livelihoods
3. abundant finfish populations to support healthy ecosystems.

Meeting these objectives entails an integrated suite of activities that address ecological and socioeconomic factors. This management plan primarily addresses the participatory, science-based decision-making process required to monitor and manage finfish targets, recognizing that complementary, essential activities are being undertaken by the Fisheries Department, a network of supportive partners including co-management organizations, and fishing cooperatives. These include, for example, the implementation of the OETS for Belize (UNCTAD, 2020), expansion of no-take zones (NTZs) and protections for ecosystems and SPAGs, marketing and traceability activities supported by NGO partners, and capacity building to facilitate community participation in fisheries management and marine conservation.

The AMF detailed in this management plan offers a science-based approach that aims primarily to enhance management of spawning aggregations, reef fish and the deep-water complex, because of their economic and ecological importance. These groups will fall under a coral reef multispecies biomass target to support management, moving towards broader ecosystem-scale management. Additionally, single and groups of species will be managed in fish baskets. Fish baskets – management groupings defined by fishery stakeholders – will include ecologically important reef species, deep-water species, spawning aggregations, micro-migratory, estuarine, pelagic and non-commercial finfish. As such, special attention will be paid to the sustainable development of the emergent deepwater complex, to simultaneously support economic development and sustainable resource use. This development may be further guided by a national business plan for the deep-slope fishery, which may draw from the outputs of the Marine Conservation and Climate Adaptation (MCCAP) project. A business plan developed in 2018 under the MCCAP project (praxi5 Advisory Group Ltd., 2018) may serve as a guide for a national business plan.

Based on the current fishery monitoring infrastructure, the initial multispecies finfish management plan aims to monitor, assess and manage the biology and ecology of spawning aggregations, reef fish and the deepwater complex (goals 1 and 3). The intent of the Belize Fisheries Department and stakeholders is to collaboratively adapt the current monitoring system and move towards a systematic shift for data collection on commercial and economic variables (e.g., market cost to fish, price, to be developed with stakeholders), at both the regional and national scale in the coming years. The economic element of the finfish management plan is an important consideration since it was highlighted in a stakeholder workshop held in June/July 2021. As such, future iterations of the management plan will emphasize this transition, including collaboration with other agencies to ensure greater connection to market/pricing mechanisms and diversification into other fisheries and markets.

4.2 Adaptive management framework using the fish baskets approach

Effective management of finfish requires an adaptive approach that recognizes the value of ongoing data collection and iterative decision-making. This adaptive approach is especially important in the context of climate change because warming contributes to shifts in species abundance and distribution.

This subsection describes the 11-step process (Figure 9) for designing and implementing an AMF for a data-limited multispecies fishery. Steps 1 to 7 focus on designing the AMF. This design process builds on previous FMPs developed using AMF in Belize, specifically for queen conch and spiny lobster. Steps 8 to 11 focus on implementing the AMF. The entire 11-step process should be repeated on a periodic basis to update and improve the AMF as fishery conditions change and more information becomes available. It is important to recognize that the entire adaptive management process must be participatory to (i) draw on the knowledge of scientists, resource users, government agencies and others; (ii) define management objectives; and (iii) create a context for learning together and working cooperatively towards a sustainably managed fishery. This reduces the potential for conflict while increasing the likelihood of compliance with regulations generated by the adaptive management process. Additionally, many indicators are strongly affected by attributes of the fishery, such as price or weather fluctuations that are better understood by fishers than by scientists or managers, putting a premium on local knowledge for interpreting these indicators. The steps for designing and implementing the AMF are shown in Figure 9 and are described in detail below.

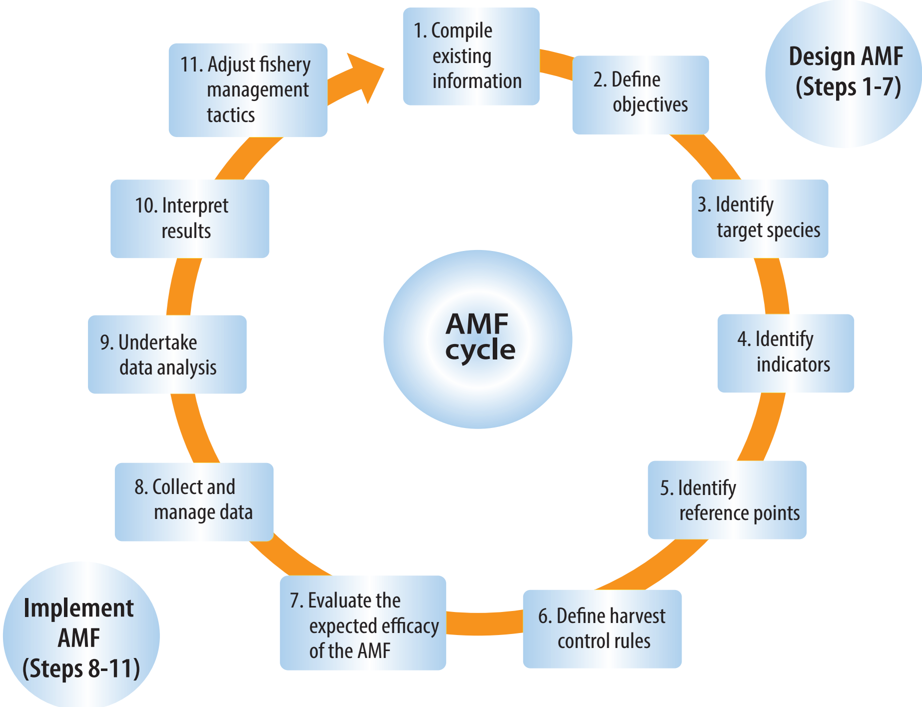


Figure 9. An 11-step process for designing and implementing a multi-indicator adaptive management framework for fisheries

Source: McDonald et al., 2017.

An AMF for Belize requires the identification of several fishery performance indicators that will be evaluated, compared with reference values, and interpreted together to reduce uncertainty associated with single indicators. The reference points define acceptable and unacceptable performance of the fishery (target reference points [TRPs] and limit reference points [LRPs], respectively). Given the goals of the Belize Fisheries Department and the use of the fish baskets approach, this section of the FMP focuses on steps 4 and 5 for designing the management framework in reference to each fish basket.

Figure 9 shows the general process used for both designing and applying an AMF. Designing an AMF begins with the definition of goals and fish baskets using the input of both managers and stakeholders (steps 1 to 3). Based on these goals, appropriate fisheries status performance indicators are chosen that can be quantified using the available data (step 4). Considering these performance indicators, a data collection and management strategy is designed, and TRPs and LRPs are specified (step 5). Finally, HCRs are defined that allow managers and stakeholders to evaluate the performance indicators against the reference points, interpret the results, and choose appropriate management actions aimed at achieving the stated goals (step 6). Once the framework is designed and implemented, performance indicators are re-evaluated each year to determine the status of the fishery and to help managers and stakeholders decide if management changes are necessary.

4.3 Performance indicators and reference points

To manage a fishery, managers need to know how it is doing with respect to fishery management goals; in other words, we need performance indicators that can measure the achievement of management objectives. For every performance indicator, both a TRP and an LRP are estimated and selected. A TRP is a numerical value (or trend) that indicates that the performance of the fishery is at a desirable level; often management is geared towards achieving or maintaining this target. This target could be a static value chosen from the literature, or a trend in historic data (for example, a target may be that the indicator is higher than a historic running average). An LRP is a numerical value that indicates that the performance of the fishery is unacceptable (e.g., severely overfished), and that management action should be taken to improve fishery performance or population levels. Similarly, these values may come from the literature or historic data.

A best practice for selecting performance indicators is to select multiple indicators from multiple independent data streams. This will reduce the uncertainty associated with any single data stream and will paint a more complete picture of the fishery. Based on data availability and the suggested best practices, the recommended performance indicators by Belize Fisheries Department are:

- fishery-dependent estimate of average length
- previous season total landings
- fishery-independent abundance estimates.

These are applied to representative species for each individual fish basket (Annex 3).

A multi-indicator framework is developed that enables decision makers to proceed with management decisions, using model-free performance indicators. Model-free performance indicators are calculated using trends in observed data, rather than stock assessment-derived estimates of biomass and fishing mortality. The AMF is adaptive so that adjustments to catch or effort are recursive and can respond to changing environments, socioeconomic conditions and fishing practices. Using stakeholder-defined objectives as a foundation, performance indicators and reference points of fishery performance are chosen that can be evaluated easily by undertaking analyses of available data.

Performance indicators from multiple data streams are used so that uncertainty in one indicator can be hedged through careful interpretation and corroboration of information from alternative indicators. During the adaptive management cycle, managers and stakeholders evaluate each indicator against the associated reference points to determine performance measures, interpret the results using scientific and local knowledge, and adjust fishery management tactics accordingly using pre-defined HCRs. The framework facilitates the interpretation of situations in which performance measures suggest divergent stock abundance or productivity levels.

When selecting reference points, the following best practices are recommended:

- For reference points of length-based indicators and of underwater visual survey-based indicators, use literature-based reference points.
- Whenever using reference points from literature, draw from studies of comparable species and geographic locations.
- For catch per unit effort (CPUE) and landings-based indicators, use a time series of data to generate reference points that are based on trends or running averages.
- If local or international scientists are available for consultation, discuss reference points with them to determine if they are appropriate for your fishery and adjust values as necessary.
- Adjust targets and limits according to risk tolerance and uncertainty. If uncertainty is high (e.g., because only one or two years of data are available), targets and limits should be more conservative to reduce the risk of overfishing.

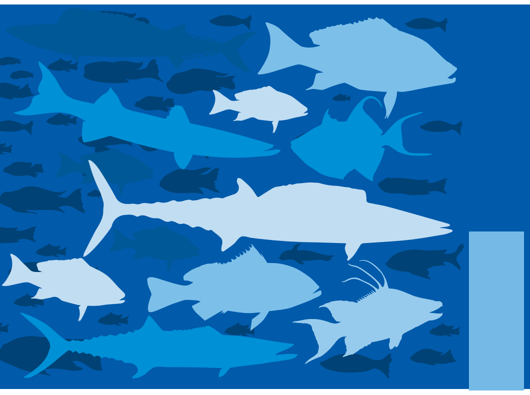
Studies in the literature have identified appropriate reference points for certain species, regions and circumstances (e.g., TRPs of SPR (spawning potential ratio)=30–40 per cent or fishing mortality=natural mortality for particular species; Annex 4). Reference points established for each performance indicator are used to assess the status of the representative target for each fish basket. Single species, multispecies and ecosystem performance indicators can all be used. For model-free performance indicators, relative proxy TRPs and LRPs can be defined in terms of trends or running averages of a particular indicator if historical time series are available for that particular indicator (e.g., CPUE is increasing or CPUE is the average value from the past five years). Additionally, proxy TRPs could be set to equal the average of that indicator over a historical time period that is thought to have represented a stable and desirable fishery condition. Setting these reference points for a particular fishery can be based on these rules of thumb but should be adjusted using local knowledge about the history of the fishery and will depend on social, ecological and economic objectives. Additionally, reference points should be sufficiently precautionary to maintain stock productivity at levels high enough to sustain desired yields and support community objectives.

To facilitate the process of identifying performance indicators, TRPs, LRPs and HCRs for the multispecies finfish fisheries of Belize, in-person adaptive management workshops were conducted to choose and evaluate indicators and reference points tied to national fishery objectives. Participants in the workshops chose model-free indicators from all available data streams that are currently being collected on a national scale. These indicators (Table 5) were selected to capture trends in the dynamics of the fishery and to monitor progress towards the objectives that the Belize Fisheries Department has identified for their fisheries management.

Table 5. Performance indicators, reference points (i.e., target and limit) and data streams identified by Belizean finfish stakeholders for managing each fish basket

Performance indicator	Target reference point	Limit reference point	Data stream
Fish total length	Running 5-year average of the representative species	Minus 10%	Landings at fish markets countrywide
Average abundance	Running 5-year average	Minus 10%	Underwater visual survey
Total landings from previous year	Running 10-year average	Minus 20%	Designated landing sites

Source: Author's compilation, 2021.



5. DATA REQUIREMENTS AND MONITORING SYSTEM

5.1 Data collected and characteristics of the monitoring system

The data collection protocols and priorities have evolved over time as the AMF has been used in the conch and lobster fisheries, and increasingly for finfish. This management plan intends to help prioritize monitoring efforts by providing a national framework for data collection in support of the finfish fishery goals.

Two main data streams have been identified to inform the current three performance indicators at the national scale; these represent the highest priority for data collection:

- fishery-dependent data including:
  - fishers' cooperatives purchase receipt data (to inform total catch from previous season)
  - landed catch and size data from local fish markets
- national fishery-independent ecosystem surveys to estimate abundance (inside and outside of MPAs)

While these are the main two data streams for calculating performance indicators, other data streams should also be considered when interpreting trends and considering management actions. These could include export data, Managed Access logbooks, local and expert knowledge, and other fishery-independent finfish surveys such as those done at Glovers Reef Marine Reserve and Port Honduras Marine Reserve. New data streams, such as early season Managed Access boat intercept surveys, could be used to add spatial resolution to the understanding of the fishery and to complement and cross-check national data streams such as fishery cooperative data.

Table 6 shows the types of finfish fisheries data collected from fishery-dependent and fishery-independent sources. These data sets are analysed and used to develop and implement management strategies and measures for the multispecies finfish fishery. Efforts are underway to create standardized data collection protocols, including a 2021 effort supported by UNCTAD and DOALOS to demonstrate a replicable methodology for finfish catch and effort data collection (Carcamo, 2021a). The protocol characterizes the finfish fishery through collection of landings and effort data over a six-month period from the Conch Shell Bay fish market in Belize City. Preliminary findings[29] were presented at the June/July 2021 finfish management workshop.

[29] To access the findings, see https://unctad.org/system/files/non-official-document/ditc-ted-29072021-oceans-finfish-Carcamo.pdf (accessed 3 December 2021).

Table 6. Types of finfish data collected and used for the management of the fishery

Description of data	Data types collected	Years available	Sampling procedure
Export from cooperative	Production of fish fillet, roe and salted fish	1977–2018	Monthly sampling of exports, by product type (lbs)
CPUE	Catch and effort at markets, supported by the Caribbean Community Fisheries Resource Assessment and Management Program (CFRAMP)	1993–1998	Monthly gathered from each fishers' cooperative
National fishery landings at markets	Production by species (monthly)	2005	Monthly reports from each fishers' cooperative, markets on fish landings
Fishery landings at markets at Conch Shell Bay fish market	Catch landings	2007–2008	Monthly reports from each fishers' cooperative, markets on fish landings
Fishery landings and effort at Conch Shell Bay fish market	Species, size and weight, gear and effort, supported by UNCTAD-DOALOS OETS project	2021	Stratified sampling over a six-month period to identify (1) the types and quantity of fishing gears used to capture the finfish landed and estimate the fishing effort applied to capture the finfish; and (2) estimate the age population structure of the finfish species landed during the study period
Underwater abundance survey	Species ID, size estimate and abundance	2008–2018	MBRS synoptic monitoring and Atlantic and Gulf Rapid Reef Assessment (AGRRA)
SPAGS monitoring	Catch landings and biological data	1998–2016	Seasonal monitoring of species identity and abundance
Rainforest	Catch and effort	2013–2018	Finfish landings at facility
MAAs monitoring	Catch trends, by gear type	2016–present	Monitoring programme to estimate catch trends
Managed Access logbook	Catch, effort	2016–present	Logbooks on catch, by species and gear type
MCCAP (deep-slope)	Species diversity at various depths	2017	MAA 9 (deep waters) to identify potential fishing grounds and the availability of commercial finfish species
SMART	Landings, species composition, gear types and area fished	2017	Finfish landings across MAAs
Fish Right Eat Right (ongoing)	Restaurant purchase data	2020–present	Our Fish mobile app and market study

Source: Carcamo, 2021a; author's compilation, 2021.

5.2 Additional data that should be collected to monitor the status of the resource and performance of the fishery

A next step for multispecies finfish data collection efforts is a standardized national data collection system with protocols for fishery-independent and fishery-dependent monitoring for the cooperatives, private companies and MAAs to support the current fishery performance indicators and future adaption of fishery performance indicators. To align with international standards for monitoring and assessing finfish, it is recommended that Belize adopts a data collection system that prioritizes collecting species- and gear-specific length and effort data from the catch. This effort would support the development of a decision-making process around understanding and managing fishing pressure on finfish.

The AMF is strengthened as new data are incorporated into the decision-making cycle. A key priority is to continue to strengthen existing data streams through increased, focused and efficient monitoring of fishery resources, including:

- fishery-dependent monitoring of gear, species, size and effort at the landing sites (e.g., cooperative, private companies and small-scale private seller), through at-sea fisher interception and via MAA logbooks
- fishery-independent monitoring, e.g., MBRS, AGRRA, SPAGs monitoring and MAA monitoring

To improve monitoring and fishery performance, the following additional data streams are recommended:

- Data should be collected on the quantity and size of each species sold at fish markets, restaurants and hotels. This type of data will complement any assessments conducted to assess the health of finfish, and the supplementary data will improve the records used to report on total landings.
- Surveys of landing sites, market and cooperatives should be conducted to assess the economics that drive the finfish fishery. A standardized communication strategy around the expansion of market monitoring also needs to be developed.
- Survey restaurants and markets that deliver fish for the tourism industry, with a focus on species identification, size and cost.
- Standardized national socio-economic data should be collected over time, including demographic information about fishery participants, costs of fishing, income earned, etc.

Development of the finfish policy requires the input of data that need to be gathered from the fishery. Therefore, there is a need for a standardized, sustainable and cost-effective data collection programme and database that can provide information about how fishing activity and fishery performance respond to the different fishery policies. The integration of the finfish data collection programme should incorporate a data management system that houses all finfish data gathered by the Belize Fisheries Department, co-managers and other independent researchers. This will facilitate the efficient and effective usage of the data sets, increase coverage, data validation and data standardization. It is recommended that a system appraisal should be conducted in the future to ensure that the data collection system meets its desired objective. This is critical if the system is to function efficiently and be sustainable in the long run.

5.3 New science and technology for monitoring and managing the finfish resources of Belize

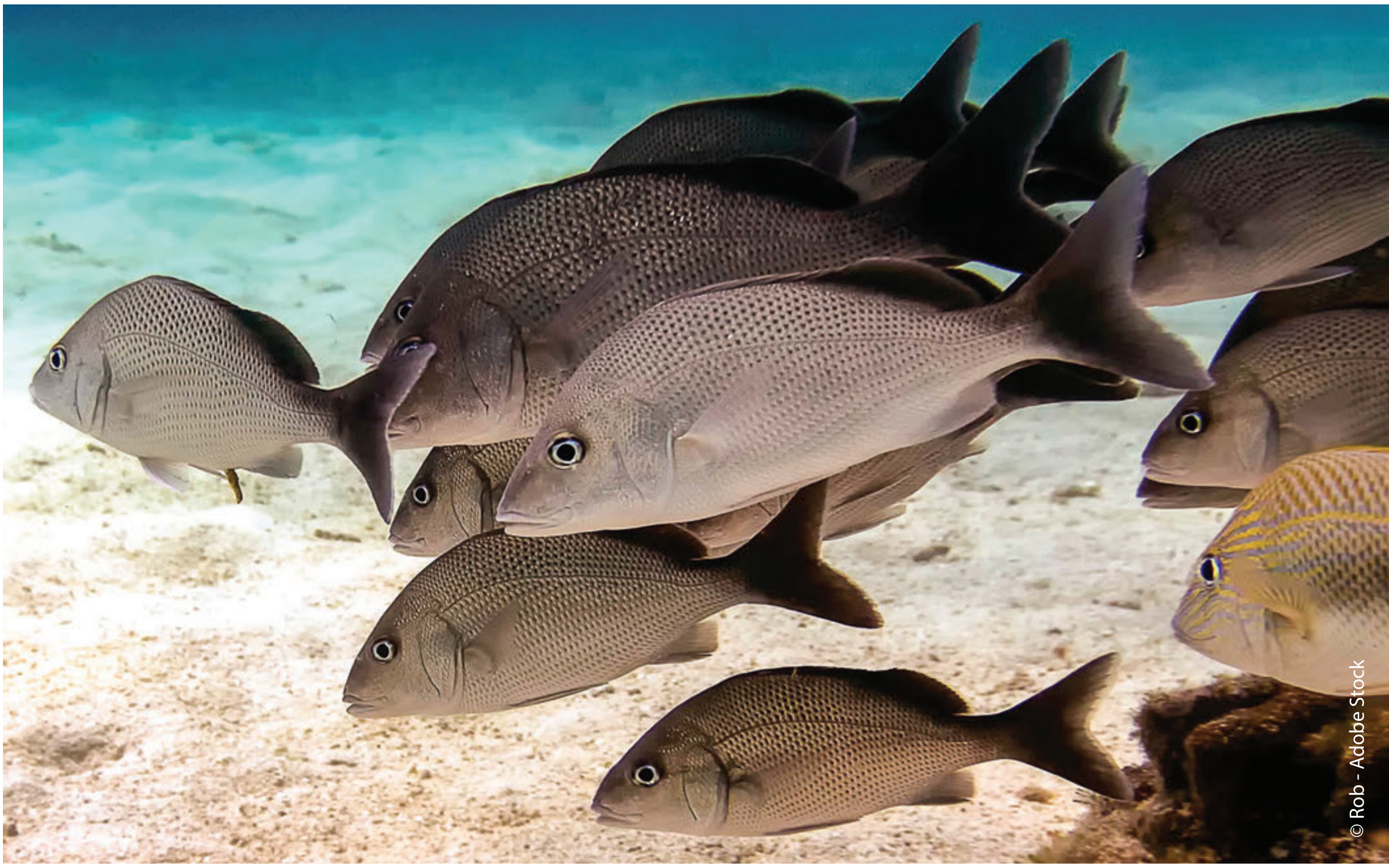
An achievable next step that will contribute to the overall goals of the finfish AMF and generate new science for science-based management is to carry out a comprehensive meta-analysis[30] of current data collection and to coordinate and streamline various finfish data sets. The meta-analysis should be a collaborative process that engages all stakeholders that have and/or are currently collecting data that pertain to the three management goals for the multispecies finfish fishery. The goals of the meta-analysis are to summarize, modify and create a data management system that meets data needs for the goals of the finfish AMF. For all relevant data streams (Table 6), stakeholders will identify how data are collected, digitized, stored and accessed, along with challenges and next steps for that data stream. As a first step towards developing such a system, the meta-analysis will outline the current landscape of data availability and management within Belize as it pertains to finfish. The second step is to use the meta-analysis to move forward the process of standardized data collection and management. It is recommended that a data management working group be formed to drive this initiative forward. The working group will be comprised of individuals who represent the type of finfish data collected around the country, including co-managers.

[30] Meta-analysis is a method for systematically combining pertinent qualitative and quantitative information to develop a single conclusion that has greater statistical power and understanding in addressing the question at hand.

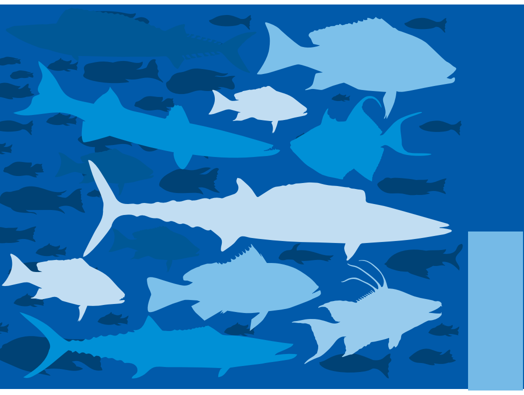
Furthermore, most science-based assessment methodologies require several different types of data streams, including species-specific life history information. Species-specific life history information is missing for many of the finfish in Belize and, more broadly, the MAR; scientific studies to fill these gaps are needed. In addition, there is a need for a concerted effort, led by the Belize Fisheries Department, to digitize all data collection efforts and integrate these data streams into a collaborative AMF database. In the interim, standard practice for ichthyologists, stock assessment scientists and managers is to borrow information from other regions via FishBase,[31] a globally sourced database with taxonomic, biometric, genetic, reproductive, metabolic and morphological data on finfish.

New scientific research and/or uptake of technological solutions to support finfish monitoring (fishery-dependent and fishery-independent) is needed as the finfish AMF moves forward. This may include: use of tablets and smart phones using programmes such as SMART to collect landings information and catch data while out at sea; installation of underwater acoustics to monitor spawning aggregations of snappers and groupers; and use of underwater drones for monitoring fish stocks and ecosystems.

Ultimately, the priority areas for finfish data collection are systematic and standardized collection of the catch metrics to help estimate and manage fishing pressure and the market dynamics of each fish basket.



[31] See https://www.fishbase.in/search.php (accessed 3 December 2021).



6. DATA ANALYSIS

6.1 Types of assessment models or other approaches used to evaluate the status of the resource and to assess the impact of harvesting strategies

Belize, like many other countries, lacks sufficient data to conduct complex fishery stock assessments capable of generating estimates of biomass and certain reference points for management (such as fishing mortality and biomass associated with maximum sustainable yield – FMSY and BMSY, respectively). Because Belize is committed to sustainable fisheries, the AMF relies on assessment of existing data to estimate the status of priority fishery target stocks (i.e., the representative species of each fish basket). Several analytical tools (EDF, 2021a, 2021b) suitable for finfish fisheries can be utilized to estimate the status of finfish in Belize, the risk of overfishing and the actual fishing mortality.

Data-limited assessment methods generate a variety of different outputs in lieu of a comprehensive stock assessment. These outputs, which serve as indicators of stock health and fishery sustainability, include:

- vulnerability to fishing
- trends in the catch and CPUE
- fishing mortality (F)
- spawning potential ratio (SPR)
- Average length
- MPA density ratio (MPA-DR, the ratio of fished biomass [or density] to unfished biomass [or density]).

As noted in Section 4 (Table 5), performance indicators identified for the management of finfish in Belize include average length, average abundance and average total landings. Trends can be analysed and interpreted using a suite of assessment methods and proxies for reference points that are relied on for fishery decision-making. For example, common reference points include:

- Natural mortality (M), which serves as a proxy for FMSY.
- SPR of 40 per cent, which serves as a proxy for a sustainable level of spawning potential.
- Density ratio of 0.2–0.5, which serves as a proxy for the biomass fraction associated with the production of pretty good yield (approximately 80 per cent of MSY) – with MPA-DR levels near 0.3 potentially associated with the start of an undesirable change in coral reef ecosystem state based on recent analysis of coral reef metric data throughout the Caribbean.

Common assessment methods for the multispecies finfish performance indicators include:

- **Productivity susceptibility analysis (PSA)** scores life history parameters important for stock productivity and attributes of the fishery that are important for determining the susceptibility of the stock to the fishery to compute a vulnerability or risk score. Vulnerability scores above 2.0 are generally associated with overfishing but do not prove that overfishing is occurring. PSA results can also be used to prioritize stocks for further analysis, data collection and precautionary management based on the risk of overfishing.

- **Total landings trends analyses** use fishery-dependent catch data to compare total landings of the current season to the previous, or within season fluctuations. Comparisons can be derived for sequential years, or as a running average between historical trends. Additionally, comparisons can be made across all species or by species of interest. Catch trends of total landings can support the interpretation of other analyses, for example of fishing mortality or SPR. Understanding how the trends in total landings fluctuate from one year to the next or in comparison to the historical trends is essential if catch trends are to be used for management.

- **Fish total length, or average size** uses fishery-dependent catch data to assess the average size of individual species that are landed at the markets. The average size landed within a current season compared to the previous season, or within season fluctuations, help to understand whether juvenile, adult or mega-spawners of a species are being landed. These proportions can be used as a reasonable representation of growth and recruitment overfishing. Comparisons can be derived for sequential years, or as a running average between historical trends. To avoid recruitment overfishing, the ratio of mature fish in the catch should be high so that each fish has a chance to spawn at least once before being harvested. To prevent growth overfishing, all or most of the fish caught should be within 10 per cent of the optimal length of harvest (L_{opt}), which is the length at which the biomass of fish in a year-class is maximized.

- **Average abundance** uses fishery-independent data to compare fluctuation in the standing or unfished abundance, and therefore the biomass of target finish. Comparisons can be derived for sequential years, or as a running average between historical trends.

6.2 Assessments take into account major uncertainties in data and assumptions

The Fisheries Resources Act of 2020 calls for a precautionary approach to managing the fishery resources of Belize.[32] Data-limited methods like those identified above require several important assumptions, are sensitive to certain parameters and may perform better for certain kinds of fisheries and fish stocks. Hence, the outputs must be carefully and cautiously interpreted together. Consistency or convergence of multiple outputs (e.g., F>M, SPR<40%, MPA-DR<0.3) increases confidence in inferred status (e.g., overfishing is occurring and the stock is overfished). Inconsistent outputs are more difficult to interpret (Annex 5) and when such inconsistency occurs, a precautionary management response is recommended.

This uncertainty around the outputs of data-limited assessments is the main rationale for the use of adaptive and participatory management. To support adaptive management, an adaptive management workshop should be conducted to carefully interpret assessment outputs to generate management guidance. The guidance will provide HCRs based on the performance indicators for use in adaptive management (see Section 7). The decision-making framework is strengthened by local and expert knowledge to interpret the assessment results. An example of the decision-making process that combines multiple assessment outputs with stakeholder expertise is provided in Table 7.

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32 Fisheries Resources Act of 2020 (Part II, section 2).

Table 7. Example interpretation of assessment results in a participatory, adaptive management framework

Assessment results (implication)	Supportive knowledge	Interpretation	Management response
Fishing mortality is greater than natural mortality (F>M) (implies overfishing is occurring) Spawning potential is low (SPR<40%) (implies overfished stock) Biomass is low relative to unfished areas (MPA-DR<0.3) (implies overfished stock)	There is no indication that other factors can explain the length composition patterns (i.e., truncated relative to an unfished composition) or MPA-DR (e.g., sampling sites close to the edge of a NTZ; NTZ very recently established, etc.) Stakeholder observations are consistent with the assessment results	Overfishing is occurring and the stock is overfished	Reduce F in order to build SPR to levels above 40% and to increase MPA-DR to greater than 0.2, the lower end of the range associated with pretty good yield (if the conservation of other ecosystem services is a management goal, it may be desirable to maintain MPA-DR levels above 0.3)

Source: EDF, 2021a.

6.3 Preparation of national reports for management of the finfish fishery

All assessments and preparation of FMPs and reports are the responsibility of the Belize Fisheries Department. The Ecosystem Management Unit has responsibility for the effective management of the network of marine reserves. This involves monitoring reef health, populations of commercial species, seagrass and mangrove productivity, and upholding the fisheries regulations. The Capture Fisheries Unit has responsibility for monitoring fisheries performance and providing relevant information for sound decision-making. These two units will spearhead data collection and information gathering that will feed into the AMF process and ultimately the preparation of national reports. Given the breadth and depth of data collection, analysis and reporting associated with the implementation of this management plan, regular collaboration and assistance from co-management partners is encouraged. National reports will be submitted to the Fisheries Council for review and recommendations prior to submission to the Minister of Blue Economy and Civil Aviation.

6.4 The future of finfish assessment and management

It is the intention of the Belize Fisheries Department that adaptive fishery management for multispecies finfish occurs on a five-year cycle. Representative stakeholders present at the June/July 2021 multispecies finfish workshop[33] identified multiple ways to improve the monitoring, assessment and ultimately the management of finfish in Belize:

Data

- increase data collection – landing sites, vendors, markets, cooperative, fishers and MAA managers
- standardized data collection – landing sites, markets, vendors, cooperatives, fishers and MAA managers
- prioritize fishery-dependent data for each fish basket
- standardized fishery-independent data
- conduct comprehensive meta-analysis of fishery-independent and dependent finfish data sets

[33] See https://unctad.org/meeting/workshop-adaptive-multispecies-finfish-management-belize (accessed 3 December 2021).

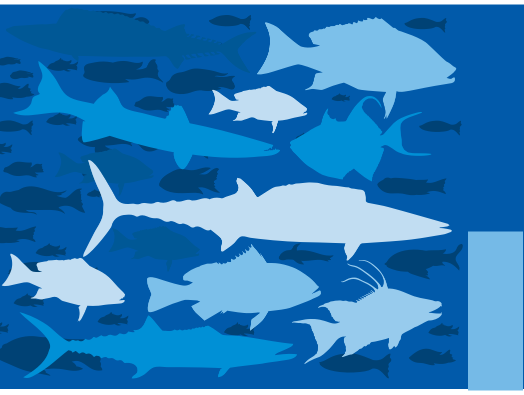
- socio-economic data, including – demographic information (e.g., Who? How old are they? Where are they fishing? etc.), fuel and food cost, boat maintenance cost, income earned per fishing trip and by targets

Data management

- transparent and accessible data management platform
- includes local, common and scientific names so that data is accessible to all stakeholders

New science

- analytical methods – methodologies (Annex 3 and Annex 7) that represent fishing pressure (e.g., estimate of fishing mortality, SPR, catch-MSY, etc.), effort (CPUE and catch methods) and market fluctuations (from fishers, traders, buyers, consumers), including price
- collect age and maturity data from finfish (otoliths)
- focus on species that are most vulnerable.



7. CONTROLS DETERMINING THE APPROPRIATE MANAGEMENT RESPONSE

7.1 Current management controls used to achieve finfish fishery objectives

The overall management strategy for the Belize multispecies finfish fishery is to maintain a sustainable and viable multispecies finfish fishery that will continue to provide benefits to Belizeans and the national economy. The current management efforts for the multispecies finfish fishery are listed in Table 8. The continued application of the controls will maintain a sustainable and viable multispecies finfish fishery. In addition to these controls, the Belize Fisheries Department has also implemented the Managed Access Program in all other fishing zones of Belize. The Managed Access Program helps to control fishing mortality in a fishing zone. The current management measures used to control fishing pressure on finfish are listed in Table 8.

Table 8. Current harvest control measures used in the management of finfish in Belize

Type of control	Years implemented	Description	Estimated effectiveness of control
Seasonal closures	2009	Closed season for critically endangered Nassau grouper (*Epinephelus striatus*; 1 December–31 March)	Some degree of illegal fishing during closed season
Minimum size and weight regulations	2009	Nassau grouper (50–76 cm total length); Nassau grouper must be landed whole	Some degree of illegal fishing
Gear ban	2011 2020	Trawling ban Gill net ban. Before the ban, all nets must be tagged and registered every year by the Belize Fisheries Department The minimum mesh size for nets is 3 inches, and the maximum length for gillnets is 100 m (about 330 ft). There is a maximum possession length of 300 m (about 985 ft) for gillnets on board any vessel at any time	
Gear specifications and restrictions	2003	Spear guns, nets, longlines, fish traps and beach traps are prohibited in marine reserves; use of SCUBA for fishing is prohibited	
Closure	2009 2020	Complete ban on the harvest of scarids (parrotfish) and acanthurids (tang/surgeonfish/doctorfish) All fish landed as fillet must include a skin patch (5 × 2.5 cm) for species identification in order to prevent circumvention of this rule Permit (*Trachinotus falcatus*), tarpon (*Megalops atlanticus*) and bonefish (*Albula vulpes*) may not be landed but are important to recreational catch-and-release fishing associated livelihoods. Nurse sharks (*Ginglymostoma cirratum*) and whale sharks (*Rhincodon typus*) are completely protected Fisheries Resources Act of 2020 protects all scheduled species, as described in Section 2	Some degree of illegal fishing

Type of control	Years implemented	Description	Estimated effectiveness of control
Protected areas (marine reserves)	1987	Eight marine reserves have been declared which are used as management tools for the protection and conservation of finfish stocks	Although the marine reserves were not exclusively designed for finfish conservation, protection has resulted in higher densities and abundance within reserves
Fishing effort control – Managed Access Program	2015	Allows a specific number of fishers to fish for a specific species and quantity. Fishing license specific to two fishing areas	Management and enforcement activities become more effective and efficient

Source: Author's compilation, 2021.

7.2 Harvest control rules

Prior to the multispecies finfish adaptive management workshop carried out in June and July 2021, the Belize Fisheries Department identified performance indicators and reference points for the science-based management of each individual fish basket. Different management scenarios were developed with stakeholders to describe possible interpretations, causes and suggested management actions to be taken when a performance indicator is above (↑) or below (↓) the TRPs (see Table 9). This table was reviewed and updated in the June–July 2021 workshop. Using Table 9 on an annual basis, managers will determine the interpretation and/or possible causes of that year's suite of indicators and the recommended responses and management actions.

In cases where a management response is required, the following actions will be taken before adjusting harvest co-ntrols:

1. verify data and calculations
2. review sampling protocol, assess size structure of the population
3. ensure that fishery-independent surveys overlap with known or assumed distribution (depth and space) of population and fishing effort
4. assess and compare results with estimates of CPUE, effort metrics, spatial distribution of effort and previous year's catch
5. double check assumptions and reference points
6. if trends persist, consult with local experts
7. if trends persist, consider adjusting harvest controls and develop a recovery plan if necessary.

The exact harvest control adjustment that should be used in any scenario will depend on several factors, including confidence in the data and trends, confidence in the interpretation of the fishery status, aversion to risk and uncertainty, and socioeconomic and political realities. While the stakeholder working group can provide suggestions for possible options, it will ultimately be up to the Belize Fisheries Department to determine what is desirable and feasible on the ground.

7.3 Harvest controls measures

In the month of March 2020, a multispecies finfish adaptive management workshop was carried out and potential harvest control measures were identified with stakeholders, to be taken when a performance indicator is above (↑) or below (↓) the TRPs (Table 10).

Table 10 lists the harvest control measures recommended during the June–July 2021 multi-stakeholder workshop. Harvest control measures are tools that managers may implement to limit fishing activity with the main objective of either limiting fishing mortality or protecting key biological or ecological features of the fishery. Size limits are a common harvest control measure for finfish, and size limits derived from peer-reviewed literature are listed in Annex 6.

Table 9. Harvest control rule matrix

Scenario	Reference point			Interpretation/ possible causes	Harvest control rules
Performance indicator	Average fish total length	Average abundance	Total landing from previous season		
1	↑	↑	↑	▌Stock productivity and fishery performance stable and/or increasing	No response required, but optionally: 1. Monitor reference point trends a) make no change (if trends are stable or just above limits) b) ease harvest rate regulation (if trends high/increasing)
2	↓	↑	↑	▌Fishery lightly harvested (i.e., fishing effort and harvest rates are low)	No response required, but optionally: 1. Monitor reference average length and total landings trends, recruitment, gear and behaviour patterns a) make no change (if trends stable/just above limits) b) ease harvest rate regulation (if trends increasing)
3	↑	↓	↑	▌Increased pressure or new gear ▌Immigration of large individuals to fishing area	No response required, but optionally: 1. Confirm/monitor values with multiple models/approaches a) no change (if trends are stable/ near limit) b) harvest rate reduction or gear restriction c) no change (if sample sizes are small)
4	↓	↓	↑	▌Potential early warning of growth and recruitment overfishing ▌Large recruitment pulse	Response recommended: 1. Confirm/monitor values with multiple models/approaches: a) no change (if trends are stable/ near limit) b) harvest rate reduction (if trends declining) c) increase minimum size limit
5	↑	↑	↓	▌High fishing pressure affecting spawning stock biomass ▌Fishing effort increased last year ▌Misreporting of landings; reported catch too high	Response required; recommended action sequence: 1. Harvest rate reduction (lower catch or reduce gear) a) Confirm/monitor with multiple models/approaches b) If trend persists, consider additional regulatory options: c) increase minimum size limit
6	↓	↑	↓	▌Potential early warning of growth and recruitment overfishing ▌Large recruitment pulse ▌Overfishing, or ▌Error in calculations	Response required; recommended action sequence: 1. Harvest rate reduction (lower catches or reduce effort, gear restrictions) 2. Confirm/monitor average size with multiple models/approaches 3. If trend persists, consider additional restrictive harvest control measures to reduce fishing pressure: a) increase minimum size limit

Scenario	Reference point			Interpretation/ possible causes	Harvest control rules
7	↑	↓	↓	▌High fishing pressure negatively affecting size structure and spawning stock biomass; fishery in danger of collapse ▌Overfishing, or ▌Error in calculations	Response required; recommended action sequence: 1. Harvest rate reduction (lower catches or reduce effort, gear restrictions) 2. Confirm/monitor average size with multiple models/approaches 3. If trend persists, consider additional restrictive harvest control measures to reduce fishing pressure: a) increase minimum size limit b) implement recovery plan
8	↓	↓	↓	▌High fishing pressure negatively affecting spawning stock biomass ▌Fishing effort increased last year ▌Misreporting of landings; reported catch too high ▌Overfishing	Response required; recommended action sequence: 1. Harvest rate reduction (lower catches or reduce effort, gear restrictions) 2. Confirm/monitor average size with multiple models/approaches 3. If trend persists, consider additional restrictive harvest control measures to reduce fishing pressure: a) increase minimum size limit b) reduce reference point for landings c) implement recovery plan

Source: Author's compilation.

Note: This matrix will be used pre-season to set an initial TAC for the season. Eight scenarios are described that include possible interpretations, causes and suggested management action for when a performance indicator is above (↑) or below (↓) the TRPs.

Table 10. Recommended harvest control measures proposed for each fish basket

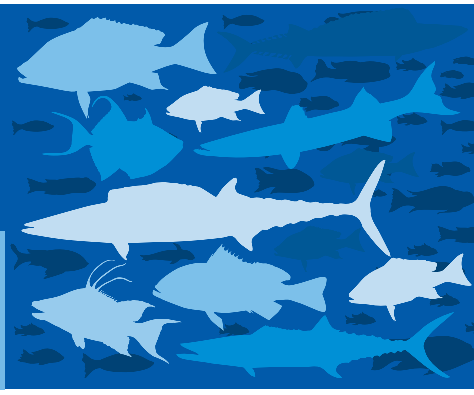
ID	Common name	Species name	Group identity	Recommended harvest control measures
1	**Dolphinfish**	***Coryphaena hippurus***	Pelagic/ migratory/ gear	Add categorization of licenses for non-commercial fishers (Managed Access Committees have responsibility for approving) Bag limits and size limits for non-commercial fishers Prohibition of sale by non-commercial fishers
	Wahoo	*Acanthocybium solandri*		
	Marlin – white/ stripe	*Kajikia albida/ Kajikia audax*		
	Swordfish	*Xiphias gladius*		
	Yellowfin tuna	*Thunnus albacares*		
	Cobia	*Rachycentron canadum*		
	Great amberjack	*Seriola dumerili*		
2	White grunt	*Haemulon plumieri*	Beach traps	Gear restriction (i.e., number and design of traps), size limits, closed seasons
	Grey snapper	***Lutjanus griseus***		
	Bluestriped grunt	*Haemulon sciurus*		
	Great barracuda	*Sphyraena barracuda*		
	Mojarra (yellowfin)	*Gerres cinereus*		
	Mojarra (pompano)	*Diapterus auratus*		

ID	Common name	Species name	Group identity	Recommended harvest control measures
3	**Schoolmaster**	***Lutjanus apodus***	Opportunistic sling	Closed season, size limit
	Mangrove/mahogany snapper	*Lutjanus mahogoni*		
	Sailor's choice	*Haemulon parra*		
	Margate	*Haemulon album*		
4	Yellow-eyed snapper	*Lutjanus vivanus*	Deep-slope fishery	License, gear type, gear spec, cap on the number fishers
	Deepwater blackfin snapper	*Lutjanus buccanella*		
	Southern red snapper	***Lutjanus purpureus***		
	Queen snapper	*Etelis oculatus*		
	Vermillion snapper	*Rhomboplites aurorubens*		
	Misty grouper	*Hyporthodus mystacinus*		
5	**Cubera snapper**	***Lutjanus cyanopterus***	Forereef/open/ handline	Closed season, size limit
	Dog snapper	*Lutjanus jocu*		
6	Mullet	*Muguil* spp.	Bait for other fisheries	TAC, limit the access and timing to capture
	Sardine	*Sardinella* spp.		
	Sprat	***Sprattus* spp.**		
7	**Snook**	***Centropomus undecimalis***	Habitat/traps/ lines/nets	Closed season
	Bay snook	*Petenia splendida*		
	Crana	*Cichlosomas urophthalmus*		
	Tuba	*Cichlasoma synspilum*		
	Blue-eye catfish (*baca*)	*Ictalurus furcatus*		
8	Spanish mackerel	*Scomberomorus maculatus*	Pelagic/ migratory/ gear – handline	Size limits, maintaining conservation areas
	Crevalle	*Caranx hippos*		
	King mackerel	***Scomberomorus cavalla***		
	Cerro mackerel	*Scomberomorus regalis*		
9	**Black grouper**	***Mycteroperca bonaci***	Large groupers	Size limit, bag, season, area-based management of SPAGs
	Goliath grouper	*Epinephelus itajara*		
	Tiger grouper	*Mycteroperca tigris*		
	Yellowfin grouper	*Mycteroperca venenosa*		
10	**Mutton snapper**	***Lutjanus analis***	Fished together, mutton needs to be managed	Closed season, bag limit, size limit
	Red hind	*Epinephelus guttatus*		
11	**Hogfish**	***Lachnolaimus maximus***	Needs to be rebuilt	Closed season, size limit and bag limit
12	**Nassau grouper**	***Epinephelus striatus***	Special considerations	Closed season, size limit
13	Yellowtail snapper	*Ocyurus chrysurus*	Resilient and rebuild	Size limit
	Lane snapper	***Lutjanus synagris***		

Source: Author's compilation, 2021.

Note: Indicator species are in bold type.

8. DECISION-MAKING: OPTIONS FOR ADJUSTING FISHERY CONTROLS



8.1 Management response for performance indicators

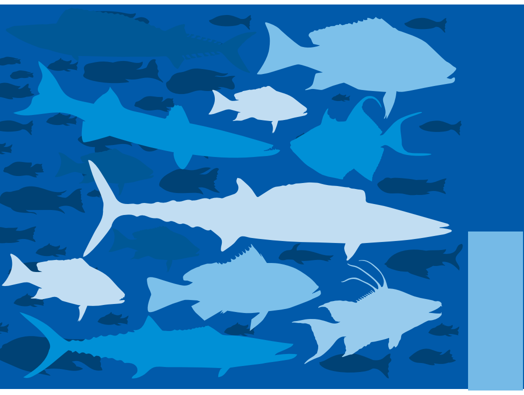
The main options for adjusting multispecies finfish fishery controls in the various scenarios are shown in Table 9. The eight scenarios shown in the list are probably the most likely situations that can occur in the multispecies finfish fishery at a given point in time in response to the possible causes as shown in the same table. The last column in Table 9 shows the suggested management responses that will be taken and associated measures to be taken.

8.2 Decision-making for appropriate management response

The Capture Fisheries Unit of the Belize Fisheries Department is responsible for fishery- dependent and fishery-independent data collection. The Ecosystem Management Unit is responsible for fishery-independent data collection in marine reserves. These data sets serve as the primary inputs for monitoring and controlling catch landings and total catch, estimation of average length, and abundance, which constitute the performance indicators to assess the current status of each fish basket. Any changes in the established values for key reference points, such as total catch from previous season or average length, are taken seriously and an in-depth analysis is done to find out the reason for such changes. The suggested management responses shown in Table 10 are then put into action to remedy the situation.

The results of such analysis are fully reviewed in-house by a technical team within the Capture Fisheries Unit, which then provides advice and recommendations to the Fisheries Administrator. The Fisheries Administrator shall provide the Fisheries Council with the proposed management plan or amendments to the plan for review and recommendations. The Fisheries Council will advise and make recommendations to the Minister on matters relating to conservation, management, use and development of fisheries; development and implementation of comprehensive fisheries policies; monitoring, review and evaluation of conservation guidelines and EBM measures; review of fisheries management plans; coordination of fisheries policies; and other fisheries matters.

It is important to note that the Fisheries Administrator shall ensure proper consultation or participation of stakeholders in the preparation and review of the fisheries management plan. Where a review of the fisheries management plan results in amendments to the plan, the Fisheries Administrator should consult with the Fisheries Council prior to submission to the Minister of Blue Economy and Civil Aviation. The proposed fisheries management plan or amendments, as approved by the Council, shall be presented to the Minister for decision-making. The Minister has 30 days to respond and approve the fisheries management plan or any amendments to the plan.



9. ENFORCEMENT AND COMPLIANCE

9.1 Surveillance and monitoring systems in place to ensure compliance

Non-compliance with fishing regulations can undermine management effectiveness and threaten fisheries sustainability. Fisheries enforcement is aimed at the fair and correct application of regulations and to ensure compliance with these rules where necessary. Effective monitoring and enforcement of the fisheries laws is vital to protect the valuable marine areas and fisheries of Belize. It is important that these are protected by detecting breaches of fisheries regulations by monitoring, control and surveillance at sea and onshore, proper evidence collection and case file preparation, effective prosecution, and the collection, analysis and use of intelligence on fishing activity to improve enforcement and compliance effectiveness. However, command and control alone may not be effective in obtaining desired levels of prevention, deterrence and compliance. Enforcement strategies must be cognizant of the factors that may influence fishers' compliance decisions, including enforcement style and approach, moral norms, perceived legitimacy of regulations, the behaviour of other fishers, fishers' attitude and social norms. This demands a strategic and targeted engagement with fishers through education and outreach to better understand the factors driving compliance and the identification of opportunities for self-regulation and community stewardship. Additionally, for enforcement to be socially acceptable to the extent where it is an effective force in building community stewardship, it has to be accountable to stakeholders and the general public; consistent in similar circumstances and in approach and treatment of violators; and transparent by educating the fishing public on the rules and what the consequences are for violations. Enforcement activities must be in accordance with the law.

Enforcement effectiveness requires a proper understanding of the structure, profile and dynamics of the fishing constituency, fishing gears used throughout the industry, the physical areas subject to fishing, and most importantly, a thorough understanding of the fisheries laws and regulations. This knowledge will allow enforcement efforts to be context suitable, proportionate and targeted to identified risks. However, enforcement also needs to be efficient to optimize the returns from enforcement efforts, and as such the best available tools and technology should be sourced and used for the required purpose, where applicable and affordable. The application of new technologies has allowed governments and fishery stakeholders to collect more data on a variety of fisheries related activities, including fish stocks, monitoring and enforcement, evaluation of the impacts of fisheries activities and fisheries policies on the fisheries resource (Cusack et al., 2021). Technologies currently employed in fisheries enforcement include global positioning system (GPS) and global navigation satellites systems (GNSS) applications, drones and low-maintenance radar stations, satellite imagery, on-board digital cameras and recorders, automatic identification systems (AIS), vessel monitoring systems (VMS), and the internet at sea. The effective use of technology in enforcement can generate several benefits, including better compliance with fisheries laws, documentation of sustainable fishing practices and access to markets that demand traceability systems and high levels of transparency and sustainability.

The multispecies finfish fishery regulations are enforced by the CCU, marine reserves personnel, co-management partners and the BNCG. The CCU operations and five of the eight coastal marine reserves are funded entirely under the Fisheries Department budget. The remaining three marine reserves are run under a co-management agreement with the Fisheries Department. Most of the funding for fisheries law enforcement activities for these three marine reserves is obtained through grant funding from various sources. Most recently, through a partnership among the Fisheries Department, BNCG and NGOs, a coordinated inter-agency approach is used to enforce fisheries regulations in MPAs and fishing areas.

Fisheries law enforcement patrols out of the Belize City office are conducted twice weekly by the CCU, while daily patrols are conducted by the marine reserve personnel. Inspections are carried out at fish markets and landing facilities, such as private export companies. Fisheries enforcement activities are guided by a fisheries enforcement protocol that was developed by the Fisheries Department. Standard operating procedures are adhered to when boarding and inspecting a vessel and carrying out arrest and prosecution. In addition to size limit restrictions, species protection and closed fishing periods, all finfish shipments are inspected by the Capture Fisheries Unit to ensure the fishers' cooperatives comply with the regulations. Export of finfish is regulated via an export permit license.

Current strategic objectives and actions within the NFPSAP include:

- Strategic objective 5.1: To continuously strengthen and improve the relationship and interaction between enforcement personnel, the fishing community and the general public.
  - 5.1.1.1 Establish a formal enforcement data and intelligence collection system.
  - 5.1.1.2 Develop and implement a strategic enforcement engagement strategy with the fishing community.
  - 5.1.1.3 Establish a publicly accessible enforcement transparency and accountability system.
- Strategic objective 6.1: To enhance enforcement and compliance effectiveness through a context-driven approach and the application of modern tools and technology.
  - 6.1.1.1 Develop enforcement profile for the fishing industry with all relevant data layers, maps and associated datasets and assessment of risk levels.
  - 6.1.1.2 Conduct needs and feasibility assessment of potential tools and technology to be used to enhance enforcement and compliance.
  - 6.1.1.3 Determine training and capacity needs of Enforcement Unit to adopt and apply new tools and technology.

9.2 Types of sanctions and penalties that can be applied in case of non-compliance with the management controls

The Fisheries Administrator has the authority to cancel and suspend fishing licenses or categories of licenses (Fisheries Resources Act of 2020, Part XV, section 71). The licensee shall be informed by the Fisheries Administrator of the intention and grounds to cancel and suspend their license. A person who is affected by the cancellation or suspension of a fishing license can appeal in writing to the Fisheries Administrator. In addition, the Fisheries Administrator can suspend, cancel, or prohibit a person from applying for a license, if that person has been convicted of offences against the Fisheries Resources Act of 2020 and its regulations (Fisheries Resources Act of 2020, Part V, section 4).

In summary, penalties are determined by offences. Person(s) who contravene provisions related to fishery areas, marine and inland water reserves or any pertinent regulations, commits an offence, and is liable to a fine not less than one thousand dollars but not more than one hundred thousand dollars or to imprisonment for a term not exceeding three years or to both the fine and imprisonment (Fisheries Resources Act of 2020, Part XI, section 3). In addition to any fine and penalty imposed on a person who contravenes the Fisheries Resources Act of 2020, he/she can be held liable to the Government of Belize for any loss or damage, including to the ecosystem, and any costs incurred in detecting, apprehending, investigating or prosecuting. For those convicted under the Fisheries Resources Act of 2020, apart from the maximum penalty, forfeiture of property upon conviction is possible (Fisheries Resources Act of 2020, Part XVI, section 74). Any person (or partner, agent or employee of another person) that takes, has in possession, transports, or sells fish contrary to the Fisheries Resources Act of 2020 commits an offence and is liable on a summary conviction to a fine not less than five thousand dollars nor more than two hundred and fifty thousand dollars or to imprisonment for a term not less than one year nor more than five years (Fisheries Resources Act of 2020, Part XIII, section 69[2]).

Contravention of any section of the Fisheries Resources Act of 2020 is an offence punishable on summary conviction by a fine of fifty thousand dollars or imprisonment for two years, or by both fine and imprisonment. These sanctions and penalties are applicable to management control measures established by the multispecies finfish management plan and mandated by law.

9.3 Current limitations of the enforcement system and potential measures that could be used to improve compliance

Funding for capacity building and adequate fisheries law enforcement has been a major challenge for the Belize Fisheries Department since it took over the expenses for the CCU from the Commercialization of Alternative Crops Project under the United States Agency for International Development (USAID). Yearly budget allocations do not compensate for inflation and higher costs of living, thus reducing the availability of human resources, fisheries enforcement equipment and fuel to conduct sea patrols. Therefore, a coordinated approach to fisheries enforcement by the CCU with the marine reserves personnel, BNCG, the Police, Maritime Unit of the Belize Defence Force and co-management partners has yielded good results and will continue to be strengthened. The inter-agency approach to strategic enforcement supported by developing technology is crucial for ensuring compliance and preventing, deterring and eliminating illegal, unreported and unregulated (IUU) fishing in the waters of Belize. Ultimately, the Fisheries Department must make additional effort to find funding from internal and external sources to counteract IUU, from both domestic and foreign fleets. Given that, the government needs to provide the capacity for Fisheries Department staff to identify and apply for enforcement funding.

Public sensitization/education programmes geared towards educating fishers and the general public on the status of the major fishery stocks, the need for controlling fishing effort and the importance of protecting juveniles and spawning stocks, will be integrated with the Managed Access, replenishment zones and National Protected Areas campaigns. In addition, as the Fisheries Resources Act of 2020 is implemented and new fisheries regulations are drafted and passed, the need for education and awareness becomes integral. The Belize Fisheries Department completed its first Communication, Education and Public Awareness Strategy and Action Plan in 2017, with the main objective of instilling behaviour change among fishers and their communities to encourage sustainable and responsible fishing that contributes to adaptation and mitigation strategies for climate change. The plan uses a multilevel approach to improve communication practice and trust between the Department and targeted audiences, raising awareness of climate change and fisheries-related issues, and growing alliances. This plan will support compliance among fishers and fishing communities as it pertains to control measures and the recommendations of the multispecies finfish management plan.

9.4 Nature, extent and estimates of illegal harvest and trade

The extent of IUU fishing in Belize is hard to quantify, making market estimation difficult. IUU fishing erodes national and regional management and conservation efforts, impeding sustainability goals. Macfayden et al. (2016) found in their meta-analysis that studies of IUU fishing have mainly focused on commercial fishing, with minimal attention paid to small-scale fleets, although small-scale fisheries contribute substantially to global catch and employ a higher proportion of fishers and workers. Studies focused on regional and national IUU fishing issues and concentrated on the Pacific Ocean, while the Americas remain unrepresented. Overall, IUU fishing estimates are not consistent, a problem exacerbated by regional and national discrepancies in definitions of illegal catch, unreported catch and unregulated catch. Most studies that estimate IUU fishing focus on components of IUU behaviour – the geography, species, fleet and gear type – with limited emphasis on quantifying total removals. These studies are also less focused on the relationship between IUU fishing and sustainability or limit their focus to increase awareness for a certain species. Others focus on using estimates to make management recommendations and actions to reduce IUU fishing.

Drivers of IUU include micro and macro level economic incentives, political factors and weak fisheries management. While unregulated fishing was once the most prominent form of IUU, other behaviours such as misreporting data are now major components of IUU fishing. Thus, there is a need for consistency in definitions across regions and countries, with a clear understanding of associated activities under each. FAO and UNCTAD support the need to study IUU estimation methodologies and develop technical guidelines for future studies.

10. SUMMARIZING GOVERNANCE

10.1 Departments or institutions with management responsibility for the finfish fishery

The Belize Fisheries Department is the only government institution mandated with management responsibility for the multispecies finfish fishery. The primary responsibility of the Department is to ensure the sound management, conservation and sustainable use of the finfish resource. For a number of years, the Fisheries Department has maintained co-management agreements with three NGOs which support it with the monitoring, control and surveillance of fishing activities within specific marine reserves. The manager, biologist and reserve rangers whose salaries are paid by these NGOs are authorized to enforce the fisheries regulations, including the regulations that pertain to finfish.

The Fisheries Department has a fisheries inspector who is responsible for the preparation of charges for fisheries law violations. Offenders are taken to a Magistrate's Court where charges are read and evidence is presented before a magistrate. The magistrate decides the amount in fines and other penalties levied against offenders in accordance with the fisheries regulations. Communication with the NGOs is ongoing. Whereas employees of these NGOs may stop and search fishing vessels and detain and arrest fisheries offenders, only the fisheries inspector can lay charges and take offenders to court.

10.2 Use of scientific information to inform decision-making

Scientific data collected from the fishery-independent surveys is critical to decision-making in the management of the finfish fishery. Currently, the previous years' catch landings and average length and abundance estimates are the most useful and easily obtained performance indicators applied in the management of each fish basket in the finfish fishery. These data sets are obtained from the annual surveys, cooperative landings and data collected at landing sites.

10.3 Existing decision rule or procedure for establishing how harvesting should be modified in light of monitoring results

The management recommendations for each scenario in the performance of the fishery are explained in Table 9.

10.4 Periodicity in revision of management controls and adjustments

Fisheries management is dynamic and management controls and associated harvest control measures are regularly revised and adjusted as necessary by the Fisheries Department. One example is the landing of fish fillet with a skin patch of 1 by 2 inches; this regulation was put in place because fishers tried to hide illegally harvested Nassau groupers under the pretence that they were other finfish. The Fisheries Department conducts revisions of management controls in consultation with the Fisheries Council. Prior to submitting to the Minister, the Council may recommend public consultation and/or adoption of the plan. The amendments are then submitted to the Minister responsible for fisheries for approval. According to the Fisheries Resources Act of 2020, a fisheries management plan is valid for a period which may not exceed five years and may be reviewed and extended by the Fisheries Administrator.

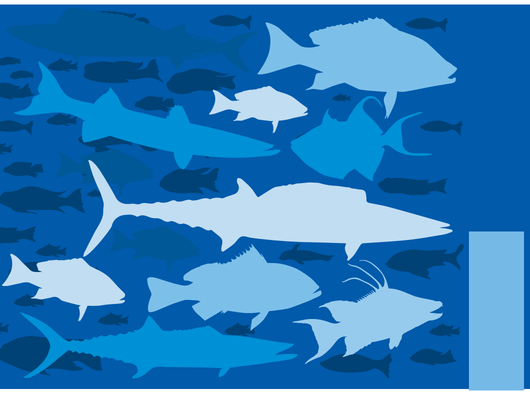
10.5 Mechanisms in place for consultation with stakeholders

The Fisheries Department maintains permanent communication with the fishing community (fishers' cooperatives, Belize Fishermen Cooperative Association, Belize Federation of Fishers, and to a lesser extent with smaller fishers' groups such as the various community fishers' associations). The fishing community plays an important role in fisheries management through the inputs and recommendations they provide during the multiple meetings, consultations and workshops held during the year. These inputs and recommendations are taken into consideration in the fisheries management and decision-making process.

The Fisheries Department holds consultations regularly with stakeholders, including fishers, representatives of the tourism sector, the general public, NGOs, conservation groups and others, on various matters that affect the fishing industry, such as the designation of marine reserves. The Fisheries Department involves fishers from various coastal communities in the decision-making process, e.g., including them as members of the Managed Access community committees that provide support to the Managed Access Task Force and make recommendations to the Fisheries Department. In addition, four out of 12 seats on the Fisheries Council are for representatives of fishing cooperatives (2) and fishers' organizations (2). This provides a platform for fishers to be deeply engaged in management control measures and implementation of the multispecies finfish management plan. The Fisheries Resources Act of 2020 (Part III, section 8) makes provision for the Council to review and make recommendations to the Fisheries Department on the fisheries management plan and/or proposed amendments. There must be consultation with or the participation of stakeholders in the preparation and revision of the plan. Stakeholders are notified via a notice in the Gazette and proposed plans are made available at public offices. They are given an opportunity to provide written and verbal comments.

10.6 Mechanisms for resolution of disputes within the fishery

Disputes within the fishing industry are uncommon since stakeholder involvement and participation occurs from the onset of the planning process for matters that affect the fishing industry. When disputes do arise, they are settled through dialogue, discussion and agreement. The Fisheries Administrator is the point person to whom issues, concerns and disputes are forwarded and these are dealt with on a case-by-case basis. Currently, the Fisheries Department does not have a conflict resolution policy and procedures manual. If a conflict or dispute arises between the Fisheries Department or Police and another authority which was conferred similar powers, the issue shall be referred to the Minister who shall decide which authority should exercise such powers.



11. FEEDBACK, REVIEW AND NEXT STEPS

11.1 Management system reviews

Fisheries management system review is best observed in the finfish fishery. The fish basket management system is designed to be reviewed regularly because finfish are dynamic and changes can occur as a result of multiple factors and conditions. The management system therefore is revisited every five years in alignment with the Fisheries Resources Act of 2020 (Part IV, section 10[5]). The performance of the fishery is assessed in accordance with the steps described in Section 7.

11.2 Mechanism for consultation to receive feedback from stakeholders

Fishers, through the cooperatives and fishers' organizations, are consulted frequently to obtain feedback on management decisions and implementation plans. The Fisheries Department has customarily shared information with fishers through special industry meetings called by the Department. This process has been formalized through the Fisheries Resources Act of 2020. To obtain participation and feedback from stakeholders on the multispecies finfish management plan, the Department will publish the specific information via a notice in the Gazette and two national newspapers. Copies of the proposed plan and/or amendments will be made available at public offices and invitations for stakeholders to submit written or oral comments within a specified period of time, the dates and places where meetings will be held to allow for public comment, will be published. Commentary and public meetings should be conducted between two and four months after the notice is published. In regard to amendments to the multispecies finfish management plan, the Fisheries Administrator will consult with the Fisheries Council which may recommend a public consultation or the adoption of the management plan. This decision is then taken to the Minister.

11.3 Scientific information used in the review

Scientific information gathered from field surveys is used to review the status and performance of the finfish fishery. Information such as fish length is the primary biological data used in the revision process. Further changes to performance indicators and analytical methods would rely on additional scientific information, such as biological parameters (e.g., theoretical maximum length [L_∞], theoretical length at age zero [T_0], length at maturity [L_{mat}], natural morality rate [M], von Bertalanffy growth parameter [k], etc.).

11.4 Policy revision and description of any changes made

The NFPSAP was developed in 2019 and endorsed by the Government of Belize.[34] The policy formulation process was iterative and included consultation with and participation of internal, primary and secondary stakeholders. The NFPSAP consists of five policy priority areas and ten policy statements. The NFPSAP guides the work of the Fisheries Department and is aligned with the Fisheries Resources Act of 2020, which embraces the principles of the ecosystem approach to fisheries and requires a focus on biodiversity targets and the socioeconomic needs of fishing communities.

11.5 Scientific research for improved management of the fishery

Though efforts have been made to collect biological, catch, landings, effort and production data for finfish, there is no centralized data management system to house data or make them accessible for analysis. Presently, the Belize Fisheries Department does not have a sustainable and effective finfish data collection programme that supplies updated information to decision makers for policy development (Carcamo, 2021b). Coordination and streamlining of finfish data sets to carry out comprehensive meta-analysis is needed. In addition, there is need for local life history studies on key species. Key priorities are outlined in Section 7.

11.6 External reviewers used in review of the management system

The Fisheries Council is comprised of experts from the Ministry of Blue Economy and Civil Aviation, Ministry of Tourism, Chief Environmental Officer, Chief Executive Officer of the CZMAI, representatives of NGOs, fishing cooperatives, fishing organizations and an expert in fisheries science.

The Fisheries Resources Act of 2020 (Part III, section 8) makes provision for a Fisheries Council, an advisory body to make recommendations to the Minister on:

(a) matters relating to the conservation, management, use and development of fisheries

(b) the development and implementation of comprehensive fisheries policies

(c) the monitoring and review, including the evaluation of, conservation guidelines and EBM measures

(d) consideration and review of fisheries management plans

(e) coordination of fisheries policies with government departments and agencies, including joint venture agreements and investments in the fisheries sector

(f) matters requiring coordination and cooperation

(g) any other fisheries matter at the request of the Minister or as required under the Act

The Council can co-opt a person who has a particular skill or knowledge to assist it for a specific purpose.

[34] A copy of the NFPSAP is available upon request from the Belize Fisheries Department.

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Annex 1.

HS codes for finfish species for exports in Belize, selected under the OETS project

HS Code	Code Description
302649000	Other mackerel *(Scomber scombrus, Scomber australasicus, Scomber japonicus)*, fresh or chilled
302692000	Snapper, croaker, grouper, dolphinfish, bangamary and sea trout, fresh or chilled
302699000	Other fish, excluding livers and roes, fresh or chilled
303290000	Other salmonidae, excluding livers and roes, frozen
303390000	Other flat fish, excluding livers and roes, frozen
303550000	Jack and horse mackerel (*Trachurus spp.*)
303749000	Other mackerel, frozen
303770000	Sea bass (*Dicentrarchus labrax, Dicentrarchus punctatus*), frozen
303792000	Snapper, croaker, grouper, dolphinfish, bangamary and sea trout, frozen
303799000	Other fish, excluding livers and roes, frozen
303839000	Other rays
303892000	Snapper, croaker, grouper, dolphinfish, bangamary
303899000	Other flying fish
305499000	Other smoked fish, including fillets
305591000	Mackerel, dried, whether or not salted, but not smoked
305599000	Other dried fish, whether or not salted, but not smoked
305691000	Mackerel, salted but not dried or smoked and in brine
305699000	Other fish salted but not dried or smoked and fish in brine
305710000	Shark fins
304109000	Other fish fillets and other fish meat (whether or not minced), fresh or chilled
304990000	Other fish fillets and other fish meat, fresh, chilled or frozen
304299000	Other flying fish fillets, frozen

Source: UNCTAD, 2020.

Annex 2.

List of common finfish species in Belize

Common name	Species name	Habitat	Priority
Mahi mahi	*Coryphaena hippurus*	pelagics/sport	moderate
Wahoo	*Acanthocybium solandri*	pelagics	moderate
Marlin – white/stripe	*Kajikia albida/ Kajikia audax*	pelagics/sport	moderate
Swordfish	*Xiphias gladius*	pelagics	moderate
Yellowfin tuna	*Thunnus albacares*	pelagics	moderate
Cobia	*Rachycentron canadum*	pelagics	moderate
Great amberjack	*Seriola dumerili*	deep-slope	low
White grunt	*Haemulon plumieri*	reef	moderate
Grey snapper	*Lutjanus griseus*	reef/spawning aggregation	moderate
Bluestriped grunt	*Haemulon sciurus*	reef	moderate
Great barracuda	*Sphyraena barracuda*	reef/migratory	moderate
Mojarra (yellowfin)	*Gerres cinereus*	estuarine	moderate
Mojarra (pompano)	*Diapterus auratus*	estuarine	moderate
Schoolmaster	*Lutjanus apodus*	reef/spawning aggregation	moderate
Mangrove/mahogany snapper	*Lutjanus mahogoni*	reef/spawning aggregation	moderate
Sailor's choice	*Haemulon parra*	estuarine	moderate
Margate	*Haemulon album*	estuarine	moderate
Yellow-eye snapper	*Lutjanus vivanus*	deep-slope	moderate
Deepwater blackfin snapper	*Lutjanus buccanella*	deep-slope	moderate
Southern red snapper	*Lutjanus purpureus*	deep-slope	moderate
Queen snapper	*Etelis oculatus*	deep-slope	moderate
Vermillion snapper	*Rhomboplites aurorubens*	deep-slope	moderate
Misty grouper	*Hyporthodus mystacinus*	deep-slope	moderate
Cubera snapper	*Lutjanus cyanopterus*	reef/spawning aggregation	low
Dog snapper	*Lutjanus jocu*	reef/spawning aggregation	moderate
Mullet	*Muguil* spp.	estuarine	high
Sardine	*Sardinella* spp.	forage fish	high
Sprat	*Sprattus* spp.	forage fish	high
Snook	*Centropomus undecimalis*	estuarine	moderate
Bay snook	*Petenia splendida*	fresh water	moderate
Crana	*Cichlosomas urophthalmus*	fresh water	moderate
Tuba	*Cichlasoma synspilum*	fresh water	moderate
Blue-eye catfish (*baca*)	*Ictalurus furcatus*	fresh water	moderate
Spanish mackerel	*Scomberomorus maculatus*	migratory	high
Crevalle	*Caranx hippos*	migratory	high
King mackerel	*Scomberomorus cavalla*	migratory/pelagics	high
Cerro mackerel	*Scomberomorus regalis*	migratory	high
Black grouper	*Mycteroperca bonaci*	reef/spawning aggregation	high
Goliath grouper	*Epinephelus itajara*	reef	high
Tiger grouper	*Mycteroperca tigris*	reef/spawning aggregation	high
Yellowfin grouper	*Mycteroperca venenosa*	reef/spawning aggregation	high
Mutton snapper	*Lutjanus analis*	reef/spawning aggregation	high
Red hind	*Epinephelus guttatus*	reef/spawning aggregation	high
Hogfish	*Lachnolaimus maximus*	reef	high
Nassau grouper	*Epinephelus striatus*	reef/spawning aggregation	high
Yellowtail snapper	*Ocyurus chrysurus*	reef/spawning aggregation	moderate
Lane snapper	*Lutjanus synagris*	reef/spawning aggregation	moderate

Source: Belize Fisheries Department and collaborators, 2021.

Note: This list was reviewed and updated during the June/July 2021 workshop, with input from local stakeholders.

Annex 3.

Data streams, performance indicators, reference points and assessment methods

Data stream: Underwater visual surveys

Performance indicator options	Target reference point	Limit reference point	Assessment methods	Target species
Fished:unfished density ratio (for key target species) Pros: a relatively quick and cheap way to assess the status of target species Cons: assumes that a fully-functioning and well-enforced NTZ has been sited appropriately with representative habitat; not useful for highly mobile targets	Fished:unfished density of target species > 0.6	Fished:unfished density of target species < 0.4	Density ratio	Fish and invertebrates that are habitat associated; not a good indicator for highly mobile targets
Fished:unfished biomass ratio (coral reef threshold aggregated across species) Pros: provides an estimate of ecosystem status and capacity to support fishing; useful for setting precautionary management to meet ecosystem-based fisheries management goals Cons: assumes that a fully-functioning and well-enforced NTZ has been sited appropriately with representative habitat; not useful for highly mobile targets. Assumes NTZs are representative of historical, unfished biomass	Fished:unfished biomass ratio > 0.5	Fished:unfished biomass ratio < 0.25	Coral reef thresholds	Multi-species finfish fishery
Average length Pros: easy, cheap metric to assess changes in the status of a fishery Cons: does not capture selectivity of the fishery, or if fishing is conducted in nursery grounds	Decrease in the size of unfished individuals outside of the NTZ, in comparison to previous years	Rapid decrease in the size of individuals outside of the NTZ, in comparison to previous years	Average length	Multi-species, habitat associated targets, not a good indicator for highly mobile targets

Data stream: Fishery-dependent length composition survey

Performance indicator options	Target reference point	Limit reference point	Assessment methods	Target species
Fishing mortality (F) Pros: mortality rates are critical for determining abundance of fish populations Cons: all the models assume equilibrium conditions. Most of these methods only reflect fish that have recruited to a fishery and do not reflect the full age structure of a stock	F/M <1 (F is fishing mortality, M is natural mortality)	F=2M	Catch curve Mean length (Lbar) Bounded mean length mortality estimator Mean weight mortality estimator	Finfish (groupers, snapper, grunts, etc.) and invertebrates with indeterminate growth (lobsters, crabs). Use with care for targets that have deterministic growth and episodic recruitment
SPR Pros: can be used with fishery-independent and dependent data Cons: assumes equilibrium conditions and an index based on the early life history of a fish; it must be remembered that many things can happen to the fish before it is large enough to harvest	slow growing species, M/k< 1 (grouper) SPR > 40% (M is natural mortality, k is von Bertalanffy growth rate) fast growing species, M/k >1 (lobster) SPR =20%	slow growing species, M/k< 1 (grouper) SPR <40% fast growing species, M/k >1 (lobster) SPR <20%	Length-based SPR (LBSPR)	Finfish (groupers, snapper, grunts, etc.) and invertebrates with indeterminate growth (lobsters, crabs). Use with care for targets that have deterministic growth and episodic recruitment
Average length Pros: easy, cheap metric to assess changes in the status of a fishery when stratified across sampling unit (gear, efforts, fishing zone) Cons: with little to no historical information on the length of the catch or with no information on gear selectivity, the average length could bias the expected potential size distribution	Increase in average length	Decrease in average length of mature adults	Average length	All targets, especially nearshore targets. In an ideal scenario an historic record of average length would be used to compare current to past estimates
Froese indicators Pros: proved estimate of the status of the stock, in comparison to sustainability reference points Cons: does not contribute to biomass sustainability reference points	100% of catch – optimal < 10% of the catch are *megaspawners* 90% of the catch are mature adults	<80% of catch – optimal < 20% of the catch are *megaspawners* 50% of the catch are mature adults	Froese sustainability indicators	All fish and invertebrate targets with known length–age/maturity relationships

Data stream: individual catch reporting system and boat intercept/landing site survey

Performance indicator options	Target reference point	Limit reference point	Assessment methods	Target species
CPUE Pros: can be used to infer population trends of an exploited stock. Standardized time series of CPUE are often regarded as indices of abundance Cons: seldom proportional to abundance history and an entire geographic range. Can be skewed, depending on sampling regime. May have species-specific biases	Stable CPUE	Rapidly decreasing CPUE, previous year or in comparison to running average	Catch trends	All targets that do not have high selectivity of habitat stratification
Total landings Pros: when sampling is stratified, can provide an estimate of abundance Cons: seldom proportional to abundance history and an entire geographic range, because of fishing location biases and lack of sampling stratification	Increase in total landing	Rapidly decreasing total landings, previous year or in comparison to running average	Catch trends	All targets that do not have high selectivity of habitat stratification

Source: EDF, 2021a.

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Annex 4.

Common indicators, data needs and management type applicability

Indicator	Data needs	Single-species/ multi-species/ ecosystem management	Example target reference point	Example limit reference point (LRP)
SPR (model-based)	Fishery-dependent length data, life history information	Single	SPR_{Tar}=40%	SPR_{Lim}=20%
Fishing mortality (F) (model-based)	Fishery-dependent length data, life history information	Single	F_{Tar} = 0.75M	F_{Lim} = 2M
MPA-DR for target species (model-based)	Fishery-independent surveys	Single/multi	MPA-DR_{Tar} =0.4	MPA-DR_{Lim} = 0.2 (single stocks)
MPA biomass ratio (MPA-BR; aggregated across species; model-based)	Fishery-independent surveys	Ecosystem	MPA-BR_{Tar}=0.4	MPA-BR_{Lim} = 0.3 (ecosystems)
Density (aggregated across species; model-free)	Fishery-independent surveys	Ecosystem	$Density_{Tar}$ = 800 kg/HA	$Density_{Lim}$ = 500 kg/HA
CPUE (model-free)	Catch and effort data	Single/multi	CPUE increasing from running average	CPUE decreasing rapidly from running average
Previous season's total landings (model-free)	Catch data	Single/multi/ ecosystem	Previous season's total landings stable or decreasing from running average	Previous season's total landings increasing rapidly from running average (without knowledge of effort)
Fraction mature (L_{mat}) (model-free)	Fishery-dependent length data, life history information	Single	$L_{mat, Tar}$ =100%	$L_{mat, Lim}$ = 80%
Fraction megaspawner (L_{mega}) (model-free)	Fishery-dependent length data, life history information	Single	$L_{mega,Tar}$ =20%	$L_{mega,Lim}$ = 30%
Fraction optimal (L_{opt}) (model-free)	Fishery-dependent length data, life history information	Single	$L_{opt, Tar}$ =90%	$L_{opt, Lim}$ = 50%

Source: EDF, 2021a.

Annex 5.

Performance indicators: possible interpretations, management implications and suggested harvest control rules

For each performance indicator…	If the assessment result is this…	And you believe the interpretation is likely this…	Then the management implication is this…	And then the harvest control rule suggested in the literature is this…
Fishing gear	Destructive fishing practices being used	Non-destructive fishing practices are no longer able to efficiently catch fish and/or destructive fishing practices have not yet been banned	🔴	1. Ban destructive fishing practices
	No destructive fishing practices being used	Non-destructive fishing practices are able to efficiently catch fish and/or destructive fishing practices have been banned	🟡	1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls or 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
Fishing season	Increased variability in fishing season, or decreased fishing season	Ecosystem likely not healthy enough to support historical fishing season	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
	No changes in the fishing season	Ecosystem may be healthy enough to support historical fishing season	🟡	1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls or 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
Target species composition	Change in composition of caught species (fewer species, more pelagics)	Ecosystem likely not healthy enough to support historical target species	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
	No change in composition of caught species	Ecosystem may be healthy enough to support historical target species	🟡	1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls or 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
Species vulnerability	Target species have high vulnerability	Target species have high susceptibility and/or low productivity	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
	Target species have medium vulnerability	Target species have medium susceptibility and medium productivity	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
	Target species have low vulnerability	Target species have low susceptibility and/or high productivity	🟡	1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls or 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)

For each performance indicator…	If the assessment result is this…	And you believe the interpretation is likely this…	Then the management implication is this…	And then the harvest control rule suggested in the literature is this…
Fished:unfished density ratio (for key target species)	Indicator >= target	Fishing pressure appropriate for maintaining or improving the health of the ecosystem	🟢	1. Make no changes to fisheries management controls or 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (significant illegal fishing is occurring within the NTZ)	🟡	1. Consider improved enforcement of NTZ and 2. Consider targeted social marketing to improve compliance with NTZ and 3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (NTZ is new and has not yet led to substantial improvements in ecosystem health)	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (NTZ is small with large amounts of species movement between fished and unfished areas)	🟡	1. Consider expansion or relocation of NTZ and 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Target > indicator > limit	High fishing pressure putting ecosystem at risk for impending state change	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Environmental stochasticity putting ecosystem at risk for impending state change	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (significant illegal fishing is occurring within the NTZ)	🟡	1. Consider improved enforcement of NTZ and Consider targeted social marketing to improve compliance with NTZ and 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (NTZ is new and has not yet led to substantial improvements in ecosystem health)	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (NTZ is small with large amounts of species movement between fished and unfished areas)	🟡	1. Consider expansion or relocation of NTZ and 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Limit >= indicator	High fishing pressure has caused an ecosystem state change; fishery in danger of collapse	⚫	1. Close fishery and Implement fishery recovery plan
		Extreme environmental stochasticity has caused an ecosystem state change; fishery in danger of collapse	⚫	1. Close fishery and Implement fishery recovery plan

For each performance indicator…	If the assessment result is this…	And you believe the interpretation is likely this…	Then the management implication is this…	And then the harvest control rule suggested in the literature is this…
Coral reef thresholds (aggregated across species)	Unfished biomass indicator >= target **And** fished:unfished biomass ratio >= target	Fishing pressure appropriate for maintaining or improving the health of the ecosystem	🟢	1. Make no changes to fisheries management controls or 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)
		Unfished area has a low biomass and does not represent a healthy virgin area (significant illegal fishing is occurring within the NTZ)	🟡	1. Consider improved enforcement of NTZ and 2. Consider targeted social marketing to improve compliance with NTZ and 3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low biomass and does not represent a healthy virgin area (NTZ is new and has not yet led to substantial improvements in ecosystem health)	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low biomass and does not represent a healthy virgin area (NTZ is small with large amounts of species movement between fished and unfished areas)	🟡	1. Consider expansion or relocation of NTZ and 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area does not have comparable habitat to fished area (unfished area habitat not as healthy as fished area)	🟡	1. Consider expansion or relocation of NTZ and 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Limit <= unfished biomass indicator <= target **And** Limit <= fished:unfished biomass ratio <= target	High fishing pressure putting ecosystem at risk for impending state change	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Environmental stochasticity putting ecosystem at risk for impending state change	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (significant illegal fishing is occurring within the NTZ)	🟡	1. Consider improved enforcement of NTZ and 2. Consider targeted social marketing to improve compliance with NTZ and 3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (NTZ is new and has not yet led to substantial improvements in ecosystem health)	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy virgin area (NTZ is small with large amounts of species movement between fished and unfished areas)	🟡	1. Consider expansion or relocation of NTZ and 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area does not have comparable habitat to fished area (unfished area habitat not as healthy as fished area)	🟡	1. Consider expansion or relocation of NTZ and 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)

For each performance indicator…	If the assessment result is this…	And you believe the interpretation is likely this…	Then the management implication is this…	And then the harvest control rule suggested in the literature is this…
	Limit >= unfished biomass indicator **Or** Limit >= fished:unfished biomass ratio	High fishing pressure has caused an ecosystem state change; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
		Extreme environmental stochasticity has caused an ecosystem state change; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
Fishing mortality	Indicator >= limit	High fishing pressure negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
		Extreme environmental stochasticity negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
	Limit > indicator > target	High fishing pressure affecting size structure and spawning stock biomass	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Fishers targeting nursery grounds	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Gear shift towards less selective gear (more small individuals in catch)	🟡	1. Consider implementing a gear restriction on less selective gear **and/or** 2. Consider implementing a minimum size limit (if one does not already exist)
		Strong recruitment pulse (more small individuals entering the catch)	🟢	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)
		Market selectivity for smaller individuals	🟡	1. Consider implementing a minimum size limit (if one does not already exist)
		Emigration of large individuals from fishing area	🟢	1. Make no changes to fisheries management controls
		Environmental stochasticity affecting size structure and spawning stock biomass	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Target >= indicator	Fishing pressure appropriate for maintaining or improving size structure of population	🟢	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)
		Gear shift towards more selective gear (fewer small individuals in catch)	🟢	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)

For each performance indicator…	If the assessment result is this…	And you believe the interpretation is likely this…	Then the management implication is this…	And then the harvest control rule suggested in the literature is this…
		Market selectivity for larger individuals	🟡	1. Consider implementing a maximum size limit (if one does not already exist)
		Weak recruitment pulse (fewer small individuals entering the catch)	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Immigration of large individuals to fishing area	🟢	1. Make no changes to fisheries management controls
Average length	Indicator <= limit	High fishing pressure negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
		Extreme environmental stochasticity negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
	Limit < indicator < target	High fishing pressure affecting size structure and spawning stock biomass	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Fishers targeting nursery grounds	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Gear shift towards less selective gear (more small individuals in catch)	🟡	1. Consider implementing a gear restriction on less selective gear **and/or** 2. Consider implementing a minimum size limit (if one does not already exist)
		Strong recruitment pulse (more small individuals entering the catch)	🟢	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)
		Market selectivity for smaller individuals	🟡	1. Consider implementing a minimum size limit (if one does not already exist) **or** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Emigration of large individuals from fishing area	🟢	1. Make no changes to fisheries management controls
		Environmental stochasticity affecting size structure and spawning stock biomass	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Target <= indicator	Fishing pressure appropriate for maintaining or improving size structure of population	🟢	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)
		Gear shift towards more selective gear (fewer small individuals in catch)	🟢	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)

For each performance indicator…	If the assessment result is this…	And you believe the interpretation is likely this…	Then the management implication is this…	And then the harvest control rule suggested in the literature is this…
		Market selectivity for larger individuals	🟡	1. Consider implementing a maximum size limit (if one does not already exist) **or** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Weak recruitment pulse (fewer small individuals entering the catch)	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Immigration of large individuals to fishing area	🟢	1. Make no changes to fisheries management controls
Spawning potential ratio	Indicator <= limit	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
		Extreme environmental stochasticity affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
	Limit > indicator < target	High fishing pressure affecting size structure and spawning stock biomass	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Fishers targeting nursery grounds	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Gear shift towards less selective gear (more small individuals in catch)	🟡	1. Consider implementing a gear restriction on less selective gear **and/or** 2. Consider implementing a minimum size limit (if one does not already exist)
		Strong recruitment pulse (more small individuals entering the catch)	🟢	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)
		Market selectivity for smaller individuals	🟡	1. Consider implementing a minimum size limit (if one does not already exist) **or** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Emigration of large individuals from fishing area	🟢	1. Make no changes to fisheries management controls
		Environmental stochasticity affecting size structure and spawning stock biomass	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Target <= indicator	Fishing pressure appropriate for maintaining or improving size structure of population and spawning stock biomass	🟢	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)

For each performance indicator…	If the assessment result is this…	And you believe the interpretation is likely this…	Then the management implication is this…	And then the harvest control rule suggested in the literature is this…
		Gear shift towards more selective gear (fewer small individuals in catch)	● (green)	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)
		Market selectivity for larger individuals	● (yellow)	1. Consider implementing a maximum size limit (if one does not already exist) **or** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Weak recruitment pulse (fewer small individuals entering the catch)	● (yellow)	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Immigration of large individuals to fishing area	● (green)	1. Make no changes to fisheries management controls
Froese indicators	All indicators at or better than target (L_{opt}=100%, L_{mat}>90%, L_{mega}<10%)	Fishing pressure appropriate for maintaining or improving size structure of population and spawning stock biomass	● (green)	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)
		Gear shift towards more or less selective gear	● (yellow)	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Change in recruitment	● (yellow)	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Change in spatial distribution of stock	● (yellow)	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Target > L_{opt} > limit **and/or** Target > L_{mat} > limit	Market selectivity for smaller individuals	● (yellow)	1. Consider implementing a minimum size limit (if one does not already exist) **or** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		High fishing pressure affecting size structure and spawning stock biomass	● (red)	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Fishers targeting nursery grounds	● (red)	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Strong recruitment pulse (more small individuals entering the catch)	● (green)	1. Make no changes to fisheries management controls **or** 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)
		Emigration of large individuals from fishing area	● (green)	1. Make no changes to fisheries management controls
		Environmental stochasticity affecting size structure and spawning stock biomass	● (yellow)	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)

For each performance indicator…	If the assessment result is this…	And you believe the interpretation is likely this…	Then the management implication is this…	And then the harvest control rule suggested in the literature is this…
	Limit > L_{mega} > target	Market selectivity for larger individuals	🟡	1. Consider implementing a maximum size limit (if one does not already exist) **or** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		High fishing pressure affecting size structure and spawning stock biomass	🔴	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Weak recruitment pulse (fewer small individuals entering the catch)	🟡	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Immigration of large individuals to fishing area	🟢	1. Make no changes to fisheries management controls
	L_{opt} < limit (L_{opt}<80%)	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
	L_{mat} < limit (L_{mat}<50%)	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan
	L_{mega} > limit (L_{mega} >20%)	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	⚫	1. Close fishery **and** 2. Implement fishery recovery plan

Source: McDonald et al. (2018).

Note: Management implications are denoted by colors, with green indicating no response is needed, yellow indicating a need for precautionary management, red indicating a need for more restrictive management, and black indicating a need for fishery closure.

Annex 6.

Suggested minimum sizes for common finfish species based on consultations and literature review

Common name	Scientific name	Minimum size
black grouper	*Mycteroperca bonaci*	25 inches
goliath grouper	*Epinephelus itajara*	40 inches
red hind	*Epinphelus guttatus*	10 inches
mutton snapper	*Lutjanus analis*	12 inches
lane snapper	*Lutjanus synagris*	8 inches
dog snapper	*Lutjanus jocu*	8 inches
cubera snapper	*Lutjanus cyanopterus*	10 inches
yellowtail snapper	*Ocyurus chrysurus*	8 inches
grey snapper	*Lutjanus griseus*	8 inches
hogfish	*Lachnolaimus maximus*	10 inches
queen triggerfish	*Balistes vetula*	12 inches
common snook	*Centropomus undecimalis*	20 inches
great barracuda	*Sphyraena barracuda*	20 inches
king mackerel	*Scomberomorus cavalla*	22 inches
(Atlantic) Spanish mackerel	*Scomberomorus maculatus*	22 inches
Cero	*Scomberomorus regalis*	22 inches

Source: Belize Fisheries Department (2017c).

Annex 7.

Data-limited assessment methods: inputs, outputs and major assumptions

Life history and expert knowledge

Productivity susceptibility analysis

This method provides guidance on the risk of overfishing a stock by using generally available life history data and expert knowledge to estimate the stock's productivity and vulnerability to fishing.

Inputs:

- life history information: length at maturity, growth rate, maximum length, aggregation behaviour
- fishery information: gear, fishing practices
- expert knowledge of fish biology and behaviour
- expert knowledge of how the fishery operates, especially with respect to characteristics that affect catchability of target species

Outputs:

- Productivity score – the biological capacity of the target population to produce its maximum sustainable yield and to recover if the population is depleted
- Susceptibility to fishing score – potential for the target to be impacted by the fishery through direct capture as well as indirect impacts, such as bycatch
- Vulnerability score – the overall vulnerability of the stock to overfishing

Assumptions:

- life history parameters are known, or can be borrowed from similar species in a similar geographic location
- scoring of productivity and susceptibility attributes is accurate and standard across species

Reference points:

- no reference point; provides risk of overfishing useful for prioritizing species for precautionary management, monitoring and assessment. Also useful for creating management categories of stocks within multispecies fisheries to simplify management

Recommendations:

- use PSA to prioritize data collection, assessment and management for targets with relatively high vulnerability (low productivity and high susceptibility) scores

Fishery-independent data

Catch trends

- Catch trends use fishery-dependent catch data to compare total catch, average catch, CPUE and/or abundance between years of interest. Comparisons can be derived for sequential years, or as a running average between historical trends. Additionally, comparisons can be made across all species or by species of interest.

Inputs:

- total catch for more than one year
- CPUE for more than one year
- abundance of the catch for more than one year
- length-frequency of the catch for more than one year

Outputs:

- total catch and trends in total catch
- CPUE and trends in CPUE
- abundance and trends in abundance
- average length and trends in average length

Input sensitivities:

- Stock status is inferred from catch statistics. It can be difficult to attribute a change in catch to a corresponding increase or decrease in biomass. Therefore, seeing an increase in catch could provide a false sense of security.

Caveats:

- this method depends on reliably tracking the total catch
- for example, raw CPUE is seldom proportional to abundance over a whole exploitation history and an entire geographic range, because numerous factors affect catch rates

Recommendations:

- Catch trends can support the interpretation of other analyses, for example of fishing mortality of SPR.
- Understanding how the trends in catch fluctuate from one year to the next or in comparison to the historic trends is essential to use catch trends for management.

MPA density ratio

This method provides an estimate of stock depletion relative to unfished levels, providing insight into the intensity of fishing pressure, by comparing fish densities on the fishing grounds to fish densities inside MPAs. In this description, we assume that fishing is banned within the MPA. Often, these types of MPAs are referred to as marine reserves or "no-take" reserves.

Inputs:

- fish density (fish counts and/or fish lengths plus area sampled), or CPUE (from fishery-independent surveys) inside and outside of no-take areas

Outputs:

- ratio of fished to unfished density as a proxy for depletion

Assumptions:

- habitat quality and productivity similar inside and outside of no-take area for sampled areas
- fish density in the MPA represents unfished conditions
- well-designed MPA (i.e., representative habitats inside and outside of the managed area, enforced, large enough for management of targets and old enough for fish populations to have equilibrated to no-take conditions)

- consistent monitoring programme
  - sites assigned randomly with the same protocol
  - the same fixed sites

Reference points:

- proxy reference points for stock status, since MSY reference points cannot be calculated using this method
- TRP, above 60 per cent (fished/reserve); no restrictions
- LRP, between 20 per cent and 60 per cent (fished/reserve), reduce length of open season
- below 20 per cent (fished/reserve) – close all year

Recommendations:

- effort controls (e.g., season length) can be adjusted in response to changes in MPA-DR as an indirect way to adjust fishing mortality aimed at moving the MPA-DR towards targets and away from limits
- for data on fish density inside and outside of MPAs that are not paired:
  - calculate average density across fished sites (density.fished)
  - calculate average density across reserve sites (density.reserve)
  - Density ratio=density.fished/density.reserve
- for paired sites inside and outside of MPAs
  - calculate density.fished/density.reserve for each pair and take the mean
- may need to divide by the density ratio observed during the year the MPA was established to account for differences in habitat between fished and reserve sites
- combined with methods that estimate F, or a reference value for F, effort can be adjusted through harvest control methods (e.g., catch limits, seasons or spatial closures) based on how far the MPA-DR is from the proxy reference point

MPA catch curve

This method utilizes length-frequency data (fish lengths) from inside and outside a MPA (here assumed to be a NTZ) to compare the slope of the right-hand side of the log transformed age-frequency histogram from inside the NTZ (an estimate of natural mortality [M]) to the slope of the log transformed age-frequency histogram outside the NTZ (an estimate of total mortality [Z]). Fishing mortality (F) can then be calculated based on the difference between these two (F = Z–M).

Inputs:

- length-frequency data inside and outside MPA (preferably collected in the same manner)
- life history parameters (growth parameters)
- number of years that the MPA has been well-enforced
- information on the sizes of fish preferred by the fishery

Input sensitivities:

- accuracy of individual fish length measurements
- accuracy of length-at-age relationships (von Bertalanffy growth parameters)
- correct fitting of the curve (sensitive to estimates of MPA age, preferred fish size)

Outputs:

- an estimate of fishing mortality (F)

Assumptions:

- assumes that a MPA has been sited appropriately, is well-enforced, and has been in place long enough for the population living inside the MPA to be a proxy for an unfished population
  - Implication: may be less accurate for highly mobile species that do not remain exclusively inside the MPA, such as snapper, tuna and mackerel.
  - This method depends on reliably tracking population size structure changes, thus it may be less accurate with small, fast growing species.

Reference points:

- stock status-based reference points for F
- TRP: M=F
- LRP: F=2M

Recommendations:

- target F/M is compared with F/M from assessment
- combined with methods that estimate F, or a reference value for F, effort can be adjusted through harvest control methods (e.g. catch limits, seasons or spatial closures) based on how far apart these values are from target F

Fishery-dependent data

Froese length-based sustainability indicators

This method estimates the proportion of the catch that is made up of juveniles, adults and mega-spawners. These proportions can be used as a reasonable representation of growth and recruitment overfishing.

Inputs:

- length-frequency of the catch
- expert knowledge of any biases in the data that would make the length composition of the catch less representative of a random sample (e.g., catchability of different sexes or length classes by the gear; catch coming from nursery grounds)
- theoretical maximum length ($L\infty$)
- theoretical length at age zero (T_0)
- length at maturity (L_{mat})

Input sensitivities:

- accuracy of individual fish length measurements and how they are measured (e.g., total length, standard length, or fork length)
- accuracy of length at maturity
- selectivity of sampling
- representativeness of sampling

Outputs:

- Three metrics of fisheries sustainability:
  - percentage of mature fish in catch
  - percentage of specimens with optimum length in catch (L_{opt})
  - percentage of "mega-spawners" in catch

Assumptions:

- life history parameters (e.g., maximum length and size frequency) are known
- length composition of the catch reflects that of the population OR selectivity of catch is accounted for by selecting a portion of the length composition data that is relatively unaffected
- L_{mat} = length at sexual maturity
- length-based proxy for MSY is $L_{MSY} = 0.75*L_C + 0.25*L\infty$ (where L_C is the length at first capture)
- length of optimal yield is L_{opt} = 2/3 of $L\infty$
- $L_{mega} = L_{opt}$ + 10 per cent

Reference points:

- proxy reference points for proportions of catch in different length categories for precautionary management, monitoring and assessment. Also useful for creating harvest control methods (e.g., size or slots limits to manage both recruitment and growth overfishing) to help with rebuilding a target fishery

Recommendations:

- percentage of mature fish in catch, with 100 per cent as target
- per cent of specimens with optimum length in catch (L_{opt}), with 100 per cent as target
- per centage of "mega-spawners" in catch, with 0 per cent as the target.
- combined with methods that estimate F, or a reference value for F, effort can be adjusted through harvest control methods (e.g., catch size limits, seasons, or spatial closures) based on how far apart these values are from size-based recommendations

Lbar (or "the mean length assessment")

This method uses fishery-dependent or independent length-frequency data. L_{bar} uses the minimum and maximum fished sizes, and the average length of the fish within the fished sizes from a fished population, along with growth parameters.

Inputs:

- fishery-dependent or fishery-independent length-frequency data of fished population
- theoretical maximum length (L_∞)
- theoretical length at age zero (T_0)
- length at maturity (L_{mat})
- natural morality rate (M)
- von Bertalanffy growth parameter (K)
- average length reported in the catch
- first length at full selectivity to the fishery

Input sensitivities:

- estimate of natural mortality (M) and growth parameters
- accuracy of individual fish length measurements
- representativeness of sampling

Outputs:

- estimate of fishing mortality (F)

Assumptions:

- life history parameters are known
- length is related to age throughout life (i.e., growth is indeterminate – the species just keeps growing longer and longer as it ages until it dies)
- recruitment is constant (i.e., juveniles are becoming adults at about the same rate each year) – this is a simplifying assumption that probably does not hold for any species
- mortality is constant – another simplifying assumption that probably does not hold for any species
- natural mortality (M) is known (this is often not the case)
- F_{MSY} = natural mortality (M)
- system is at equilibrium
- this method depends on reliably tracking population size structure changes, thus may be less accurate for small, fast-growing species
- this method is less reliable when mean fish length is very low

Reference points:

- stock status-based F reference points
- TRP: M=F
- LRP: F=2M

Recommendations

- fishing mortality is adjusted through harvest control methods (e.g., catch limits, seasons, or spatial closures) based on how far apart these values are from TRP & LRP

Mean weight

This method can use fishery-dependent or fishery-independent weight-frequency data to estimate fishing mortality (F) when no size structure data is available. It requires the von Bertalanffy growth function, as well as the length-weight relationship and the natural mortality (M). In this method, we construct a yield-per-recruit (YPR) model, which allows us to estimate the theoretical age and weight structure of the population at any size. Similar to mean length (L_{bar}), mean weight provides an estimate of F that can be compared to an estimate of M. Intuitively, increasing fishing pressure will often cause decreasing average weight and/or length.

Inputs:

- fishery-dependent or fishery-independent weight-frequency data
- life history parameters, growth parameters, natural mortality (M)
- information on the sizes of fish preferred by the fishery

Input sensitivities:

- estimate of M and growth parameters
- accuracy of individual fish weight measurements
- accuracy of length-weight relationship

Outputs:

- estimate of fishing mortality (F)

Assumptions:

- F_{MSY} = natural mortality (M)
- depends on reliably tracking population size structure changes
  - implication: may be less accurate with small, fast-growing species
- M is assumed to be known, which often it is not
- assumes equilibrium
- less reliable when mean fish length is very low

Reference points:

- stock status-based reference points
- TRP: M=F
- LRP: F=2M

Recommendations:

- fishing mortality is adjusted through harvest control methods (e.g., catch limits, seasons, or spatial closures) based on how far apart these values are from TRP & LRP

Cope and Punt length-based reference point

This method is an extension of the Froese length-based sustainability indicators to estimate reference points that indicate the stock status. Using the Froese indicators, three simple metrics that describe catch length compositions (i.e., that reflect exclusive take of mature individuals, P_{mat}; that consist primarily of fish of optimal size, the size at which the highest yield from a cohort occurs, P_{opt}; and that demonstrate the conservation of large, mature individuals, P_{mega}) to monitor population status relative to exploitation. The metrics (collectively referred to as P_x) are intended to avoid growth and recruitment overfishing. This method uses P_{obj} (the sum of P_{mat}, P_{opt}, and P_{mega}) to distinguish selectivity patterns and construct a decision tree for development of stock status indicators.

Inputs:

- length-frequency of the catch
- expert knowledge of any biases in the data that would make the length composition of the catch less representative of a random sample (e.g., catchability of different sexes or length classes by the gear; catch coming from nursery grounds; etc.)
- theoretical maximum length ($L\infty$)
- theoretical length at age zero (T_0)
- length at maturity (L_{mat})
- all length data needs to be measured as total length (TL) in order to calculate natural mortality

Input sensitivities:

- accuracy of individual fish length measurements and how they are measured (e.g., total length, standard length, or fork length)
- accuracy of length at maturity
- selectivity
- representativeness of sampling

Outputs:

- Three metrics that describe the catch:
  - percentage of the catch made up of mature adults (P_{mat}), with 100 per cent as the target
  - percentage of the catch made up of optimum length individuals (P_{opt}), with 100 per cent as the target
  - percentage of "mega-spawners" in the catch (P_{mega})
- These metrics are taken together (P_x) to determine if growth and/or recruitment overfishing is occurring and can be summed to create "P_{OBJ}" which describes the selectivity of the fishery. The value of P_{obj} can be compared with the Cope and Punt management decision tree to inform HCRs.

Assumptions:

- life history parameters (e.g., maximum length and size frequency) are known
- length composition of the catch reflects that of the population OR selectivity of catch is accounted for by selecting a portion of the length composition data that is relatively unaffected
- L_{mat} = length at sexual maturity
- length-based proxy for MSY is $L_{MSY} = 0.75*L_C + 0.25*L\infty$ (where L_C is the length at first capture)
- length of optimal yield is $L_{opt} = 2/3$ of $L\infty$
- $L_{mega} = L_{opt} + 10$ per cent
- Froese's (2004) sustainability recommendations are effective
- due to the reliance on specific size classes, this method may not be appropriate for stocks that exhibit little difference between mature (small) and optimum-sized (medium) individuals

Reference points:

- percentage optimum sized individual in catch (P_{opt}) = 1 or 100 per cent as target;
- P_{obj} ($P_{mat} + P_{opt} + P_{mega}$) = 2

Recommendations:

- $P_{obj} < 1$; fishing small sized fish, consider size restrictions
- $1 < P_{obj} < 2$
- combined with methods that estimate F, or a reference value for F, effort can be adjusted through harvest control methods (e.g., catch size limits, seasons, or spatial closures) based on how far apart these values are from size-based recommendations.

Catch curve

This method utilizes length-frequency data (fish lengths) from the catch to estimate total mortality from the slope of the log transformed age-frequency histogram generated from the length data using information on the relationship between length and weight. Fishing mortality is then estimated by subtracting natural mortality from the estimate of total mortality.

Inputs:

- same as length-based sustainability indicators, plus:
- natural mortality rate (M)
- von Bertalanffy growth parameter (K)

Input sensitivities:

- accuracy of individual fish length measurements
- accuracy of length-at-age relationships (von Bertalanffy growth parameters)
- Correct fitting of the curve (i.e., preferred fish size)

Outputs:

- estimate of fishing mortality (F)

Assumptions:

- life history parameters are known
- length is related to age throughout life (i.e., growth is indeterminate – the species just keeps growing longer and longer as it ages until it dies)
- depends on reliably tracking population size structure changes, thus may be less accurate for small, fast-growing species
- recruitment is constant (i.e., juveniles are becoming adults at about the same rate each year) – this is a simplifying assumption that probably does not hold for any species
- mortality is constant – another simplifying assumption that probably does not hold for any species

Reference points:

- stock status-based reference points for F
- TRP: M=F
- LRP: F=2M

Recommendations:

- combined with methods that estimate F, or a reference value for F, fishing mortality can be adjusted through harvest control methods (e.g., catch size limits, seasons, or spatial closures) based on how far apart these values are from TRPs and LRPs

Length-based spawning potential ratio

This method estimates the fraction of unfished reproductive potential that a fished stock may be theoretically capable of producing by calculating egg production from each length class sampled in the catch.

Inputs:

- length-frequency data from a fished population
- gear selectivity
- life history parameters (fecundity, von Bertalanffy life history parameters, natural mortality, age-at-maturity, length at age relationships)
- weight to length parameters (Wa, Wb)
- fecundity at age parameters (fa, fb)

Input sensitivities:

- accuracy of individual fish length measurements
- representativeness of the length data
- accuracy of life history information, particularly growth and maturity parameter
- sensitive to M

Outputs:

- SPR (the ratio of current reproductive capacity to maximum potential reproductive capacity of an unfished population)

Assumptions:

- dependent on reliably tracking changes in population size structure
    - implication: may be less accurate for small, fast-growing species
- fishery is in equilibrium and conditions are relatively stable (environmental conditions, fishing pressure, stock status, etc.)
- less accurate if fishing pressure has been changing dramatically year to year

Reference points:

- uses stock status-based reference points to estimate sustainable yield and maintain F.
- TRP, for fast growing targets SPR20; slow growing targets SPR40

Recommendations:

- uses estimates of F and TRP for SPR to see if current F supports sustainable yield; estimate F prior to using this method
- fishing mortality is adjusted through harvest control methods (e.g., catch limits, seasons, or spatial closures) based on how far reference value for F and reference points for SPR

Surplus production or biomass dynamics

This method estimates stock biomass and fishing mortality using catch, effort and any available indices of relative abundance without the inclusion of stock age or length structure. This model does not reflect any age structure in a population, and the dynamics of natural mortality, growth and recruitment are aggregated into a single intrinsic rate of population biomass increase, modified by fishing mortality. Estimated biomass and fishing mortality can be examined relative to reference points to determine stock status.

Inputs:

- total catch, stock biomass (if discards are low, then can be just landings)
- preferably more than 10 years of catch and abundance data
- catchability
- effort
- index of relative abundance

Input sensitivities:

- life history phenomena not incorporated (e.g., age of recruitment)
- survival
- growth

Outputs:

- estimate of MSY

Assumptions:

- catch is known without error
- stock is undifferentiated (no age, size, or gender differences)
- catch and/or index is linearly related to the stock abundance
- entire population covered by catch and index

Reference points:

- stock status-based reference point for estimating sustainable yield
- F_{MSY}
- F10%B
- F40%B
- B_{MSY}

Recommendations:

- fishing mortality is adjusted through harvest control methods (e.g., catch limits, seasons, or spatial closures) based on how far apart these values are from TRP & LRP
- surplus production models produce relative estimates of MSY and F_{MSY}, good estimates of q (the parameter that scales abundance indices into biomass estimates) and are scaled to steepness of the recruitment curve to increase the certainty

More complex methods: calculating average catch, overfishing level, total allowable catch and maximum sustainable yield

Depletion-corrected average catch

Depletion-corrected average catch (DCAC) samples depletion over a given period (t), F_{MSY} /M, M, and B_{MSY} /B_0 and then uses this information with average catches over the time period in order to calculate the average catches while accounting for the catch that went towards reducing the stock to productive levels. The method calculates the average catches accounting for the removal of the "windfall harvest" of less productive biomass that may have occurred as the stock became depleted.

Inputs:

- historical catch data (preferably ten years or more)
  - average catch
  - ~ relative change in stock size during the period the catches were taken
- natural mortality rate (preferably 0.2 or smaller)
- F_{MSY} /M

Input sensitivities:

- assumes that the average catch has been sustainable if abundance has not changed
- performs poorly with low starting abundance levels, and should be used with caution for targets that are in a rebuilding programme

Outputs:

- sustainable yield (based on average catch), not to be used for overfishing levels (OFL, does not account for low stock size)

Assumptions:

- average catch is sustainable if stock abundance has not changed substantially, corrected for the initial depletion in fish abundance
- $B_{MSY} = 0.4B_0$
- $F_{MSY} = cM$, where c = the tuning adjustment which may have a value of <1
  - c is generally assumed to equal 1, making $F_{MSY}/M = 1$, and thus making the assumption that F_{MSY} equals M

Reference points:

- stock status-based reference point to estimate sustainable yield, as a reference value to control F
- F_{MSY} /M
- B_{MSY} /B_0

Recommendations:

- fishing mortality is adjusted through harvest control methods (e.g., catch limits, seasons, or spatial closures) based on how far apart these values are from TRP & LRP for OFL

Depletion-based stock reduction analysis

Depletion-base stock reduction analysis finds a stock reconstruction that matches the input level of depletion and historical catch, to calculate an OFL by sampling F_{MSY}, depletion and the reconstructed unfished biomass. The process is stochastic and samples various values for all four inputs, each sample leading to an estimate of unfished biomass and OFL recommendation. This method is similar to the DCAC with the addition of a stock reduction analysis to estimate MSY-based reference points and relative stock condition.

Inputs:

- complete time series of historic catches
- level of current depletion
- F_{MSY} /M
- M
- the most productive stock size relative to unfished (B_{MSY}/B_0)
- estimate of age at recruitment to the fishery
- combines DCAC with stochastic stock reduction analysis
- Input sensitivities: same as DCAC

Outputs:

- probability distributions for biological reference points such as:
    - unfished biomass, MSY and OFL, and the distributions of stock size over time

Assumptions:

- same as DCAC

Reference points:

- stock status-based reference point to estimate sustainable yield, as a reference value to control F
- F_{MSY} /M
- B_{MSY} /B_0

Recommendations:

- fishing mortality is adjusted through harvest control methods (e.g., catch limits, seasons, or spatial closures) based on how far apart these values are from TRP and LRP for OFL.

MPA-based decision tree

This method estimates a TAC from data collected inside and outside of no-take reserves. The estimate can be improved by adding length composition data and is also improved over time by repeated sampling and adjustment.

Inputs:

- life-history characteristics such as size and age at maturity and natural mortality
- fishery-independent monitoring of CPUE by size class, OR
- age-length data collected from inside and outside marine reserves
- current catches or running average can be used to set initial TAC for decision tree

Input sensitivities:

- accuracy of individual fish length measurements
- accuracy of length-at-age relationships
- accuracy of the mean generation time of the target from FishBase

Outputs: TAC

Assumptions:

- habitat quality and productivity similar inside and outside of no-take area for sampled areas
- populations within MPAs are representative of unfished populations (i.e., MPAs are old enough and well-enforced enough for fish populations to have equilibrated to unfished conditions)
- results from relatively small MPAs can be extrapolated to generally much larger fishing areas

Reference points:

- proxy reference point to size-specific catch rate (inside/outside NTZ), as a reference value to control F
- size-specific CPUE reserve: CPUE fished

Recommendations:

- fishing mortality is adjusted through harvest control methods (e.g., TAC or spatial closures) based on how far apart these values are from TRP & LRP for OFL

Catch-MSY

This method estimates MSY from catch time series, estimated unfished stock size, estimated stock size at the end of the time series, and life history information.

Inputs:

- catch time series (catch plus discards)
- estimated ranges of stock size in the first and final years of the catch data ($B_{initial}$ and B_{final})
- life history information (r, K)

Input sensitivities:

- r and K are assumed to be constant
- biomass as a fraction of the carrying capacity at both the beginning and end of the time series, and the growth rate
- based on Schaefer surplus production, overall effects of recruitment, growth and mortality are pooled into a single production function

Outputs: MSY estimate

Assumptions:

- population growth and carrying capacity do not change over time
- production is based on the Schafer model
- catch is known without error
- stock is undifferentiated (no age, size, or gender differences)
- only a narrow range of r-K combinations can maintain the population
- population does not collapse or exceed the carrying capacity
- ignores the age structure of the stock and does not consider individual growth, recruitment or the vulnerability of the fish to the fishing gear

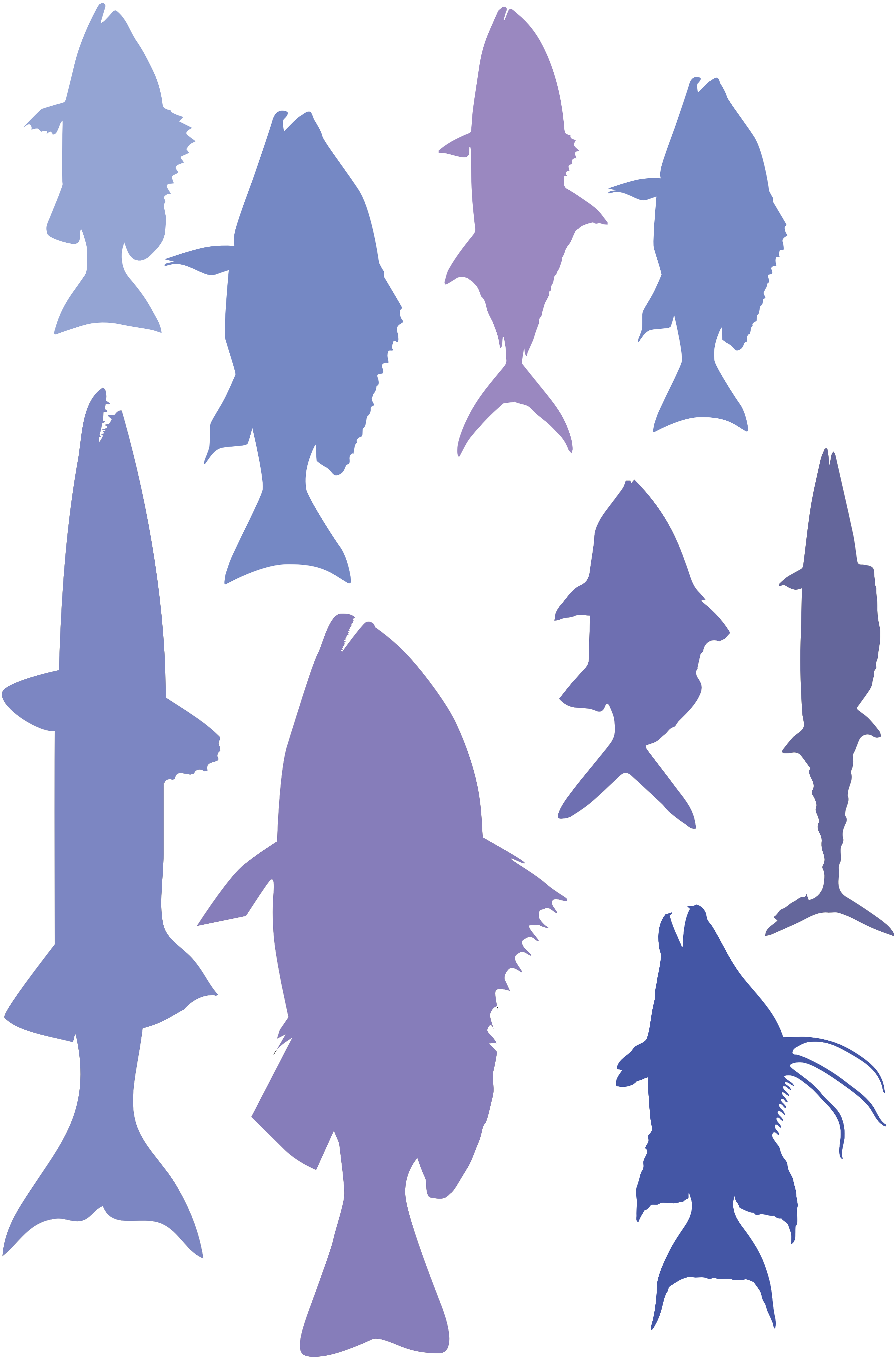
Reference points:

- stock status-based reference point to estimate sustainable yield, as a reference value to control F
- MSY is calculated as:
- MSY=r*K/4
- B_{MSY} =K/2
- F_{MSY} =r/2

Recommendations:

- fishing mortality is adjusted through harvest control methods (e.g., catch limits, seasons, or spatial closures) based on how far apart these values are from TRP & LRP for OFL

Source: EDF, 2021a.



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