ASSESSING STOCK ABUNDANCE, SIZE, AND SPATIAL DISTRIBUTION OF FIVE CITES-LISTED SEA CUCUMBER SPECIES IN PAPUA NEW GUINEA

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ABSTRACT

The sea cucumber fishery plays a crucial role in Papua New Guinea's coastal economy, providing significant annual revenue and direct benefits to local communities. In response to declining sea cucumber populations, a fishery moratorium was introduced in 2010, prompting comprehensive stock assessment surveys conducted by the National Fisheries Authority across various provinces. By 2020, a Non-Detrimental Finding (NDF)—which determines whether export of a species is non-detrimental to its survival—permitted the trade of two teatfish species under CITES, with three additional species approved in 2022 and effective from 2024. In this study, management strategies are investigated, including NDF implementation, by thoroughly evaluating stock assessment data.

The results indicate that Candy cane (*Thelenota rubralineata)* was uncommon, with significantly lower density compared to White teatfish (*Holothuria fuscogilva)*, Black teatfish (*H. whitmaei)*, Prickly redfish (*Thelenota ananas)*, and Amberfish (*T. anax)*. A partial recovery was observed in White teatfish and Prickly redfish, suggesting a positive trend in abundance and recruitment during the moratorium period. However, populations of Black teatfish exhibited fluctuations, and Amberfish showed inconsistencies. Size distribution analysis revealed compliance with NFA regulations, although discrepancies were noted for Black teatfish and Prickly redfish regarding legal size requirements.

Recommendations include using 2016 mean density as a reference point and revising the sizes of Black teatfish and Prickly redfish to ensure they exceed the size at maturity. Additionally, a complete ban on Candy cane from the fishery and targeted stock assessment surveys were proposed.

Keywords: Sea cucumber fishery, stock assessment, CITES-listed species, abundance and size structure, spatial distribution, Papua New Guinea.

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1 INTRODUCTION

1.1 1.1 Background

The sea cucumber fishery plays an important role in the livelihoods of coastal communities in Papua New Guinea (PNG). The fishery is extensive, conducted in most coastal and island communities, and targets more than 23 species with different market values. This is a small-scale, informal fishery with multiple landing points, mostly carried out from the shore or on canoes and other small vessels. Sea cucumbers are mostly processed, dried, and exported as bêche-de-mer (BDM). BDM production is an attractive source for coastal communities, as once dried, BDM is shelf-stable, and it has a high value relative to its size (Barclay et al., 2019).

The sea cucumber fishery is of dominant economic significance in Papua New Guinea, standing as the most valuable coastal fishery in the country. During the period when the fishery was active, it ranked second only to tuna as Papua New Guinea's leading export product, contributing over 30 million US dollars in export revenue. Approximately 10 million dollars from this revenue directly benefits coastal and island communities each year (National Fisheries Authority, 2015). In essence, the sea cucumber fishery has emerged as the primary coastal fishery in PNG, playing a pivotal role in generating revenue that directly supports the livelihoods of coastal and island populations.

Sea cucumber exploitation has a notable history in PNG. Regional markets for BDM have existed for centuries, and export records date back to 1873. In 1900, (BDM) exports reached approximately 37 tonnes per year (Kinch et al., 2008a). During most of the 20th century, annual exports fluctuated below 50 tonnes per year. Starting in the mid-1980s, the fishery expanded greatly with increasing incomes in the main market, China. Annual exports increased rapidly between 1985 and 1993, reaching 650 tonnes per year (Hair et al. 2016). During this period, PNG emerged as a major player in the global sea cucumber industry, ranking as the third largest producer and supplying 10 percent of the global demand, predominantly to Asian Markets (Kinch et al., 2008b) (Pakoa & Bertram, 2013). Between the 1990s and 2010, annual exports ranged between 400 and 800 tonnes. This increase was driven by increasing prices and an influx of buyers entering the market, and it was made possible by the spatial expansion of the fishery, improved harvest efficiency, and greater demand for lower-value and newly commercialised sea cucumber species (Hair et al. 2016; Hair et al. 2019). At this time, the PNG sea cucumber fishery operated in all maritime provinces of the country, supporting up to 200,000 people and providing up to 30% of annual village income (Hair et al., 2018).

In 2009, severe depletion of wild sea cucumber stocks nationwide led NFA to impose a moratorium on the fishery. Sea cucumber fisheries are prone to boom-and-bust cycles, where depletion follows periods of heavy fishing (Anderson et al., 2011). To address the signs of overfishing in the PNG sea cucumber fishery, the PNG government implemented a Management Plan for BDM in 2001. This plan introduced several key measures, including the establishment of a Total Allowable Catch (TAC) for each province, which was enforced through export control via licencing. Additionally, the plan implemented a closed season to regulate fishing activities. The TAC was determined based on available stock assessment data or historical catch records (Kinch et al., 2008b). However, the fishery still operated under a management framework that required robustness in monitoring, leading to extensive overfishing and localised depletions. In 2009, the NFA imposed a moratorium on fishing sea cucumbers and selling BDM. The moratorium aimed to allow sea cucumber spawning populations to recover (Barclay et al., 2017). The moratorium had a large impact on communities that relied heavily on BDM as a source of income and livelihood. During the closure period, the NFA conducted an annual sea cucumber stock assessment initially in eight provinces and gradually expanded the survey to cover other provinces to monitor sea cucumber population recovery. The surveys concluded that recovery had occurred for some species, recruitment was limited for others, and most sea cucumbers were below the minimum legal size in 2016 (Hair et al., 2018).

The seven-and-a-half-year moratorium ended in 2017, and the sea cucumber fishery was opened with a revised Beche-de-mer Management Plan gazetted in 2016 (Hair et al., 2019). Despite the introduction of new management strategies, failure to adhere to their implementation significantly contributed to uncontrolled and overshooting of the provincial Total Allowable Catch (TAC) during the 2017 and 2018 open seasons. For example, in the first post-moratorium season, the TAC for the New Ireland Province of 43 tonnes was attained in less than two months and was exceeded by at least 36 tonnes (Hair et al., 2019). In 2018, 1,109 tonnes of BDM were exported from PNG, a quantity higher than the annual exports before the ban. The lack of compliance with the management measures of the plan, including the inability to monitor BDM purchases in real time, exacerbated the exploitation pressure on sea cucumber stocks, leading to detrimental consequences for the sustainability of the fishery. Because of these challenges, the fishery was once again closed in 2019 to facilitate the assessment and evaluation of potential management options by the National Fisheries Authority. However, amid the additional pressures stemming from the COVID-19 pandemic, the decision was made to reopen the fishery in 2020.

1.2 The CITES-listing of some of the sea cucumber species

The reopening of the fishery in 2020 presented the NFA with further challenges, particularly following the inclusion of White Teatfish (*Holothuria fuscogilva*) and Black Teatfish (*Holothuria whitmaei*) in the Appendix II listing of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) during the 2019 COP18 meeting in Geneva. Article IV of the Convention mandates the production of a Non-Detrimental Finding (NDF) document, outlining clear guidelines and measures to ensure the sustainable management and conservation of these species (Rose, 2014). Following guidelines, the NFA developed an NDF for these two species, which served as a crucial framework for management and regulations during the 2020 fishing season (NFA, 2020). During the 2022 CITES COP19 meeting in Panama, three additional species, Prickly redfish (*Thelenota ananas)*, Amberfish (*Thelenota anax)*, and Candy cane (*Thelenota rubralineata)*, were listed under Appendix II (COP19, 2022), and as a result, PNG is required to produce NDFs to facilitate the trade of the listed species.

1.3 Rationale

The sea cucumber fishery serves as a very important source of income for coastal and island communities in Papua New Guinea, making it a vital aspect of their livelihoods. However, the imposition of additional restrictions by international conservation bodies, such as CITES, poses an extra burden on these communities. The National Fisheries Authority is a government organisation mandated in PNG to manage marine resources within its waters sustainably and profitably. Under the Constitution, the NFA has the authority and responsibility to implement measures that ensure the long-term viability of marine resources while also supporting the socioeconomic well-being of local communities. The NFA is obliged to assist communities in developing strategies to navigate these restrictions effectively while providing support and resources to mitigate their impact and promote sustainable practices that benefit both the environment and the people.

2 OBJECTIVES

2.1 General Objective

The overall objective of this report is to conduct a comprehensive assessment of the five sea cucumber species listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and provide the necessary information for an NDF document. This information includes the population structure and statutes, recent harvest based on catch data, management measures enforced by the NFA, and other biological and ecological considerations. Ultimately, the goal is to promote the long-term sustainability of both CITES-listed species and the broader sea cucumber fishery in Papua New Guinea.

2.2 Specific objectives

- Analyse stock assessment data of five sea cucumber species to determine stock density, recruitment, and abundance, and compare the findings with past surveys.
- Evaluate the size structure of sea cucumbers to compare their sizes at maturity with published length data for the five species.
- Investigate the spatial distribution of the five sea cucumber species across sites in each province.
- Propose recommendations for developing management strategies for the five species.

3 LITERATURE REVIEW

3.1 The significance and challenges of sea cucumber fishery management globally and in the Pacific.

Sea cucumber stocks are currently facing severe fishing pressure on a global scale, with significant catches and multi-species fisheries prevalent in the Asian and Pacific regions. Despite not being traditionally associated with fishing activities, many coastal communities have come to rely on sea cucumber harvesting as an alternative source of income (Kinch et al., 2008b). Since the late nineteenth century, the Pacific Sea cucumber fishery has witnessed cycles of growth and decline. The surge in demand from Asian markets during the 1980s catalysed increased fishing efforts, which subsequently led to the depletion of high-valued species (Kinch et al., 2008a). Consequently, low-valued species that were previously not exploited have now become the primary targets of the fishery. This shift has raised widespread concerns regarding the long-term sustainability of sea cucumber harvesting (Conand, 2018). The state of many Pacific sea cucumber fisheries is a significant concern for the region. Numerous fisheries are in poor condition, necessitating closure as countries urgently implement measures to prevent further collapse. This alarming situation can be attributed to the lack of effective fisheries management frameworks, regulatory measures, and enforcement capacities in many countries (Pakoa & Bertram, 2013).

Establishing precise and thorough goals in fisheries management is essential for directing key actions, including the formulation of key management objectives, indicators, and reference points related to sea cucumber stock density. Additionally, managers and stakeholders should reach a consensus on reference points, such as target reference points with stock density (Purcell, 2010). Thus, efforts must be dedicated to conservation endeavours aimed at formulating and implementing comprehensive systems that involve scientific research, community engagement and policy development.

3.2 Fisheries management in Papua New Guinea and challenges posed by conservation bodies such as IUCN and CITES

The management of sea cucumber fisheries in Papua New Guinea faces obstacles stemming from overfishing and inadequate institutional oversight (Barclay et al., 2019). Despite the fishery's significant economic importance, unregulated fishing practices and the collapse of breeding stocks prompted the implementation of a moratorium in 2009 (Purcell, 2010). The updated Sea Cucumber Management Plan incorporates various measures, such as enhancing reporting mechanisms and point-based export criteria, aimed at strengthening TACs and deterring non-compliant operators. Additionally, size restrictions were implemented to ensure that adults had a chance to breed before being fished, and mandatory closures were enforced to further safeguard sea cucumber stocks. In addition, some regulation powers, such as limiting TAC and the number of export licences, were transferred from the national level to the provinces (Barclay et al., 2017) (NFA, 2018).

Because no other stock assessment surveys have been conducted in recent years, the study conducted by Kaly (2007), Skewes (2002), and other relevant studies summarised by Kinch

(2008) were evaluated to compare stock densities and abundance in PNG (Kaly et al., 2007) (Skewes et al., 2002) (Kinch et al., 2008b) (Table 1). For the length distribution study, the minimum legal size stated in the PNG Sea Cucumber Management Plan (NFA, 2018) will be used to compare the size at maturity for each species compiled by Skewes et al. (2014).

Table 1. Stock densities extracted from Kinch (2008), show the highest densities for each sea cucumber and the minimum legal size stipulated under PNG´s Sea Cucumber Management Plan (2018) compared with Skewes et al (2014).

Species	**Mean density ind/ha (Kinch, 2008)**	**Minimum Legal Size (NFA, 2018)**	**Length at Maturity (Skewes, 2014)**
White teatfish (*Holothuria fuscogilva*)	23.0	35 cm	32 cm
Black teatfish (*Holothuria whitmaei*)	16.8	22 cm	26 cm
Prickly redfish (*Thelenota ananas*)	12.0	25 cm	30 cm
Amberfish (*Thelenota anax*)	6	20 cm	N/a
Candy cane (*Thelenota rubralineata*)	<0.1	25 cm	N/a

Another challenge in the sea cucumber fishery in PNG is from both the International Union for Conservation of Nature (IUCN) and CITES. The IUCN has classified 16 sea cucumber species as threatened with extinction, with seven species classified as endangered and nine as vulnerable (Leopold et al., 2013). The listing of the five commercial sea cucumber species under the CITES Appendix II is a concern in the Pacific, particularly PNG which did not support both the COP18 and 19 proposals, mainly due to fear of implementation difficulties and necessary capacity building (Simone et al., 2020). Additionally, it implores PNG’s concerns regarding the implementation of CITES regulations and their impact on the country’s sea cucumber fishery.

The proposal submitted to the CITES committee for deliberation on the five species was based on low density across range states (CITES, 2019), and most of the data on stock density were derived from published reports, including Kinch’s (2008) study, which serves as a comparative benchmark for this research.

3.3 Biological and ecological characteristics

There is a large number of sea cucumber species in the Pacific, primarily due to the conducive environment of warm tropical waters, which facilitates a high level of speciation. These sea cucumbers commonly prefer coastal areas, including seagrass beds near mangroves, as well as both hard and soft substrates within coral reefs (Kinch et al., 2008a). The population densities of sea cucumbers vary across different habitats, and their abundance is affected by anthropogenic pressures, including overexploitation and coastal development (Ru et al., 2022).

3.3.1 White teatfish (Holothuria fuscogilva - Cherbonnier, 1980*)*

The white teatfish (Figure 1) is widely distributed across the tropical Indo-Pacific region (Kinch et al., 2008b). It is categorised as a high-value species due to its market value (Purcell, 2014).

While the recorded depth range for the species is 0-50 m, most are caught between depths of 15–30 m (Conand, 2018). White teatfish typically inhabit outer reef slopes at depths between 10 and 50 m. Female White teatfish reach maturity at approximately 4 years of age and a total length of 32 cm. They spawn once a year during the warm season. This species can live for up to 12 years, reaching a maximum total length (TL) of 57 cm (Skewes et al., 2014). The established minimum harvestable size is 35 cm.

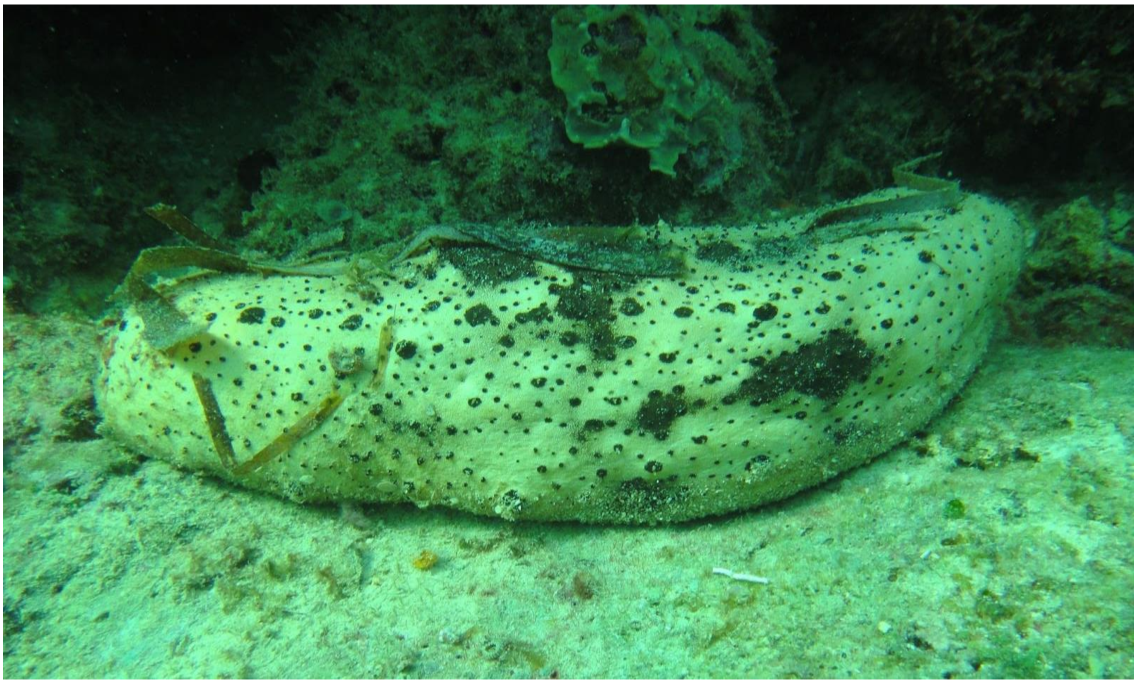

Figure 1. White teatfish (Holothuria fuscogilva) on a sandy bottom.

3.3.2 Black teatfish (Holothuria whitmaei, Bell 1887*)*

The black teatfish is also a premium valued and sought-after species present in the waters of PNG and is frequently found in the Indian Ocean and the Western Pacific (Purcell, 2014) (Kinch et al., 2008b). It predominantly inhabits coral reef environments, with the highest densities found on reef flats (Conand, 2008). However, they can also be found on back-reef slopes and reef fronts at depths ranging from 0 to 30 m. Female Black teatfish reach maturity at approximately 4 years of age and a total length of 26 cm. This species typically lives between 5 and 10 years and can grow to a maximum size of 56 cm in total length (Conand et al., 2013a) (Skewes et al., 2014). In Milne Bay Province, this species is one of the main targeted species due to its higher value (Skewes et al., 2002).

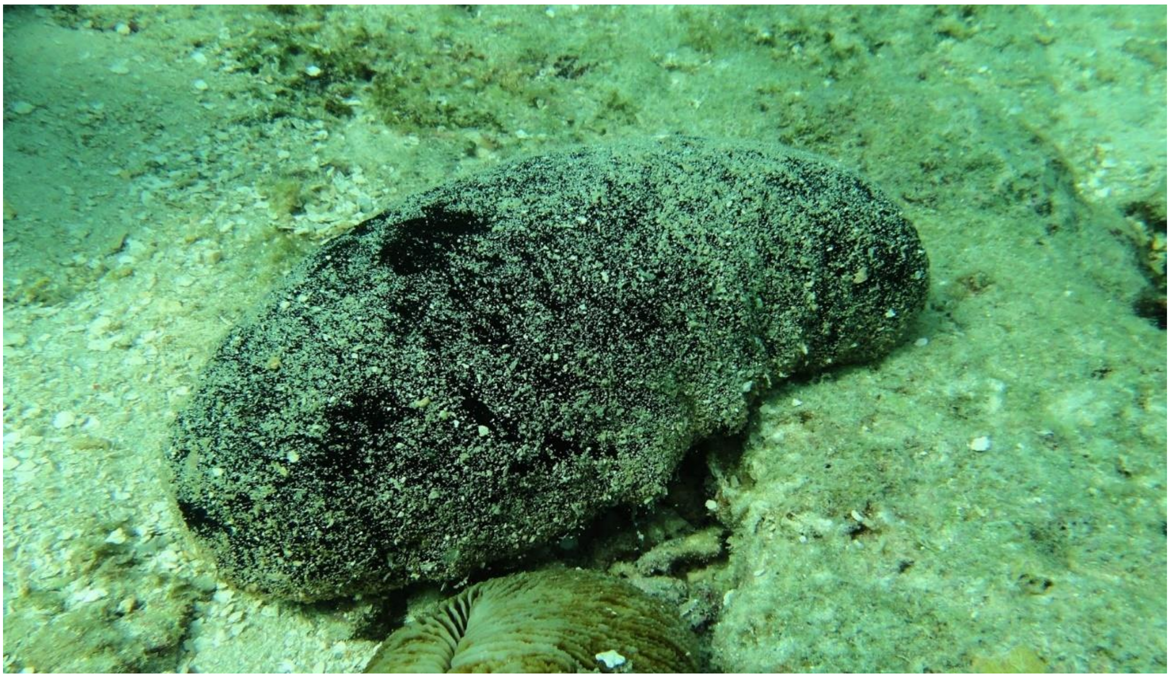

Figure 2. Black teatfish (Holothuria whitmaei) on sandy, hard substrates and rubble.

3.3.3 Prickly redfish (Thelenota ananas - Jaeger, 1833*)*

Prickly redfish (Figure 3) is grouped under medium-value species (Purcell, 2014). This species is one of the largest sea cucumbers in the world, with an average length of 45 cm. However, they can grow even larger, reaching up to 80 cm and weighing up to 5 kilograms when fully grown. They predominantly inhibit reef slopes and channels and are often spotted in outer reef flats (Pinca et al., 2009).

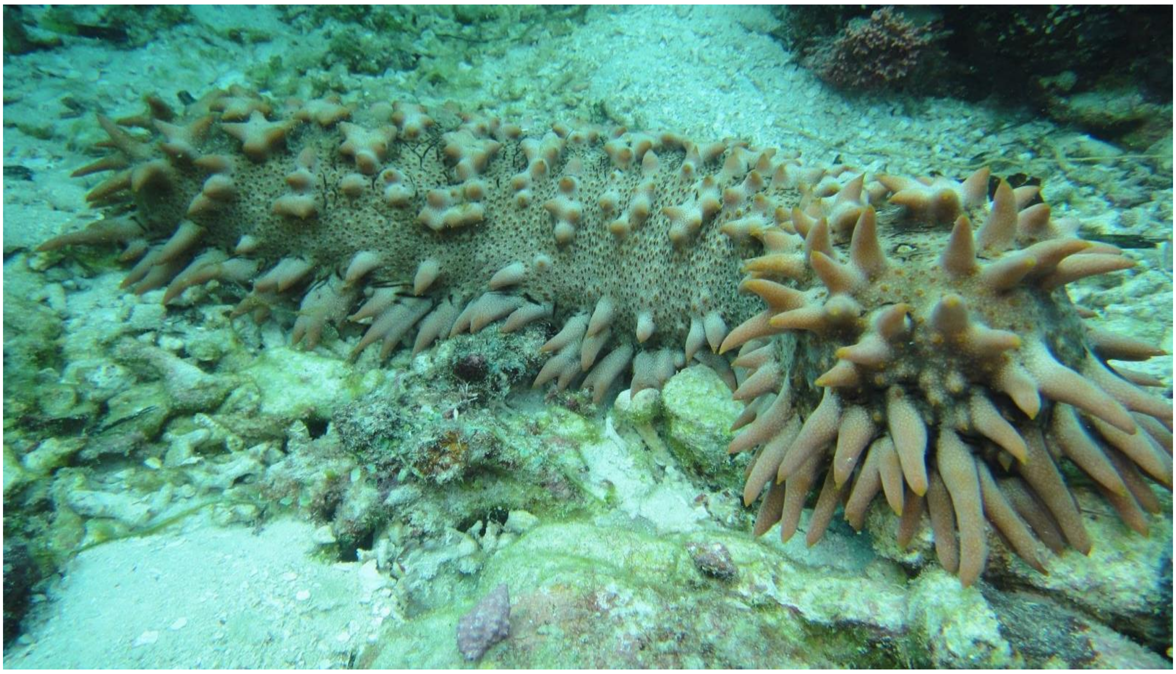

Figure 3. Prickly redfish (Thelenota ananas) on hard substrate.

3.3.4 Amberfish (Thelenota anax- Clark, 1921*)*

Amberfish are typically found in various habitats, such as reef slopes, outer lagoons, and areas with coral sandy patches. While they predominantly inhabit these environments, they can occasionally be found in shallower waters at depths ranging from 10 to 30 m. This species is the largest commercial sea cucumber species, but little is known about its biology (Conand et al., 2013b). Its commercial value is grouped under low value, indicating that it fetches a relatively modest price in the market compared to the other species studied (Purcell, 2014).

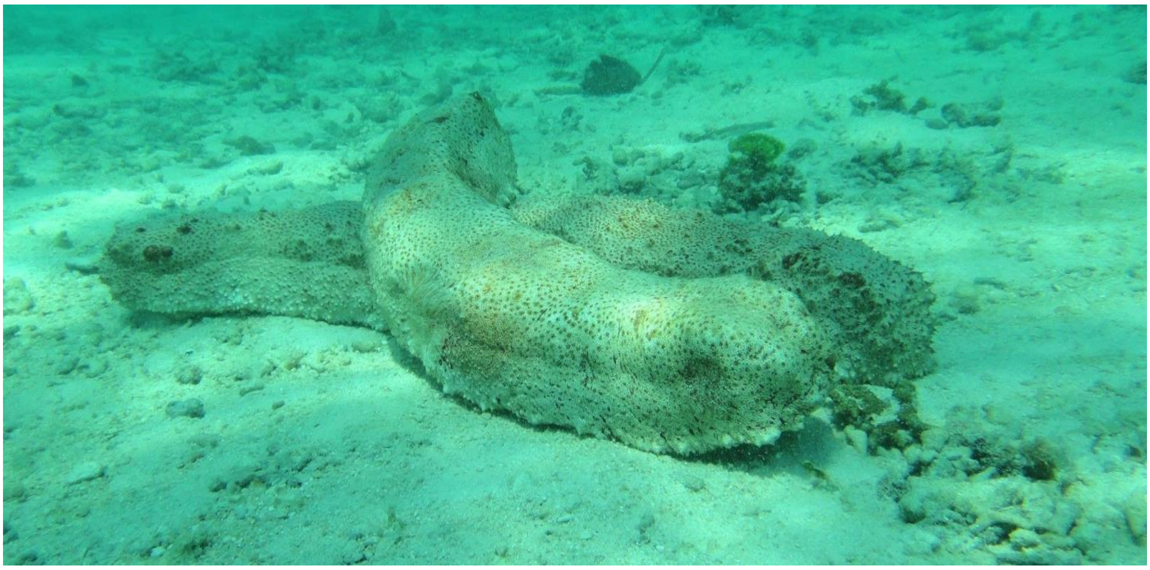

Figure 4. Amberfish (Thelenota anax) usually inhabit sandy bottoms at depth of 10-20 meters.

3.3.5 Candy cane (Thelenota rubralineata - Massin & Lane, 1991*)*

T. rubralineata is reported to be found in PNG waters (Kinch et al., 2008b) (Kinch et al., 2008a), and its market value is in the medium range (Purcell, 2014). It is primarily found on outer reef slopes and lagoons at a depth of 20 m. Its reproductive parameters, including age at maturity, generational length, and production, are unknown (Conand et al., 2013a). It is rare and is infrequently identified in surveys throughout its range (Pinca et al., 2009) (Conand et al., 2013b) (Andréfouët et al., 2019) (Figure 5).

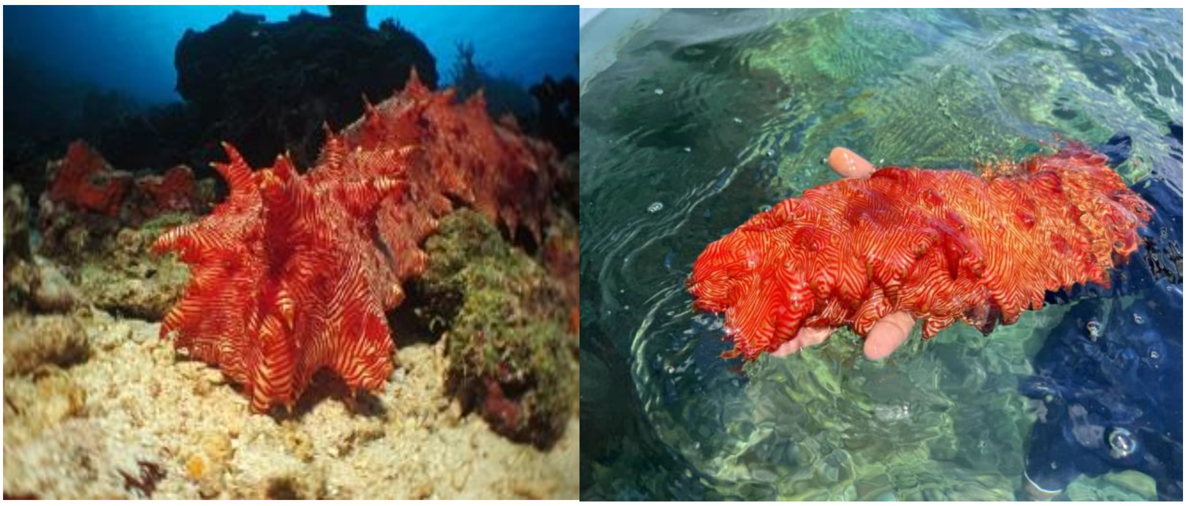

Figure 5. Candy Cane (Thelenota rubralineata,) left photo – www.miguelsdiving.com

4 MATERIALS AND METHODS

4.1 **Stock assessment surveys**.

This study used data collected during stock assessment surveys conducted to evaluate the status of sea cucumber stocks in PNG. The methodology is based on a stock assessment survey conducted by Kaly et al. (2007) in Papua New Guinea's New Ireland Province (Kaly et al., 2007). The stock assessment data cover the period from 2010, after the moratorium was initiated, to 2023. There is a gap in the data for 2017, when the fishery was open. The surveys were conducted in eight of the 14 maritime provinces of PNG. For this report, we utilised data from three provinces: Milne Bay, Manus, and the Autonomous Region of Bougainville (AROB) (Figure 6).

Figure 6. Map of PNG indicating the three provinces where stock assessment survey data were used in the study. (Source. https://www.mapsofworld.com/answers/geography/what-are-the-key-facts-of-papua-new-guinea/attachment/map-of-papua-new-guinea/#)

4.1.1 Survey methodology

Survey locations were chosen in provinces renowned for sea cucumber harvesting. Areas within the coastal boundaries governed by Local Level Governments (LLGs) were selected within these provinces. Within these LLGs, specific sites were identified in each *ward*, and further selections were made based on reef habitats (Table 2), sufficiently extending to accommodate 10 transects, each measuring 100 m in length and 4 m in width (Figure 7).

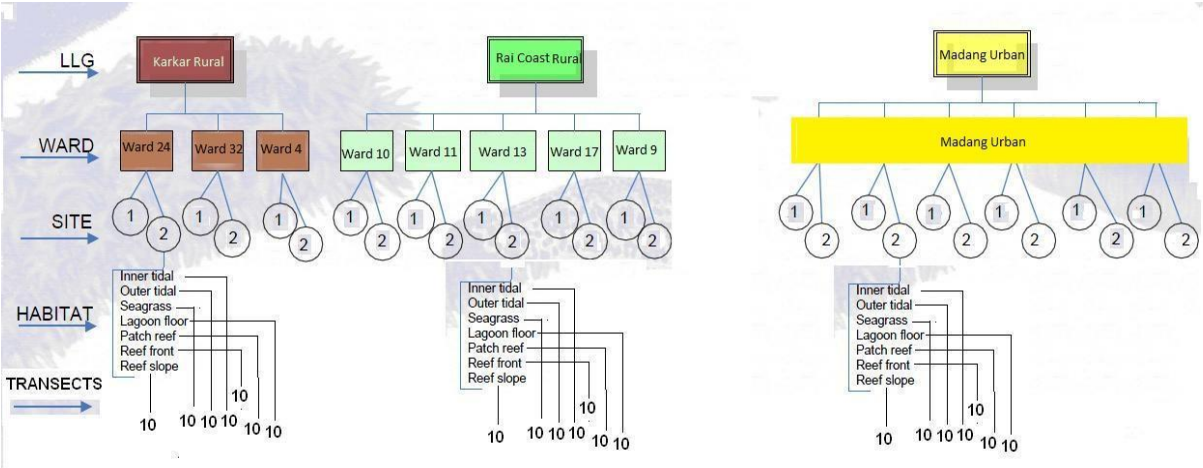

Figure 7. Stock assessment survey design adopted from Coastal Fisheries and Development Project and NFA, Kaly et al., 2007.

Each transect was surveyed by a team of three officers using a combination of scuba diving, snorkelling and reef wading. The officers recorded the number, species, and length of all sea cucumbers observed, considering variations in depth and visibility conditions.

Table 2 . Definitions of habitats used in the study.

	Habitat	Description and type
1	Reef Flat	Consists mostly of shallow, hard reef substrata. The following strata were all fit into reef flat: reef crest, mid reef and reef front
2	Reef Slope	Fore-reef strata descending from 4 to 15 meters on the wave-exposed side of the reef crest.
3	Lagoon	Mostly sand substrata, leeward of the reef flat. It is often with patchy reef or pool surrounding reefs.
4	Seagrass	Mostly sandy, with patches of seagrass substrata near mangroves and in between reef flats and reef crest

4.1.2 Data Preparation

The data were collected and stored in Excel files by different field officers, each aligning the variables of the data according to their preferences. Consequently, the datasets contained numerous inconsistencies in format, structure, and naming conventions, making it difficult to merge and analyse them cohesively. Therefore, it was necessary to standardise the data by aligning columns, standardising sites and location names to ensure uniqueness, and accurately identifying species by both their Latin and common names. The data included information on 31 species of sea cucumbers recorded across the three provinces analysed, but only five were subject to further analyses in line with the objectives of the study.

4.2 Analysis and interpretation

Time series of length distributions were compiled for each species in the three provinces studied. Patterns in length distributions were examined and compared with the minimum legal size (MLS) as designated in the PNG National Beche-de-mer Management Plan 2018 and with length at maturity estimates taken from Skewes et al. (2014) (Table 1). This analysis was carried out to determine the proportion of individuals surpassing the length-at-maturity threshold, which provides information on the population capable of reproduction, thereby, influencing recruitment and stock recovery.

The density and abundance of each of the five species in each province were estimated using survey data.

The mean density of each species by reef habitat (reef flat, reef slope, lagoon, and seagrass) and province was estimated following Purcell et al. (2009) as:

$$\overline{x}_{s,h,p} = \frac{\sum n_{s,h,p}}{nt_{s,h,p}}$$

where $\overline{x}$ = is the mean density per transect of species *s* at habitat *h* and province *p, n* is the number of sea cucumbers, and *nt* is the number of transects. Density per transects were converted to area density by multiplying the density per transect by the area of each transect, measured in hectares (400 m^2, 0.04 ha).

The resulting density estimates were compared with those of previous studies conducted in Papua New Guinea, as compiled by Kinch (2008). The maximum recorded mean density from Kinch´s report was employed as a reference benchmark, representing the density values observed when exploitation rates were low.

The total population abundance was estimated by scaling up the area density values with the total coverage of each reef habitat in each province, calculated using reef habitat mapping provided by Government of PNG (2015). Abundance was estimated using all observations and only specimens with lengths smaller than the age-at-maturity to explore patterns of recruitment. Patterns in length distribution, density, and abundance were evaluated in relation to the fishery moratorium period. All statistical analyses were performed using the R statistical software (v4.3.1; R core team 2023).

5 RESULTS

5.1 Spatial abundance and distribution of species

While a comprehensive species distribution map covering the entirety of Papua New Guinea would have been beneficial to showcase the abundance and distribution of the key species in the study, this was not possible because the study focused on only three provinces known for their significant sea cucumber production. The graphs presented in this report illustrate the locations where species were observed and recorded during the survey, along with the corresponding number of individuals found. The primary objective was to assess the abundance and distribution within specific locations across the three provinces examined in this study.

The results indicate that nearly all four species out of the five were observed across the three provinces; however, Candy cane appeared to be less common in most instances and recorded only in the province of Manus. The White teatfish was the most prevalent among the five species, displaying widespread occurrence across the three provinces and nearly all reef habitats. Following closely are the Black teatfish and Prickly redfish which are almost like Amberfish, although their mean density across provinces remains relatively low. Of the five species under study, Candy cane stands out with the lowest density due to nil records in one province, while the other two provinces show presence in reef slopes with mean densities of 0.028 and 0.169, respectively. Consequently, this species was excluded from further analysis.

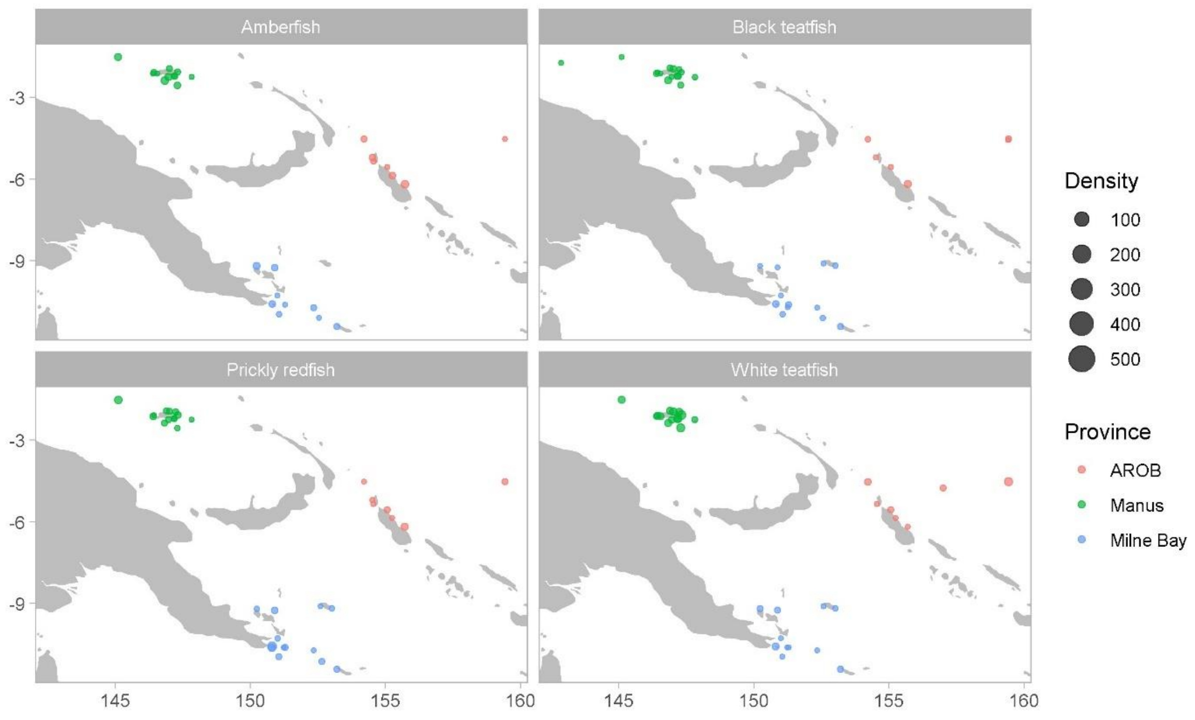

Figure 8. Distribution of the four species across the three provinces based on density per hectare. The size of the circle indicates the magnitude of the density, with larger circles representing higher densities.

As illustrated in Figure *8*, the density levels of the four species across the three provinces appeared relatively consistent, as reflected by the sizes of the circles. However, it is crucial to highlight the differences in species occurrence across various locations, as detailed in Figures 14, 15, and 16.

5.2 Stock density and abundance.

5.2.1 Stock density

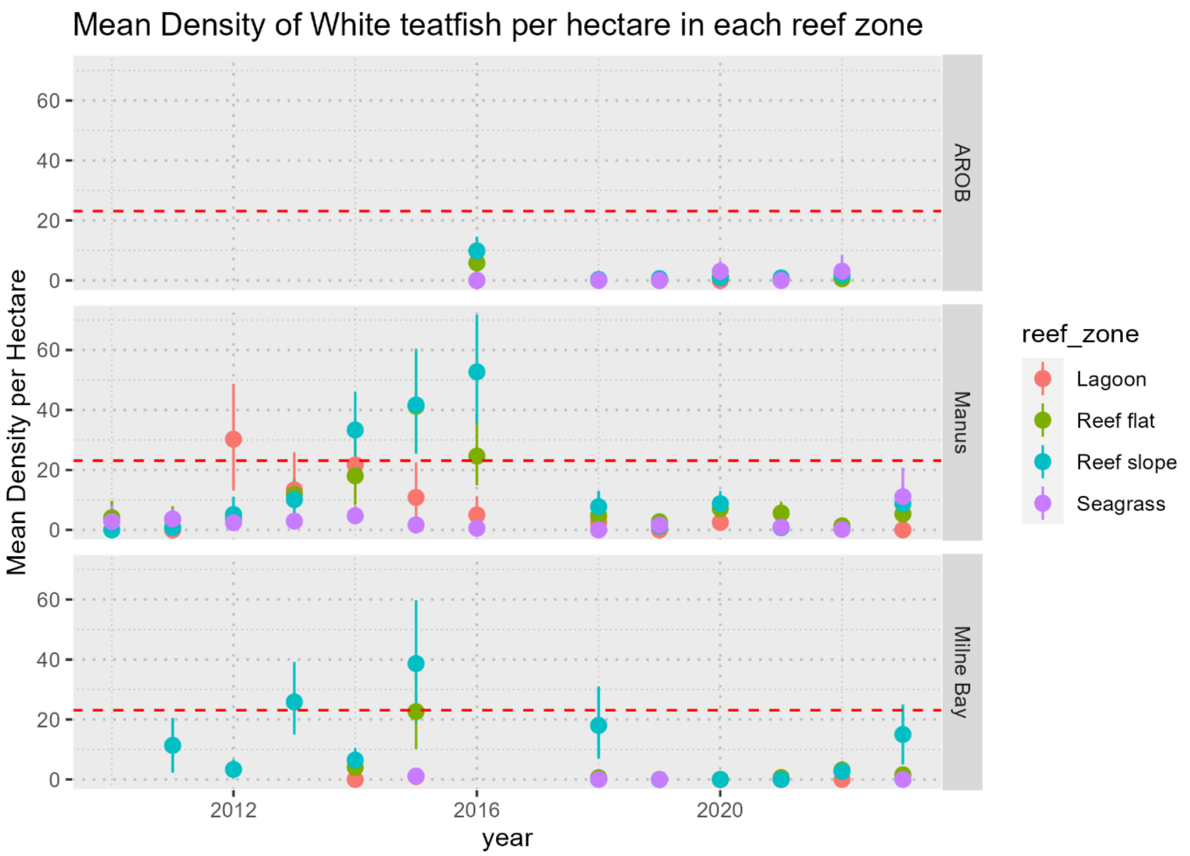

Figure 9. The mean density of White teatfish (Holothuria fuscogilva) across each reef zone. The red dotted lines indicate the reference value of 23 individuals per hectare.

The observed densities of White teatfish across the three provinces were at their lowest point in 2010. For instance, in Manus Province, the mean density was recorded at its lowest at 1.63 ± 0.82 ind ha^{-1}. The values were significantly lower than the reference benchmark mean density of 23 ind/ha (Kinch, 2008), which proves that White teatfish stocks were depleted prior to the moratorium. There was significant recovery in all habitats in the provinces of Manus and Milne Bay during the moratorium, attaining peak levels in 2016 before the opening of the fishery in 2017. The impact of the opening of the fishery is evident in the reduction of density estimates, which fell below the reference line from Kinch (2008). This suggests that management efforts were ineffective and overfishing occurred over the short period in which the fishery was opened.

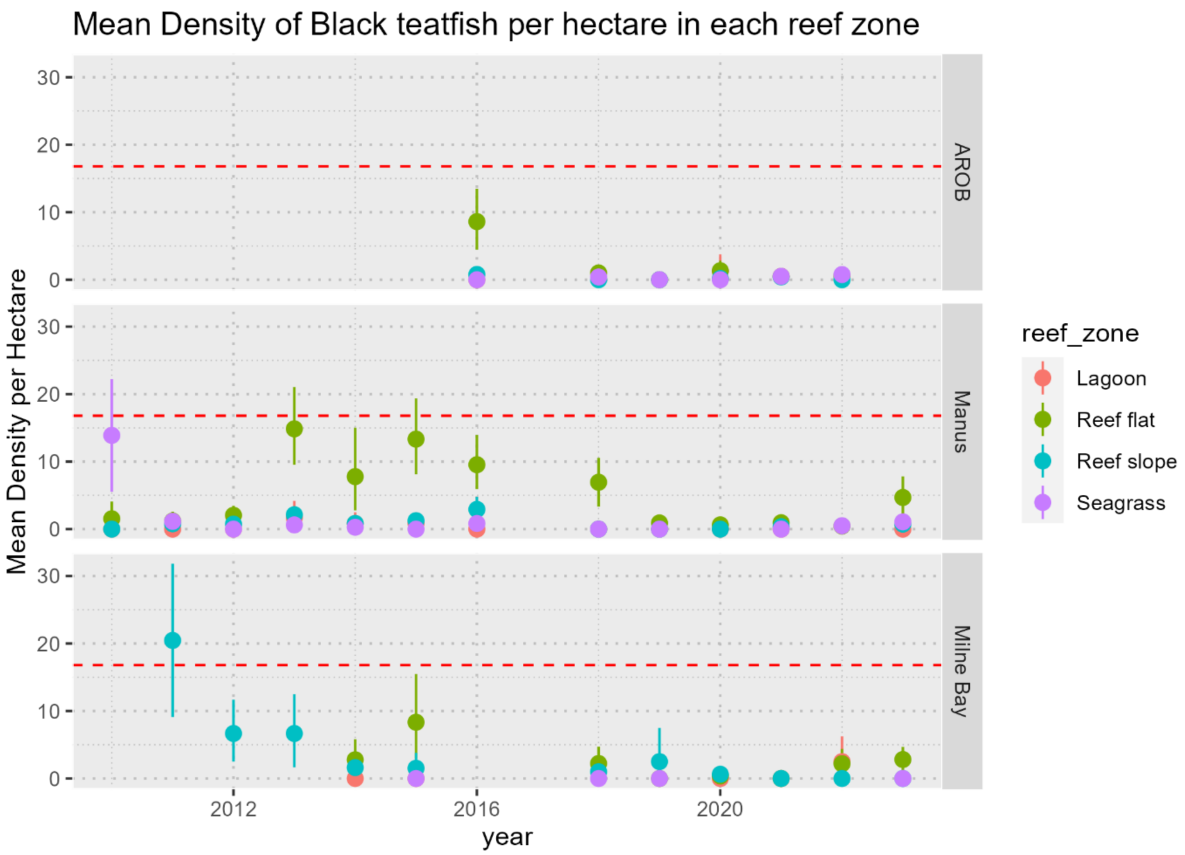

Figure 10. Average density of Black teatfish (Holothuria whitmaei) across various reef zones within each province. The red dotted lines indicate the reference value of 16.8 individuals per hectare.

The mean density per hectare of Black teatfish showed inconsistent trends, with most values falling below the benchmark reference from Kinch (2008). The graph indicates that reef flats are the primary habitat for Black teatfish. They were also found on reef slopes and lagoons. Across the three provinces, an average density of 13.3 individuals or below was observed in 2015 and 2016 data, with a significant decrease observed after the fishery opening in 2017. Similar to the White teatfish, management strategies were not effective, and overfishing has occurred. Although stock assessment surveys for the AROB commenced in 2010, the data utilised for analysis only began in 2016. This limited dataset accounts for the absence of a clear trend from the beginning.

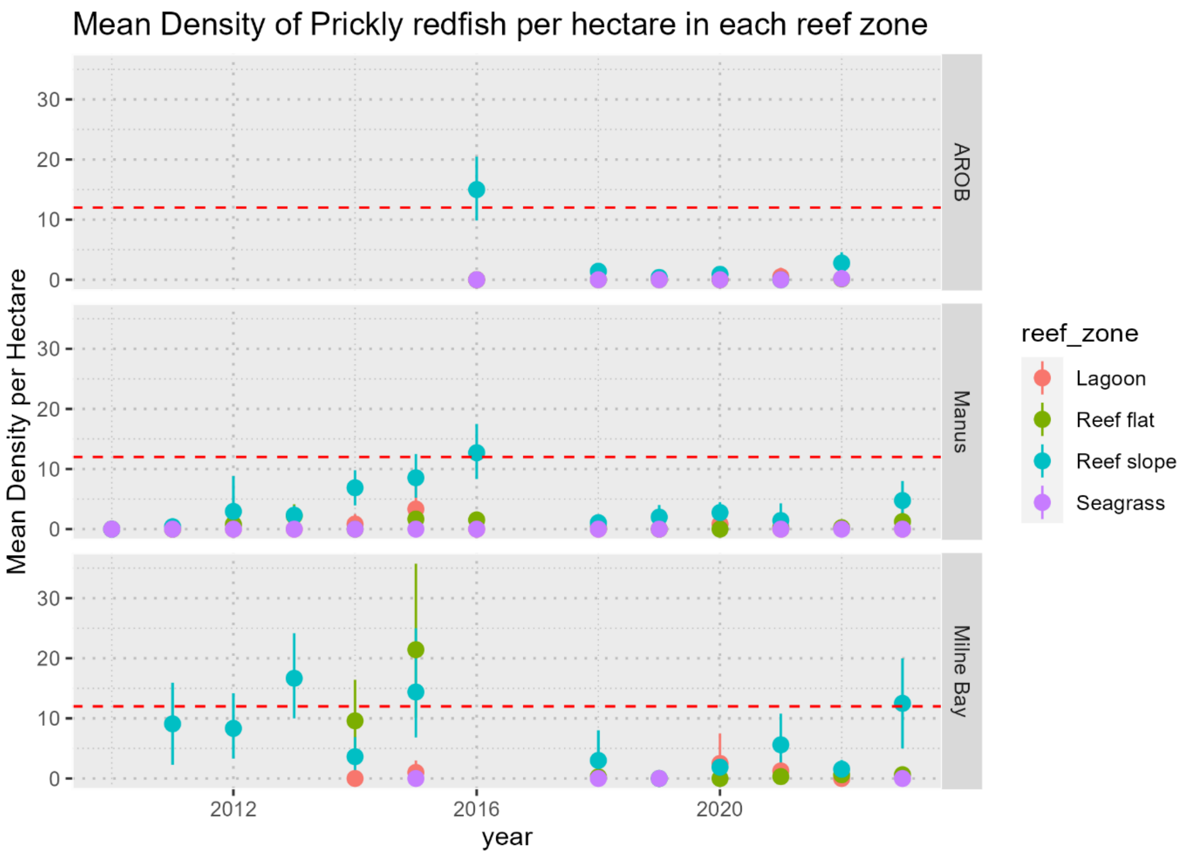

Figure 11. The mean density of Prickly redfish (Thelenota ananas) across different reef zones. The red dotted lines indicate the reference value of 12 individuals per hectare.

The observed densities of Prickly redfish were below the reference value of 12 individuals per hectare during the entire study period, except during 2015 and 2016, just before the fishery was reopened (Figure 11)Figure *11*. The mean density was highest in two reef zones: the reef slope and seagrass. This species is typically found along reef slopes and passages within reef areas, extending to depths ranging from 10 to 20 m (Kinch et al., 2008b).

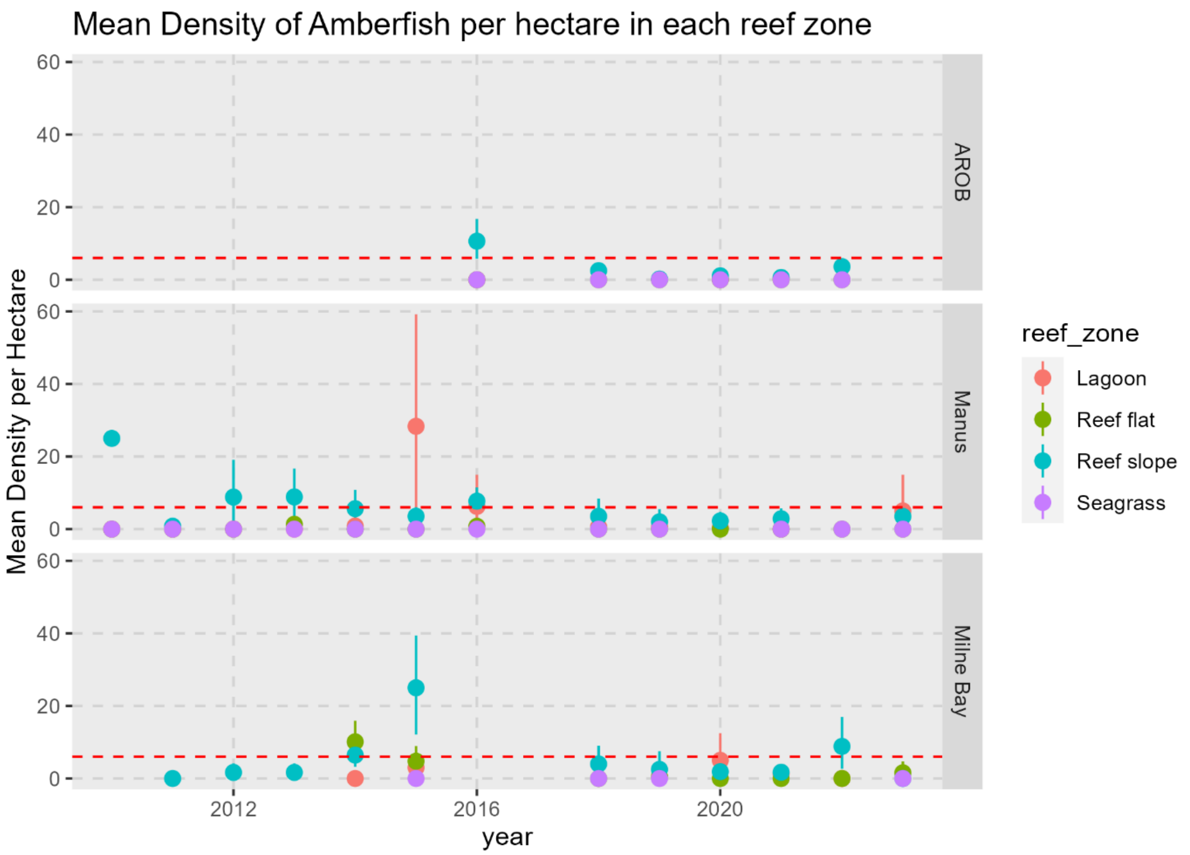

Figure 12. Mean density of Amberfish (Thelenota anax) in each reef zone per province. The red dotted lines indicate the reference value of six individuals per hectare.

The density of Amberfish was observed to be below the reference value of six ind/ha in most locations and years. In the Milne Bay province observed densities in 2014-2015 during the period when the fishery was closed. Notably, very high densities were observed in 2015 in the lagoon habitat of Manus Province. In general, they are distributed across various reef zones, particularly prominent on reef slopes and in seagrass areas. Although commonly found on reef slopes and in lagoonal passages (Pinca et al., 2009), this study suggests a higher prevalence in seagrass habitats.

5.2.2 *Stock abundance assessment*

A comprehensive analysis of the total population abundance estimate was conducted to discern the abundance of each species within various reef zones. The reef flat and reef zones exhibited notably higher abundance levels than the seagrass and lagoon habitats (Figure 13).

Figure 13. Total abundance of all four species in each reef zone. The scale is not equivalent across all plots; therefore, care should be taken when reading this figure.

Most of the undersized species appear to be confined to reef flats and seagrass habitats, particularly Black teatfish and White teatfish, which are most prevalent in the Manus and Milne Bay provinces. Milne Bay being the province with the highest reef areas present high abundance for all species across (Figure 14).

Figure 14. Total abundance estimates of undersized individuals in each reef zone for the three species. The scale is not equivalent across each plot; therefore, care should be taken when reading this figure.

5.3 Length frequency distribution assessment

The analysis revealed that the majority of the species studied have grown to a size that meets the legal requirements set forth by the National Fisheries Authority for sea cucumber management. Additionally, the sizes align with the length at which sea cucumbers reach maturity. The preceding graphs depict the size distribution of each sea cucumber species relative to both the NFA´s minimum legal size requirements and the size at which each species attains maturity, as reported by Skewes et al. (2014).

The length distribution graph for White teatfish, illustrated in Figure 15, reveals significant variability in the proportion of mature individuals reaching the size at maturity (32 cm), as reported by Skewes et al. (2014), compared to those meeting the minimum legal size requirement (35 cm) specified in the National Beche-de-mer Plan 2018 (NFA, 2018).

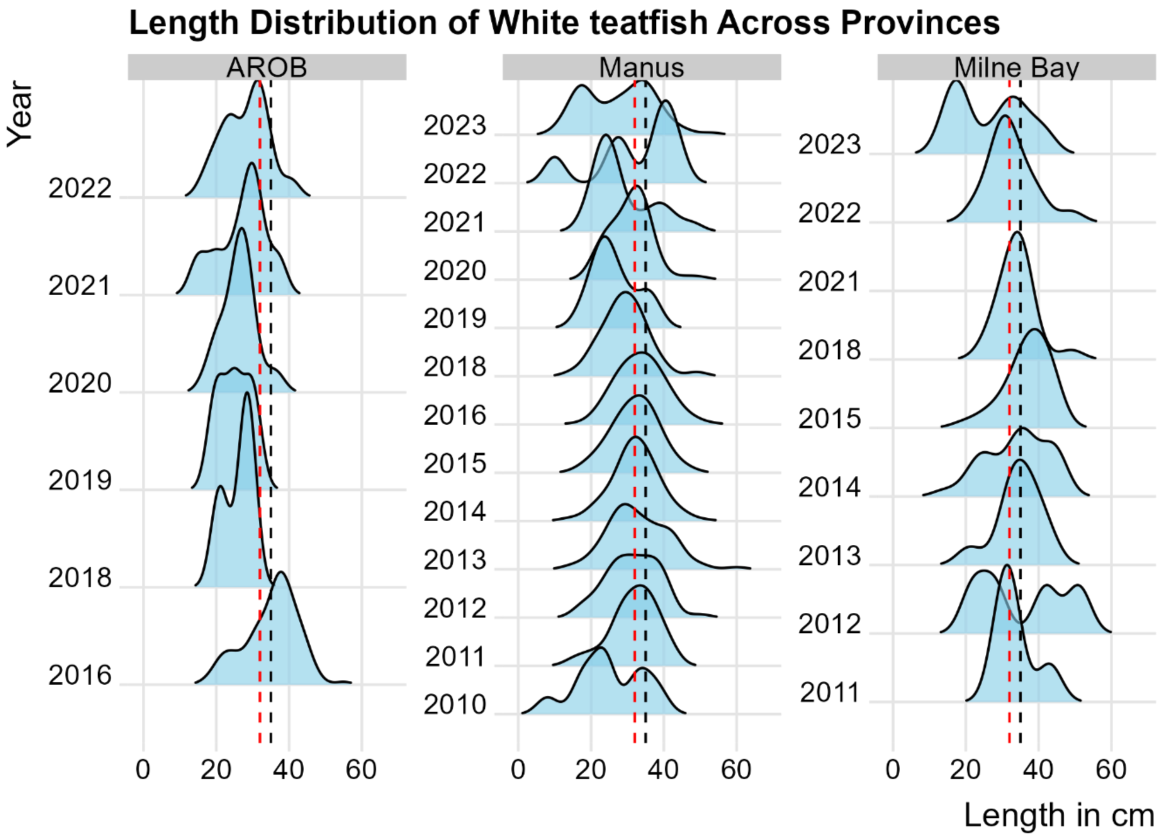

Figure 15. Live length distribution of White teatfish over time presented, with the minimum legal harvestable size of 35 cm marked by a black dotted line and size at the maturity stage of 32 cm highlighted by red dotted lines.

In the size-frequency distributions for 2015 and 2016 across the three provinces, 50–70 percent of the White teatfish were mature and met the legal-size criteria. Remarkably, within that period, the decision was made by the management of NFA to lift the moratorium, and the fishing season commenced in 2017. However, following the opening of the season in 2017, the length distribution shifted to the right, indicating a decrease in mature individuals and suggesting that adult populations were heavily harvested during the opening phase.

Unlike the White teatfish, the length distribution indicates that in most years, nearly 90 percent of the population has reached maturity and meets the minimum legal size limit set by the NFA (Figure 16)Figure *16*. However, there is a discrepancy: the size at maturity suggested by Skewes et al. (2014) is 26 cm, which is higher than the NFA´s minimum legal-size limit of 22 cm. This suggests that PNG harvested Black teatfish before they reached maturity and had the chance to spawn, hindering population replenishment.

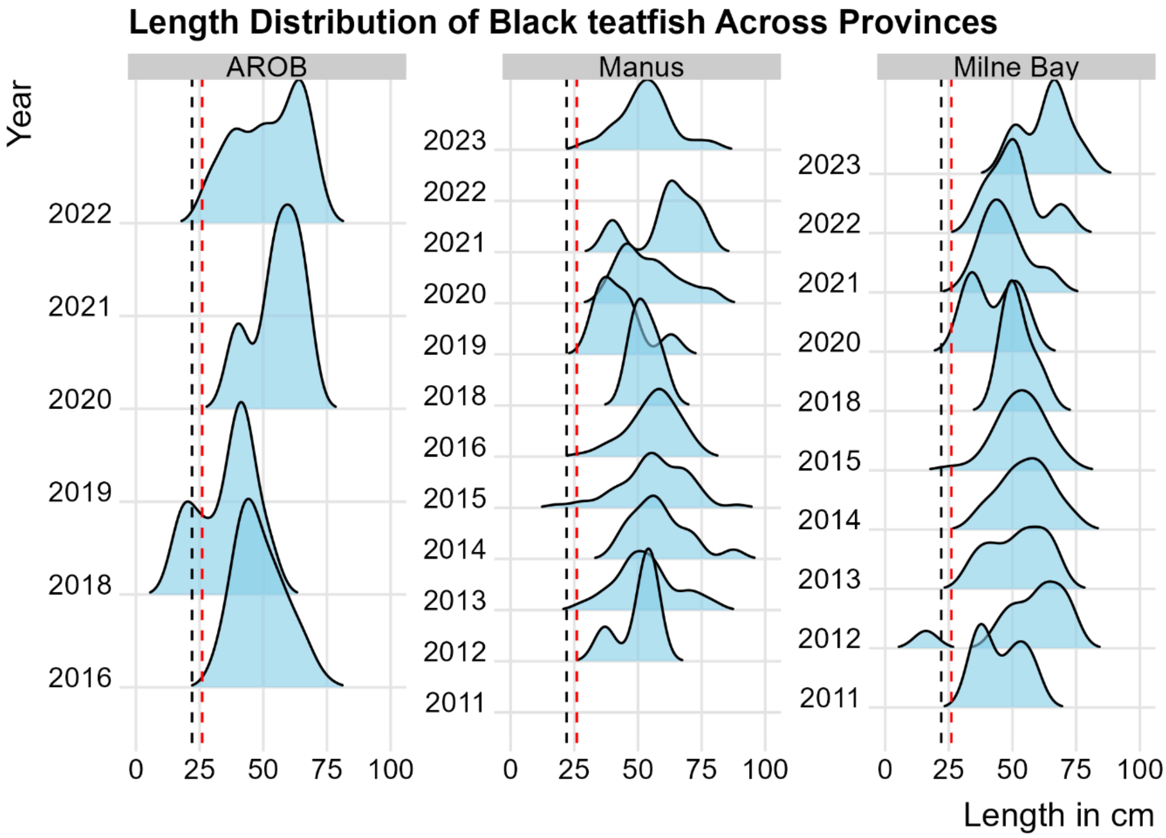

Figure 16. Live length distribution of Black teatfish over time with the minimum legal harvestable size of 22 cm marked by a black dotted line and size at the maturity stage of 26 cm highlighted by red dotted lines.

The size distribution graph for Prickly redfish in Figure 17 reveals that during the surveys, nearly 95 percent of the individuals reached maturity and exceeded the minimum legal size requirement.

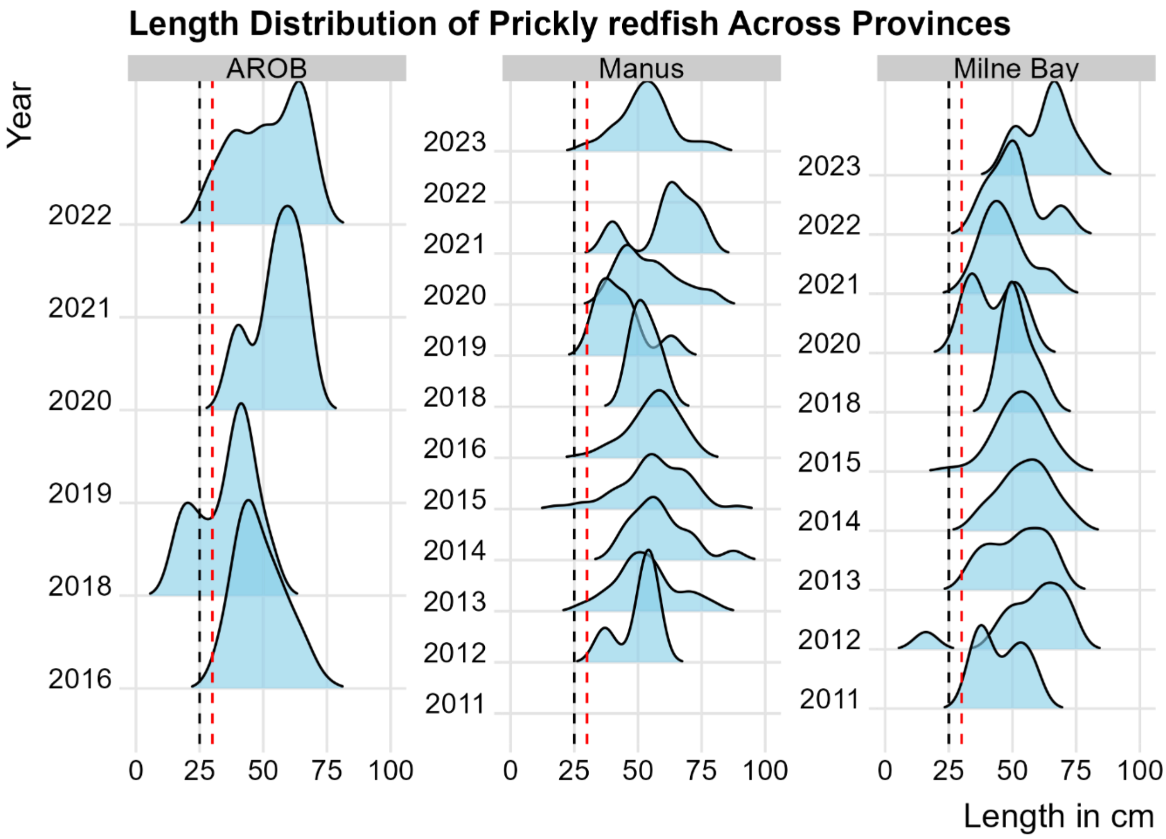

Figure 17. Live length distribution of Prickly redfish over time is presented, with the minimum legal size of 25 cm marked by black dotted line and size at maturity of 30 cm highlighted by red dotted lines.

However, similar to the length frequency results observed for Black teatfish (Figure 16)Figure *16*, the minimum legal size defined by the NFA is lower than the size at maturity recommended by Skewes et al. (2014). This discrepancy implies that the NFA´s harvestable size limit may lead to fishing of Prickly redfish before they mature and reproduce. Thus, this also warrants the minimum size limit to be set above the size at maturity.

The length distribution of Amberfish depicted in Figure 18 indicates that nearly 98 percent of the species surpass the minimum threshold size designated by the regulatory framework of the Beche-de-mer Management Plan (NFA, 2018). However, critical information, such as age or size at maturity and maximum size, is unknown (Conand et al., 2013a).

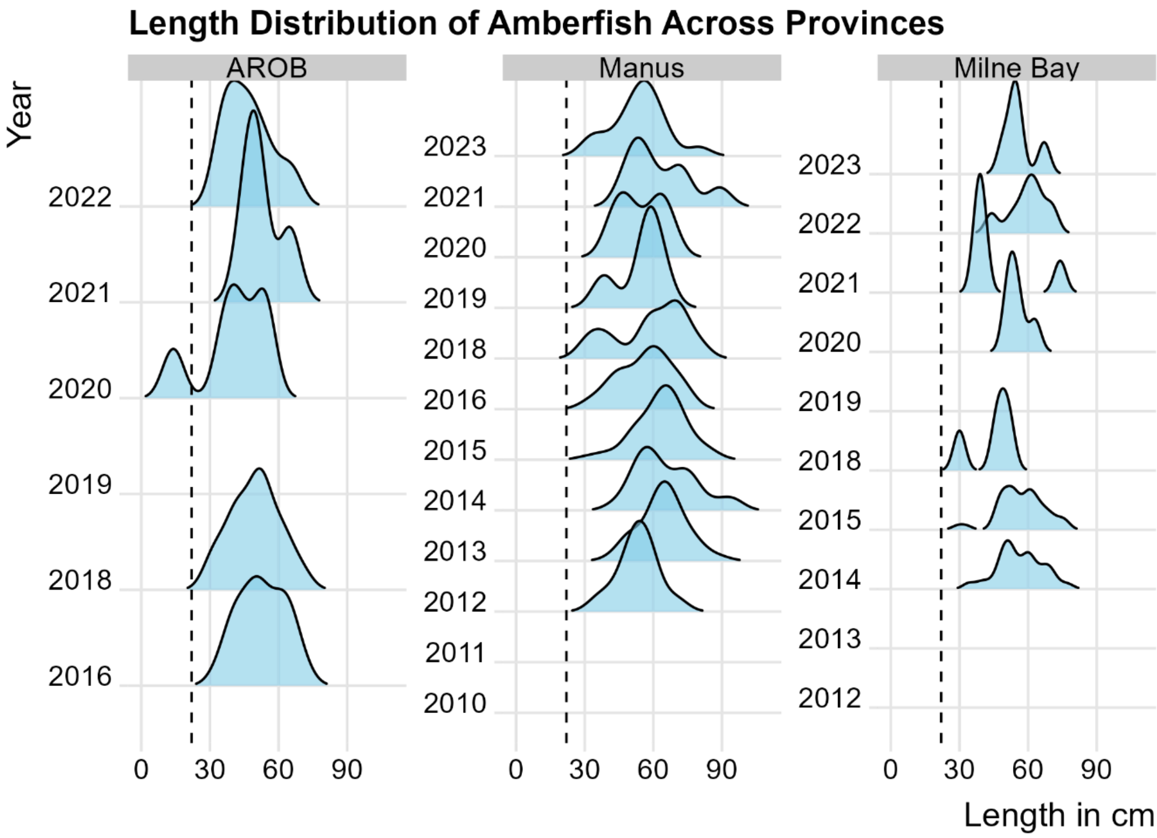

Figure 18. Live length distribution of Amberfish over time, with minimum legal harvestable size of 22 as per the Sea Cucumber Management Plan (NFA, 2018). Size at maturity is not available.

6 DISCUSSION

While using stock assessment data from 2016 as a benchmark for density and abundance might not be entirely reliable, it holds significance because of the significant changes that prompted the NFA management to reopen the fishery after a seven-and-a-half-year moratorium. Population density and biomass estimates are fundamental components for evaluating management strategies (Purcell, 2014). The stock assessment results presented in this study indicate a partial recovery in at least two species, the White teatfish and Prickly redfish*,* when compared with the reference values from Kinch (2008). However, the findings for Black teatfish showed fluctuations between survey periods compared to the two described. In contrast, Amberfish exhibited consistently low abundance densities throughout the moratorium period, with occasional peaks observed only in certain reef habitats in 2015.

The stock abundance and density of all four species, except Cany cane, exhibited consistent growth throughout this study. The AROB's trend is expected to follow this pattern, although its data start in 2016, showing an initial peak that declines after the moratorium was lifted. This pattern was also observed in the abundance of AROB, peaking in 2016, dropping during fishery opening, and then increasing again. Despite fluctuations, the recruitment and abundance of White teatfish have consistently increased. However, Black teatfish and Prickly redfish exhibited inconsistent recruitment levels without clear patterns, indicating variability in their abundance over time.

The 2002 stock assessment survey conducted by Skewes et al. (2002) revealed that most of the studied species were primarily located on reef edges or slopes, with Black teatfish predominantly found on reef tops (Skewes et al., 2002). Similarly, in this study, we observed that White teatfish, Prickly redfish, and Amberfish were mainly situated on reef slopes across all three provinces. However, Black teatfish were primarily distributed in reef flats and seagrass areas, with mean densities ranging from 8.6 individuals per hectare in one province to as high as 14.85 in another.

Tropical commercial sea cucumber species are often noted for their tendency to grow to significant sizes once they reach adulthood, which is an important parameter related to reproductive fitness when food is available (Conand, 2018). The findings from the size distribution analysis indicated that most of the species examined tended to be larger, with many reaching maturity and meeting the legal size requirements. This suggests that these species have attained sizes consistent with the regulations outlined by the NFA in the sea cucumber management plan (NFA, 2018). However, the study identified an inconsistency regarding two species: Black teatfish and Prickly redfish. Their size limits outlined in the management plan seem to be smaller than the size at which these species typically reach maturity (Skewes et al., 2014) and the minimum recommended live length proposed by Govan (2018). The results presented on the size structure display more size at maturity than juveniles which means more adult breeding populations.

The distribution of the studied species within the three provinces indicated clear signs of recruitment over the moratorium period. Ideally, it would be beneficial to observe a broader distribution of species across all of PNG by analysing data from other surveyed provinces.

6.1 Spatial distribution

The study's focus on three specific provinces known for substantial sea cucumber production made it unfeasible to create a comprehensive species distribution map covering all of Papua New Guinea (PNG). Instead, the illustration in the results depicts the observed species locations and the corresponding number of individuals found during the survey. The main goal was to evaluate the abundance and distribution within these selected locations across the three provinces under examination.

The conspicuous abundance of White teatfish in the Milne Bay province, documented in only nine locations, is intriguing, especially considering the province's substantial share of PNG's reef area (Skewes et al., 2002). Given that these species, including the White teatfish, are commonly found on reef slopes spanning depths of 10 to 50 meters, the efficacy of survey searches may influence the results, depending on the gear types and depth ranges utilised with access to isolated barrier reefs.

In addition, the Autonomous Region of Bougainville comprises 25 locations, yet only 12 of these locations documented the presence of White teatfish. The highest abundances were observed in the Carterets and Mortlock Islands.

6.2 Candy cane (*Thelenota rubralineata*)

Candy cane is reported to be widespread in the Central Indo-Pacific, including PNG, but are rare (Conand et al., 2013b). However, the results did not show any substantial range, despite its presence being noted in some provinces. The overall mean density was recorded at 0.1169 ind/ha, with seven individuals in Manus Province and 0.028 in/ha in AROB.

Candy cane are rare in French Polynesia (Andréfouët, et al., 2019). Historically, Candy cane has had limited trade activity because of their naturally sparse populations. However, it has gained commercial traction in the Indo-Pacific region, including Papua New Guinea and the Solomon Islands (Kinch et al., 2008b). Trade data for this species are scarce, with some countries not recording export figures at the species-specific level. The data analysed for this report indicate a paucity of information available for the species under examination, resulting in limited discussion regarding the Candy cane.

6.3 White teatfish (*Holothuria fuscogilva*)

White teatfish was included in Appendix II of CITES as of 2020 and faced regulatory measures coinciding with the commencement of PNG's fishery opening in the same year. These measures include the implementation of a Non-Detrimental Finding, which established a harvest limit of 16 tonnes for the White teatfish across PNG based on the 2020 stock assessment survey (NFA, 2020). Notably, the White teatfish commands the highest market value among sea cucumbers in PNG (Barclay et al., 2019).

The White teatfish population experienced its lowest density across the three provinces during the 2010 stock assessment survey, which was conducted during the moratorium period. The results analysed by province showed that the mean density plummeted to its lowest point, reaching 1.63 ±0.82 individuals per hectare in Manus. Similarly, other provinces, such as Milne

Bay, exhibited a low density of 0.847 ± 0.134 individuals per hectare during the moratorium phase. However, a discernible uptrend in the mean densities was observed throughout the analysis, indicating a positive correlation between time and density increase. The increase was notable in 2015 and 2016, surpassing the reference benchmark set by Kinch (2008).

The density abundance of White teatfish predominantly inhabits reef slopes (Purcell & Tekanene, 2006). Figure 8 illustrates that areas with higher mean densities are typically associated with reef slopes. The Findings from Murphy et al. (2021) indicate that White teatfish density per hectare on reef slope areas varies, ranging from 0 to 2.28, with some locations reaching up to 6.9, and the highest recorded density being 17.7 individuals per hectare. However, it is important to note that the results of this study represent the mean density per hectare across all sites, rather than specific locations. For instance, in Milne Bay Province, the mean density was 45.3 ind/ha, while Manus had a mean density as high as 53.4 ind/ha in 2015 and 2016. It is crucial to understand that these figures reflect the overall mean density across the entire reef slope area in these provinces, compared to the Torres Strait study conducted by Murphy et al. (2021).

The most interesting observation in the study regarding the mean density result presented in Figure 9 is that the mean density of White teatfish recovered from depletion surpassed the reference density of 23 ind/ha (Kinch et al., 2008b) in 2016. Additionally, it exceeded the population density limit of 40 individuals per hectare, as cited in the proposal paper published by CITES to list the two teatfish species (CITES, 2019). However, the trend shifted during the opening period of 2017, with the mean density nearly reverting to the levels observed in the 2010 stock assessment. Subsequently, there has been a gradual recovery in density owing to the moratoriums implemented in 2019 and 2021.

6.3.1 Length distribution of White teatfish

Skewes et al. (2014) emphasised the importance of growth and age parameters as initial estimates for sea cucumber species used in population models. They specifically identified the size at maturity for the White teatfish to be 32 cm (Skewes et al., 2014). Subsequently, the National Fisheries Authority of PNG set the live legal size limit at 35 cm (NFA, 2018). Additionally, the Melanesian Spearhead Group (MSG) collaborated to establish a standard legal size limit of 35 cm (Govan, 2018).

In this study, an equivalent proportion of *white teatfish* individuals fell under two categories: those deemed undersized and those considered harvestable size, reflecting whether they were below or above the legally designated size limit (Figure 15)Figure *15*.This distribution curve of lengths conveys a key perception of recruitment and subsequent growth within the population, notably during the moratorium period.

6.4 Black teatfish (*Holothuria whitmaei*)

In 2020, the Black teatfish was also listed under Appendix II of CITES. As PNG is a party to the agreement, the inclusion initiated regulatory actions, including the establishment of an NDF for both White and Black teatfish in preparation for the 2020 fishing season. The NDF set specific harvest limits for Black teatfish across PNG, with a total of 4 tonnes. However, based on stock assessment data from a 2020 survey, only four provinces qualified, including Milne

Bay and Manus provinces, receiving 1 tonne each. This regulatory measure was aimed at ensuring the sustainable harvest of the Black teatfish (NFA, 2020).

6.4.1 Density abundance for Black teatfish

Black teatfish are most commonly observed in reef flats, although they are rarely found on reef slopes and intertidal crests (Conand, 2008). The mean density per hectare of Black teatfish exhibited variability over the duration of the seven-year moratorium, as shown in Figure 10. In this study, only one province exhibited a strong association with reef flats, although there was a notable peak (14.2 ind./ha) in 2010 recorded in seagrass habitats. Equally, Milne Bay province showed most of the Black teatfish on the reef slope and observed a peak in 2011 (21.3 ind./ha) on the reef slope. The initial mean density peaking in 2010 and 2011 observed in Figure 10 may be due to oversight in survey methodologies or the possibility of errors and requires further investigation. The mean density also fell below the reference benchmark density of 16 individuals per hectare from Kinch (2008) used in this study, indicating that the recovery of Black teatfish was not as strong as that of White teatfish. In most cases, the highest mean density observed in the study was 13.88 individuals per hectare in 2013 and 13.3 individuals per hectare in 2014, all falling short of the density benchmark.

6.4.2 Length distribution of Black teatfish

Female Black teatfish mature at approximately four years of age at a length of 26 cm and attain a maximum size of 56 cm (Skewes et al., 2014). The minimum legal length set by the Queensland Department of Primary Industries and Fisheries (QDPIF) is 30 cm (Murphy et al., 2021), while the Melanesian Spearhead Group (MSG) proposes a minimum legal size of 30 cm (Govan, 2018). The length distribution analysis in Figure 10 shows that most of the Black teatfish species are above both the legal length of 22 cm set by the PNG National Fisheries Authority Sea cucumber management plan (NFA, 2018) and the size at maturity recommended by Skewes et al. (2014).

Although sea cucumber species typically exhibit contraction in size, a notable concern arises with the legal-size limit set for PNG at 22 cm, which is below the size at maturity estimated by Skewes et al. (2014). The legal threshold falls below the size at maturity for these species, indicating a considerable mismatch between the legal size requirement and the size at which these species reach reproductive maturity.

6.5 Prickly redfish (*Thelenota ananas*)

Prickly redfish is one of the three *Thelenota* species recently included in the CITES COP19 meeting in 2022. PNG has not yet developed an NDF for this species and other Thelenota species, primarily because the fishery has remained closed since the 2020 season. Prickly redfish is considered more common than the other two *Thelenota* species and is probably one of the largest sea cucumber species, often surpassing 5 kg in live weight (Pinca et al., 2009) (Purcell et al., 2012). This species is a high-value sea cucumber species harvested in PNG and is commercially important (Kinch et al., 2008b).

6.5.1 Density Abundance for Prickly redfish

Prickly redfish predominantly inhabit reef slopes, reef channels, or passages, preferring rubble and hard bottoms covered with layers of coral and sand at depths between 10-20 m (Conand et al., 2013a) (Kinch et al., 2008b). The stock assessment survey conducted in 2002 recorded Prickly redfish in nine areas, with the highest mean density recorded at 2.88 ind./ha (Skewes et al., 2002). The stock assessment survey in the province of New Ireland recorded 2.4 ind/ha on reef slopes, 0.3 ind/ha on reef flats, and 0.2 ind/ha in lagoons (Kaly et al., 2007).

The highest recorded density of Prickly redfish by Kinch (2008) was 12 individuals per hectare, serving as the reference benchmark for this study. However, the observed results indicate that almost all densities fell below this benchmark in 2010, until a slight surge in 2016. Notably, the mean density appeared to be highest in the two reef zones: the reef slope and seagrass, as illustrated in Figure 10. Prickly redfish are typically found along reef slopes and passages within reef areas at depths ranging from 10 to 20 meters (Kinch et al., 2008b). In this study, the Prickly redfish was found to be most prominent on reef slopes. Although the study by Skewes et al. (2002) in Milne Bay was conducted based on Local Level Government (LLG) areas, the results presented in Figure 11 represent the overall mean density abundance for the three provinces. Interestingly, the mean density in each reef habitat observed in this study was higher than that reported in previous studies. For instance, Murphy et al. (2021) recorded a density of 16.4 individuals per hectare (ind/ha) on reef slopes, with the highest density (55.2 ind/ha) observed on barrier reefs (Murphy et al., 2021).

In comparison with this study, the mean density abundance for the 2016 survey on the reef slope was 9.86 ind/ha in AROB, 53.2 ind/ha in Manus, and 44.2 ind/ha in the Milne Bay. This variation can be attributed to the effect of the moratorium, which has likely influenced the population changes in Prickly redfish across the surveyed provinces.

As observed from the analysis of the White teatfish and Black teatfish, the Prickly redfish also exhibited a low density after the fishing season opening, indicating a depletion of stocks within just three years of the fishery opening. The data from 2023 show a surge after the further moratorium, which is a positive sign of recovery. However, there are evident gaps in management that need to be addressed to ensure the sustainability of the species population.

6.5.2 Length Distribution for prickly redfish

Prickly redfish typically reach a maximum length of 80 cm and an average length of approximately 45 cm. In Papua New Guinea, the average fresh length ranges from 45 to 80 cm, with an average fresh weight of approximately 2.6 kg (Purcell et al. 2012). Skewes et al. (2014) established growth parameters for the Prickly redfish, setting the minimum legal size at 50 cm under the QDPIF regulations. They indicated the size at maturity as 30 cm, with individuals reaching a maximum size of 80 cm (Skewes et al., 2014).

Further evaluation of sea cucumber fisheries across the Melanesian Spearhead Group advocated for standardising sea cucumber size regulations among all MSG countries. In particular, the Prickly redfish was suggested to have a length limit of 45 cm. While Papua New Guinea's National Sea Cucumber plan enforces a legal limit of 22 cm, other MSG members, such as the Solomon Islands and Vanuatu, have set theirs at 35 cm (Govan, 2018) (NFA, 2018).

In this study, the majority of the species observed across all three provinces displayed a trend similar to that of the Black teatfish, with most individuals reaching both the legal size and the size at maturity length. However, it is important to note that the size limit enforced by the NFA is 22 cm, which is significantly lower than the recommended size. Furthermore, the size at maturity, set at 30 cm, exceeds the legal size limit, highlighting a notable discrepancy between regulatory standards and the species' biological requirements. Therefore, changes to the plan to suit the biological parameters are necessary.

6.6 Amberfish (Thelenota anax)

Amberfish is another of the three species of the genus *Thelenota* listed under CITES. This species is reported to be one of the heaviest sea cucumbers with an average live weight recorded in PNG to be 3.34 kg (Purcell et al., 2012) (Hammond et al., 2020). Amberfish is recorded to be of low value (Kinch, 2008) and previously considered to be non-commercial, but has increasingly become an important commercial species after other high valued species have been depleted (Conand et al., 2013c)

6.6.1 Density abundance of Amberfish

Amberfish are commonly found on reef slopes and outer lagoons near passages at depths between 10 and 30 m (Conand et al., 2013c). In the New Ireland Province of PNG, the density of this species decreased from 1 to 0.7 individuals per hectare from 1992 to 2006 (Kaly et al., 2007). The highest density recorded in the Milne Bay province was 3,71 ind./ha and 3.13 ind./ha in two LLGS (Skewes et al., 2002).

In this study, Figure 12 illustrates a significant decline in Amberfish density, particularly in 2011, notably in the Milne Bay Province. Conversely, Manus Province recorded a density of 2.1 ind./ha in seagrass areas in 2010. Manus also experienced a peak in the lagoon area in 2015, with a mean density of 28.3 ind/ha, followed by a decrease to 6.25 ind/ha in the same reef habitat in 2016. However, the overall density abundance of Amberfish remains below the reference benchmark, indicating that the species has not fully recovered. This is further supported by the absence of any discernible trend in the recruitment abundance of this species, leading to its exclusion from the recruitment analysis.

To further clarify the reasons behind the notable increase observed in 2015 in Manus Province, followed by a decline in 2016, the discrepancy can be traced back to habitat identification, particularly in one specific location. This also highlights the importance of harmonising data records during surveys.

6.6.2 Length distribution analysis of Amberfish

The length distribution of Amberfish indicates that nearly 98 percent of the species surpass the minimum threshold size designated by the regulatory framework of the Beche-de-mer Management Plan (NFA, 2018). However, critical information, such as age or size at maturity and maximum size, remains largely unknown (Conand et al., 2013a). Care must be taken when applying management strategies for the trade utilisation of this species.

7 CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Population density and biomass estimates are fundamental to evaluating management strategies for sea cucumber populations. These metrics, ideally calibrated against historical data, provide significant insights into the effectiveness of management efforts (Purcell, 2014). In this study, Kinch (2008) served as a reference benchmark for density estimates. By comparing current population densities with historical data, changes over time can be assessed, and trends that inform management decisions can be identified.

The stock assessment results presented in this study highlight a partial recovery in two sea cucumber species, White teatfish and Prickly redfish, when compared with the reference provided by Kinch (2008). This indicates positive trends in recruitment and abundance of these species. However, the assessment also revealed fluctuations in the population of Black teatfish and inconsistent abundance patterns for Amberfish during the moratorium period.

Overall, the stock abundance and density of most species showed consistent growth trends, with clear signs of recruitment over the moratorium period (2010-2016). However, the impacts of fishing seasons (2017-18, 2020) on recruitment aspects were evident, stressing the importance of management measures, such as moratoriums, in sustaining sea cucumber populations.

The analysis of size distribution suggests that many individuals reached maturity, consistent with the regulations outlined by the NFA sea cucumber management plan (NFA, 2018), while highlighting discrepancies in the legal size requirements for Black teatfish and Prickly redfish. Recommendations for improving management capacity include revising size limits to align with size at maturity, enforcing minimum size limits, and establishing harvest control rules based on catch and effort triggers. Additionally, there is a need for separate stock assessment studies targeting the five species in areas of habitat preference.

7.2 Recommendations

7.2.1 Density Threshold

As observed in this study, most species reached above the density threshold from Kinch (2008) in 2015 and 2016. These years have become focal points for the study because of the clear trend in species density surpassing previously known thresholds which indicates significant population growth or recovery for most species under consideration. However, Black teatfish presented a contrasting narrative, as it did not reach the density threshold and followed a similar trend to other species under study. It is worth noting that this study only evaluated three of the 14 maritime provinces; a broader examination, including assessments from other provinces, may yield a different understanding of the mean density of Black teatfish.

Considering the aforementioned factors, it is prudent to recommend that the 2016 stock assessment data be employed as a reference point for future studies, management decisions, and policy formulation.

An example of utilising the 2016 data will be stock density indicators and reference points to measure the performance of management and harvest strategies. 2016 data as the target reference point and set the 2010 density as the limit reference point (*Figure 19*).

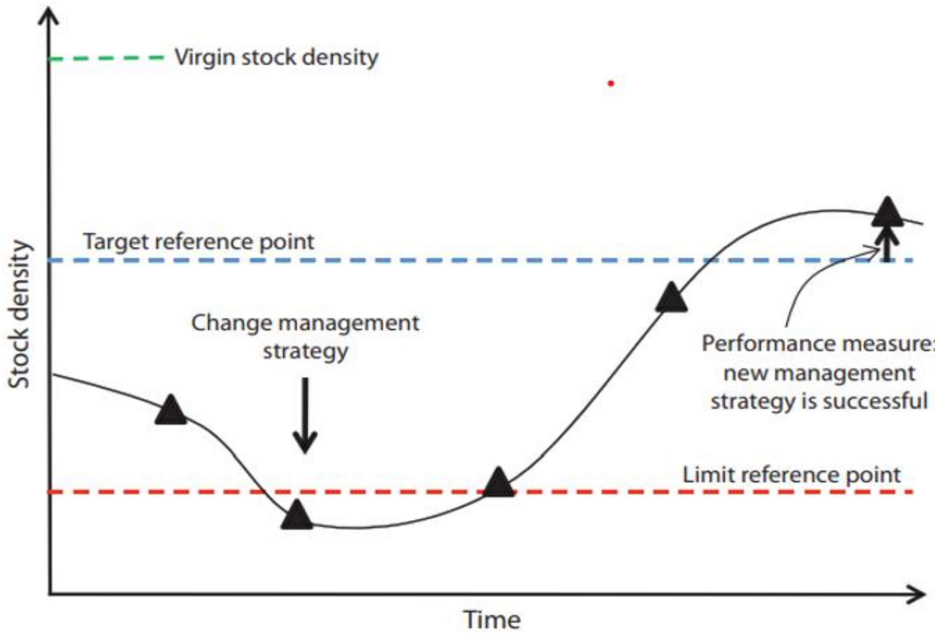

Figure 19. Stock density indicators and reference points: target reference point 2016 data and limit reference point 2010 data (adapted from Pinca et al. (2009).

7.2.2 Setting Size limits

The minimum legal size was established under the PNG Sea Cucumber Fishery Management Plan. In the study, two species, Black teatfish and Prickly redfish were found to have minimum legal-size limit established under the PNG Sea Cucumber Fishery Management Plan, set below the size at which they typically reach maturity, as reported by Skewes (2014). It is recommended the minimum legal size of these two species be reviewed and adjusted to ensure it aligns appropriately with the size at which maturity is reached, thus fostering a sustainable management of their populations.

7.2.3 Candy cane (Thelenota rubralineata)

Candy cane warrants a decisive prohibition from the sea cucumber fishery, primarily because of its rarity, as indicated by the analysis provided in this report. Numerous studies have consistently highlighted its scarcity in terms of density and abundance. Hence, it is imperative to implement stringent measures to safeguard this species from further depletion.

7.2.4 Catch Quotas

TAC monitoring has been standard practice in PNG since the inception of the initial management plan. However, its implementation has been somewhat sporadic, with limited trials conducted for species such as Black teatfish and White teatfish during the 2020 season. Moving forward, it is strongly advised that TACs be allocated separately and subjected to precise monitoring, especially for CITES-listed species. This approach ensures more targeted and effective regulation of fishing activities, thereby promoting the sustainable management of its populations.

7.2.5 Conduct targeted Stock Assessments

Conduct a separate, well-defined stock assessment study targeting the five species that are well represented throughout the country. This will provide more comprehensive data for developing effective management strategies.

7.2.6 Improve Data Harmonization

Ensure uniformity in habitat identification and data collection procedures during surveys to reduce inconsistencies in findings. Additionally, standardised and efficient assessment sampling protocols should be established to accurately estimate population abundance.

7.2.7 Conduct research on breeding seasonality.

Conduct research on the growth rates and breeding times of each sea cucumber species to ascertain breeding seasonality. This is important because the breeding season does not coincide with the fishery open season.

7.2.8 Enhance Monitoring and Enforcement

Strengthen monitoring and enforcement efforts to deter illegal fishing activities and ensure compliance with size limits and regulations.

7.2.9 Further analysis of data from Other Provinces within PNG

Further analysis of the data from other provinces in PNG is essential to accurately assess the distribution and abundance of the five sea cucumber species. This can be used to inform an effective management strategy in terms of allocating TACs by species and province.

The analysis conducted in this study sheds light on significant gaps in the management of sea cucumber fisheries in Papua New Guinea. Disparities in density between fishing opening periods and moratoriums highlight the need for improved management strategies to ensure sea cucumber population sustainability. Addressing these gaps is crucial for the long-term health of PNG’s marine ecosystems and the livelihoods of communities that rely on sea cucumber fisheries.

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