Overview of Fisheries in the CNMI and Potential Impacts of Gillnet Fishing in Saipan Lagoon

CNMI Division of Fish and Wildlife Technical Report 24-01

Nathan Van Ee
Michael C. Tenorio
Francisco Villagomez
Keena Leon Guerrero
Nicholas Robie

9 February 2024

About DFW Administrative Reports

Administrative Reports are produced by CNMI Division of Fish and Wildlife to quickly disseminate information that is valuable to our fellow scientists, managers, and community members. Contents of Administrative Reports can communicate any information considered relevant to the communities we serve and may include scientific research, standard operating procedures, or comments on proposed management actions.

Administrative Reports move through an internal review process in DFW's Technical Review Committee, but they may not be externally peer reviewed. Reports may be adapted and published into a traditional journal format at a later date. DFW Administrative Reports may be references as long as proper credit is given to the authors.

Local fish names used in this report were referenced from a University of Guam Technical Report (Kerr, 2012). In some cases, spelling was adjusted due to differences between the CNMI and Guam.

Suggested citation:

Van Ee, N.J., Tenorio, M.C., Villagomez, F., Leon Guerrero, K., Robie, N. (2024). Overview of Fisheries in the CNMI and Potential Impacts of Gillnet Fishing in Saipan Lagoon. Div. of Fish and Wildlife, DLNR, Saipan, MP. Admin. Report: 24-01. https://opd.gov.mp/library/reports/fisheries-overview-gillnet-impacts.pdf

Further Information:
Division of Fish and Wildlife
Department of Lands and Natural Resources
Caller Box 10007, Lower Base Saipan, MP 96950
Tel: (670) 664-6000

Author Contributions

This report was a collaborative effort by multiple staff at the Division of Fish and Wildlife Fisheries Research and Development Section (DFW-FRDS). Specific staff roles are further described below.

Nathan Van Ee: Conceptualization, data aggregation/curation/analysis, data modeling, original figures, writing - report outline, executive summary, broad fishery overview, extraction rates, lagoon fishery dynamics, potential adverse effects from gillnet fishing, case studies, conclusion, Appendices 1 and 3, review and editing, final edits.
Michael C. Tenorio: Analysis – species caught during net-use exemption events, writing - broad fishery overview, types of net fishing in the CNMI, species caught during net-use exemption events, Appendix 2, review and editing.
Francisco Villagomez: Analysis – cost of gill net fishing, original figures, writing – about this document, lagoon fishery dynamics, gill net fishing costs, review and editing.
Keena Leon Guerrero: Writing – Saipan lagoon background, review and editing.
Nicholas Robie: Writing - review and editing.

Acknowledgements

DFW-FRDS communicated with several individuals during the development of this document and would like to acknowledge helpful contributions from John Gourley at Micronesian Environmental Services, Kylie Hasegawa at the Division of Coastal Resources Management, and Robert Gillett from Gillett, Preston and Associates. Additional thanks is extended to the members of DFW's Technical Review Committee whose helpful comments and constructive criticism improved this document.

Table of Contents

List of Abbreviations

Abbreviation	**Definition**
ACL	Annual Catch Limit
CNMI	Commonwealth of the Northern Mariana Islands
CPUE	Catch Per Unit Effort
CSD	Central Statistics Division
DCRM	Division of Coastal Resources Management
DFW	Division of Fish and Wildlife
DLNR	Department of Lands and Natural Resources
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
FAD	Fish Aggregating Device
FMP	Fisheries Management Plan
FRDS	Fisheries Research and Development Section
HB	House Bill
JAMS	Johnston Applied Marine Sciences
LBSP	Land Based Sources of Pollution
LB-SPR	Length-Based Spawning Potential Ratio
MES	Micronesian Environmental Services
MMCA	Managaha Marine Conservation Area
MPA	Marine Protected Area
NCS	Nighttime Commercial Spearfishing
NMIAC	Northern Mariana Islands Administrative Code

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PIFSC	Pacific Islands Fisheries Science Center
SCUBA	Self Contained Underwater Breather Apparatus
SGCN	Species of Greatest Conservation Need
SPR	Spawning Potential Ratio
SWAP	State Wildlife Action Plan
TAC	Total Allowable Catch
USD	United States Dollar
WPacFIN	Western Pacific Fisheries Information Network
WPRFMC	Western Pacific Regional Fishery Management Council

About this Document

On February 3, 2023, the 23rd Northern Marianas Commonwealth Legislature for the House of Representatives introduced House Bill 23-5 (HB-23-5) to legalize the use of gillnets, known locally as *tekken*, for non-commercial purposes only within the Saipan lagoon. Since the establishment of the gillnet ban in the early 2000s, there have been similar bills to repeal the regulation put in place by the Department of Lands and Natural Resources (DLNR) Division of Fish and Wildlife (DFW). Out of at least thirteen similar legislative bills, two were enacted into law allowing the use of net fishing in Rota and Tinian.

This document was developed by DFW Fisheries Research and Development Section (FRDS) to provide policymakers, natural resource managers, and stakeholders with contextual information on the local fishery and the potential impacts of HB-23-5. It was initially released internally to the DFW Director on April 10, 2023, to provide to the legislator's Natural Resource Committee. After review by DFW's Technical Review Committee, it was resubmitted for broader public release on January 31, 2024.

The document provides information moving from general to specific. It begins with an overview of fisheries in the Commonwealth of the Northern Mariana Islands (CNMI) and estimates of marine resource extraction rates. Next, it provides lagoon-specific information on current and previous monitoring efforts and generates estimates of lagoon resource extraction rates. The following section explains the net types used in the lagoon fishery along with current net-use restrictions, exempted activities, estimated costs of exempted activities, and species composition from exempted harvests. Finally, case studies for four important local reef fish species are presented to provide a deeper look into the health of these species as they relate to the lagoon and a potential gillnet fishery. Key results from the overview and case studies are presented in the following executive summary.

Executive Summary

CNMI fisheries are composed of three major sectors: pelagic, bottomfish, and reef fish. Of these three sectors, reef fish harvested from the lagoon is the primary catch for subsistence fishers. Saipan's lagoon is subject to some of the highest reef fishing pressure in the CNMI, with recent total extraction estimates by DFW of 96,000-160,000 lbs/yr. The lagoon harvest accounts for nearly 20% of Saipan's total fishery and ~77% of Saipan's coral reef fishery (Trianni et al., 2018b). In 2021, Saipan's total fishery (i.e., commercial and subsistence) was estimated to be worth just over $2 million USD/yr to fishermen (Gillet and Fong, 2023). In contrast, an economic study in 2019 found that coral reef tourism in the CNMI was worth $65 million USD/yr (Eastern Research Group, 2019), underscoring that the vast majority of economic gains from coral reefs in the CNMI are in tourism, not fishing.

While it may have relatively low economic value, fishing in the CNMI has high cultural value with an emphasis on the practice of sharing the catch with family and friends. Traditional fishing methods on Saipan consisted of a variety of methods including nets, which were deployed primarily in Saipan's lagoon. However, research in the 1990s showed that increases in gear efficiency, such as the adoption of a monofilament line, may have allowed certain nets to harvest fish at an unsustainable rate (Trianni et al., 2018a). Additionally, weighted nets, such as gillnets, dragnets, and surround nets, dragged across the bottom of the lagoon were damaging fish habitat with the potential to negatively impact the fishery. The indiscriminate harvest of undersized fish and bycatch of rays and sea turtles in abandoned nets was also concerning (Variety News Staff, 2011). For these reasons, specific types of nets were banned in the lagoon in 2003 (Fair Fishing Act, 2000). However, regulations allowed cultural events, such as fiestas and funerals, to apply for an exemption permit. This allows communities to celebrate their traditions while ensuring that harvest levels are monitored and sustainable.

Proper enforcement and monitoring of exempted net-use events are expensive, with estimated direct costs to DFW staff approaching $5,000 USD/net/fishing day. In 2017, increased permitting of net-use events for funerals outpaced DFW's enforcement funding and capacity and fewer than 20% of events receiving proper enforcement. As a result, permitted net-use extraction was estimated to be six times greater than DFW's recommended net-use annual catch limits (ACL). Increased gillnet permitting via HB-23-5 is likely to have a similar impact, overwhelming enforcement capacity and exceeding ACLs.

DFW is in the process of reassessing fish populations in the southern and central lagoon with survey results expected by January 2024. In the meantime, DFW used previous catch data (2011-2016) and life history information to develop species-specific models of four fish commonly harvested within the lagoon, *hangon* (Pacific orangespine unicornfish, *Naso lituratus*), *hiyok* (Striped surgeonfish, *Acanthurus lineatus*), lagoon *mafute'* (Thumbprint emperor, *Lethrinus harak*), and *tátaga* (Bluespine unicornfish, *Naso unicornis*). Our results suggest that two lagoon stocks (*hiyok* and *tátaga*) are harvested beyond sustainable levels, and two lagoon stocks (*hangon* and lagoon *mafute'*) are harvested sustainably but are approaching the threshold for unsustainable harvests. The primary fishing practice damaging stocks appears to be the harvest of sexually immature fish, which can lead to smaller harvests as fewer fish reach spawning size and reproduction rates decrease (Vasilakopoulos et al., 2011). Recent widespread damage to or loss of critical lagoon fish habitats such as *kuraling* (corals) (Maynard et al., 2018) and *chaiguan* (seagrasses) (Kendall et al., 2017) due to persistent lagoon water quality issues may also be impacting stocks negatively. Lagoon stocks and harvest yields would benefit from increased protections such as updated species-length restrictions, bag limits, and better enforcement of current marine conservation laws. Adopting broader ecosystem-based management strategies that protect, enhance, and restore essential fish habitats may help restore the lagoon fishery.

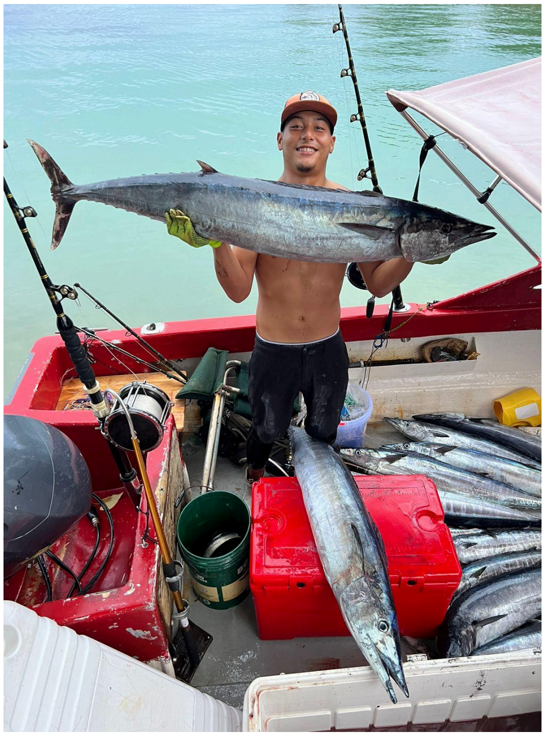
Allowing additional gillnet activities in Saipan's lagoon would increase the already high fishing pressure in this area, likely resulting in even greater juvenile fish mortality and negatively impacting future lagoon harvests. Gillnets also pose a high risk to essential fish habitats in the lagoon. Given the lack of enforcement funding and capacity along with the current state of key lagoon species and habitats, additional take by gillnet activities is inadvisable.

CNMI Fisheries Overview

Broad Fishery Characteristics

Over the last 30 years, fisheries in the CNMI have been described with three major sectors: pelagic, reef, and bottom fishing. Of these three, commercial landings from the pelagic fishery have comprised 57% of the market on average. Reef fish and bottom fish have respectively made up 36% and 6% of the total commercial fishery on average. The remaining 1% includes invertebrates such as octopus, squid, lobster, and other marine resources (DFW Commercial Receipt Book Program). Though small in terms of pounds landed, bottomfish and invertebrates, such as lobster, are an important part of the CNMI fishery because they attract a high price per pound.

CNMI's Major Fisheries



Pelagic

The pelagic fishery is made up of small-scale trolling vessels less than 20 ft long that typically operate within 20 miles of Saipan. Trips are generally limited by fuel range and weather conditions. Trolling vessels harvest pelagic fish species such as *bunitu* (Skipjack tuna, *Katsuwonus pelamis*), *makuro'* (Yellowfin tuna, *Thunnus albacares*), *botågue'* (Mahimahi/dolphinfish, *Coryphaena hippurus*), *toson* (wahoo, *Acanthocybium solandri*), and a variety of *taghalar* (billfish, *Istiophoridae spp.*), with *bunitu* dominating the pelagic market (DFW Commercial Receipt Book Program).

Austin Benavente shows off a large wahoo, one of many, caught during a day of trolling CNMI waters. Photo credit Masaki Kitami.

Bottomfish

Slightly larger vessels harvest bottomfish species both within the CNMI's exclusive economic zone (EEZ) and at offshore banks outside of the CNMI's EEZ. Bottom fishers target a variety of species which are often separated into two main groups: 1) deepwater (>350 ft) and 2) shallow water (< 350 ft). *Buninas* (deepwater snappers, *Etelis spp.* and *Pristipomoides spp.*) are the most popular deepwater bottomfish targets. Target species include *abuninas* (onaga, *Etelis coruscans*), *buninon agaga'* (ehu snapper, *Etelis carbunculus*), *lehi* (silvermouth, *Aphareus rutilans*), *buninon rayao amariyu* (gindai snapper, *Pristipomoides zonatus*), *kålikåli* (yellowtail kalikali, *Pristipomoides auricella*) and *opåkapåka* (pink opakapaka, *Pristipomoides filamentosus*). In recent decades, *pingulin tåhdong* (sickle pomfret/monchong/"wonderwoman", *Taractichthys steindachneri*) has also become a popular deepwater bottomfish target. Shallow bottomfish targets include various species of *gådao* (groupers, *Serranidae spp.*) and tarakitu (trevally, *Carangidae spp.*), but is dominated by emperors, in particular *mafute' tåhdong* (redgill emperor, *Lethrinus rubrioperculatus*). Some bottomfish vessels participate in both fisheries depending on the season.

A cooler filled with a multispecies array of fish including mafute' tåhdong, gådao, tarakitu, and satmoneten mattingen (Cinnabar goatfish, Parupeneus heptacanthus). Fish caught shallow bottom fishing off Saipan's west coast in ~300 ft of water. Photo credit Nathan Van Ee.

Reef Fish

Nearshore reef fish is the third fishery that contributes to the CNMI markets and is by far the most diverse in terms of species composition, with over 200 species contributing to market landings (Matthews et al., 2019). Nearshore reef fishing activities have remained relatively constant over the past ten years. Spearfishing, hook and line, cast net, and gleaning are all common methods within this fishery.

Trianni et al., (2018b) reports that nighttime spearfishing is the primary method used for harvesting coral reef fish in the CNMI. Access to preferred fishing grounds is seasonal since safe fishing access is limited by weather conditions. When the weather permits, fishing outside the reef is conducted with the use of small boats. This generally occurs between April and October. During this time, fishers can access more remote areas including the windward side of Saipan, Tinian, Aguijan, and Rota. Occasionally, larger vessels will fish in the northern islands. These trips target higher-value species such as *Mahongang* (spiny lobster, *Panulirus argus*) and *laggua* (large-bodied parrotfish, *Scaridae spp.*), which are sold mainly to restaurants and hotels. However, shore-based spearfishing in Saipan's lagoon area continues to be the dominant source of coral reef fish sold in the market likely due to near year-round access (Trianni et al., 2018b).

Mi'i Tekopua (aka Chinese Poksu) displays a large stringer of reef fish harvested from the lagoon area near Sugar Dock Beach. Species include odda' (Striated surgeonfish, Ctenochaetus striatus), hugupaon rayao amariyu (Whitecheek surgeonfish, Acanthurus nigricans) numerous species of palakse' (Parrotfish, Scaridae spp.) and såksåk (Soldierfishes, Myripristes spp.) Photo credit: Mareko Tekopua.

Seasonal runs by species such as *atulai* (Bigeye scad, *Selar crumenopthalmus*), *I'i'* (juvenile trevally, *Carangidae spp.*), *Ti'ao* (juvenile goatfish, *Mullidae spp.*), and *mañåhak* (juvenile rabbitfish, *Siganidae spp.*) are an important component of the CNMI's recreational and subsistence coral reef fishery. Primary harvest methods for these species are hook & line and *talaya* (cast net). *Atulai* landings also make their way into the market and can become an important seasonal source of income for some fishers.

Within the past five years, commercial landings of coral reef species have increased slightly. This upward trend should be interpreted carefully. While a slight recovery of the fishery is possible, the increasing trend may also be due to increased participation in the fishery due to recent economic hardships such as the Covid-19 pandemic, greater sampling effort by DFW's Fishery Data Section, improved data reporting compliance by participants, or updated data analysis methods.

An Outside View of CNMI’s Fishery

The Western Pacific Regional Fishery Management Council (WPRFMC) described the fishery dynamics of the CNMI over the last few decades in a recent report (Box 1).

Box 1: Fisheries in the CNMI and Recent Changes

The CNMI has had numerous changes in its fisheries over the past twenty years. In the mid-1990s, commercial fishing activities increased significantly. Commercial SCUBA fishing became a common method, not only to support local demand for reef fish, but to bolster exports to Guam as well. Large-scale commercial bottomfish fishing in the Northern Islands of the CNMI peaked starting in the mid-1990s through 2002, with landings being both sold locally and exported to Japan. Troll fishing continued to be dominant during this period. An exploratory, deepwater shrimp fishery also developed but did not last due to internal company issues and gear losses. Around this time, a sea cucumber fishery also began on Rota before migrating to Saipan; ultimately, however, this fishery was found to be unstable and was subsequently halted. Several fishing companies entered the fisheries only to close down a few years later. The CNMI reached its highest population during the last two decades, most of whom have been migrant workers from Asia. The tourism industry has also been increasing, which contributes to the high demand for fresh fish. Subsistence fishing within the nearshore waters of Saipan, Tinian, and Rota has also increased. In the 2000s, small-scale troll, bottom, and reef fish fisheries persisted, with landings sold locally. Federal and state support was provided multiple times to further develop fisheries in the CNMI with intermittent success. An exploratory longline fishery was funded and operated in the CNMI in the mid-2000 for about two years but eventually closed down due to low productivity of high-value, pelagic fish, among other issues within the business. A few larger (40-80’) bottomfish fishing vessels were also operational during this period, with a majority of them fishing the northern islands and offshore banks. A few of these vessels were recipients of financial assistance to improve their fishing capacities. Fisheries in the CNMI have generally been relatively small and fluid, with 16-20’ boats fishing within 20 miles from Saipan. Many of these small vessels conduct multiple fishing activities during a single trip. For example, a company that is supported mainly by troll fishing may also conduct bottomfish fishing and spearfishing to supplement their income. Fishing businesses tend to enter and exit the fishery when it is economically beneficial to do so, as they are highly sensitive to changes in the economy, development, population, and regulations. Subsistence fishing continues; however, fishing methods and target species have shifted in step with population demographics and fishery restrictions. Nearshore hook and line, cast net, and spearfishing are common activities, but fishing methods such as gillnet, surround net, drag net, and SCUBA-spear have been restricted or outright banned in the CNMI since the early 2000s. (WPRFMC, 2022)

Data from the DFW’s Fishery Data Section Commercial Receipt Book Program show trends that reflect WPRFMC’s dynamic narrative above (Figure 1). Notably, increased landings of reef fish in the late 1990s were likely due to the unregulated practices of SCUBA spearing and various net fishing methods, which may have depleted reef fish stocks leading to declines through the early 2000s. However, the SCUBA-spear ban, net-use restrictions, and development of Marine Protected Areas in the early 2000s may have helped to reduce the decline of reef fish seen in the markets (Trianni et. al., 2018a).

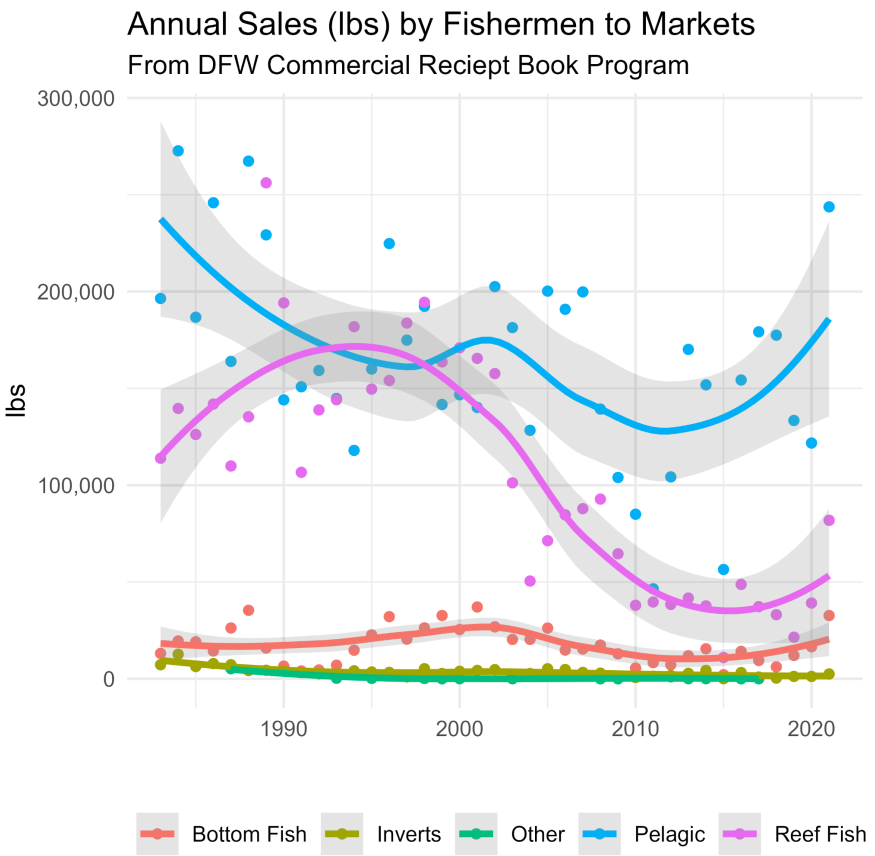


Figure 1: Annual Sales by Fishermen to Markets by Fishery Sector. Points show raw data, lines show loess smoothed data trends, and colors denote different sectors of the fishery. Shaded gray around each trend shows 95% confidence interval (standard error). Landings in the reef fish market peaked in the late 1990s, likely due to the unregulated use of SCUBA and various net-fishing methods including gillnet. After decreases in landings following the SCUBA-spear ban, and net-use restrictions, reef fish landings stabilized and then increased slightly in 2021. Increases may be due to increased fishery participation in light of the economic hardships from the COVID-19 pandemic, but could also be due to increased data collection efforts, greater reporting compliance, or a slight recovery of the fishery.

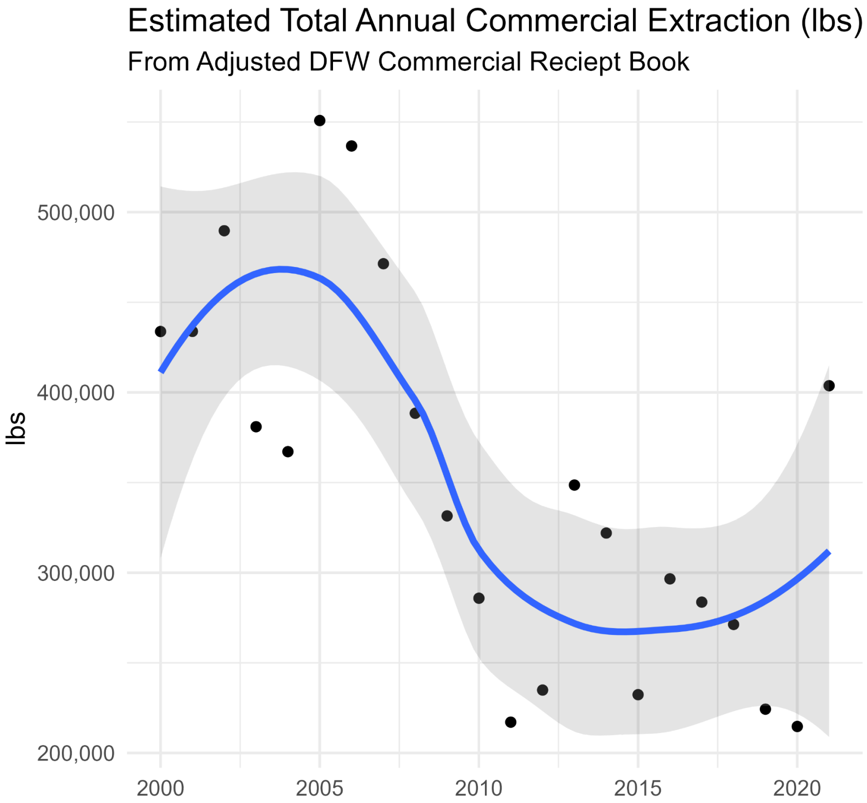
Marine Resource Extraction Rates

Marine resource extraction rates are an important fishery management benchmark. CNMI DFW's Fishery Data Section documents landings of commercial and non-commercial fishery resources through several fishery data collection programs. These programs were established at various times within the past 40 years. The following sections provide insight into the information collected, estimates generated, and discussions related to the estimates.

Commercial Fishery

It is important to note that the Commercial Receipt Book Program is not a census of all fishing in the CNMI, but a record of fish purchases from participating vendors. There are several fish resources not accounted for in this data such as vendors that do not participate in the Commercial Receipt Book Program, direct sales from fishermen to end consumers, and a large subsistence-based fishery. Thus, the total annual rate of extraction (lbs/yr) is likely to be substantially higher than the values presented in Figure 1.

To help account for the portion of commercial fishing that is missed each year, DFW estimates its percent coverage of the commercial fishery in the Commercial Receipt Book Program. NOAA Fisheries uses this information to produce "WPacFIN's Best Estimated Total Commercial Landings."



Source: adapted from https://apps-pifsc.fisheries.noaa.gov/wpacfin/total-landings.php

Figure 2: Estimated Total Annual Commercial Extraction.

Points show raw data, blue line shows loess smoothing to help visualize long-term trends in the fishery. The grey area shows 95% confidence areas (standard error). Total marine resource extraction peaked in the early 2000s concurrent with population trends. 2021 was an unusually high year with annual extraction of just over 400,000 lbs. The average annual extraction since 2010 is closer to 275,000 lbs.

For 2021, an estimated 403,740 lbs of commercial marine resources were extracted with an estimated value to fishermen of $1,175,803. However, 2021 was an unusually high year for the CNMI, and the average annual commercial extraction since 2010 has been lower at 277,207 lbs, worth approximately $719,089 to fishers (Gillet and Fong, 2023).

The CNMI Department of Commerce Central Statistics Division (CSD) estimated a median household income of $19,201 for 2016 CNMI residents (CNMI CSD, 2017). Thus, over the last decade, we can approximate that the average value of the commercial fishery would only have been able to support 37.5 households full-time at a median household income. However, many fishing households rely on alternative income streams and report minimal financial gains from fishing activities (Van Beukering et al., 2006; Hospital and Beavers, 2014). Moreover, much of the value of the CNMI fishery is not in the commercial sector, but in subsistence fishing and the cultural practice of sharing the catch with family and friends.

Subsistence Fishery

How much of CNMI's marine resource extraction is subsistence-based? Determining the average fate (i.e., final destination) of a fish is one way to estimate an answer to this question. Hospital and Beavers (2014) surveyed 112 small-boat fishermen on the islands of Saipan (80%), Tinian (10%), and Rota (10%) and determined the average fate of the catch. The results are summarized in Table 1.

Table 1: Average Catch Fate from 112 Small Boat Fishermen

On average smallboat fishermen give away the largest portion (38%) of their catch to friends, family, and crew. Roughly equal amounts of the catch are either consumed at home (28%) or sold (29%). Only a small fraction of the catch is released (2%) or exchanged for goods and services (3%).

Percentage of Catch	**Fate of Catch**
28%	consumed at home
38%	given away to relatives, friends, or crew
29%	sold
2%	released
3%	exchanged for goods and services

Results showed that home consumption and participation in traditional fish-sharing networks comprised the bulk of the CNMI's smallboat fishing industry. While there was a good deal of variety in catch fate among the boat-based fishers, even fleet high liners, fishers that sell to the market regularly, reported keeping ~22% of their catch for personal consumption. The survey did not include shore-based fishermen. It is possible that shore-based fishermen, who predominantly harvest lagoon and nearshore reef-associated species, retain a different proportion of their catch for personal consumption than boat-based fishers.

Total Fishery

If the results from the Hospital and Beavers survey are representative of the larger CNMI fishery, we can estimate that the commercial fishery represents approximately one-third of the CNMI's total marine resource extraction. However, other studies have recently estimated the split between commercial and subsistence fisheries to be closer to 50:50 (Gillett and Fong, 2023). By dividing the mean commercial landings from the last decade (~275,000 lbs/yr) by this range of one-third to one-half, we can estimate that the mean total annual extraction from CNMI waters since 2010 is between 550,000-840,000 lbs. This translates to an average harvest of 1,500-2,300 lbs/day across all the fishing sectors.

Putting this average daily landings figure into terms of food security and independence, it is important to note that fish in the CNMI are almost always sold whole (Fisheries Data Section Supervisor, personal communication). Thus, estimates of landings in pounds generated in this section include a large portion of the catch that is inevitably discarded such as the guts, scales, gills, head, fins, and frame. The edible portion of a whole fish is estimated to be 45% by weight (Sea Grant, 2024). The average healthy sedentary adult needs to consume approximately 0.08% of their total body weight in protein (Wempen, 2022). For example, someone who weighs 165 lbs requires 0.13 lbs/day of protein. Many fresh ocean fish are close to 20% protein (USDA, 2015). Dividing daily protein requirements by this ratio (i.e. 0.13/.2) we can estimate that a 165 lbs adult would need to eat 0.65 lbs/fish/day to meet their daily protein requirements if there was no other source of protein in their diet. With this information, the total CNMI fishery is estimated to provide enough protein to support between 1,040-1,592 165 lbs adults per day, roughly 2.16-3.32% of the ~48,000-person population of the CNMI (US Census Bureau, 2020).

Concluding Remarks

Fisheries in the CNMI consist of small-scale artisanal fishers that may participate in one or all of the major pelagic, bottomfish, or reef fish subsectors. Landing patterns are dynamic with pulses of seasonal fishes overlaid on an already complex multisector, multispecies fishery. In the last 20 years, pelagic landings have increased while reef fish landings initially declined before stabilizing in the 2010s. Bottomfish landings are smaller but more consistent and this sector may be underutilized. In 2021, the CNMI fishery contribution to the Gross Domestic Product (GDP) was 1.44 million, 0.12% of the CNMI's 2019 GDP (Gillet and Fong, 2023). While current landings may only support a small proportion of the population's protein needs, to some people, fishing may represent both their primary means of subsistence and income. Moreover, the practice of sharing fish harvests with family and friends remains an important part of the local culture.

But how much of this harvest comes from Saipan's lagoon? What other lagoon-specific information do we have to inform nearshore fishery management decisions?

Saipan Lagoon

Dynamics of Saipan’s Nearshore Fishery

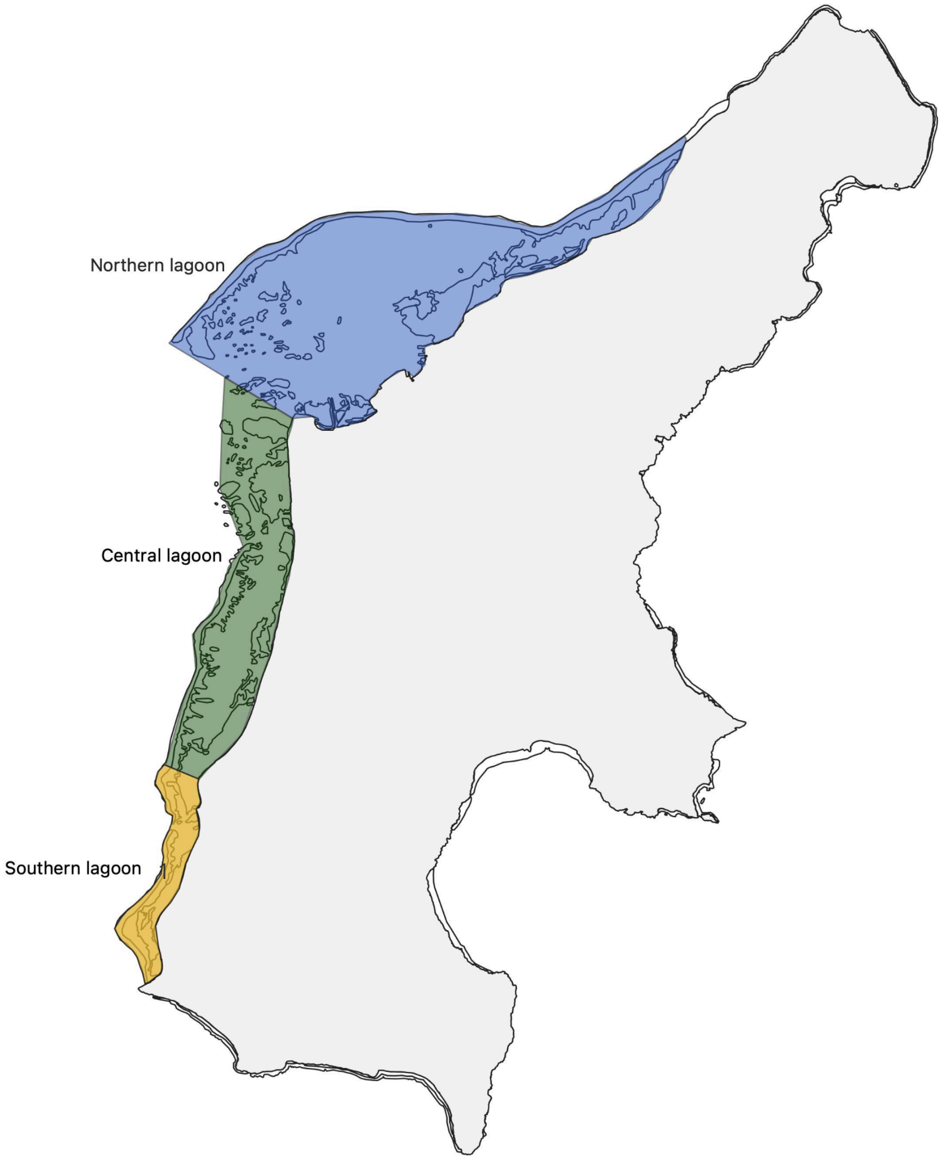


Figure 3: Saipan Lagoon and Lagoon Areas.
The northern lagoon (blue) is the largest and deepest section of Saipan’s lagoon (0-40 ft). Even within the barrier reef, strong winter currents and wind-driven waves make it less accessible than other lagoon areas. The central lagoon (green) is the next largest area with moderate depths ranging from 0-12 ft. Access to this area is nearly year-round. The southern lagoon (yellow) is the smallest and shallowest (0-5 ft) area. Calm conditions in this area are only occasionally disturbed by seasonal storms and typhoons.

Background

A lagoon is a shallow body of water separated from larger bodies of water by sandbars, coral reefs, and other natural barriers (NOAA, 2023). The Saipan lagoon extends along the wind-sheltered western side of the island, with a nearly continuous barrier reef that harbors a rich diversity of marine life (Trianni et al, 2018; Kendall et al., 2017). The lagoon plays a crucial role in the economy, tourism, and culture of the CNMI, attracting roughly half a million visitors to the CNMI in 2017 (Mariana Visitors Authority, 2017). The diversity of habitats within the lagoon offers tourists and locals many recreational activities including snorkeling, diving, parasailing, kite surfing, and more. The total revenue of Saipan's coral reef-related tourism was estimated at $42.3 million USD/yr in 2005 (Van Beukering et al., 2006), and then reevaluated at nearly $65 million USD/yr in 2019 (Eastern Research Group, 2019). The lagoon also provides a local source of protein to the people of Saipan as subsistence, commercial, recreational, and traditional fishing practices all occur within the lagoon.

Lagoon Fishery Dynamics

Fish Monitoring in the Lagoon

Because of the lagoon's ecological and commercial importance to fisheries, fish monitoring efforts were established in the late 1970s if not earlier with regular reef fish surveys beginning in the 1980s (Amesbury et al., 1979; Graham, 1994). With its establishment in 1981, the CNMI Division of Fish and Wildlife has been the leading agency tasked to monitor the CNMI's nearshore fishery resources. Early monitoring efforts in the lagoon highlighted the need to establish fishing restrictions on the use of poisons, explosives, SCUBA while fishing, and certain types of nets to reduce fishing pressure and fishing power and distribute fisheries resources equally to the people of the CNMI (Trianni et al., 2018a).

Routine monitoring of the lagoon and the CNMI nearshore fishery is important to effectively manage resources. Previous fisheries-independent surveys of resources in the Saipan lagoon were conducted by DFW-FRDS in 2005, 2007, and 2011. Surveys were conducted by trained divers who, using either SCUBA or snorkel depending on the depth, identified and counted fish species at nearly 200 different sites in Saipan's south and central lagoon. Results from these surveys revealed the important role the lagoon plays in providing critical nursery habitat for a variety of fish species and showed an increased probability of encountering adult food fish in the post-net-ban era (Trianni, 2018a).

On-going efforts to survey reef fishes in the lagoon are being carried out by DFW FRDS at the time of writing (March, 2023). Preliminary investigations suggest the need to enhance/restore lagoon habitat to increase productivity in the area and offset recent habitat losses due to coral bleaching and other water quality related stressors (DFW unpublished data).

Non-extractive diver surveys are an important way to gather information on the overall status of a fishery as well as the condition of essential fish habitat areas. This information is referred to as fishery-independent data. However, it is also important to understand the extractive portion of the fishery (i.e., what the fishers are removing from the population). This type of information is referred to as fishery-dependent data. While the CNMI Creel and Commercial Receipt Book Programs provide one source of fishery-dependent data, their programs target the entire CNMI fishery and often lack the specificity needed to answer detailed questions about the status of specific nearshore reef fishes. Targeted coral reef biosamping combined with life history analysis can provide managers with the specific harvest and life history trait details needed to manage the coral reef fishery at the species level.

A Coral Reef Fish Biosampling Program

Box 2: A Coral Reef Fish Biosampling Program

In 2009, the National Marine Fisheries Service (NMFS) Pacific Islands Fisheries Science Center (PIFSC) initiated discussions with U.S. outer island management agencies to develop plans to implement commercial coral reef fish market sampling programs based in the major population centers of the CNMI, Guam, and American Samoa. Preliminary market sampling on Saipan began in December 2010, followed by program implementation in January 2011. (Trianni et al., 2018b)

To gain a better understanding of the CNMI fishery, the National Marine Fisheries Service (NMFS) Pacific Islands Fisheries Science Center (PIFSC) implemented a coral reef fish market sampling program (Box 2). This NMFS PIFSC-funded coral reef fish biosampling program persisted through 2018 before shifting efforts to bottomfish to align with current NOAA jurisdiction.

The biosampling program provided some of the most detailed information ever collected on CNMI's nearshore coral reef fishery. Early results from the program underscored the importance of Saipan's lagoon to the fishery, showing that of the 10,554 nighttime commercial spearfishing (NCS) trips documented between 2011 and 2014, 77% were shore-based fishing in the lagoon (Trianni et al., 2018b). Average monthly NCS landings were dominated by these shore-based trips, which also drove the total mean fisher catch per month and catch per unit effort (CPUE) when compared to boat-based trips.

The biosampling project found that surgeonfish made up the vast majority of the shore-based NCS landings by both number and weight. Within the surgeonfish family, culturally iconic species, *hiyok*, *hangon*, and *tátaga*, accounted for nearly 81-91% of shore-based landings by number and 82–92% by weight (Trianni et al., (2018b). The authors also noted that *tátaga* and *gualåfi* (Pacific longnose parrotfish, *Hipposcarus longiceps*) harvested from shore-based fishing efforts were frequently smaller than the length-at-maturity where 50% of fish are reported to be reproductively mature (L_{50}). Furthermore, certain *palaksi* species (Blue-barred parrotfish, *Scarus ghobban)* landings mainly comprised lengths 20-30 cm, which were all classified as sexually immature individuals by a recent histological analysis (CNMI DFW unpublished data).

The biosampling program made it clear that shore-based fishing in Saipan's lagoon was the backbone of CNMI's coral reef fishery, supplying the market with year-round fresh reef fish. However, it also revealed some alarming practices within the lagoon fishery, in particular, the high harvest rate of sexually immature fish. Previous work has shown that when the fishing mortality of immature fish exceeds half that of mature fish, stock status falls below precautionary thresholds (Vasilakopoulos, 2011). Further study of lagoon extraction patterns and methods that target juveniles or inadvertently harvests immature fish is needed to understand the impacts of current fishing practices on stock status. Most importantly for the concerns of this document, the biosampling project produced detailed estimates of shore-based, boat-based, and total reef fish landings. These findings can be used to generate lagoon extraction rate estimates.

Lagoon Extraction Rates

Trianni et. al., (2018b) estimated a monthly average take of 8,160 lbs by commercial night spearfishermen. 5,300 lbs of those reef fish were extracted by shore-based fishermen, with 77% of landings coming from the leeward aspect of Saipan which is a shoreline area dominated by Saipan's Lagoon. By multiplying the shore-based extractions by 0.77, we can estimate that on average, close to 4,000 lbs of reef fish a month (~133 lbs/day) are harvested from Saipan's lagoon by the shore-based commercial nighttime spearfishing industry. If we want to account for subsistence fishing, we can assume, as before, that the commercial market accounts for 30-50% of the total fishery. This would give estimates of 96,000-160,000 lbs of annual extraction from Saipan's lagoon (~260-440 lbs/day). However, estimates do not account for boat-based trips that fished the lagoon as those numbers were not reported in Trianni et al., (2018b). Thus, lagoon extraction estimates are likely higher than what is reported here.

Previously, we estimated that the mean total annual extraction from CNMI waters since 2010 is likely between 550,000-840,000 lbs (1,500-2,300 lbs/day). With the above estimates of lagoon extraction, we can see that reef fish extraction from the Saipan lagoon accounts for nearly 20% of Saipan's total fishery, underscoring the importance of this relatively small area (31.2 km^2) to the local community.

Questions to Ponder

These introductory sections have provided an overview of fishing dynamics in the CNMI and specifically in Saipan's lagoon. The extraction rate estimates provide a useful management benchmark, but should also lead to several key follow-up questions:

- Are current lagoon extraction rates sustainable?
- How much can be harvested from the lagoon before negative impacts are realized?
- How much can be extracted with a gillnet?
- What are the potential consequences of gillnet extraction?

In the following section, we will describe different types of net fishing activities in the CNMI and estimate gillnet power (i.e., the potential extraction rates) and costs (i.e., the financial commitment needed to ensure sustainable use). Finally, we will use the current net-use restriction database to show which fish species are currently harvested by net fishers.

Gillnet Fishing

Types of Prohibited Net Fishing in the CNMI

There is a variety of net fishing equipment and methods that have been used to harvest nearshore resources in the CNMI. Both the equipment and methodology have evolved over the years. The following section briefly describes how gillnets, surround nets, drag nets, trap nets, and seine nets, have been used in more recent CNMI history.

Gillnets (*Tekken*)

Modern gillnets consist of thin monofilament lines woven into a mesh weighted down by led weights along the bottom end and kept taught by floats along the upper end (Figure 4a). This net captures fish by entangling their gills within the monofilament mesh (Figure 4b). Mesh sizes vary for targeted fish species and sizes. In the CNMI, this net is used in a variety of ways. They are set along the channels on reef flats. They are also used on seagrass and shallow patch reef habitats, similar to how surround nets are used.

Figure 4: a) Typical gillnet used in the Mariana Islands. b) A parrotfish caught in a gillnet during permitted net-use activity on Saipan. Source: CNMI DFW FRDS

Surround Nets (*Chenchulun Umesugon*)

Surround nets consist of thin nylon or fiber rope woven into a mesh and weighted down by led weights along the bottom end and kept tight by floats along the upper end (Figure 5a). These nets capture fish by trapping them within the enclosure (Figure 5b). These nets have commonly been used to capture schooling *atulai* as well as a variety of coral reef fish species. Surround nets are not designed to entangle fish gills. When used in shallow lagoon areas such as seagrass beds and sandy patch reefs, surround nets are often used to concentrate fish into a small area where fish are easily harvested by hand spear.

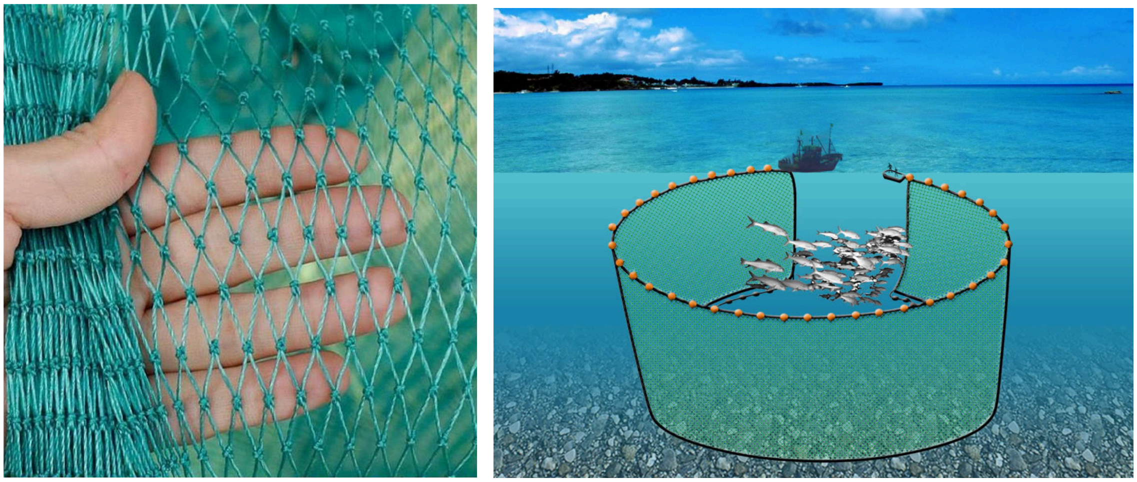


Figure 5: a) Close up view of common surround net. Source: zipy.ro b) Illustration of surround net fishing. Source: agritech.tnau.ac.in

Drag Nets (*Chenchulun*)

Drag nets consist of the same material as surround nets, but some have a pocket at the midpoint of the net, which fish are concentrated towards (Figure 6). Weights on this net are generally heavier to keep the net affixed to the seafloor.

Figure 6: Fish caught using a drag net. Source: new.grabone.co.nz

Trap Nets (*Gigao*)

Trap nets are stationary nets that are staked to the shore or in estuaries (Figure 7). These are locally known as *Gigao*. They consist of similar material as the surround net but are not kept in place by weights. A trap net has a holding compartment to which fish are funneled.

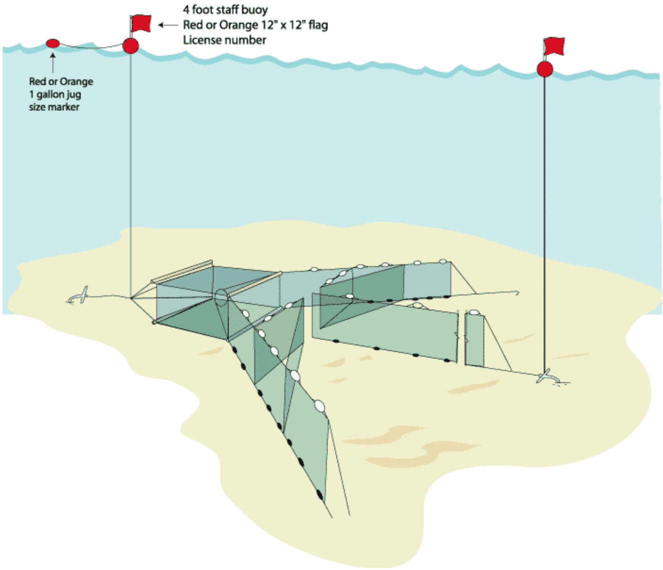


Figure 7: Illustration of a trap net or gigao. Source: michiganseagrant.org

Seine Nets (*lagua*)

A seine net is a long net, with or without a bag in the center (Figure 8). Multiple materials are used to construct seine nets (e.g., monofilament line, multifiber nylon, etc.). This net is used for surrounding a certain area and is operated with two long ropes fixed to its ends for hauling and herding the fish. This net is usually used along the shoreline on sand or in habitats with minimal rocks.

Figure 8: Seine net fishing.
Source: https://www.floridagofishing.com/fishing-beach-seining.html. (Photo Courtesy of Florida Marine Science Educators Association)

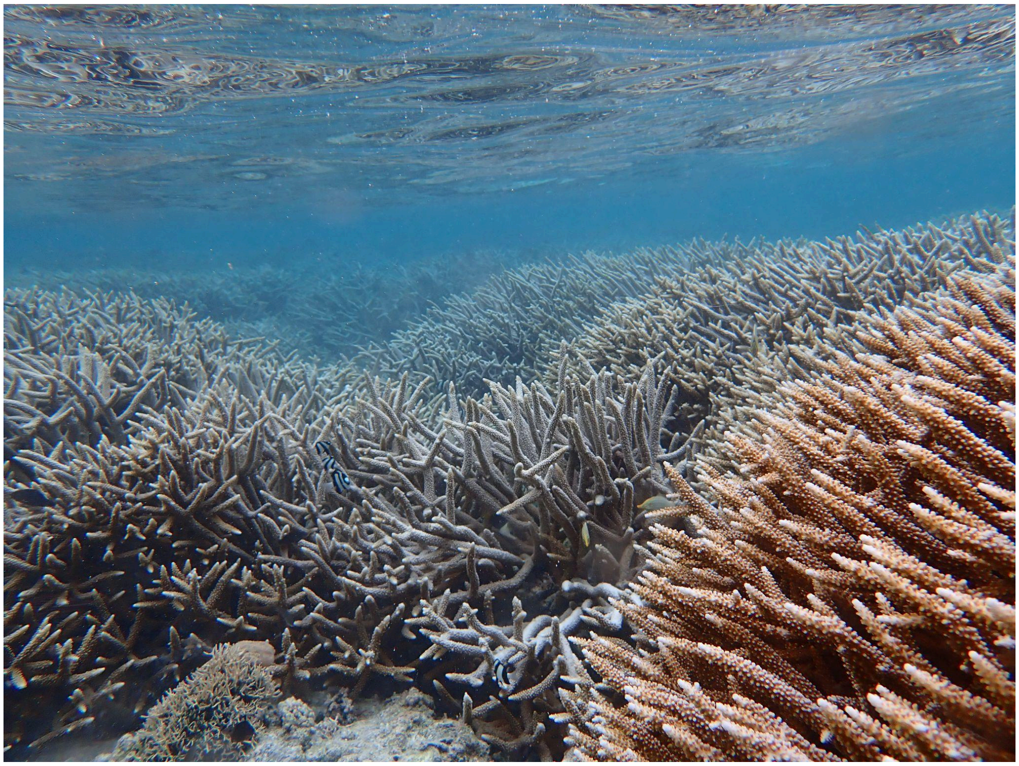
Potential Adverse Effects from Net Fishing

There are two major risks associated with net fishing: 1) damage to benthic habitats and 2) indiscriminate catch. These risks are high during the time of active fishing but can be mitigated with responsible fishing techniques. Nets that are lost, abandoned, or left unattended pose a very high risk to fish, wildlife, and habitats.

Damage to Benthic Habitats

Gillnets, as well as other weighted nets, have the potential to snag and damage benthic structures. Snagging is most likely to occur in complex benthic habitats that have large amounts of surface area. A study of the artisanal bottom-set gillnet fishery of Portugal found that 85% of gillnet deployments caught corals (Dias et al., 2020). Saipan's lagoon has three basic habitat types, *unai* (sand), *chaiguan* (seagrass), and *kuraling/åcho tasi* (coral/rubble). Potential damages from weighted net-use are smallest in *unai*, moderate in *chaiguan*, and high in *kuraling/åcho tasi* habitats. *Unai* areas of the lagoon are generally flat, with only very simple or no benthic structures likely to snag on a net. *Chaiguan* habitats are much more complex, with many areas for fish to hide, but are flexible. If done carefully, nets can be pulled through *chaiguan* with only minor damage to the habitat. In some cases, taller *chaiguan* species such as *Enhalus acoroides* may need to be untangled from the net to avoid damage. *Kuraling/åcho tasi* presents the most complex substrate and unlike *chaiguan*, *kuraling* is inflexible and brittle. Nets cannot be pulled through these habitats without risking serious damage. Snags must be meticulously untangled by hand to avoid damage. *Kuraling* are sensitive, slow-growing organisms. Damage to *kuraling* caused by net use can have long-lasting effects.

A gillnet set near the *mamati* (reef), where wave energy may cause the user to lose control of the net, has a high likelihood of becoming entangled and damaging *kuraling*. Branching *kuraling* such as staghorns (*Acropora spp.*), which are historically common in the lagoon backreef and patch reef areas (Houk and Van Woesik, 2008), are particularly susceptible to entanglement and damage due to their shape and fragility. This type of *kuraling* is listed as a species of greatest conservation need (SGCN) in DFW's 2015-2025 State Wildlife Action Plan (SWAP)(Liske-Clark, 2015). Moreover, Endangered Species Act (ESA) listed species such as *Acropora globiceps* are found in the lagoon patch reefs and near the *mamati*. Damages to ESA-listed species come at a high cost to both the environment and the net user, with fines ranging from $500-$25,000 USD (United States ESA, 1973).



A healthy kuraling (Staghorn coral, Acropora Spp.) thicket at Pau Pau Beach. This species of kuraling is particularly delicate and exempted net-use activities must avoid these habitats. Photo Credit: Nicholas Robie.

A recent DFW study found that backreef and patch reef areas with high coral coverage in Saipan's lagoon were fish biomass and diversity hotspots (Van Ee et al., 2023c). Allowing gillnet activities in such areas could produce high yields to the net user but ultimately at the cost of the habitat and long-term sustainability of the angler. Even permitted and enforced use of gillnets in patch reef, backreef, and reef channel areas pose a higher risk to habitat than those that target *unai* and *chaiguan* areas. This is why DLNR/DFW net-use exemption permit requirements typically limit exempted activities to *unai* and *chaiguan* areas.

Indiscriminate Catch

A spearfisher can visually identify, size, and select a target fish before pulling the trigger or letting the sling fly. A hook-and-line fisher does not know which fish will bite but can return non-target species to the water unharmed in most cases. Even some forms of net fishing (e.g. surround net) allow for the initial live capture of fish, followed by a selection process of harvest and by-catch release. Gillnets that are allowed to "soak" (i.e. when they are left unattended for a while) do not allow for this type of selectivity. Fish that become entangled in the net, unless untangled and harvested or released quickly by an active fisher, will likely suffer from serious injury and stress and, left long enough, may suffocate and die (Fishcount, 2019).

A study in Baja California, Mexico was conducted to quantify and compare the ecosystem impacts of four fishing gears (i.e. lobster traps, fish traps, set gillnet, and drift gillnet) in small-scale fisheries. Set gillnets had the highest overall impact on non-target species and habitats, with higher discard rates than the other gear types (Shester & Micheli, 2011). Saipan's lagoon is a diverse and complicated ecosystem. DFW recorded 169 different species in a survey of Saipan's central and southern lagoon areas (Van Ee et al., 2023c). Many of the species encountered were non-target species or juveniles, not suitable for harvest. Coral reef ecosystems are complex, with many species interacting with each other or providing mutually beneficial services (e.g. cleaner wrasses removing parasites from larger reef fish). Fatal by-catch of non-target species can impair ecosystem functions, reducing the health and resilience of the lagoon. Similarly, the harvest of juvenile fish food-fish (i.e. fish that have not had an opportunity to spawn at least one time) can negatively impact stock status, reducing future food-fish landings.

Some gillnet fisheries have tried to mitigate by-catch by regulating net mesh size. The thought behind this concept is that mesh size can be made large enough that juveniles can swim through the net unharmed but small enough to entangle and capture adult fish. Mesh size restrictions can be an effective management tool in low diversity or targeted fisheries where fishers are harvesting from specific populations with known growth and maturity patterns. However, nearshore coral reef areas are often complex multi-species fisheries that make mesh restrictions difficult to implement effectively. Observations from DFW's net-use exemption database found that fish from 24 families and over 90 unique species have been caught during exempted net-use activities (see Appendix 2). The diverse assemblages of fish within the catch have varied body types and life history traits including drastic differences in length at maturity. Thus, implementing a single mesh-size restriction that would ensure that only adult fish of every species are caught is not possible.

The ideal mesh size to target adults of one population could also entangle juveniles and sub-adults of another population, negatively impacting that fishery. For example, consider two common target species, lagoon *mafute* (Thumbprint emperor, *Lenthrinus harak*) and *tátaga* (Bluespine unicornfish, *Naso unicornis*). *Tátaga* can grow to be over 50.0 cm long whereas most mafute are < 30.0 cm. *Mafute* mature at about 19.6 cm but *tátaga* do not mature until they are > 29.2 cm long. DFW's best available estimates of *mafute'* show a relatively stable population whereas *tátaga* populations appear to be in decline (see "Case Studies" section). Both adult *mafute'* and juvenile *tátaga* can be found in lagoon backreef and patch reef areas. Thus, a well-intentioned sustainable harvest of adult *mafute'* via gillnet could have seriously negative effects on the *tátaga* fishery by inadvertently entangling and injuring or killing juveniles.

Although the CNMI's net-use restriction has been in place for approximately 20 years, DFW staff continue to receive reports of illegal net fishing and abandoned nets in the lagoon. Abandoned and unattended nets are even more likely to entangle corals, fish, and other marine creatures than actively monitored nets. Abandoned nets pose a particularly dangerous threat to the CNMI's endangered *haggan* (Sea turtle, *Cheloniidae spp.*) species, *haggan karai* (Hawksbill sea turtle, *Eretmochelys imbricata*) and *haggan betde* (Green sea turtle, *Chelonia mydas*). In August of this past year, a family rescued a *haggan* from an abandoned net at Saipan's Obyan beach (Manglona, 2023). Had the family not intervened, the *haggan* would have likely drowned.

Current Net Fishing in Saipan Lagoon

In 2003, the CNMI implemented regulations that restricted the use of multiple net types with exemptions for certain cultural and ceremonial activities (Box 3). The goal of the regulation was to reduce indiscriminate fishing in the CNMI, decrease habitat damage and ghost fishing from abandoned nets, and reduce the fishing power provided by new technologies (e.g., monofilament line) to allow for a more equitable distribution of fisheries resources to the people of the CNMI (Trianni et. al., 2018a). Despite existing exemptions afforded to community members, net fishing in Rota and Tinian was made possible via legislative action in 2010 and 2014 when the Fair Fishing Act of 2000 was amended (see 2 CMC § 5631). The most common net fishing gear used within the lagoon for exempted activities are gillnets and surround nets. Surround nets are used mainly during the St. Remedios Fiesta, while gillnets are used for other fiesta and funeral fishing events.

Box 3: Current Net-use Restrictions

§ 85-30.1-401(a)(2) No person shall use drag nets/beach seines (*Chenchulun* and *lagua*), trap net (*Chenchulun managam*), surround net (*Chenchulun Umesugon*) or gill nets (*Tekken*) for taking of fish or other sea life

§ 85-30.1-405(e) Exemptions: The Secretary, after consultation with the Director of the Division of Fish and Wildlife, may in certain cases make an exemption to the ban on the use of certain types of nets for net fishing for ceremonial purposes when cultural practices warrant an exemption, such as for a funeral or a fiesta. The Secretary must specify the extent and duration of the exemption in writing and this information must accompany the recipient of the exemption at the time the net fishing is undertaken. (NMIAC § 85-30.1-400 Fishing Regulations)

The Estimated Cost of net-use Exemptions

Net exemptions on Saipan are permitted by DLNR/DFW and are usually restricted to a certain number of fishing days and a maximum total weight of fish, whichever comes first. Permits typically allow up to 200 lbs but can vary by event. A condition of each permitted activity includes enforcement and monitoring by DFW staff, which is funded by a combination of local (Enforcement Section) and federal dollars (Fishery Data Section and FRDS).

How much does it cost for proper enforcement and monitoring of gill net activities? Answering this question requires understanding the context of net-use exemption events and DFW's associated staffing requirements.

A typical net-use exemption event can require up to seven DFW staff: two to three enforcement officers, two Fishery Data Section personnel, and one to two FRDS staff. DFW enforcement officers are required to be on-scene before exempted net-use activities can begin. Exempted events are usually limited to the hours of 8:30 am - 3:30 pm but can vary with each permit. Ideally, enforcement officers are present on the water (via boat or jetski), in the water (via mask, snorkel, and fins), and on the land (via truck). Prior DFW experiences with fish either left hidden in the water to be retrieved at a later date, transferred to an unmonitored vessel, or smuggled ashore into a waiting vehicle to be sold illegally at the market have necessitated this high enforcement effort (Enforcement Section, personal communication). Once net landings have been secured, two Fishery Data Section personnel are called by the enforcement officers to meet them on land and process the catch. One member identifies, weighs, and measures each fish, while the other records the data. Paper data records are later entered into the DFW net-use exemption database which is used to monitor the net-use fishery and inform future management decisions. For catches with many and varied fish species, it is often useful and sometimes necessary to have one or more biologists from the FRDS section to help identify and process the fish. In recent years, the lack of enforcement funding and broken-down enforcement vessels has required additional support from FRDS staff.

Large permitted events can last multiple days, requiring temporary storage of landed fish before fish are prepared for the cultural event. Due to previous compliance issues, DFW's current standard permit conditions require enforcement staff to follow the catch from the point of landing to the authorized permit holder's designated fish storage area. This condition helps ensure that landings are used for the intended cultural event, and do not make their way to the market. Despite this effort, reports of fiestas without fish served and testimonies of net-landed fish making their way to the market persist.

Average hourly wages for DFW Data and Enforcement Section staff positions vary from \$8.30-\$17.20/hr. Direct charges related to the net-use events often extend beyond the day of the event including staff time spent preparing boats and data collection equipment as well as post-event cleanup and data entry. Thus, a single fishing day often results in multiple days of staff effort, further increasing the cost of exempted activities.

From 2005–2018, DFW spent approximately $348,061.74 in direct costs on the enforcement and monitoring of gill net activities (Table 2). Per fishing day estimates of direct costs (i.e. staff time charged to a specific activity) amounted to an average of $4,714.11 per fishing day per net. The total cost is likely greater than this due to indirect costs such as fuel, data housing, and administrative time.

Table 2*: Estimated direct cost to the CNMI DFW for permitted gill net activities (2005 -2018). Estimate does not include fuel costs for travel to and from fishing sites, paper materials for data housing and collection, energy/supplies costs for power consumption, or administrative costs. Enforcement, Data, and Fisheries staff salaries were estimated based on a 5% increase each year. Estimated costs were calculated by the number of fishing days of each event multiplied by the number of staff hours and their respective salaries. Costs do not account for inflation.*

Year	Total # of fishing days	Average # of fishing days	# of Event	Direct costs ($)	Est average $ per day per net
2005	1	1	1	$2,419.95	$2,419.95
2006	5	2	3	$12,736.59	$2,547.32
2007	11	2	5	$29,495.26	$2,681.39
2008	14	4	4	$39,515.18	$2,822.51
2009	4	4	1	$11,884.26	$2,971.07
2010	1	1	1	$3,127.44	$3,127.44
2011	13	4	3	$42,796.52	$3,292.04
2012	3	3	1	$10,395.92	$3,465.31
2013	4	2	4	$14,590.76	$3,647.69
2014	7	4	2	$26,877.71	$3,839.67
2015	Nd	Nd	Nd	Nd	Nd
2016	6	6	1	$25,526.91	$4,254.49
2017	14	2	9	$62,697.68	$4,478.41
2018	14	1	10	$65,997.56	$4,714.11
Total	**97**	**2.26**	**45**	**$348,061.74**	**$3,741.27**

Nd = No data

Note: The total number of fishing days and number of events may be greater than reported and may result in greater costs. Direct cost is the estimated staff time charged to gill net activities.

Proper enforcement of net-use activities is necessary but has high direct costs. This puts strain on a department that lacks adequate funding for the level of enforcement required if an increase in gillnet-use results from passing HB-23-5[1]. Based on a cost ratio of 50:50 direct to indirect costs, we can estimate the total financial burden of permitted gill net activities in the CNMI to be ~$10,000 per net per day. But what about the marine resource extraction side of the story? How much is currently harvested from the lagoon via permitted net-use activities?

---

[1] A meeting with local fishermen was held on February 8, 2023 by the house bill's author. Statements made during the meeting led the DLNR Secretary to request a response from the DFW-FRDS (see Appendix 1).

Exempted Net-use Extraction Rates

Net-exempted activities are supposed to be monitored and remain within the annual catch limits (ACL) set by DFW. The ACL for net-use activities for 2023 is 1,500 lbs. Typically, six fiestas are granted exemptions every year with catch limits of 150-250 pounds per event totaling an estimated 900-1500 pounds of fish/yr extracted from the lagoon. By themselves, these fiestas fall within the current ACL and provide important events for local communities to celebrate their traditions and share the catch amongst one another. However, in addition to fiestas, DLNR began to permit exemptions for funerals starting in 2017. Due to interoffice communication issues and the expense/logistics of monitoring an event that can last multiple weeks, not all funeral permits were recorded and/or enforced by DFW, thus actual extraction rates and species composition are unknown.

To help account for this knowledge gap, DFW has estimated that an average three funerals per month received exemptions in 2017, with 150-200 pounds allowed per event. At that rate, we can estimate that 7,200 pounds of additional fishery resources were harvested within the lagoon by permitted funerals in 2017.

Under current CNMI law, (i.e. NMIAC § 85-30.1-400, see box 3) both fiestas and funerals are eligible for net-use exemptions. However, funerals occur more frequently and sporadically and last longer than annual fiestas, making proper enforcement difficult. The estimated cumulative landing of 8,700 pounds of fish in 2017 for all exempted events far exceeded the ACL of 1,500 pounds. While this issue was somewhat resolved though less-frequent permitting, it serves as a cautionary tale for how even a small number of net-use events can quickly exceed established limits. If HB-23-5 is allowed to pass, similar issues are likely to arise.

It is difficult to predict the effect of permitted net-use activities without knowing which species have been harvested. This is particularly concerning for funeral events, which have not been enforced or documented with the same level of detail as fiestas. While an ACL can provide a useful management tool, it contains no species-specific information. For an ACL to perform as intended, it must be informed by and tailored to species composition data from previous harvests.

Species Caught During Net-use Exemption Events

Permitted events with proper enforcement and data collection keep a log of the fished area, fishing effort, species caught, and individual fish length and weight measurements. These data are maintained in DFW's net-use exemption database and used to help inform management decisions.

From this database, we can see that numerous species of fish are caught within the permitted net fishing activities in the Saipan lagoon. Twenty-four finfish families have been identified in the sampled net landings. Within those families, approximately 92 species have been recorded (see Appendix 2). Commonly targeted food fish species such as two species of *mafute'* (i.e. Thumbprint emperor, *Lenthrinus harak,* and Orangestripe emperor, *Lenthrinus obsoletus*) and *atuali* tend to dominate net-use landings (Figure 9) with fish in the emperor family (*Lethrinidae spp.*) accounting for nearly half of all landings (Figure 10). Outside of net-use exemptions, these fish are also some of the most popular targets for recreational and subsistence hook and line fishers. Increased landings by net fishers in the lagoon may reduce landings for those fishers using other methods.

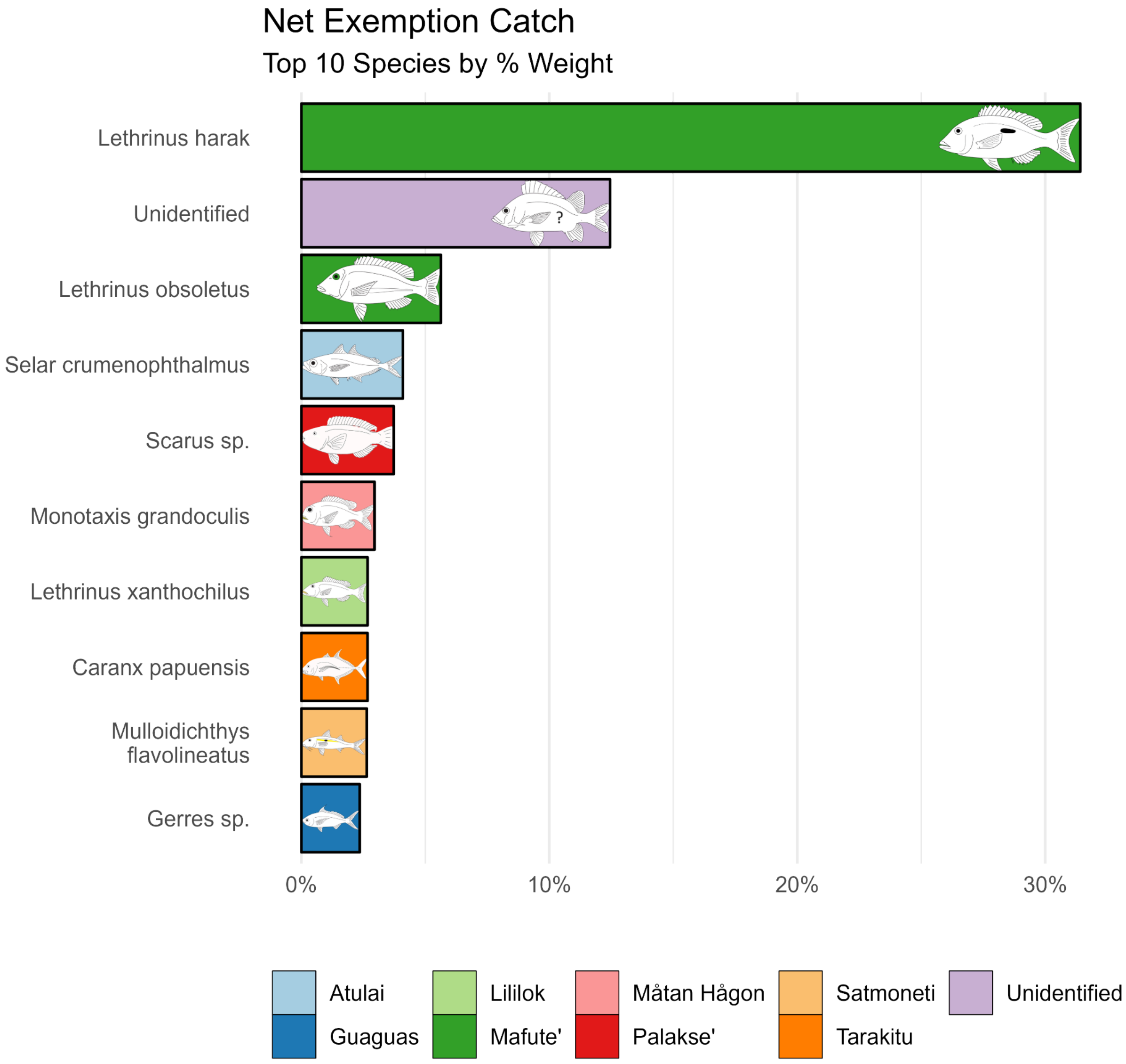


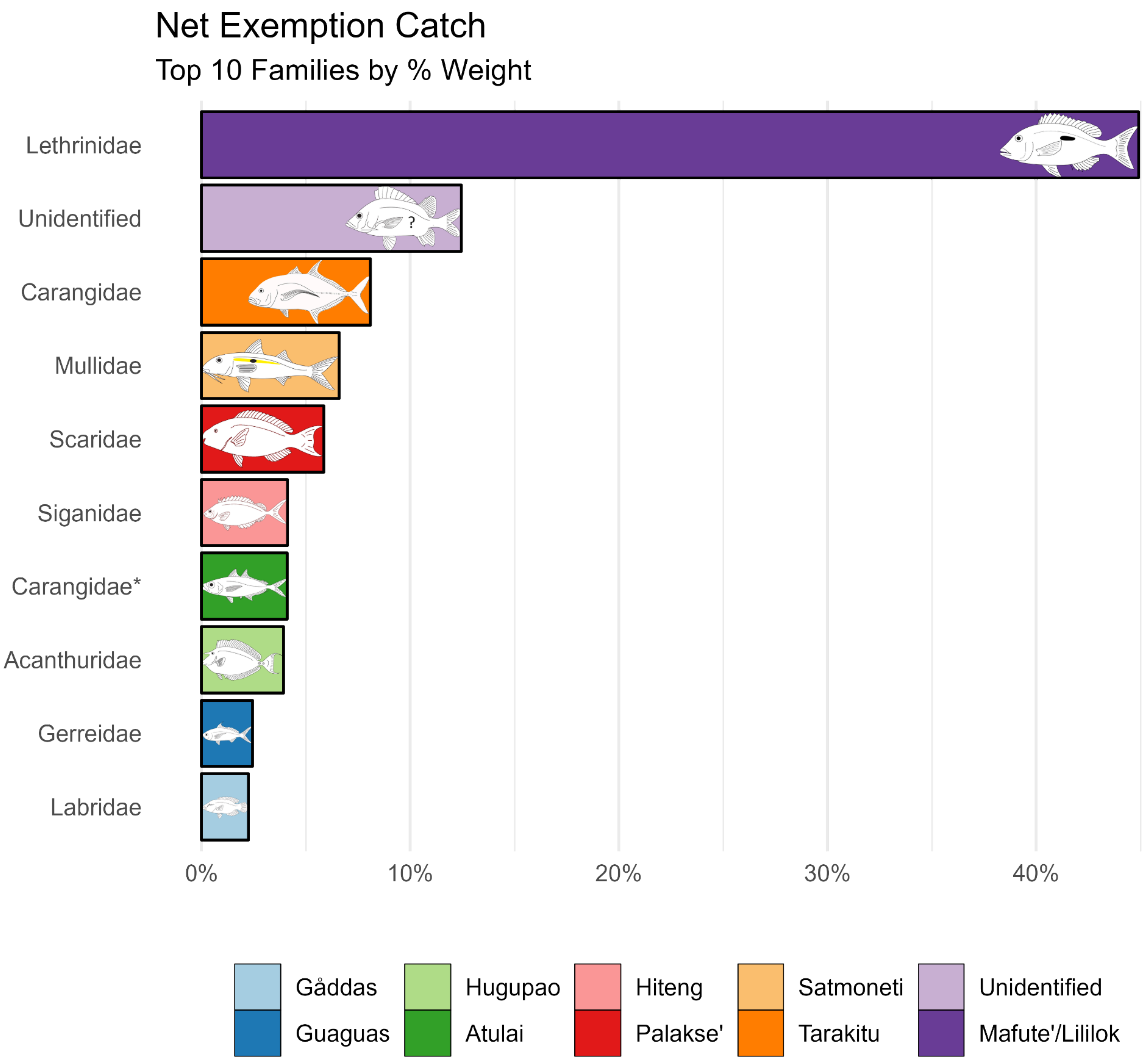
Figure 9: Net fishing exemption percent catch by weight by species.

Mafute' (dark green) species such as L. harak and L. obsoletus dominate net-use exemption catch. A large portion of the catch is unidentified (light purple), underscoring the need for better staff training. Atulai (light blue) make up a substantial portion of the overall catch despite only being targetted at a few select events in 2017. This shows how easily schooling-species, like atulai, can be harvested with a net.

A summary of catch composition by weight within the net fishing exemption activities shows that landings of lagoon *mafute'* (thumbprint emperor, *Lethrinus harak*) dominate the catch. This is likely due to the areas and methods used to catch these fish. A majority of the areas where exempted nets were set consisted of *unai* (sand), *chaiguan* (seagrass), and *kuraling*/*åcho tasi* (coral/rubble) substrates, the preferred habitat for this fish. The depths at which these nets are set also contribute to the catch composition.

The other species of *mafute'* (Orange-stripe emperor, *L. obsoletus*) is the second most commonly caught species by weight behind those that were unidentified. This *mafute'* species has some overlapping habitat preferences with the lagoon *mafute'* (Thumbprint emperor, *L. harak*) but is more commonly found in seagrass beds than in sand or coral/rubble habitats and is generally less common (DFW unpublished data).

Atulai (Bigeye scad, *Selar crumenophthalmus*) is the next most common catch in permitted net fishing activities (Figure 9). However, unlike many of the other species caught with a net, *atulai* is a species that can be specifically targeted and isolated. This is because *atulai* is a seasonal schooling species that tends to swim either near the surface or mid-water column. This makes it easy to locate, surround, and catch with nets deployed from a boat. Just a handful of permitted events in 2017 that specifically targeted *atulai* during their seasonal schooling period contributed to this anomaly in the data and underscores the fishing power of a net.



**Atulai is in the carangidae family but is separated here since atualai is typically targetted separately from other carangid species.*

Figure 10: Net fishing exemption percent catch by weight by family.

Mafute'/Lililok (Emperors, Lethrinidae spp.) (dark purple) dominate net-use exemption catch at ~45% of all landings by weight. A large portion of the catch remains unidentified (light purple), underscoring the need for better staff training. Exempted activities capture a variety of food-fish families.

When looking at the percent catch composition by weight for each family, *mafute'/lililok* (Emperors, *Lethrinidae spp.*) continues to dominate. The species caught within this family are, in order of frequency, *mafute'*, (Thumbprint emperor, *L. harak*, Orangestripe emperor, *L. obsoletus*, Pacific yellowtail emperor, *L. atkinsoni)*, *lililok*, (*L. xanthochilus*, *L. olivaceus)* and *Måtan Hågon* (Bigeye emperor, *M. grandoculis*). All species combined within this family compose nearly 45% of net exemption landings.

Current species composition is due primarily to net location and method. Alternative methods and locations could produce different species compositions. For example, nets set along small channels of the western lagoon are likely to land more surgeonfish and parrotfish. However, these areas are generally restricted within the permit conditions, since setting nets in these areas is likely to cause damage to coral substrate. Unmoderated funeral exemptions are a fisheries liability since they tend to utilize gillnet techniques that may target reef/channel areas.

DFW-FRDS provides a total allowable catch (TAC) recommendation for net-exempted activities. The TAC methodology is based on a target spawning potential ratio (SPR) of 50% for the emperor fish family (FRDS, 2015). Emperors were chosen since they are the dominant catch in currently documented exempted activities. However, managing an entire fishery based on one family-level analysis is challenging since species utilize different habitats and have different life history traits. Moreover, DFW-FRDS lacks species composition data from most funeral events due to the lack of enforcement capacity. To deal with this issue, DFW-FRDS has begun to develop species-specific models to determine a stock's reproductive health via the spawning potential ratio (SPR). This effort provides much greater detail on the status of a stock. These updated methods are further defined and discussed in the following section with case studies for four common reef fish caught predominantly in Saipan’s lagoon.

Case Studies

Growth Characteristics and Status of Four Key Reef Fish Caught Predominantly in Saipan's Lagoon

Like many island and coastal communities, CNMI's people rely heavily on nearshore marine resources. To gain an understanding of the status of these resources, we developed case studies on four common reef fish species: *hangon* (Pacific orangespine unicornfish, *Naso lituratus*), *hiyok* (Striped surgeonfish, *Acanthurus lineatus*), lagoon *mafute'* (Thumbprint emperor, *Lethrinus harak*), and *tátaga* (Bluespine unicornfish, *Naso unicornis*). These case studies were developed using a modeling approach that required species-specific life history parameters and fish lengths from catch data. A simplified explanation of this approach is explained here in a question/answer format. Full mathematical details are available in Appendix 3 as well as a list of the final model inputs and outputs. For each species, we provide information on growth and fishery characteristics, population status, and recommendations for future management.

Explanation of Method and Key Terms

The primary tool used to develop these case studies is a mathematical model that compares the target "fished" population with a theoretical "unfished" population. In this case, the target "fished" population is represented from harvest data collected in Saipan's lagoon while the "unfished" population is simulated based on life history data (explained in more detail in the following section) we have on the target species. The most important metric that comes from this analysis is the spawning potential ratio (SPR). SPR is the total weight of spawning fish in the fished population divided by the total weight of spawning fish in the unfished population.

SPR will always be between 0 and 1 and can be interpreted as a percentage. For example, an SPR of 0.5 means that the fished population has 50% or half of the reproductive capacity of the unfished population. The "best" target value for SPR depends on the goals of the managers and the life history parameters of the specific species in question. For less-known fisheries (e.g., those without a formal stock assessment program), a minimum SPR of 30% is recommended to avoid recruitment overfishing (Clark, 1993). Managers have found that an SPR of 40% is a good "rule of thumb" target that produces a large sustainable yield for many harvested species (Clark, 2002). However, others have cautioned that for long-lived, slow-growing, fish with lower reproductive capacity, an SPR of 50%-60% may be necessary (Restrepo et al., 1998).

The modeling approach required the following data:

1. Life history parameters
2. Measured fish lengths from fisher catch of the targeted population

Life History Parameters

Where do life history parameters come from?

Life history parameters come from measurements of fish that help managers determine growth rates, age at maturity, maximum length, and more. Fish growth and maturity patterns can be affected by a number of local conditions such as water temperature, fishing pressure, food availability, etc. Since growth patterns are affected by these variables, it is best to take measurements of fish from the area you are hoping to model. If this is not possible, measurements from a similar or nearby area can be used cautiously.

Where did the life history parameters for this report come from?

DFW-FRDS has a life history program that collects and processes CNMI fish. Many of our parameters came from this internal effort (DFW unpublished data). However, we cannot collect and analyze every species of fish in the CNMI. Thus, some parameters result from work done by partner agencies such as NOAA and Micronesia Environmental Services (MES) which also collect fish in the CNMI. Other parameters were borrowed from life history research conducted in Guam or other areas of Micronesia, which have similar environmental conditions to the CNMI.

What are life history parameters?

Life history parameters are species-specific numbers that can be used to model fish growth and reproduction. Each parameter can be thought of as a quantitative answer to a species-specific question. For example, consider the following questions regarding *hangon* as an example species.

We might ask how large a *hangon* can grow and what size it needs to be to produce offspring. These questions can be answered by estimating the species parameters L_{inf} (read as L infinity) and L_{50}, which are the average maximum length of a fish species and the length at which 50% of fish have reproduced, respectively. In the CNMI, *hangon* can grow up to 30 cm long but are closer to 25 cm long on average. *Hangon* are estimated to start reproducing at a length of 14.5 cm though sexual maturity can vary from fish to fish.

Other questions we might ask are how long can *hangon* live and what proportion of *hangon* die of natural causes (e.g., non-human predation, age, etc.)? The maximum age of a *hangon* (denoted mathematically as t_{max}) in the CNMI is estimated to be about 30 years. Estimating the natural mortality rate (M) of a fish species is challenging, but it can be done using the longevity method which assumes that M is constant through time (see Appendix 3, Eq 9). For *hangon* in the CNMI, DFW has estimated an M of 10%/yr.

Once we understand the natural growth, reproduction, and mortality of a fish, we can create a model of it. The model can help us estimate what a pristine or “unfished” population would look like. Next, we need to develop a similar model showing what the “fished” population looks like for comparison. For this type of model, we do that by analyzing fish length data taken from fisher catches.

Lengths from Fisher Catch

Why use length data?

Fish length measurements are one of the easiest, most cost-efficient, and most useful forms of data collected by fishery biologists (Quinn & Deriso, 1999). Hordyk et al., (2015) developed a length-based spawning ratio potential method (LB-SPR) that can estimate SPR based on length frequency data collected from fishermen's catches[2]. In other words, the model lets us compare the lengths of fish from real fisher's catch data to the lengths of fish in the modeled “unfished” population.

Where did the length data for this report come from?

We used fish lengths from the National Marine Fisheries Service Pacific Islands Fisheries Science Center (NMFS PIFSC) funded coral reef fish biosampling program (years 2011-2016) to generate the estimates of SPR in the following section. The coral reef biosampling program contains fish lengths from multiple areas in the CNMI, including some measurements from fish caught in northern island areas like Sarigan. For this analysis, we filtered length catch data to include only those fish caught within the lagoon area. The definition of “lagoon” for the biosampling project includes areas outside of the reef on the fore reef slope to a depth of ~40 ft, which is the approximate depth limit for most freediving commercial nighttime spearfishers (John Gourley, personal communication).

Thus, the catch data used in this analysis are representative of the shallow coral reef fish population harvested by commercial nighttime spearfishers from 2011 to 2016 within or adjacent to Saipan’s leeward barrier reef that forms the structure of Saipan’s lagoon. These data, though dated, are the best available length frequency data on the population available at this time. However, they do not account for fish that spearfishers kept for subsistence. Local expert opinion suggests that this subsistence portion of the fishery may include landings of smaller-sized fish than what was accounted for by the commercial biosampling program (Mike Tenorio & John Gourley, personal communication). If this is the case, our results may be biased towards higher lengths and can be interpreted as overly optimistic.

---

[2] The actual model used was the Growth-Type-Group LB-SPR (GTG-LB-SPR) (Hordyk et. al., 2016) which accounts for “Lee’s Phenomenon”, the fact that fish of the same age with different growth patterns are harvested differently in a fishery due to sized-based selectivity.

What assurance do we have that the model results are accurate?

A model is not magic, but a management tool. A picture takes a snapshot of a real event and compresses it into a shareable/usable format. A model takes complicated real-life data and compresses outputs into a few key numbers to guide management decisions. Every model is just an estimation like every picture is just a snapshot. We can never be certain that the results are exact. However, models have proven to be useful tools and are used in a variety of fields around the world to help make decisions.

One way to improve the results from a model is to "tune" a model to a different set of data. Each parameter (e.g., $L_{inf,}$ $L_{50,}$ M, etc.) has some variability associated with it. The variability could be within a single study (e.g., DFW staff estimated an L_{inf} of 26.4 ± 3.1 cm), or between different studies. For example, one study may find L_{inf} for *hangon* to be 20.4 cm (Taylor et. al., 2014) but another may estimate an L_{inf} of 26.4 cm (DFW unpublished data). Which number should be used in the model? To handle this very question, DFW "tuned" our LB-SPR model to the catch data set from the northern island of Sarigan. Model parameters were adjusted slightly ("tuned") over multiple iterations to produce an SPR of 95%. This process assumes that the island of Sarigan represents a very lightly fished area with close to pristine "unfished" conditions. Once the model parameters were fit on the Sarigan data, those same parameters were used to produce an SPR for catch data from within Saipan's lagoon. This method avoids some of the logistic complexities involved with Monte Carlo uncertainty analysis (see Nadon et al., 2019) and allows us to provide a single best estimate of SPR to stakeholders.

Hangon (Pacific orangespine unicornfish, *Naso lituratus*)

Growth Characteristics

Hangon are relatively early-maturing surgeonfish that have a 50% chance of being sexually mature at a length of 14.5 cm (Taylor et al., 2014), which is only 55% of its average maximum length (i.e. L_{inf} = 26.4 cm). Most surgeonfish are not reproductive until reaching 79% of L_{inf} (Prince et al., 2023). In this case, that would be 20.8 cm. This mismatch suggests that Marianas *hangon* have unusually rapid reproductive capacity compared to most surgeonfish. The largest *hangon* can reach sizes around 30 cm, but on average plateaus closer to a length of 26.4 cm (Figure 11). The oldest *hangon* in the DFW database was caught in the northern islands and was 30 years old.

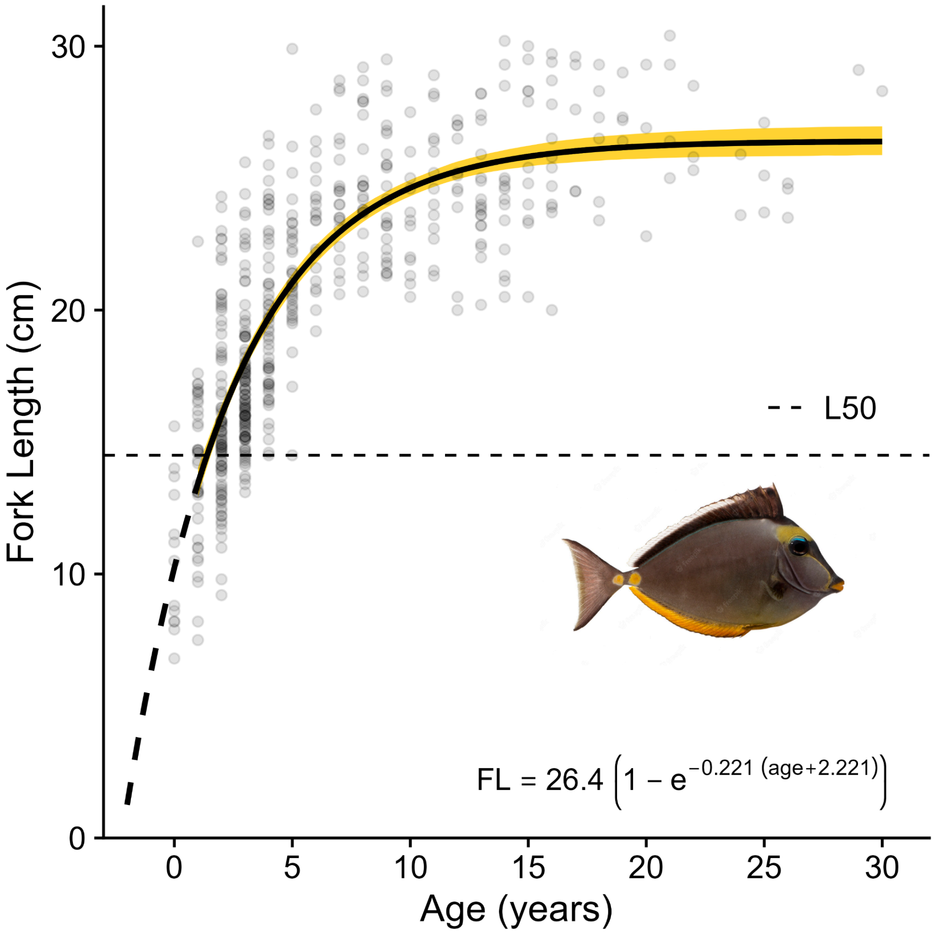


Figure 11: Hangon growth model (length by age) based on DFW life history database.

Hangon are relatively fast-growing and early-maturing unicornfish. On average, surgeonfish reach reproductive length at 79% of L_{inf} *(Prince et al., 2023). In this case, that would be 20.8 cm. Hangon in the Marianas, however, have been shown to reach maturity at 14.5 cm, or 55% of* L_{inf} *(Taylor et al., 2014).*

Fishery Characteristics

By count, 79% of *hangon* catch sampled from Saipan markets 2011-2016 came out of Saipan's lagoon (Figure 12 and Table 3). Within the lagoon, 38% were caught in the northern zone, 34% in the central zone, and 15% in the southern zone, with the remaining 14% coming from a mixture of two or more lagoon zones. Virtually all *hangon* caught were above their L_{50}.

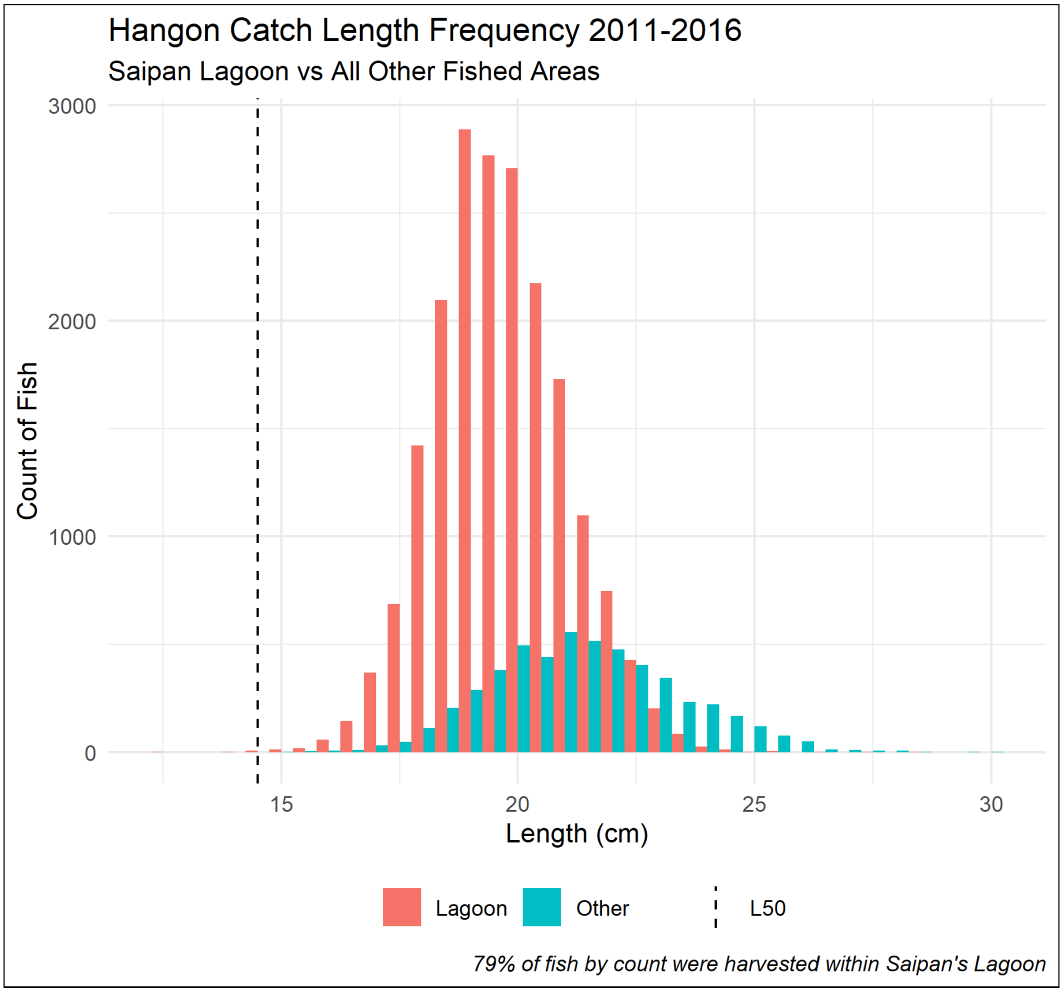


Figure 12: Hangon catch length frequency by area.

79% of the hangon harvested by NCS 2011-2016 were from Saipan's lagoon area. Although hangon harvested from the lagoon are smaller than hangon harvested in other areas, almost all hangon harvested were larger than L_{50}*. This helps maintain a viable hangon fishery despite high fishing pressure.*

Table 3: Hangon catch summaries by area.

Location	**Total Fish**	**Weight (lbs)**	**Average Length (cm)**	**Average Weight (g)**	**Percent by Count**	**Percent by Weight**
Lagoon	19692	7418	19.7	171	79%	74%
Other	5234	2553	21.4	221	21%	26%

Population Status

Our best estimate of *hangon* spawning potential ratio for the lagoon area is 0.3, or 30%. It appears that the relatively early maturation of *hangon* (i.e., 14.5 cm) has helped sustain this population despite high fishing pressure since almost all fish caught are > 14.5 cm.

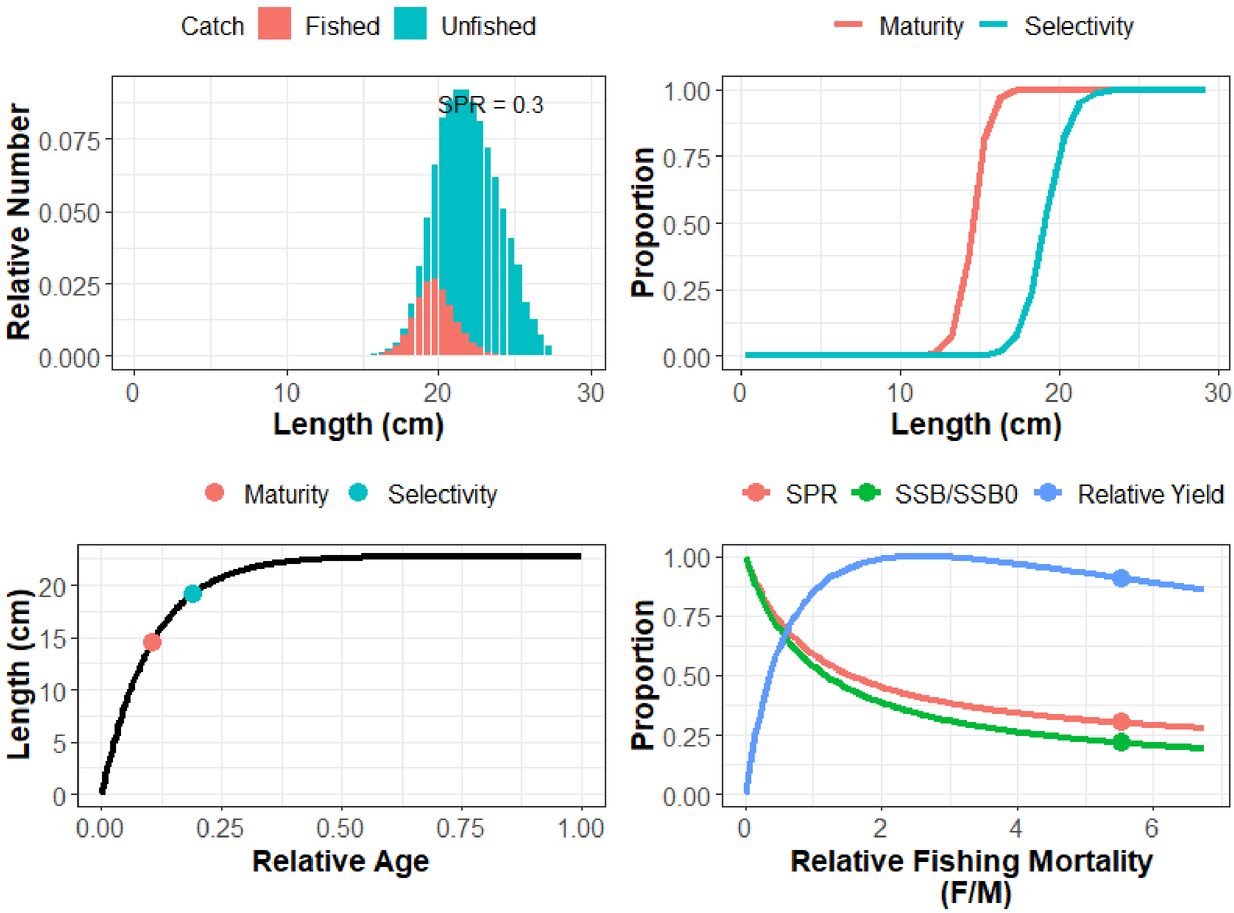


Figure 13: Hangon LB-SPR model results. Top left shows lagoon harvest (red) vs theoretical harvest from an unfished population (blue). Top right shows logistic models of hangon maturity and selectivity with hangon maturing well before they are caught in the fishery. Bottom left shows hangon maturity and selectivity benchmarks in terms of length and relative age. Bottom right shows SPR (red), percent of standing stock biomass (green), and relative yield (blue). Note that relative yields are on the right side of maximum relative yields, indicating that relative yields would be increased if SPR was closer to 40%.

Recommendation

An SPR of 30% is high enough to indicate sustainable take but low enough to caution against actions that would increase take and decrease SPR below 30%, such as the allowance of additional gillnet take. Furthermore, this model was built on 2011-2016 market data and does not account for subsistence fishing, which may harvest fish < 14.5 cm and thus impact the fishery negatively.

Though relative yields of *hangon* were high, this fishery could be further enhanced by management action. Hardly any *hangon* harvested was below the L_{50} limit of 14.5 cm for females. However, the current length restriction is a bit too small at 5.5 inches (14 cm) (NMIAC § 85-30.1-615). Increasing *hangon* size restrictions from 5.5 to 7.0 inches could help increase SPR and also better protect male *hangons* that do not mature until reaching a length of 17.8 cm. Moreover, fishery yields in terms of weight can be increased by allowing fish to reach larger sizes before harvest (i.e., a "let them go, let them grow" strategy). For *hangon*, a 27% increase in length from 5.5 to 7.0 inches would result in a more than doubling of total weight, helping maximize yields in this fishery. Because *hangon* are rapid growers in their first few years of life, these weight gains could be realized in just 1-2 years.

Hiyok (Striped surgeonfish, *Acanthurus lineatus*)

Growth Characteristics

Of the surgeonfish examined in this study, *hiyok* are the latest-maturing, with 50% of fish sexually mature at a length of 18.8 cm (Leon Guerrero, 2023 *in preparation*).[3] The largest *hiyok* in the Marianas can reach sizes around 23.5 cm but on average plateau closer to a length of 21.2 cm (Figure 14). These data indicate that *hiyok* must attain 89% of their average maximum length before they are reproductively active. Notably, *hiyok* do not appear to live as long in the populated southern islands of the CNMI (i.e. Rota, Tinian, Saipan) as they do in the northern islands, perhaps due to high fishing pressure. The oldest *hiyok* in the southern CNMI was caught at Lau Lau Bay in 2003 and was 16 years old. In contrast, the oldest *hiyok* in the entire database was 30 years old, caught in the waters of Guguan in 2014.

---

[3] Leon Guerrero later updated this parameter as 18.9 cm however we used 18.8 cm in this analysis.

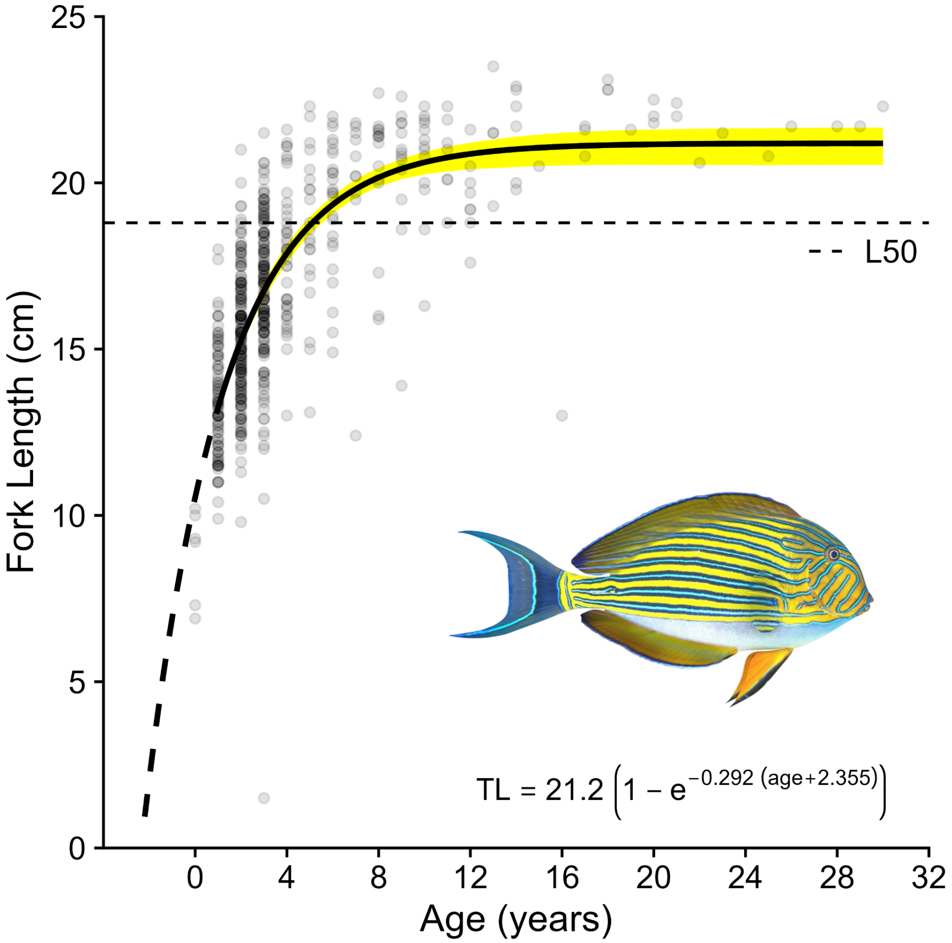


Figure 14: Hiyok growth model (length by age) based on DFW life history database.

Hiyok are the relatively latest-maturing surgeonfish in this study, with 50% of fish sexually mature at a length of 18.8 cm. The L_∞ for hiyok is 21.2 cm. These data indicate that hiyok must attain 89% of their average maximum length before they are reproductively active.

Fishery Characteristics

By count, 52% of *hiyok* catch sampled from Saipan markets 2011-2016 came out of Saipan's lagoon (Figure 15 and Table 4). Within the lagoon, 19% were caught in the northern zone, 44% in the central zone, and 17% in the southern zone, with the remaining 20% coming from a mixture of two or more lagoon zones.

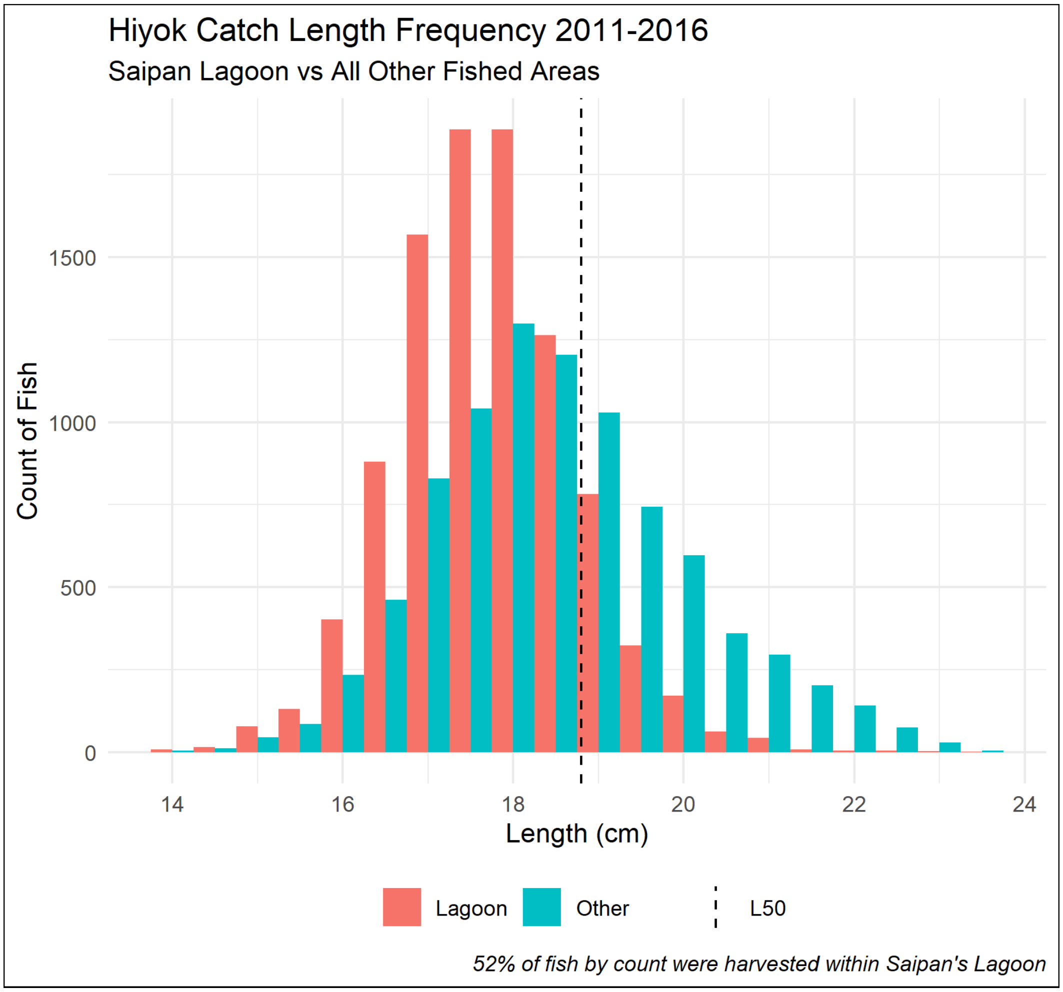


Figure 15: Hiyok catch length frequency by area.

Roughly half of all hiyok from the NCS database were landed in Saipan's lagoon area. 85% of lagoon-landed hiyok were below the fishes' L_{50} whereas 60% of hiyok landed from outside of the lagoon were undersized.

Table 4: Hiyok catch summaries by area.

Location	**Total Fish**	**Weight (lbs)**	**Under sized Fish**	**Average Length (cm)**	**Average Weight (g)**	**Percent by Count**	**Percent by Weight**	**Percent Under sized**
Lagoon	9528	3076	8122	17.7	146	52%	49%	85%
Other	8694	3237	5218	18.5	169	48%	51%	60%

Population Status

Our best estimate of *hiyok* spawning potential ratio for the lagoon area is 0.1, or 10% (Figure 16). It may be that the relatively late maturation of *hiyok* (i.e., 18.8 cm) combined with high fishing pressure on immature fish has damaged the lagoon's *hiyok* population. 85% of fish caught within the lagoon were undersized as were 60% of fish caught in all other areas (Table 4). Notably, Saipan and Tinian's *hiyok* population experienced a large die-off event in 2014, during the middle of the coral reef biosampling project (FRDS 2015). This die-off event may have impacted typical catch patterns for this fish.

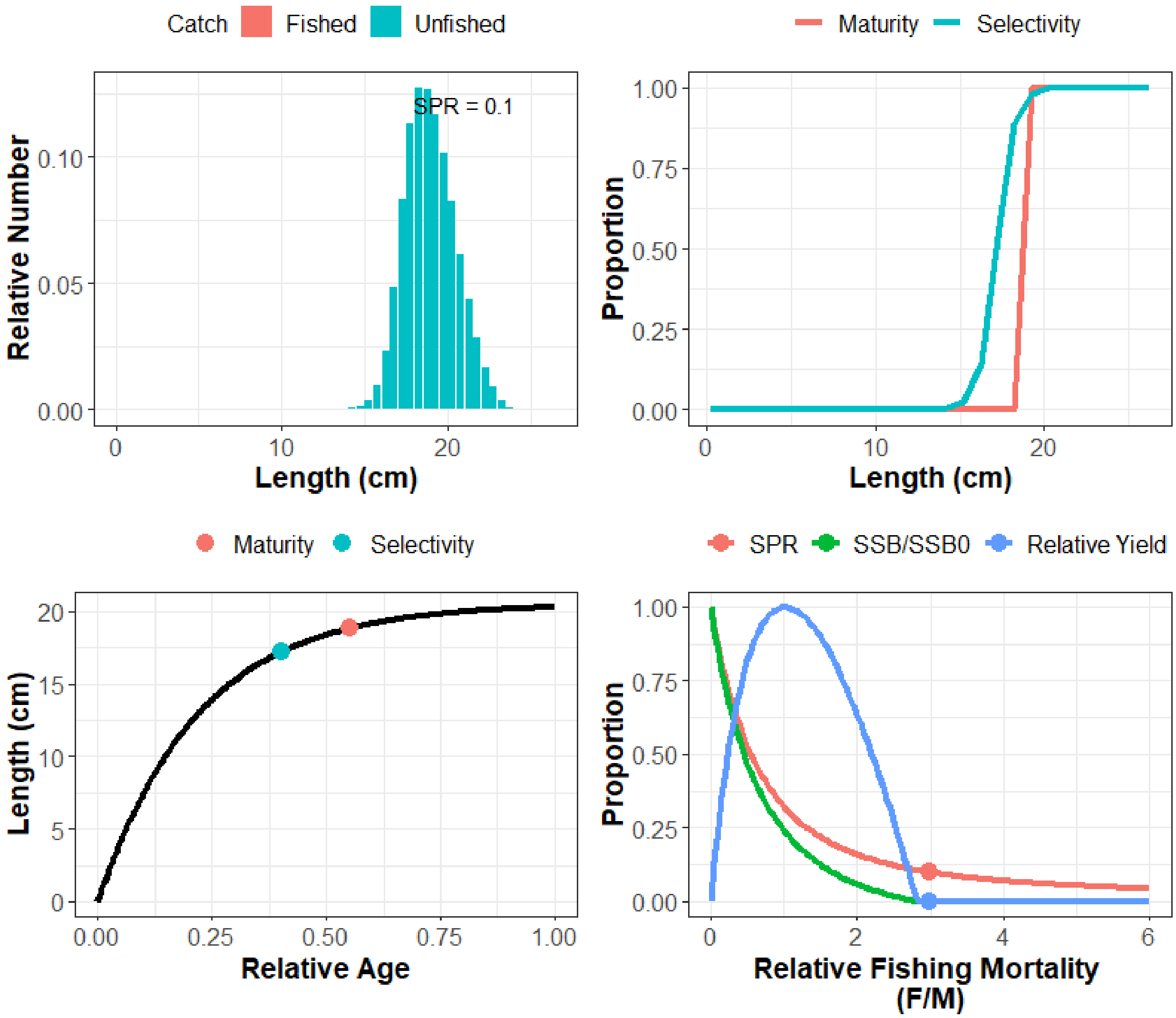


Figure 16: Hiyok LB-SPR model results. Top left shows lagoon harvest (red - so small it is imperceivable) vs the theoretical harvest from an unfished population (blue). Top right shows logistic models of hiyok maturity and selectivity indicating that hiyok are caught by the fishery before reaching sexual maturity. Bottom left shows hiyok selectivity and maturity benchmarks in terms of length and relative age. Bottom right shows SPR (red), percent of standing stock

biomass (green), and relative yield (blue). Note that relative yields are near zero, suggesting that this fishery may be in peril and benefit from additional management interventions.

Recommendation

An SPR of 10% is low enough to trigger management intervention. DFW must take action to help bring SPR back up to a 30% minimum (40% target) by updating length restriction regulations from 6.5 to 7.5 inches (16.5 to 19.0 cm) which reflects our latest understanding of this fish's reproductive lifecycle in the CNMI (Leon Guerrero, 2023 *in preparation*).

At this time, additional restrictions beyond length regulations such as daily bag or annual catch limitations may be needed to afford the stock a chance to recover. Additional fishing pressure from gill net harvest could have long-lasting negative effects on this population and should be avoided. Moreover, *hiyok* are reef and especially high-energy reef-crest associated species. The setting of gill nets in high-energy reef areas is inadvisable since it is likely to result in the tangling of nets with subsequent damage to the surrounding corals (See Potential Adverse Effects from Net Fishing). Corals provide essential fish habitat to reef-associated species such as *hiyok*. Recent coral bleaching events (Maynard et al., 2018) and impaired water quality in the lagoon (Knapp et al., 2020; Sinigalliano et al., 2021) may also impact *hiyok* habitat, damaging the population.

It is difficult to know the full effects of the 2014 die-off event. DFW should consider collecting up-to-date harvest data on this fish and rerunning the LB-SPR analysis with the new data. Additionally, the recently calculated L_{50} parameter (Leon Guerrero, 2023 *in preparation*) is considerably higher than L_{50}'s calculated for this fish from similar regions. This study should be reviewed for accuracy and DFW should run an additional model using an alternative L_{50} to estimate the effect generated by this higher-than-expected parameter.

Lagoon *Mafute'* (Thumbprint emperor, *Lethrinus harak*)

Growth Characteristics

Lagoon *mafute'* are a shorter-lived fish compared to the fish analyzed thus far. The oldest lagoon *mafute'* in the DFW database was caught at Abuni Beach in 2006 and was 9 years old. They have a 50% chance of being sexually mature at a length of 19.6 cm, which is 77% of their L_{inf}. The largest lagoon *mafute'* can reach sizes near 33.5 cm but on average plateau closer to a length of 25.5 cm (Figure 17).

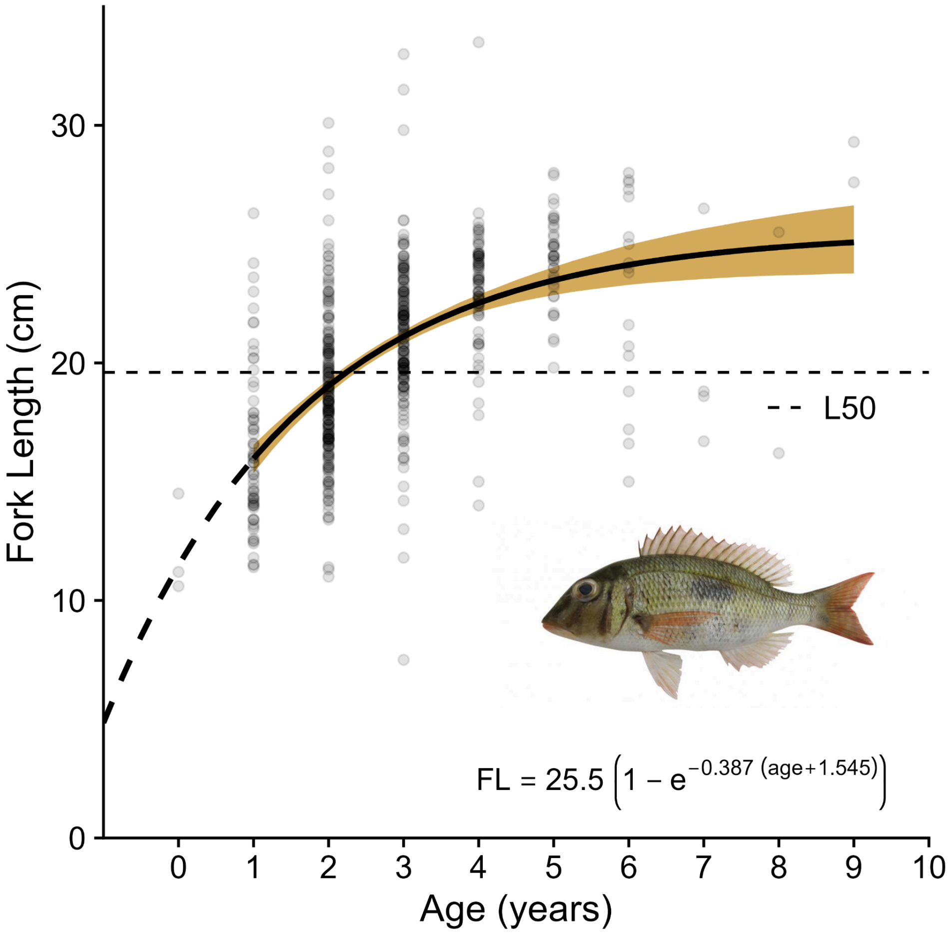


Figure 17: Mafute' growth model (length by age) based on DFW life history database.

Lagoon mafute' have a much shorter life span than the other fish in this analysis, with a maximum age of nine recorded in the Saipan. Sexual maturation at 19.6 cm is 77% of this fish's L_{inf}, *25.5 cm.*

Fishery Characteristics

By count, 96% of lagoon *mafute'* catch sampled from Saipan markets 2011-2016 came out of Saipan's lagoon (Figure 18 and Table 5). Within the lagoon, 39% were caught in the northern zone, 50% in the central zone, and 8% in the southern zone, with the remaining 3% coming from a mixture of two or more lagoon zones.

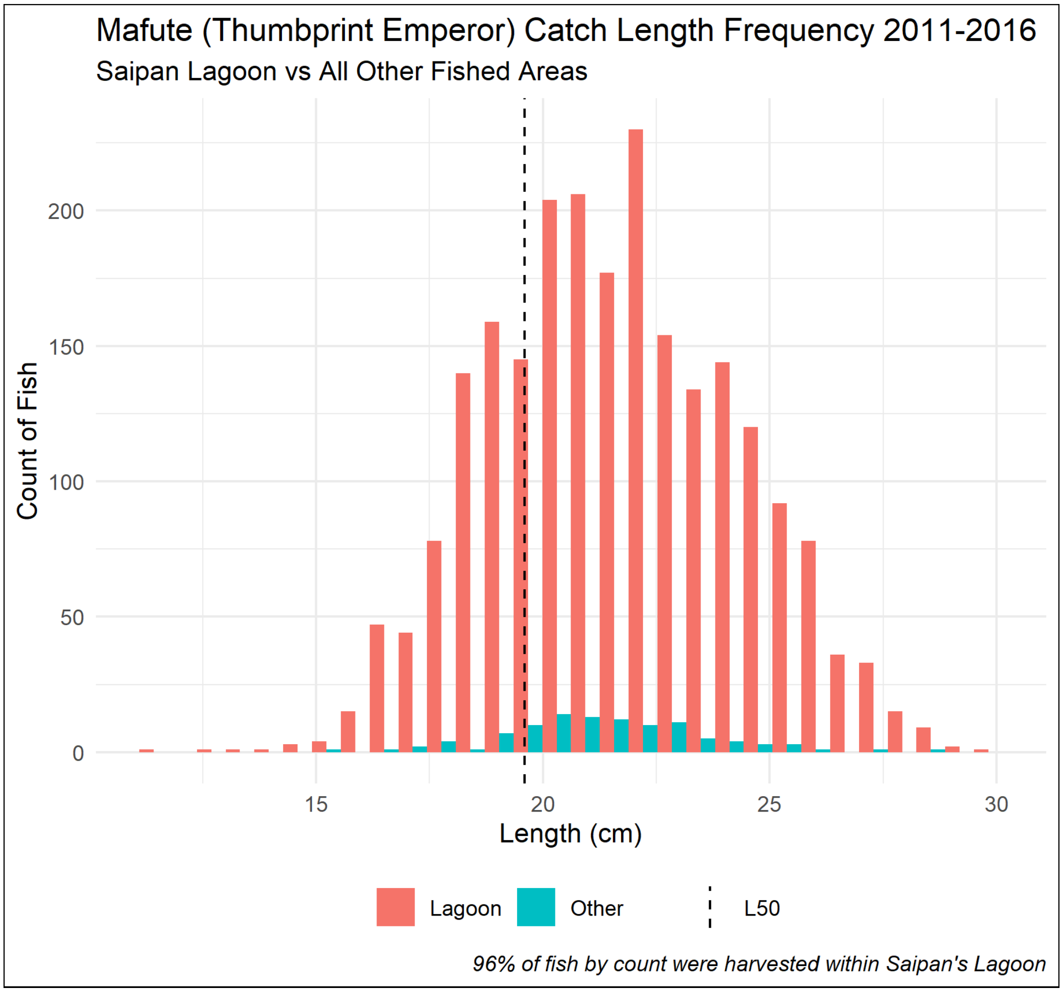


Figure 18: Mafute' catch length frequency by area.

Lagoon mafute' are almost exclusively caught within the lagoon area (96%). Nearly one-fourth of the lagoon mufute' harvested are below L_{50}*, indicating that fishery yields could be higher if fish were allowed to grow larger before harvest.*

Table 5: Mafute' catch summaries by area.

Location	**Total Fish**	**Weight (lbs)**	**Under-sized Fish**	**Average Length (cm)**	**Average Weight (g)**	**Percent by Count**	**Percent by Weight**	**Percent Under-sized**
Lagoon	2274	1031	556	21.7	206	96%	96%	24%
Other	104	45	19	21.3	195	4%	4%	18%

Population Status

Our best estimate of lagoon *mafute'* spawning potential ratio for the lagoon area is 0.33, or 33% (Figure 19). It appears that the relatively early maturation of *mafute'* (i.e., 19.6 cm) has helped sustain this population despite high fishing pressure. However, 24% of fish caught in the market sampling data were < 19.6 cm, suggesting that minimum size regulations and enforcement could increase SPR to a level closer to 40%, enhancing the fishery and increasing yields.

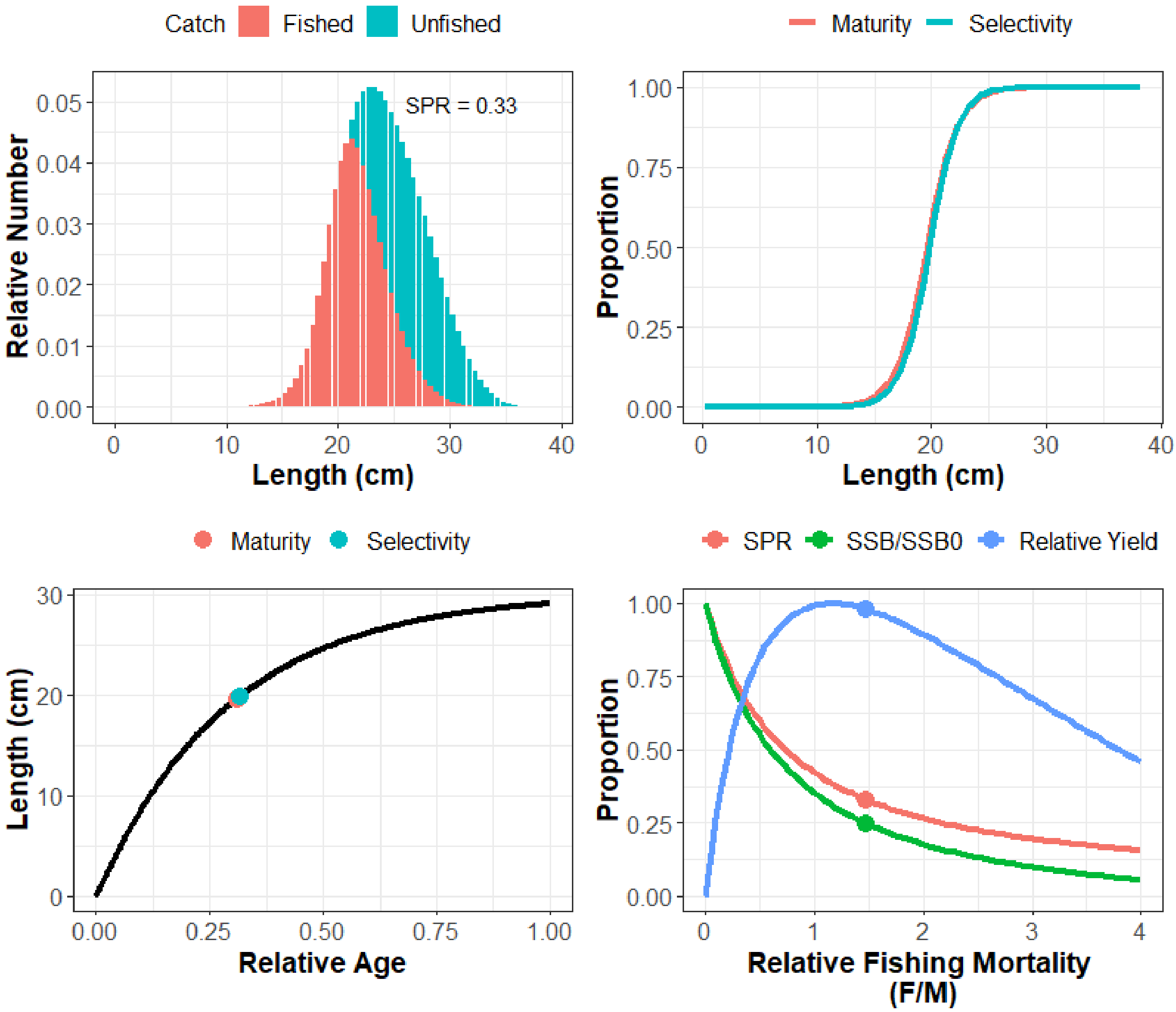


Figure 19: Mafute LB-SPR model results. Top left shows lagoon harvest (red) vs theoretical harvest from an unfished population (blue). Top right shows logistic models of mafute' maturity and selectivity indicating that mafute are generally caught by the fishery as they reach sexual maturity. Bottom left shows mafute' selectivity and maturity benchmarks in terms of length and relative age. Bottom right shows SPR (red), percent of standing stock biomass (green), and

relative yield (blue). Note that relative yields are near the peak, indicating that this fishery is relatively healthy though yields would be better if SPR was closer to 40%.

Recommendation

An SPR of 33% is high enough to indicate sustainable take but low enough to caution against actions that would increase take and decrease SPR below 30%, such as the allowance of gillnet. Furthermore, this model was built on 2011-2016 market data which predominantly represents the nighttime commercial spearfishing industry and does not account for subsistence and recreational fishing, which may harvest fish < 19.6 cm and thus impact the fishery negatively (i.e., decrease the SPR).

Since 24% of *mafute'* harvest in Saipan's lagoon was composed of under-sized fish, enforcing the current length restriction of 8.0 inches (20.3 cm) should help reach the SPR goal of 40%. Preliminary results from DFW's current lagoon surveys show a steep increase in *mafute'* abundance in sandy areas that contain additional benthic structures such as patch reefs, rubble, or seagrasses (DFW unpublished data). Habitat restoration projects that provide benthic cover to bare-sand areas of the lagoon could help enhance this fishery.

Tátaga (Bluespine unicornfish, *Naso unicornis*)

Growth Characteristics

Compared to *hangon*, *tátaga* are relatively slow-growing late-maturing fish that have a 50% chance of being sexually mature at a length of 29.2 cm (Taylor et al., 2014). The largest *tátaga* can reach sizes over 50.0 cm but on average plateau closer to a length of 40.6 cm (Figure 20), which is 72% of L_{inf}. The oldest *tátaga* from Guam's database was 23 years old (Nadon et al., 2019), though DFW caught a *tátaga* in the northern islands that was 30 years old. In Hawaii, *tátaga* have been known to live as long as 50 years (Nadon et al., 2019).

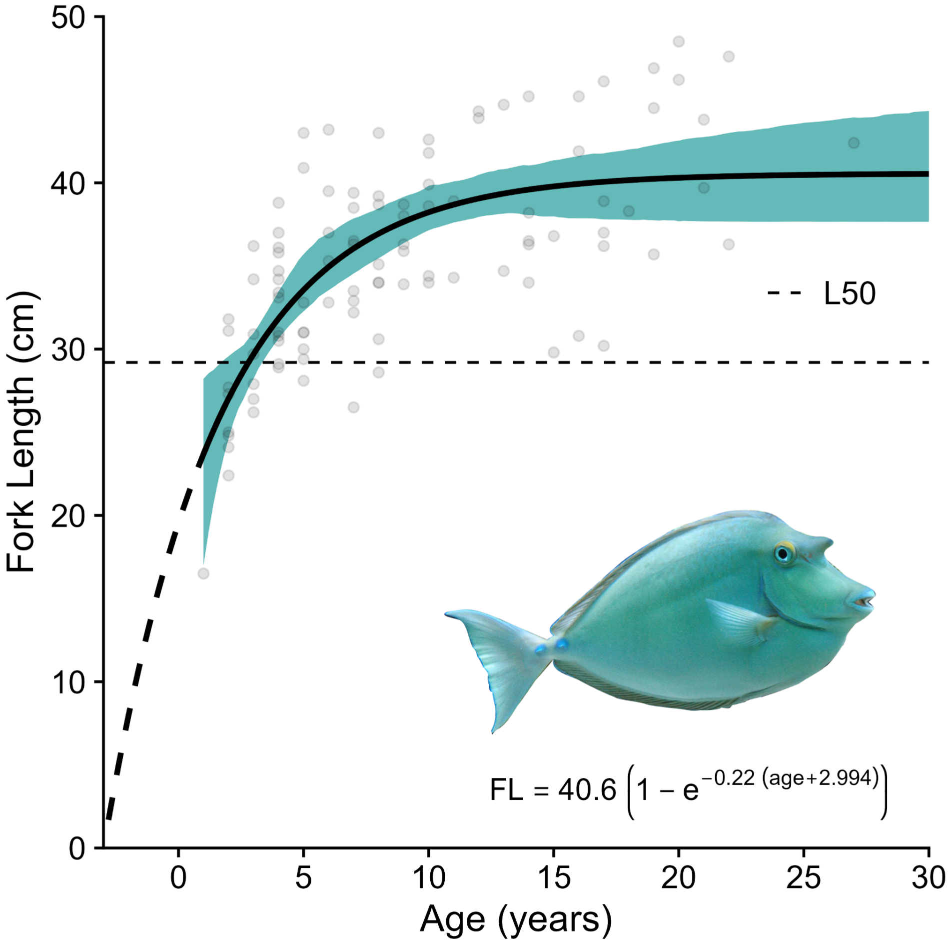


Figure 20: Tátaga growth model (length by age) based on DFW life history database.

Fishery Characteristics

By count, 75% of *tátaga* catch sampled from Saipan markets 2011-2016 came out of Saipan's lagoon, though this only represented 58% of the fishery by weight due to the small sizes of fish landed in the lagoon (Figure 21 and Table 6). Within the lagoon, 46% were caught in the northern zone, 36% in the central zone, 12% in the southern zone, with the remaining 6% coming from a mixture of two or more lagoon zones. 84% of *tátaga* landed in the lagoon were under-sized (i.e., <29.2 cm).

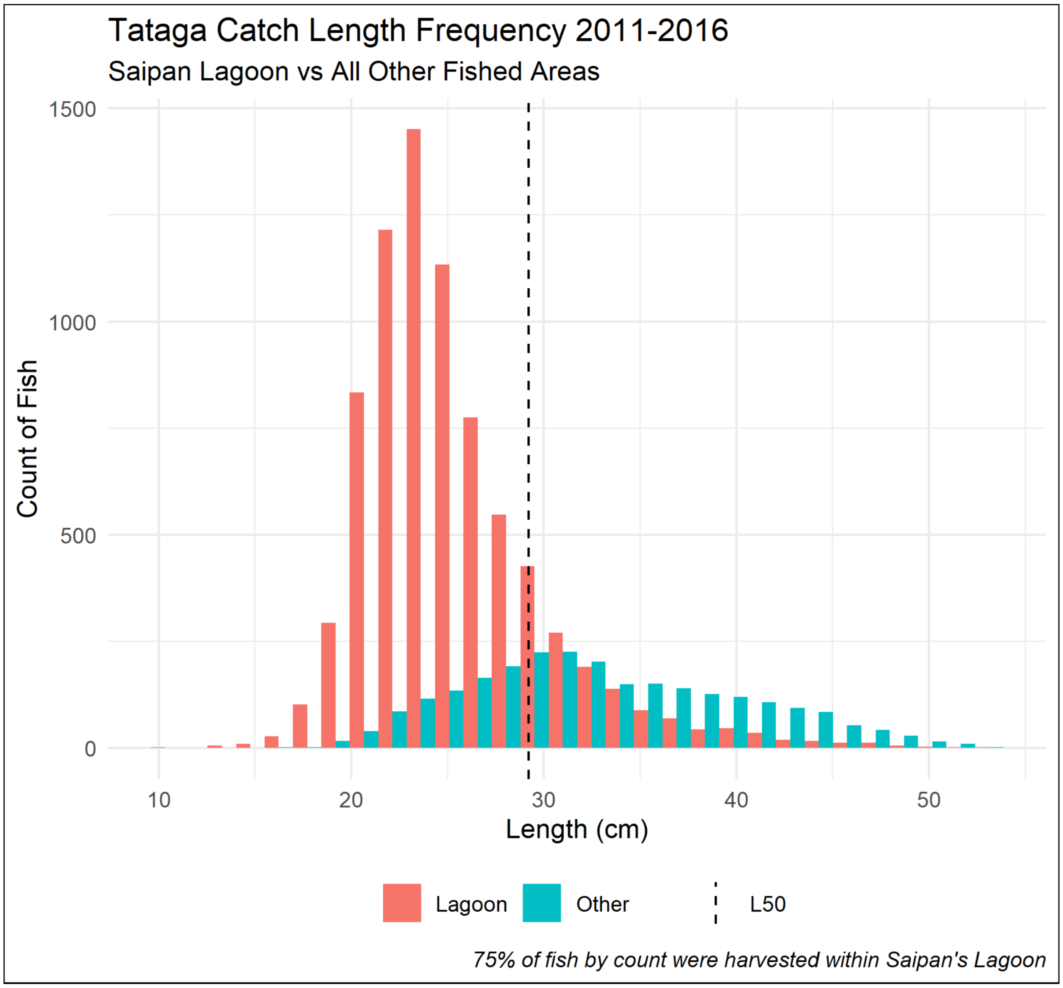


Figure 21: Tátaga catch length frequency by area.

Table 6: Tátaga catch summaries by area.

Location	**Total Fish**	**Weight (lbs)**	**Under-sized Fish**	**Average Length (cm)**	**Average Weight (g)**	**Percent by Count**	**Percent by Weight**	**Percent Under-sized**
Lagoon	7777	6115	6526	25.3	357	75%	58%	84%
Other	2526	4455	804	33.1	800	25%	42%	32%

Population Status

Our best estimate of *tátaga* spawning potential ratio for the lagoon area is 0.03, or 3%. If this estimate is correct, it is a critically low SPR that demands increased management efforts to help recover this iconic species within the lagoon area. The low SPR for *tátaga* may be attributable to the harvest of individuals that have not had a chance to reproduce (i.e., fish < 29.2 cm) which represents 84% of fish caught within the lagoon.

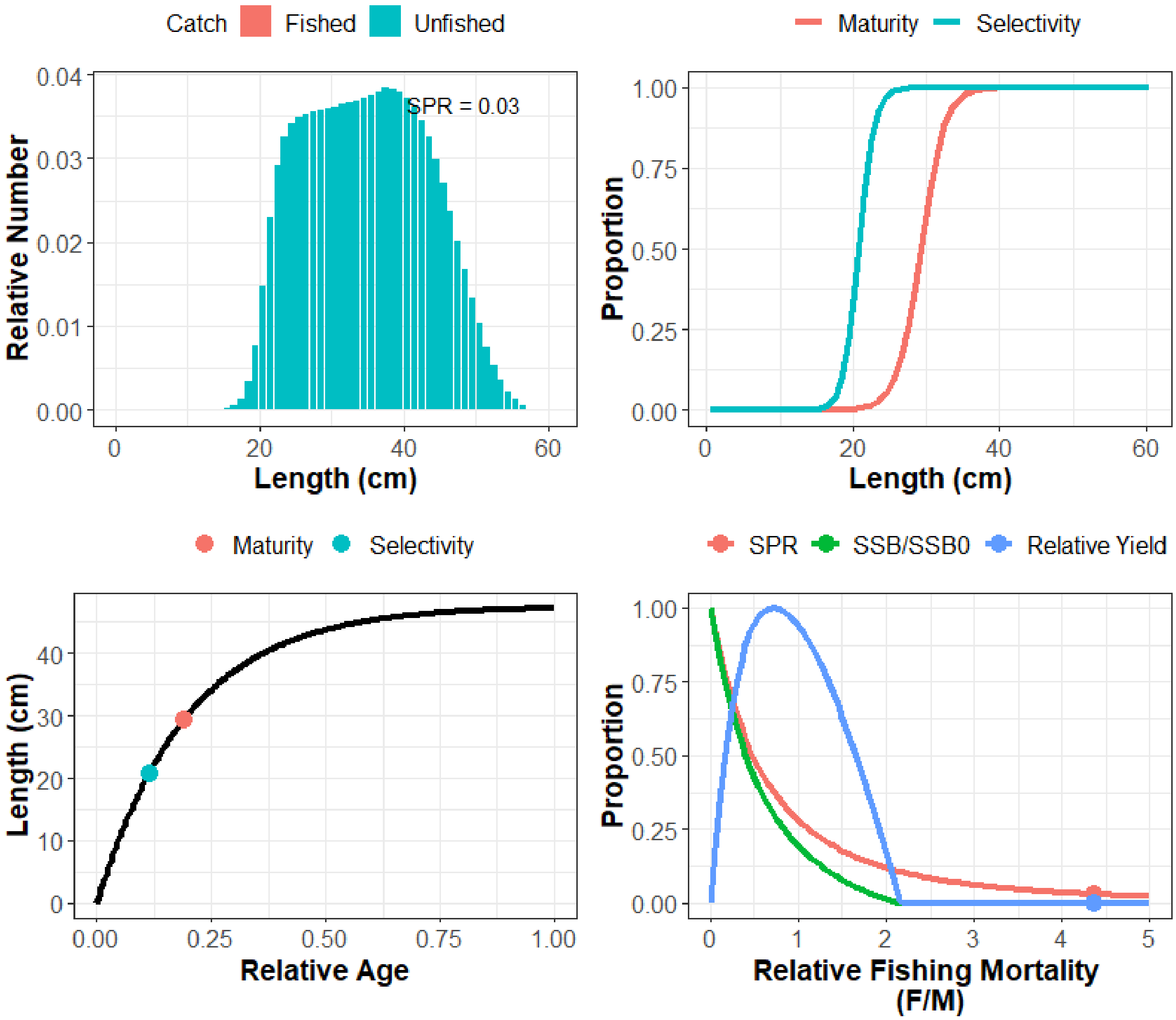


Figure 21: Tátaga LB-SPR model results. Top left shows lagoon harvest (red - so small it is imperceivable) vs theoretical harvest from an unfished population (blue). Top right shows logistic models of tátaga maturity and selectivity indicating that tátaga are caught by the fishery well before reaching sexual maturity. Bottom left shows tátaga selectivity and maturity benchmarks in terms of length and relative age. Bottom right shows SPR (red), percent of standing stock biomass (green), and relative yield (blue). Note that relative yields are near zero, indicating that this fishery is in peril and requires management intervention.

Recommendation

The practice of landing undersized tátaga from Saipan's lagoon is at best inadvisable and likely highly unsustainable. Moreover, relative *tátaga* yields are far below their maximum, suggesting that management intervention could greatly enhance the fishery.

The current length restriction for *tátaga* is 10.0 inches (25.4 cm). This restriction needs to be revised to 11.5 inches (29.2 cm) to better reflect our current understanding of this species' reproductive life cycle. Moreover, the current restrictions have not been adequately enforced. DFW enforcement staff require additional training and financial support to ensure that adequate enforcement efforts are made to protect this iconic species.

But if current harvest practices are unsustainable, how has the *tátaga* fishery persisted? Extraction of biological resources, such as the harvest of fish, can have various lagging effects depending on the life history traits of the population being harvested and the demographics of the catch. For example, the impacts of systematically harvesting fish before they have reached maturity may not be felt for years until the overharvested portion of the population has joined the adult spawning population and older spawning adults have either been harvested or died of natural mortality. For long-lived fish like *tátaga*, this generational turnover could take decades. Adult *tátaga* populations outside of the reef may subsidize the current lagoon fishery. Spawning adults may have found refuge from spear-based fishing methods in the deeper waters. It is also possible that large spawning adult fish do exist at higher numbers in the lagoon, but have become adept at avoiding detection and capture by spearfishers.

Previous data collected during DFW's tagging project provides some support for this last hypothesis. Using a permitted surround net and help from a local net-fishing expert, DFW was able to capture and tag a large number of adult *tátaga*, many of which were greater than 40 cm (DFW unpublished data). If large adult *tátaga* are present in the population but absent from the commercial fishery, LB-SPR results presented here may be overly pessimistic. More importantly, this situation provides an example of a departure from one of the key modeling assumptions of LB-SPR, that the fish harvested are representative of the larger population. Departures from model assumptions can be difficult to resolve. In this case, developing a new selectivity curve to account for fish that evade capture by spear may be possible but would require additional studies and data to parameterize that function. However, even if large adult fish persist within the lagoon, continued harvest of juveniles is likely to have a detrimental impact on the fishery.

Summary of Results from Case Studies

Species-specific length-based models of SPR showed that two fish, *hangon* and *mafute'*, had SPRs within the acceptable management range of 30-40%. However, both of these fish had SPRs closer to 30%, suggesting that the fishery could be more productive if SPR was increased to the target of 40%. Due to the additional uncertainty associated with harvests from subsistence fishing, the CNMI may want to consider a more conservative target SPR of 50%, especially for slower-growing fish or those with lower reproductive output.

Modeled SPR estimates for *tátaga* (3%) and *hiyok* (10%) are concerning. These estimates of SPR are critical enough to trigger internal follow-up measures by DFW-FRDS. The DFW-FRDS team will conduct an initial review of the LB-SPR model parameters and a sensitivity analysis followed by an alternative age-based modeling approach for comparison. If deemed necessary, these modeling efforts can be further complimented by targeted fishery-dependent and fishery-independent data collection efforts to provide up-to-date estimates of SPR. If follow-up estimates remain in the critical zone, more extreme management action may be necessary to correct the fishery (e.g., annual catch limits, gear restrictions, moratoriums, etc.).

Updating, promoting, and enforcing L_{50} length restrictions provides a simple first-step management option for all the fish examined in these case studies. In some cases, such action may be all that is needed to correct/enhance the fishery. Since most harvest by boat-based fishers already falls within the regulations, enforcement staff should focus the majority of their attention on commercial purchaser compliance and shore-based nighttime commercial spearfishers on the lagoon side of the island. Additional data collection efforts on harvest from subsistence fishers by Fishery Data Section staff would help fill existing knowledge gaps. Alternative regulatory options for species of concern could include daily bag limits, seasonal closures, slot limits, and further gear restrictions were appropriate.

Once regulations are updated and a reassessment of these stocks has been conducted, it is possible to review an additional permitted gillnet harvest option. Of the species examined here, the one best suited for this type of harvest activity is lagoon *mafute'*, since this stock appears to be relatively stable and inhabits sand and seagrass areas that are less likely to be damaged by gillnet use. An allowance of additional gillnet take must be weighed against take by rod and reel and spearfishers since these fishing methods would be competing with each other.

Conclusion

Review and FRDS Recommendation

DFW is the agency tasked with conserving, protecting, and enhancing the fish, game, and wildlife resources of the Northern Mariana Islands for the benefit of its citizens. FRDS is the branch of DFW responsible for scientific research that studies specific fish and their life history traits, monitors populations and their associated habitats, and makes recommendations to enhance future fishery productivity. In some cases, recommendations may include regulatory action.

The goal of the current net-use restrictions is to allow resources to recuperate within Saipan's lagoon for community-wide benefit. Adherence to the current net-use restrictions and updates to current size regulations should help promote recovery of target food fish species within the lagoon, ultimately allowing for greater sustainable harvests. However, this success will only be realized with citizen compliance, proper enforcement, and legal and political support.

Saipan's lagoon is subject to the highest reef-fishing pressure of any area within the CNMI. Preliminary results from the assessment of four important reef fish species suggest that some relatively quick-growing or early-maturing species have been able to adapt to this pressure although other slower-growing or later-maturing species appear to be in decline. None of the species examined in this document appear to be under-utilized (i.e., have an SPR > 40%). Relative gains to the fishery are possible if fish are allowed to reach a larger size before harvest. This can be accomplished with updates to length restrictions, education and outreach campaigns, and increased enforcement. Given the already high extraction rates from the lagoon fishery and evidence from the case studies above, DFW FRDS cannot support legislation that would increase harvest from the lagoon's already heavily fished resources. Opening up the lagoon to gillnet fishing in its current state brings a high risk for negative downstream effects.

If take by gillnet is to be allowed despite DFW FRDS's recommendations, strict enforcement is needed to ensure that the long-term damages are minimized. Each net must be clearly marked and registered to a single licensed user who will be liable for all activities and potential damages caused by the net. All sexually immature fish must be returned unharmed. Sensitive areas such as the backreef, channels, and reef crest should not be targeted by gillnet. Areas inhabited by ESA-listed species must be surveyed, mapped, and avoided. Finally, additional restrictions on other fishing methods like nighttime spearfishing, hook and line, and cast net, will be necessary to offset the increase in take due to increased gillnet fishing. This would necessitate additional enforcement and monitoring funds, which come at a high cost and are well beyond current enforcement funding and effort capacity. Ultimately, allowance of a lagoon gillnet fishery is likely to redistribute resources into the hands of a select few net holders, undoing the work of the Fair Fishing Act of 2000. If the overarching goal of HB-23-5 is to increase sustainable subsistence fishing in the lagoon, FRDS has judged that it will fail at this aim.

The Path Forward

FRDS recommends an alternative approach to increase lagoon harvests and general fishery yields. Instead of simply taking more fish from already heavily fished areas, FRDS suggests that the CNMI finds ways to increase overall fishery productivity. This can be achieved with five simple guidelines:

1) **Know the fishery**

Fundamental knowledge of where a species lives, how large it grows, how long it lives, at what size it becomes reproductive, when/where it reproduces, what it eats, and which habitats it requires helps managers create precise and effective regulations. Targeted regulations will vary according to the risk factors associated with a specific species or group of similar species.

For example, an annually spawning fish that forms large aggregations may have regulations that close that fishery during known spawning periods or close specific areas where fish are known to spawn. Similarly, if fishery knowledge shows that juveniles are being harvested at an unsustainable rate then species or group-specific size regulations could be an effective management strategy.

2) Grow the fishery

Generally, letting fish spawn at least once before harvest has been shown to be a widely effective management strategy (Vasilakopoulos et. al., 2011). Allowing fish to grow to spawning size also helps in terms of fishery yields since fish weight increases exponentially with length.

Looking outside of the lagoon, another way to grow the fishery is to expand it to include underutilized areas and species. Increasing pelagic fisheries productivity through the enhancement and expansion of DFW's Fish Aggregating Device (FAD) Program may help shift fishing effort from slow-growing nearshore resources to faster-growing pelagic ones. Bottom fishing is another sector of the fishery that the CNMI should look to expand. Bottom fishing grounds in the northern islands and along the West Marianas Ridge remain in nearly pristine unexploited condition and could prove an important resource to the people of the CNMI.

3) Monitor, manage, and moderate take

Generally, a moderately fished population produces greater yields than a heavily exploited one. For most reef fish, setting a target SPR between 30-40% should help maximize sustainable yields (Clark, 2002). To achieve this, continued monitoring efforts and updated SPR analysis is needed. In cases where certain species have an SPR below 30%, additional regulations such as bag limits, ACL's, or moratoriums may be necessary to help the species recover and increase long-term fishery productivity. This type of monitoring and management is already conducted by NOAA in federally managed waters. A CNMI Fisheries Management Plan (FMP) would formalize this management process for local waters. Well-managed oceans will help ensure sustainable take for generations to come.

4) Protect, restore, and enhance habitats

The CNMI has shouldered a large number of natural disasters in the last decade including two super typhoons and multiple mass bleaching events (Maynard, 2018). These disasters have severely damaged key habitats such as *kuraling* and *chaiguan*. While there is little that the CNMI can do to deal with large environmental phenomena such as typhoons and bleaching events, there are several local controllable factors that also harm essential fish habitats. Land-based sources of pollution (LBSP) such as sediment runoff, excess nutrients, bacteria, and pathogens, continue to impair water quality in Saipan's nearshore area (Sinigalliano et al., 2021; Knapp et al., 2020). CNMI residents in the early 2000s identified LBSPs as their primary concern regarding threats to the local marine ecosystem (Van Beukering et al., 2006). The same household survey indicated that the public was willing to pay higher taxes to see increased protections for the marine environment that reduced LBSPs. More recently, a 2023 survey showed that the public still ranks LBSPs as the second most important threat to CNMI waters behind climate change (Sablan, 2023). Better interagency communication, formalization of sustainable construction/development methods, and stronger permitting processes that protect lagoon and other nearshore waters should be a CNMI priority.

The CNMI must also identify and prioritize areas for restoration in locations where habitat damage has occurred. Despite ongoing restoration efforts by partner agencies such as the Division of Coastal Resources Management (DCRM) and private organizations like Johnston Applied Marine Sciences (JAMS), more work is needed. Continued research that helps managers understand how fish use different habitats and at which life stages they move between them may allow for targeted projects that produce the highest returns in long-term fishery yields. Protecting, restoring, and enhancing essential fish habitats provides an additional avenue for restoring fishery productivity in the lagoon and nearshore habitats.

5) Communicate, obey, enforce, evaluate, and update laws as needed

Evaluating the efficacy of any regulation is difficult when few citizens know of or comply with it. The CNMI has several fishing regulations including gear restrictions, special protections for *kuraling* and several invertebrate species, a handful of no-take marine reserves, and five species/group-specific size regulations (NMIAC § 85-30.1-400 Fishing Regulations). However, finding and interpreting these regulations is not always easy. For regulations to be effective, the public must first be made aware of the underlying laws as well as the logic and supporting data behind the regulatory action. Despite shortcomings in regulatory transparency and communication, a recent public perception survey found that citizens identified the enforcement of marine conservation laws as the most important conservation measure in the Mariana Islands (Sablan, 2023).

DFW should work on revitalizing regulatory signage and websites. Additional education and outreach materials can provide fishers with updated regulatory information in an easy-to-digest format. Fisher forums that allow the community to participate in future regulatory actions may also prove useful. Once citizens are aware of regulations and have had an opportunity to comment and make suggestions, the onus to obey is on them. Enforcement officers are responsible for knowing and enforcing regulations without bias. Increased enforcement efforts may require initial financial support from the CNMI government but could become self-sustaining through a combination of external grant sources and the collection of citation and fishing license fees.

By following these five guidelines, the CNMI should be able to enhance fishery productivity sustainably. FRDS will continue to collect life history data, monitor fish populations, and suggest regulatory updates as needed. DLNR will continue to collaborate with funders such as NOAA PIFSC, WPRFMC, and Saltonstall-Kennedy to find ways to expand the CNMI's fishery to include underutilized areas and species. Continued collaborations between government agencies and private contractors will help build sustainable development practices and find ways to protect and restore nearshore habitats. Education, outreach, and community events will ensure that the community is actively involved in fishery management decisions. Finally, citizen compliance and enforcement action ensure that planned management objectives are actualized. If everyone does their part, this iterative process will aid recovery and provide larger sustainable yields to fishers and a healthier ecosystem for the community to enjoy.

Final Comment

The CNMI has a rich 4,000-year-old history of interdependence between its people and marine resources. On Saipan, harvests from the lagoon were and continue to be an important resource, connecting the people of the CNMI across space and time. Care must be taken to ensure that future generations can enjoy the ocean's bounty and participate in their cultural heritage. This can be accomplished through continued monitoring of resources, protection, and restoration of essential habitats, and moderating harvests to sustainable levels. Evidence provided in this document shows that the lagoon's resource extraction capacity is a species-specific question. Continued research that enhances species-specific knowledge will help tailor management efforts and improve regulatory efficacy. Working to protect, recover, and enhance the lagoon is a worthwhile endeavor, providing benefits to the CNMI's fishery, economy, and cultural heritage.

References

Amesbury, S.S., Lassuy, D.R., Myers, R.F., and Dyndzik, V. (1979). A Survey of the Fish Resources of Saipan Lagoon. *University of Guam Marine Laboratory*, Technical Report No. 52, prepared for Office of Coastal Zone Management, Commonwealth of the Mariana Islands, March 1979, 58 p.

Clark, W. G. (1993). The effect of recruitment variability on the choice of a target level of spawning biomass per recruit. Pp. 233-246 In G. Kruse, D. M. Eggers, R. J. Marasco, C. Pautzke and T. Quinn II [eds.] *Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations. Alaska Sea Grant College Program*, P. O. Box 755040, Fairbanks AK.

Clark, W. G. W. (2002). F35% revisited ten years later. *North American Journal of Fisheries Management*, 22: 251–257.

CSD, (2017). 2016 CNMI Household Income and Expenditure Survey. *Central Statistics Division, Department of Commerce*. https://commerce.gov.mp/hies-2016-population

Dias Vítor, Oliveira Frederico, Boavida Joana, Serrão Ester A., Gonçalves Jorge M. S., Coelho Márcio A. G. (2020). High Coral Bycatch in Bottom-Set Gillnet Coastal Fisheries Reveals Rich Coral Habitats in Southern Portugal. *Frontiers in Marine Science.* 7 https://www.frontiersin.org/articles/10.3389/fmars.2020.603438

Erediano, E. T. (2023, February 9). Local fishermen support gillnet fishing in Saipan lagoon. *Marianas Variety.* https://www.mvariety.com/news/local-fishermen-support-gillnet-fishing-in-saipan-lagoon/article_e7feb836-a7ac-11ed-ba67-7f92490801fa.html

Fair Fishing Act (2000). HB-12-16 The Fair Fishing Act of 2000. *Northern Mariana Islands Legislature*. https://faolex.fao.org/docs/pdf/mnp72822.pdf

Fisheries Research and Development Section (2015). Epizootic fish kill events of Hiyok (Blue-lined surgeonfish, Acanthurus lineatus) from Tinian and Saipan. *Commonwealth of the Northern Mariana Islands, Division of Fish and Wildlife,* Technical Report 15-01.

Fishcount (2019). Gillnetting. *Fishcount Organization*, United Kingdom. http://fishcount.org.uk/fish-welfare-in-commercial-fishing/capture/gillnet

Gillett R. and Fong M. (2023). Fisheries in the economies of Pacific Island countries and territories (Benefish Study 4). *Noumea, New Caledonia: Pacific Community*. 704 p. https://purl.org/spc/digilib/doc/ppizh

Graham, T. (1994a). Biological analysis of the nearshore reef fish fishery of Saipan and Tinian, *CNMI Division of Fish and Wildlife,* Technical Report 94-02

Graham T (1994b). Reef fish resources of the CNMI: a review of the fisheries, research, and management. *CNMI Division of Fish and Wildlife* Technical Report 94-03

Hospital, J., and Beavers, C. (2014). Economic and Social Characteristics of Small Boat Fishing in the Commonwealth of the Northern Mariana Islands. Page 58. National Marine Fisheries Service, NOAA, Administrative Report H-14-02, *Pacific Islands Fisheries Science Center*, Honolulu, Hawaii.

Houk, Peter & Van Woesik, Robert. (2008). Dynamics of shallow-water assemblages in the Saipan Lagoon. Marine Ecology-progress Series - MAR ECOL-PROGR SER. 356. 39-50. 10.3354/meps07252.

Kendall, M. S., Costa, B., McKagan, S., Johnston, L., & Okano, D. (2017). Benthic Habitat Maps of Saipan Lagoon. *NOAA* Technical Memorandum NOS NCCOS 229. Silver Spring, MD. 77 pp. https://doi.org/10.7289/V5/TM-NOS-NCCOS-229

Knapp, Melissa & Geeraert, Naomi & Kim, Kiho & Knee, Karen. (2020). Submarine Groundwater Discharge (SGD) to Coastal Waters of Saipan (Commonwealth of the Northern Mariana Islands, USA): Implications for Nitrogen Sources, Transport and Ecological Effects. *Water*. 12. 10.3390/w12113029.

Liske-Clark, Jill. (2015). Wildlife Action Plan for the Commonwealth of the Northern Mariana Islands, 2015-2025. *CNMI Division of Fish and Wildlife.*

Manglona, Thomas (2023, August 15). Saipan family rescues critically endangered turtle trapped in fishing net. *Kuam News*, https://www.kuam.com/story/49423171/saipan-family-rescues-critically-endangered-turtle-trapped-in-fishing-net

Mariana Visitors Authority, (2017). Commonwealth of the Northern Mariana: Visitor Arrival Statistics FY 2016. *Mariana Visitors Authority,* https://ver1.cnmicommerce.com/ei-visitor-arrivals/, 2/17/2023.

Matthews, T., J. Gourley, A. Flores, M. Ramon and M. Trianni, (2019). Length-weight relationships for 83 reef and bottomfish species from the commonwealth of the Northern Mariana Islands. *Pacific Islands Fish. Sci. Cent.* Admin. Rep. H-19-04, 7 p.

Maynard J., McKagan, S., Johnson S., (2017). Assessing resistance and recovery in CNMI during and following a bleaching and typhoon event to identify and prioritize resilience drivers and action options. *Marine Applied Research Center LLC (MARC)* of Wilmington, NC. Final Progress Report Grant No. NA17NOS4820088.

NOAA, (2023). What is a lagoon? National Ocean Service website, https://oceanservice.noaa.gov/facts/lagoon.html, 01/20/2023.

Restrepo VR, Thompson GG, Mace PM, Gabriel WL, Low L., MacCall AD, Methot RD, Powers JE, Taylor BL, Wade PR, et al. (1998). Technical guidance on the use of precautionary approaches in implementing national standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. *NOAA Technical Memorandum NMFSF/ SPO-031, NOAA, USA*: 54 pp

Sablan C, (2023, October 18). The Ocean Connects Us: Exploring Community Led Ocean Conservation in the Mariana Islands. [Presentation and Community Discussion] *American Memorial Park Visitors Center, Saipan, MP.*

Sea Grant, (2024). Market Forms of Fresh Fish and Cleaning Methods. *University of North Carolina, Sea Grant.* https://ncseagrant.ncsu.edu/mariners-menu/market-forms-of-fresh-fish-and-cleaning-methods/

Shester, G. G., & Micheli, F. (2011). Conservation challenges for small-scale fisheries: Bycatch and habitat impacts of traps and gillnets. *Biological Conservation*, 144(5), 1673–1681. https://doi.org/10.1016/j.biocon.2011.02.023

Sinigalliano C, Kim K, Gidley M, Yuknavage K, Knee K, Palacios D, Bautista C, Bonacolta A, Lee HW and Maurin L (2021) Microbial Source Tracking of Fecal Indicating Bacteria in Coral Reef Waters, Recreational Waters, and Groundwater of Saipan by Real-Time Quantitative PCR. *Front. Microbiol.* 11:596650. doi: 10.3389/fmicb.2020.596650

Tenorio, M.C. (2017). Allowable Biological Catch for Net-Use Exemptions, *CNMI Division of Fish and Wildlife* Interoffice Memorandum.

Trianni, M. S., Tenorio, M. C., McKagan, S. C., & Dunn, W. O. (2018a). Evaluation of a Fishery Resource Response to a Net-Use Restriction in Saipan Lagoon, Commonwealth of the Northern Mariana Islands. *Pacific Science*, *72*(3), 291–306. https://doi.org/10.2984/72.3.1

Trianni, M. S., Gourley, J. E., & Ramon, M. S. (2018b). Spatial, temporal, and biological characteristics of a nearshore coral reef fishery in the Northern Mariana Islands. *Marine and Coastal Fisheries*, *10*(3), 283-297. https://doi.org/10.1002/mcf2.10024

United States. (1983). The Endangered Species Act as amended by Public Law 97-304 (the Endangered Species Act amendments of 1982). *Washington* :U.S. G.P.O., 1983.

US Census Bureau, (2020). 2020 Census Population of the Commonwealth of the Northern Mariana Islands: Municipality and Village. *US Department of Commerce.* https://www2.census.gov/programs-surveys/decennial/2020/data/island-areas/commonwealth-of-the-northern-mariana-islands/population-and-housing-unit-counts/commonwealth-northern-mariana-islands-phc-table02.pdf

US Department of Agriculture, (2015). USDA National Nutrient Database for Standard Reference, Release 27 (slightly revised). *Agricultural Research Service, Nutrient Data Laboratory*. http://www.ars.usda.gov/ba/bhnrc/ndl

Van Beukering, P.J.H. & Haider, Wolfgang & Wolfs, Esther & Lui, Yi & Leeuw, Kim & Longland, Margo & Sablan, Joel & Beardmore, Ben & Di Prima, Sabina & Massey, Eric & Cesar, Herman & Hausfather, Zeke. (2006). The economic value of the coral reefs of Saipan, Commonwealth of the Northern Mariana Islands. https://www.researchgate.net/publication/258438613_The_economic_value_of_the_coral_reefs_of_Saipan_Commonwealth_of_the_Northern_Mariana_Islands

Variety News Staff (2011, March 15). The perils of net fishing. *Marianas Variety*, https://www.mvariety.com/news/local/the-perils-of-net-fishing/article_9557c07f-584f-58ae-ac00-c69e9a24e8e6.html

Vasilakopoulos, Paris & O'Neill, Finbarr & Marshall, C.. (2011). Misspent youth: Does catching immature fish affect fisheries sustainability?. *ICES Journal of Marine Science*. 68. 1524. 10.1093/icesjms/fsr075.

Wepmen K., (2022, April 29). Are you getting too much protein? *Mayo Clinic Health System.* https://www.mayoclinichealthsystem.org/hometown-health/speaking-of-health/are-you-getting-too-much-protein

Appendices

Appendix 1: DFW-FRDS Comments to Statements Made by Proponents of HB-23-5

Background

On February 8, 2023, Rep. Denita Yangetmai along with other supporters of HB-23-5 held a press conference at the Carolinian Village pavilion in Garapan. During the conference, several important fishery-related topics were discussed and statements were made that caught the attention of DLNR Secretary, Sylvan Igisomar, who asked DFW-FRDS staff to comment on the statements. Since DFW-FRDS did not attend the press conference, an article on the event published by Marianas Variety on February 9, 2023, was used as a reference (Erediano, 2023). In the following section, proponents' statements have either been directly quoted or inferred from the article by DFW-FRDS staff.

Food to the Table

Statement

House Bill 23-5 will help subsistence fishers and their families cope with the local economic downturn by helping them “bring food to their table".

Response

A gillnet is a powerful piece of fishing equipment. A well-placed gillnet is likely to catch far more fish than could be caught with other gear such as cast net, spear, or hook and line in the same time frame. In the short term, gillnets could allow for increased yields for subsistence fishers with access to a net.

However, an increase in relative fishing pressure in the short term could result in a decrease in relative yield in the long run. For example, in 2013, total landings for *hangon* were above average, estimated at 13,930 lbs. But in the following years, landings fell to < 2,000 lbs until recovering slightly in 2021 to 3,645 lbs (WPacFIN data portal).

We can conduct some simple math to convert this into a daily harvest rate in terms of fish by using the data above. Of the 13,930 lbs landed in 2013, 74% were likely caught in the lagoon with an average weight of 171 grams or .38 lbs. Thus converting, we find

$$13,930\ \frac{lbs}{yr} \times\ 74\% \times \frac{1\ hangon}{.38\ lbs} \times \frac{1\ yr}{365\ days} \simeq 74.3\ \frac{hangon}{day}$$

If we conduct the same math for 2021, we find that last year's estimated extraction rate was ~19.5 hangon/day for the entire lagoon fishery. A single gill net set on the reef to block a channel is capable of catching this many *hangon* in a matter of hours. Is it ethical to put that much fishing power in the hands of a single net owner?

A harvest method that targets the same populations that are already harvested to the maximum capacity (i.e., SPR ~40%) is not increasing sustainable yields to the fishery, but simply redistributing fish from one gear type to another. Increased harvest by gillnet would equate decreased harvest for other methods like spearfishing and hook and line. Moreover, if opening the lagoon to gillnet fishing creates conditions in which harvests increase beyond a species's regenerative capacity (i.e., SPR < 40%), then long-term fishing yields of that population will decline and everyone who depends on that resource will suffer.

The high fishing power of a gillnet leads to multiple management and logistical issues. For example, consider the following questions:

- Who determines how much harvest is allowable for subsistence?
    - The legislator?
    - DLNR?
    - DFW?
- What metric should be used to cap catch at subsistence levels?
    - Lbs/fisher/day?
    - Lbs/family/day?
    - Total annual catch limits?
- How will excess catch be distributed?
    - By the fisher?
    - By enforcement?
    - By the Mayor’s Office?
- Who will monitor the net activity and for how long?
    - Enforcement section?
        - How will it be paid for?

The people of the CNMI need to consider the power of a gillnet seriously and understand the potential logistic and management issues created by gillnet fishing.

Unequal Access to Fishing Gear in CNMI

Statement

“Fishermen on Rota and Tinian are allowed to practice dragnet, surrounding net, trap nets, and other fishing methods in the waters surrounding their islands, but Saipan fishermen can only use talaya or throw net for subsistence fishing.” -Louie Tilipao, a local fisherman

Response

The local fishermen who pointed out the discrepancy in CNMI law regarding net-use regulations is correct. Despite existing exemptions afforded to community members, net fishing in Rota and Tinian was made possible via legislative action in 2010 and 2014 when the Fair Fishing Act of 2000 was amended (see 2 CMC § 5631).

While the amendment was not endorsed by DFW, the idea of area-based fisheries management merits further discussion. There is a significant difference between the population size of Saipan (43,385) versus that of Tinian (2,044) and Rota (1,893) (US Census Bureau, 2020). Holding all else equal, higher population size leads to greater demand for fish, higher fishing pressure, and reduced fishery resources. Effective resource management should consider these population differences as well as other local factors and use the best available science to adjust local regulations accordingly.

MPA Productivity

Statement

The presence of Saipan's marine protected areas (MPAs) since the early 2000s has allowed for spawning and migration of fish throughout the lagoon. This increase in lagoon productivity is enough to offset the use of gillnets.

Response

This response takes a bit more time. First, we need to understand the difference between an MPA in theory and an MPA in practice and how it is possible for an MPA to "work" for one species, but not another. We will also look at data from an MPA in Saipan's lagoon, Managaha Marine Conservation Area (MMCA) to underscore the importance of moving beyond "paper parks" to actively managed conservation areas.

The Role of Marine Protected Areas

Theoretically, MPA no-take zones should enhance biological diversity and abundance of marine organisms (Bohnsack, 1990; Bohnsack & Ault, 1996), provide a buffer against marine losses due to unpredictable changes in the environment (Airamé et al., 2003), and export fish larvae, recruits, and adults into the larger fishery (Carr et al., 2003).

But have CNMI MPAs produced such benefits? To answer this concerning the issue at hand, fishing in Saipan's lagoon, let us look at the only "no-take" MPA within Saipan's lagoon, MMCA.

Managaha Marine Conservation Area

The MMCA is Saipan's largest MPA, designated in 2000 with public law No. 12-12. MMCA contains about 500 ha around the island of Managaha, which resides within Saipan's northern lagoon, just north of Saipan's primary shipping channel. MMCA's borders extend through a large lagoon area and across the barrier reef to include areas on the adjacent forereef slope.

DFW-FRDS has been monitoring CNMI's MPAs with underwater visual census techniques (e.g., diver surveys) since each MPA's designation. A DFW-FRDS internal report (Trianni, 2008) showed initial increases in relative fish abundance for 11 out of 12 analyzed food fish groups in MMCA from 2000 - 2007, the years directly preceding and following MMCA's designation. An additional experiment in 2005 paired survey sites within MMCA boundaries with sites of similar habitat structure outside of the protected area. Results showed that fish counts were significantly higher within MMCA than outside of it for the forereef slope and shallow patch reef habitats. Thus, early studies seemed to show that the MPA was "working" as far as increasing biomass within the MPA boundaries. However, increases of fish biomass within the MPA do not always directly translate to increased yields for fishers via MPA "spillover" effects.

No official study of MPA spillover effects has been conducted in the CNMI. Some qualitative evidence of MPA productivity could be drawn from the case studies of four fishes reviewed earlier in this document. Each fish was landed at higher frequencies in the central and northern lagoon, areas adjacent to MMCA. It is possible that spillover from MMCA is responsible for at least some of this apparent productivity. However, higher fish landings in this area are more likely a result of a suite of other factors, such as a larger geographic footprint, deeper waters, better habitat, and greater fishing effort.

Characteristics of a Successful MPA

To optimize an MPA's spillover effect, the following population-specific characteristics should be considered:

1. **Sufficient Size**
   a. **Statement:** The area should be large enough to contain the various essential fish habitats needed by a population (i.e., fish that must travel outside of the MPA borders to finish a specific portion of their life cycle are no longer adequately protected).
   b. **Questions to ask:** Which population(s) are we targeting for protection? Is the population protected through its entire life cycle?
2. **Strong protections**
   a. **Statement:** "Not all MPAs are the same; they range from full protection in "no-take" areas to minimal protection with many extractive activities. Some exist only on paper, not in practice" (Grorud-Colvert, K. et al., 2021).

    b. **Questions to ask:** What regulations are in place? Which types of activities are permissible and when? What happens when protections are violated?

3. **Active Management**
    a. **Statement:** The MPA process does not end at its designation but is an adaptive process. Continued monitoring, plan/goal review, and updates to protections/regulations are needed to ensure success. Moreover, current protections and overall MPA efficacy cannot be determined if they are not adequately enforced.
    b. **Questions to ask:** How are current MPAs monitored/managed? What are the outcomes of available studies? Have protections been enforced?

Whether or not the MMCA is large enough is a population-specific question. While some smaller-bodied, sedentary, or resident sub-populations may have all their essential habitats within the MPA borders, it is likely that larger, roving species with more dynamic life cycles lack at least one essential habitat and are thus only partially protected within MPA borders.

On paper, MMCA is designated as a "no-take" zone but allows exemptions for scientific research, cultural and traditional practices, or educational studies. Thus, Johnson and Villagomez (2022), classified MMCA as a lightly protected area in their recent analysis of MPAs within the Mariana Islands. Unfortunately, even these light protections have not been adequately enforced, and in recent years DFW staff have found unpermitted fishing gear tangled in the docks and nearby reef areas within MMCA's borders. Perhaps due to this lack of enforcement, fish biomass estimates within MMCA show a declining trend (Figure A1-1).

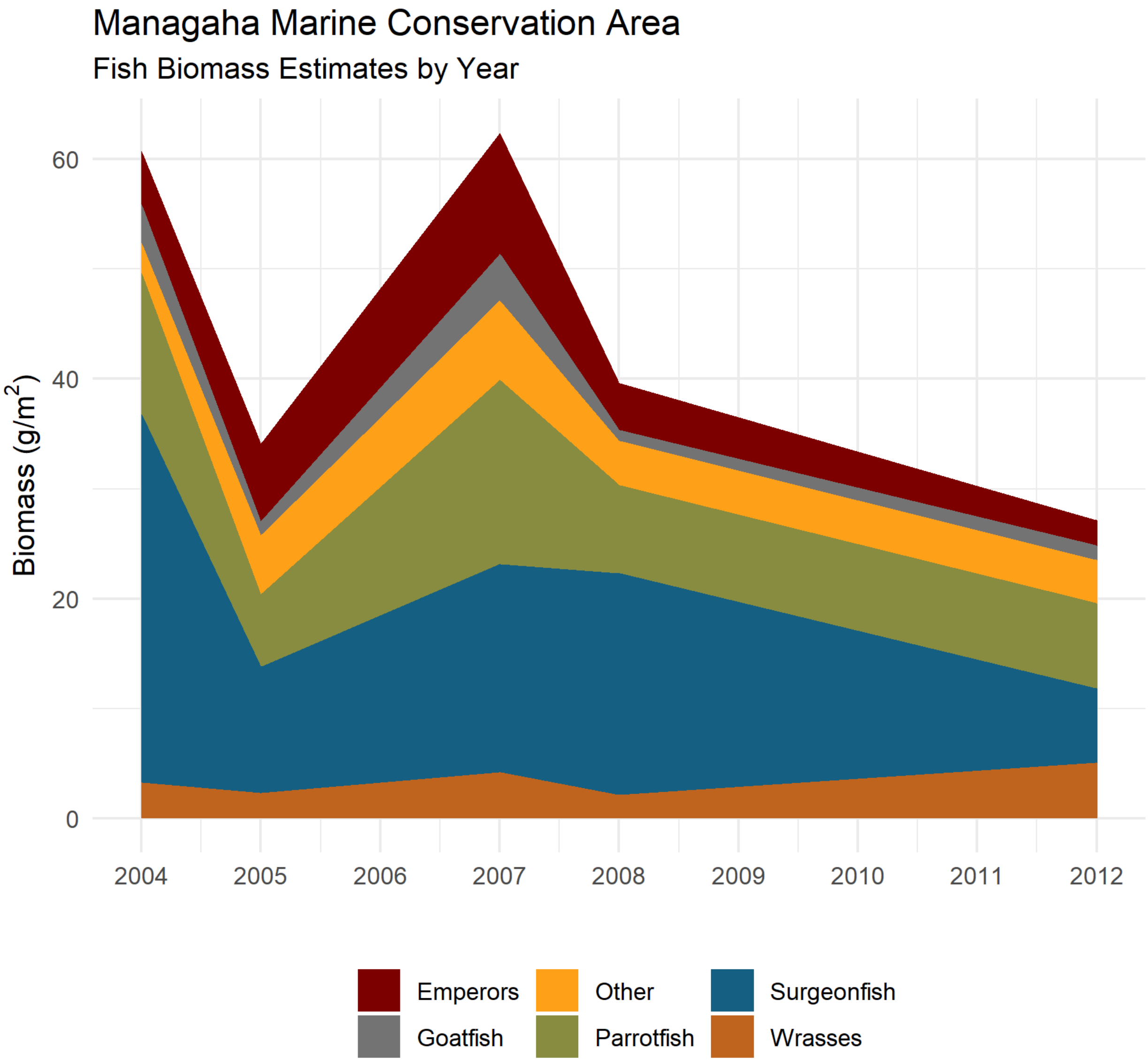


Figure A1-1: MMCA Fish Biomass Estimates by Year

Fish surveys were conducted in 2004, 2005, 2007, and 2012. Results are variable but generally show a declining trend in biomass.

An MPA that struggles to maintain healthy biomass within its borders is not likely to produce a large spillover effect to adjacent areas. While protections for the MMCA exist on paper, they have yet to be realized with adequate enforcement and management. Thus, relying on surplus MPA production to subsidize cultural gillnet fishing is inadvisable at this time. Current MPA boundaries, monitoring, protections, and goals need review followed by decisive enforcement action before additional harvest methods should be considered.

Mesh Size Restrictions

Statement

Limiting the mesh size to no less than 1.5 inches when stretched will ensure that only adult fish are caught, making the use of gillnets “eco-friendly and sustainable”.

Response

Mesh size restrictions can be an effective management tool in low diversity or targeted fisheries where fishers are harvesting from specific populations with known growth and maturity patterns. However, nearshore coral reef areas are often complex multi-species fisheries that make mesh restrictions difficult to implement effectively. Observations from DFW’s net-use exemption database found that fish from 24 families and over 90 unique species have been caught during exempted net-use activities (see Appendix 2). The diverse assemblages of fish within the catch have varied body types and life history traits including drastic differences in length at maturity. Thus, implementing a single mesh-size restriction that would ensure that only adult fish of every species are caught is not possible.

The ideal mesh size to target adults of one population could also entangle juvenile and sub-adults of another population, negatively impacting that fishery. For example, consider two common target species, lagoon *mafute’* and *tátaga*. *Tátaga* can grow to be over 50 cm long whereas most *mafute’* are < 30 cm. *Mafute’* mature at about 19.6 cm but *tátaga* do not mature until they are > 29.2 cm long. DFW’s best available estimates on *mafute’* show a relatively stable population whereas *tátaga* populations appear to be in decline. Thus, a well-intentioned sustainable harvest of adult *mafute’* via gillnet could have seriously negative effects by inadvertently entangling juvenile *tátaga*.

Appendix 2: Species List of Fish Caught by Net-Use Exemption Activities

Net Exemption Catch Species List

Acanthuridae
Acanthurus lineatus
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus olivaceus
Acanthurus sp.
Acanthurus triostegus
Acanthurus xanthopterus
Naso annulatus
Naso lituratus
Naso unicornis
Naso vlamingii
Balistidae
Balistes sp.
Balistoides viridescens
Rhinecanthus rectangulus
Sufflamen sp.
Belonidae
Hyporhamphus dussumieri
Strongylura leiura
Tylosurus crocodilus
Carangidae
Carangidae sp.
Carangoides ferdau
Carangoides orthogrammus
Caranx ignobilis
Caranx melampygus
Caranx papuensis
Caranx sexfasciatus
Caranx sp.
Gnathanodon speciosus
Trachinotus baillonii
Trachinotus blochii
Carcharhinidae
Carcharhinus melanopterus
Chanidae
Chanos chanos
Diodontidae

Labridae
Cheilinus chlorourus
Cheilinus trilobatus
Cheilinus undulatus
Cheilio inermis
Coris aygula
Coris sp.
Epibulus insidiator
Hemigymnus melapterus
Hologymnosus doliatus
Oxycheilinus sp.
Oxycheilinus unifasciatus
Lethrinidae
Gymnocranius sp.
Lethrinus atkinsoni
Lethrinus harak
Lethrinus obsoletus
Lethrinus olivaceus
Lethrinus rubrioperculatus
Lethrinus xanthochilus
Monotaxis grandoculis
Lutjanidae
Lutjanus sp.
Mugilidae
Crenimugil crenilabis
Mugil sp.
Mullidae
Mulloidichthys flavolineatus
Mulloidichthys vanicolensis
Parupeneus barberinus
Parupeneus bifasciatus
Parupeneus cyclostomus
Upeneus taeniopterus (U.arge)
Nemipteridae
Scolopsis bilineata
Priacanthidae
Heteropriacanthus cruentatus
Scaridae

Diodon sp.
Fistulariidae
Fistularia commersonii
Gerreidae
Gerres oyena
Gerres sp.
Hemiramphidae
Hemiramphus lutkei
Hemiramphus sp.
Holocentridae
Myripristis sp.
Sargocentron sp.
Sargocentron spiniferum
Kyphosidae
Kyphosus sp.

Calotomus carolinus
Chlorurus microrhinos
Chlorurus sordidus
Hipposcarus longiceps
Leptoscarus vaigiensis
Scarus ghobban
Scarus psittacus
Scombridae
Scomberoides lysan
Selar crumenophthalmus
Serranidae
Epinephelus sp.
Siganidae
Siganus argenteus
Siganus punctatus
Siganus spinus
Sphyraenidae
Sphyraena barracuda
Sphyraena qenie
Sphyraenadae sp.

Appendix 3: Case Study Model Equations, Inputs, and Outputs

Model Equations

The GTG-LBSPR model used in this report requires life history parameters derived from the Von Bertalanffy growth equation (VBGE), as well as estimates of length at maturity, and natural mortality rates. A size-based selectivity model is determined from the catch data and assumes that gear selectivity is logistic.

Together, these parameters are used to predict the size structure of fished stocks at equilibrium. By assuming steady state (i.e., constant recruitment and mortality rates), the GTG-LBSPR model can describe the number-per-recruit in individual length classes using the recursive equation:

$$N_{L+dL} = NL\left(\frac{L_{inf} - L - dL}{L_{inf} - L}\right)^{\frac{Z_L}{K}} \qquad \text{Eq. 1}$$

where N_L is the number of fish in length class L, dL is a small increment in length, L_{inf} and K are parameters of the VBGE, and Z_L is the total mortality rate at length class L (equal to the sum of fishing mortality rate at length L (F_L) and natural mortality rate (M), which is assumed constant, (see Eq. 8). F_L is assumed to be size-dependent and can be described using a logistic selectivity equation:

$$F_L = \frac{1}{1 + e^{-ln(19)\frac{L - L_{S50}}{L_{S95} - L_{S50}}}} \qquad \text{Eq. 2}$$

where L_{S50} and L_{S95} are the size at 50% and 95% selectivity, and F is the background fishing mortality rate. The cumulative per-recruit density between length class L and L+dL can then be described as

$$\check{D}_{L+dL} = \frac{\frac{1}{Z_L}(N_L - N_{L+dL})}{\sum_L \frac{1}{Z_L}(N_L - N_{L+dL})} \qquad \text{Eq. 3}$$

which is standardized to sum to 1.

The equations described above are for an individual growth trajectory (i.e., a single L_{inf} value). By varying L_{inf} using the CV Linf parameter (coefficient of variation associated with individual variability in L_{inf}), we can use these equations to calculate the density at length vector $\check{D}_L$ for a number of different growth-type groups (G). It is then possible to obtain the expected length structure by summing the density for all individual length classes across the G growth-type groups:

$$\dot{D} = \sum_1^G \check{D}_{L+dL,g} \qquad \text{Eq. 4}$$

The length-based model described here can also be used to calculate the spawning potential ratio. Assuming that egg production is proportional to weight, we can describe fecundity-at-length (Fec_L) as:

$$Fec_L = Mat_L L^{\beta} \qquad \text{Eq. 5}$$

where Mat_L is maturity-at-length which can be described using a logistic function of format similar to Eq. 2 (replacing L_{S50} and L_{S95} with L_{mat50} and L_{mat95}). The β parameter is from the length-weight relationship ($W = \alpha \cdot L\beta$). Using this equation, it is now possible to calculate spawner-biomass-per-recruit (SSBR) for each length class and ultimately obtain SPR by summing SSBR across all length classes and all growth-type groups for both the fished stock (numerator) and the unfished stock (denominator):

$$SPR = \frac{\sum_g \sum_L \frac{1}{(M + F_L)} (N_{L,g} - N_{L,g+dL}) Fec_L}{\sum_g \sum_L \frac{1}{M} (N_{L,g} - N_{L,g+dL}) Fec_L} \qquad \text{Eq. 6}$$

With estimates of L_{inf}, K, CV L_{inf}, $L_{mat50,}$ and $L_{mat95,}$ it is now possible to estimate F, L_{S50}, and L_{S95} from a population size structure by minimizing the multinomial negative log-likelihood (NLL) following the function:

$$NLL = arg\ min \sum_i O_i ln(\frac{P_i}{\tilde{O}_i}) \qquad \text{Eq. 7}$$

where O_i and $\tilde{O}_i$ are the observed number- and proportion-at-length (respectively) in each *i* length class and P_i is the estimated proportion-at-length for each *i* which can be calculated by multiplying the $\ddot{D}$ in Eq. 4 by the estimated selectivity curve. The GTG-LBSPR model makes similar assumptions to other relatively simple length-based approaches (e.g., mean length-SPR), mainly that the stock is in a mostly steady-state (recruitment- and mortality-wise) and that the VBGE appropriately describes fish growth. The current implementation of this model also assumed logistic selectivity, logistic length-at-maturity, and constant natural mortality at all sizes.

Natural mortality was attained using the longevity method of analysis:

$$M = \frac{-ln(S)}{t_{max}} \qquad \text{Eq. 8}$$

Where M is the natural mortality rate (assumed constant at all sizes), t_{max} is the maximum observed age of a fish, and *S* is the surviving proportion of a cohort that attains an age of t_{max}.

Model Inputs and Outputs

Species Name	**Parameter Type**	**Parameter Name**	**Value**	**Comments**
Naso lituratus	input	Linf	22.75	from tuning Linf to NI data to produce SPR of 0.97
Naso lituratus	input	L50	14.50	from Taylor et al. 2014
Naso lituratus	input	L95	16.00	estimate from DFW staff
Naso lituratus	input	M/k	0.47	from DFW parameters
Naso	input	k	0.22	from unsexed DFW VB curve

lituratus				
Naso lituratus	input	M	0.10	calculated using longevity method
Naso lituratus	input	tmax	30.00	oldest fish in DFW record from the Northern Islands
Naso lituratus	input	S	0.04	Assumption borrowed from Hordyk et al. 2015. Range 1-5% depending on species
Naso lituratus	output	SL50	19.12	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Naso lituratus	output	SL95	21.28	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Naso lituratus	output	FM	5.78	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Naso lituratus	output	SPR	0.30	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Acanthurus lineatus	input	Linf	20.5	Tuned Linf to NI catch data for SPR = 0.97
Acanthurus lineatus	input	L50	18.8	from Leon Guerrero (*in prep* 2023)
Acanthurus lineatus	input	L95	18.81	Approximates knife edge maturity
Acanthurus lineatus	input	M/k	1.02	from DFW parameters
Acanthurus lineatus	input	k	0.24	from unsexed DFW VB curve
Acanthurus lineatus	input	M	0.24	calculated using longevity method
Acanthurus lineatus	input	tmax	14.00	oldest fish in DFW record from Saipan
Acanthurus lineatus	input	S	0.033	Assumption borrowed from Hordyk et al. 2015. Range 1-5% depending on species
Acanthurus lineatus	output	SL50	17.17	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Acanthurus lineatus	output	SL95	18.7	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Acanthurus lineatus	output	FM	2.87	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Acanthurus lineatus	output	SPR	0.10	Calculated GTG-LBSPR Model Output Lengths from 2011-2016

Lethrinus harak	input	Linf	30.10	Trianni 2016
Lethrinus harak	input	L50	19.60	Trianni 2016
Lethrinus harak	input	L95	23.50	estimate from DFW staff
Lethrinus harak	input	M/k	1.35	from Trianni 2016 k and DFW calculated M
Lethrinus harak	input	k	0.26	Trianni 2016
Lethrinus harak	input	M	0.35	calculated using longevity method
Lethrinus harak	input	tmax	9.00	oldest fish in Trianni 2016
Lethrinus harak	input	S	0.04	Assumption borrowed from Hordyk et al. 2015. Range 1-5% depending on species
Lethrinus harak	output	SL50	19.81	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Lethrinus harak	output	SL95	23.41	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Lethrinus harak	output	FM	1.49	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Lethrinus harak	output	SPR	0.33	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Naso unicornis	input	Linf	47.50	from tuning Linf to NI data to produce SPR of 0.98
Naso unicornis	input	L50	29.20	Taylor et al. 2014 (Guam)
Naso unicornis	input	L95	34.00	estimate from DFW staff
Naso unicornis	input	M/k	0.91	k from Taylor et al. 2014 (Guam), M from longevity
Naso unicornis	input	k	0.22	Taylor et al. 2014 (Guam)
Naso unicornis	input	M	0.20	calculated using longevity method
Naso unicornis	input	tmax	23.00	oldest fish in Guam’s database

Naso unicornis	input	S	0.01	Assumption borrowed from Hordyk et al. 2015. Range 1-5% depending on species
Naso unicornis	output	SL50	20.80	Calculated GTG-LBSPR Model Output Lengths from of 2011-2016
Naso unicornis	output	SL95	23.84	Calculated GTG-LBSPR Model Output Lengths from of 2011-2016
Naso unicornis	output	FM	4.17	Calculated GTG-LBSPR Model Output Lengths from 2011-2016
Naso unicornis	output	SPR	0.03	Calculated GTG-LBSPR Model Output Lengths from 2011-2016