SEYCHELLES FISHERIES AUTHORITY

Seychelles sea cucumber survey

Final report

Seychelles Fisheries Authority

Fisheries Research Department

2025

Citation

Seychelles Fisheries Authtority (2025) Seychelles sea cucumber survey. Final Report

Acknowledgments:

The successful completion of the 2025 sea cucumber survey was made possible through the dedicated support and collaboration of many partners. Sincere appreciation is extended to the crew of the R/V *L'Amitié* for their dedicated support throughout the fieldwork and at sea operations during the 2025 sea cucumber survey. Gratitude is also given to the Fisheries Research Section for their assistance with fieldwork and data analysis, and to the Institut de recherche pour le développement (IRD) local representatives for their support with fieldwork. Special thanks are due to the sea cucumber vessel *MV Galate* and its crew for their collaboration and assistance. The collective efforts and cooperation of all involved were instrumental in ensuring the successful completion of the 2025 sea cucumber survey.

Contents

1 Background 8
1.1 Management 9
1.2 Stock assessments 11
1.3 Project objectives 12
2 Methods 14
2.1 Sample design 14
2.2 Survey timing and duration 18
2.3 Constraints and issues 17
2.4 Cruise logistics and path analysis 17
2.5 Field sampling 17
2.6 Data entry and storage files 17
2.7 Data analyses 18
3 Survey report 20
3.1 Data Validation 21
4 Results 23
4.1 White teatfish (*Holothuria fuscogilva*) 23
4.2 Pentard/Flower teatfish (*Holothuria spp.* (type "Pentard")) 30
4.3 Prickly redfish (*Thelenota ananas*) 34
4.4 Black teatfish (*Holothuria nobilis*) 39
4.5 Golden sandfish (*Holothuria lessoni*) 44
4.6 Other species 48
5 Discussion 52
5.1 Recommendations: 54
References 58
Appendix A Timing issues 60
Appendix B Depth Analysis 61
Appendix C Bathymetry plots 68
Appendix D Survey sites 70
Appendix E Provisional Cruise Schedule 74
Appendix F Provisional cruise ship paths 75
Appendix G Species survey codes 77

Appendix H Cruise plan 80
Appendix I Stratified ananlysis approach 93

Figures

Figure 1. Catch data for the period 2001-2024 7

Figure 2. Sites planned to be surveyed for the 2025 survey, by transect type. 15

Figure 3. Sites sampled in 2025 survey, by transect type. 20

Figure 4. Overall (left) and stratum (right) average (stratified) density (No. per Ha) for White teatfish (*H. fuscogilva*) at repeated sites in 2004 2021 and 2025 (error bars = 1 s.e.) (n=117). 23

Figure 5. Stock estimate (in numbers of individuals) for White teatfish (*H. fuscogilva*) for the entire fishery (left) and for each stratum (right), for each year surveyed (error bars are 60% CI). 24

Figure 6. Comparison of 2004 , 2021 and 2025 fishery population estimates of White teatfish with that of 2011 (Koike, 2017) (error bars are 1 s.e.) *2011 survey utilises a different survey dataset and fishery area. 25

Figure 7. CPUE (number caught per minute dived) of white teatfish for 2004 to 2021 season from available fishery logbook data. 26

Figure 8. Combined trends in population estimates (blue bars) and catch-per-unit-effort (CPUE; red diamonds) for White teatfish (*H. fuscogilva*) on the Mahé Plateau from 2004 to 2025. 26

Figure 9. Overall (right) and stratum (left) average (stratified) density (No. per Ha) for Pentard/Flower teatfish (*H. spp.* (type "Pentard")) at repeated sites in 2004,2021 and 2025 (error bars = 1 s.e.) (n=117). 29

Figure 10. Stock estimate (in numbers of individuals) for Pentard/Flower teatfish (*H. spp.* (type 'Pentard")) for the entire fishery (left) and for each strata (right), for each year surveyed (error bars are 60% CI). 30

Figure 11. CPUE (number per minutes dived) of Pentard/Flower teatfish for 2004 to 2023 from available fishery logbook data. 31

Figure 12. Combined trends in population estimates (blue bars) and catch-per-unit-effort (CPUE; red diamonds) for Pentard/Flower teatfish on the Mahé Plateau from 2004 to 2025 32

Figure 13. Overall (right) and stratum (left) average (stratified) density (No. per Ha) for Prickly redfish (*T. ananas*) at repeated sites in 2004, 2021 and 2025 (n=117) (error bars = 1 s.e.). 33

Figure 14. Stock estimate (in numbers of individuals) for Prickly redfish (*T. ananas*) for the entire fishery (left) and for each stratum (right), for each year surveyed (error bars are 60% CI). 34

Figure 15. Comparison of 2004, 2021 and 2025 population estimates or Prickly redfish with that of 2011 (Koike, 2017) *2011 survey refers to a different survey dataset and fishery area. 35

Figure 16. CPUE (number per minutes dived) of Prickly redfish for 2004 to 2023 season from available fishery logbook data. 36

Figure 17. Combined trends in population estimates (blue bars) and catch-per-unit-effort (CPUE; red diamonds) for Prickly redfish on the Mahé Plateau from 2004 to 2025 36

Figure 18. Overall (right) and stratum (left) average (stratified) density (No. per Ha) for Black teatfish (*H. nobilis*) at repeated sites in 2004, 2021 and 2025 (n=117) (error bars = 1 s.e.)…..... 38

Figure 19. Stock estimate (in numbers of individuals) for Black teatfish (*H. nobilis*) for the entire fishery (left) and for each strata (right), for each year surveyed (error bars are 60% CI). 39

Figure 20. Comparison of 2004, 2021 and 025 population estimates or Black teatfish with that of 2011 (Koike, 2017) *2011 survey refers to a different survey dataset and fishery area. 40

Figure 21. CPUE (number per minutes dived) of Black teatfish for 2004 to 2019 season from available fishery logbook data. 41

Figure 22. Combined trends in population estimates (blue bars) and catch-per-unit-effort (CPUE; red diamonds) for Black teatfish on the Mahé Plateau from 2004 to 2024. 41

Figure 23. Comparison of a stock reduction model for Black teatfish for statistical area 4 based on logbook data to 2017, and projections of stock recovery under 3 scenarios for future catches (green line represents catch reduction (MRAG, 2017); with the results of the 2004 and 2021 survey for the entire study area (axis different scales). 42

Figure 24. Overall (right) and stratum (left) average (stratified) density (No. per Ha) for Golden Sandfish (*H.lessoni*) at repeated sites in 2004, 2021 and 2025 (n=117) (error bars = 1 s.e.)..... 43

Figure 25. Stock estimate (in numbers of individuals) for Golden sandfish (*H.lessoni*) for the entire fishery (left) and for each strata (right), for each year surveyed (error bars are 60% CI). 44

Figure 26 CPUE (number per minute dived). Values before 2021 represent mixed Sandfish species, while from 2021 onward they represent only Golden Sandfish (*H. lessoni*) .....45.....

Figure 27 Overall average (stratified) density (No. per Ha) for non-priority species at repeated sites in 2004,2021 and 2025 (n=117) (error bars = 1 s.e.).. 48

Figure 28. Stock estimates (in numbers of individuals) for all species for the entire fishery. 49

Figure 29. Stock estimate (in numbers of individuals) for all sea cucumbers for the entire fishery (left) and for each strata (right), for each year surveyed (error bars are 1 s.e.). 49

Figure 30. Percentage change in density between 2004, 2021, and 2025 at 115 repeated survey sites across the Mahe Plateau, sea cucumber fishery for priority species. The change statistics include 90% confidence intervals to determine significance at the 0.05 level (one-tailed test). 52

Figure 31. GMRT V3.9 depth map from NOAA. 60

Figure 32. Area of depth categories from GMRT. 61

Figure 33. Ships track depth soundings for 2004 survey overlain on GMRT v3.9 bathymetry. Note that Amirante plateau is not shown 62

Figure 34. Ships track depth soundings for 2004 survey overlain on GEBCO 2021 bathymetry 62

Figure 35. Regression analysis of GEBCO 2021 bathymetry against 2004 survey ship tracks depth soundings 63

Figure 36. Regression of GEBCO2021 bathymetry data against of field data 64

Figure 37. Regression analysis of GMRT v 3.9 bathymetry against 2004 survey ship tracks depth soundings 64

Figure 38. Regression analysis of GMRT v 3.9 bathymetry versus field data depths 65

Figure 39. Proportion of Mahe plateau by depth category based on ships depth soundings 2004 survey 66

Figure 40. Depth profile from 2004 survey. 68

Figure 41. Map of sampling locations for DIVE and Video priority and additional survey sites during the 2025 sea cucumber survey.. 85

Tables

Table 1. Quota per species for the Seychelles sea cucumber fishery for 2024/2025 season in the Authorised Zones. 8

Table 2. Sea cucumber landings (in number) from the Authorised zones of the Seychelles EEZ for the past 4 seasons. Number of trips undertaken is also included. 9

Table 3. Overall Quota utilisation by the end of each fishing seasons from the Authorised zones of the Seychelles EEZ for the past 4 seasons. Number of trips undertaken is also included. 9

Table 4. Strata (depth and plateau based) statistics for 2021/2022 sample sites. 15

Table 5. Number of sample sites in 2025 16

Table 6. Sampled Site counts for 2025 survey 21

Table 7. Species observed during surveys in 2004 and 2021. 21

Table 8. Stock estimate for White teatfish (*H. fuscogilva*) in 2004,2021 and 2025. For each stratum and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117). 24

Table 9. Stock estimate for Pentard/Flower teatfish (*H. spp.* (type 'Pentard")). For each strata and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117)..... 30

Table 10. Stock estimate for Prickly redfish (*T. ananas*). For each strata and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117).34

Table 11. Stock estimate for Black teatfish (*H. nobilis*) in 2004, 2021 and 2025. For each strata and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117)..... 39

Table 12. Stock estimate for Golden sandtfish (*H. lessoni*) in 2004,2021 and 2025. For each strata and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117). 44

Table 13. Table of recommendations. 53

Table 14. Average catches for the period 2009-2017 and population estimates from surveys in 2004, 2011-12 and 2025. 59

Table 15. Site strata types and number of sites per strata..... 85

1 Background

The modern sea cucumber fishery in Seychelles began in the late 1980's, marked by a rapid increase in catch volumes (Aumeeruddy and Conand, 2008). Historically targeted species were Black teatfish (*Holothuria nobilis*), White teatfish (*Holothuria fuscogilva*), Sandfish (*Holothuria scabra*), Prickly redfish (*Thelenota ananas*), Pentard (*Holothuria. spp.* (type "Pentard"); also called Flower teatfish and Surf redfish (*Actinopyga mauritiana* complex; also called Red Surfish, Yellow Surfish and White belly) (Aumeeruddy and Payet, 2004; MRAG, 2017; SFA unpublished data).

Although catch records prior to the year 2000 are incomplete, available data from the early 2000s (2001–02 to 2006–07 seasons) indicate relatively low total catches in the sea cucumber fishery (Figure1). From the 2007–08 season onwards, Pentard (Flower teatfish) became the dominant species in the catch, peaking with over 300,000 pieces landed in 2009-10. Following this peak, the total catch declined until 2018–19, experienced a rebound in 2020–21, and then gradually decreased again in subsequent seasons. Other species such as White teatfish, Prickly Redfish, and Black teatfish showed notable contributions in earlier years but have remained at lower and more stable levels in recent seasons.

Since introduction of Total Allowable Catch (TAC) quotas in 2018, Flower teatfish has continuously been given the highest quota allocation in the fishery compared to all other species.

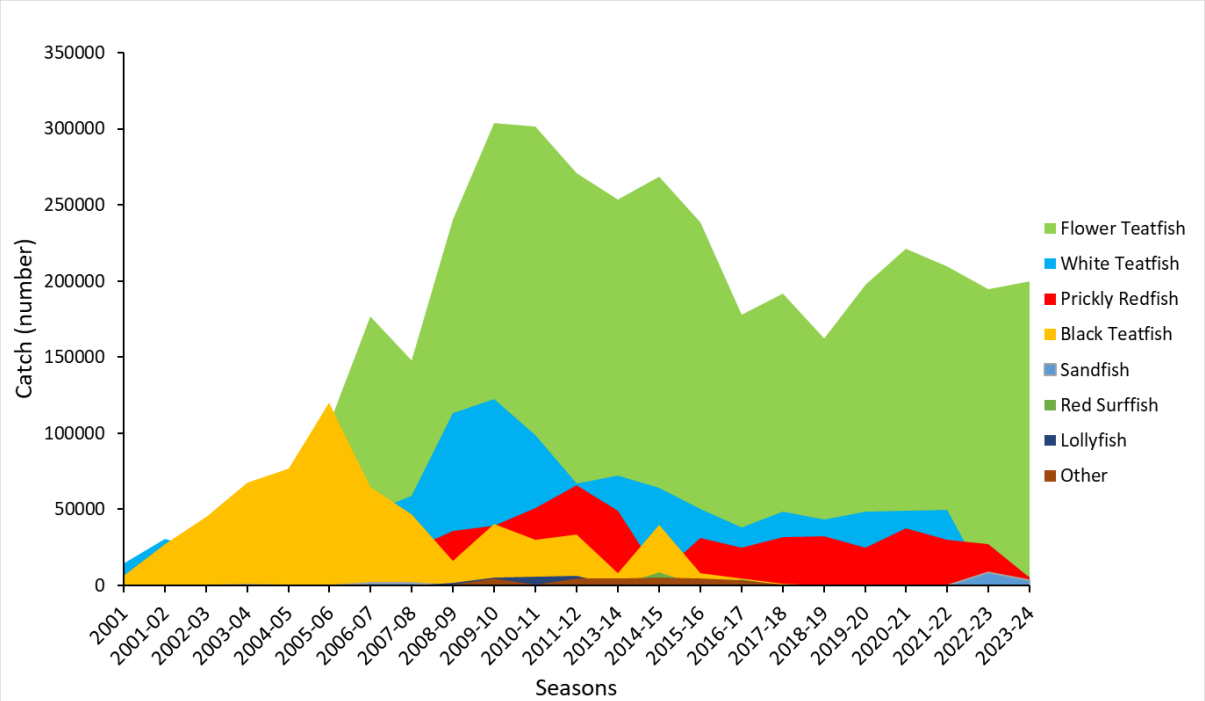


Figure 1. Catch data for the period 2001 – 2023/24 collected through logbooks.

1.1 Management

In 1999, in response to declining catch rates and a lack of baseline information on the status of the stock, the Seychelles Fishing Authority (SFA) introduced management measures for the fishery, including issuing a limited number of non-transferable fishing licenses (25), and limiting the number of divers per license (4), and mandating logbook and receipt books that had to be submitted to the SFA on a monthly basis (Aumeeruddy and Payet, 2002).

In addition, a closed season was introduced in 2008 from the months of July to September.

Further measures were introduced in 2018, including species TACs and quota allocations. Fishers could only target three species of sea cucumber: Pentard (Flower teatfish), White teatfish and Prickly redfish. In 2021, the TAC was reviewed and the overall quota for Pentard was reduced by 10% for the 2021-2022 season. Additionally, White teatfish was banned from the fishery in 2022 and replaced with Golden sandfish (*Holothuria lessoni*) for at least three years after which it will be reassessed (Table 1).

Table 1. Quota per species for the Seychelles sea cucumber fishery for 2024/2025 season in the Authorised Zones.

(Number)	Pentard (Flower teatfish)	Golden sandfish	Prickly red	Total
Total Quota	240,475	100,000	45000	385,475
Quota per vessel	9619	4000	1800	15,419

Between 2021/2022 and 2024/2025, the number of sea cucumbers landed in the fishery showed a clear declining trend. In 2021/2022, total landings were highest at nearly 295,000 individuals, with Pentard (Flower teat) making up the majority of the catch. Over the following years, catches steadily decreased, with totals dropping to 269,315 in 2022/2023 and further down to 229,791 in 2023/2024. By the 2024/2025 season, landings fell significantly to 173,119 individuals, the lowest in the series. Across all seasons, Pentard remained the dominant species in landings, while contributions from Golden Sandfish, Prickly Redfish, and White teatfish were smaller but still notable. Overall, the data indicates a sharp reduction in fishing output over the four-year period (Table 2). Notably, during the 2023/2024 fishing season, out of the 25 licensed sea cucumber vessels, two were engaged in exploratory fishing in the Joint management area of Mauritius and Seychelles (JMA). In the 2024/2025 season, this number increased to six licensed vessels conducting exploratory fishing in the JMA. Therefore, the number of vessels conducting sea cucumber fishing during the last two seasons was lower than in previous fishing seasons.

Table 2. Sea cucumber landings (in number) from the Authorised zones of the Seychelles EEZ for the past 4 seasons. Number of trips undertaken is also included.

Seasons	Number of trips	Pentard (Flower teat)	Golden sandfish	Prickly red	White teatfish	Total landing
2021/2022	140	213322	-	31322	50326	294970
2022/2023	132	223199	11676	34140	-	269315
2023/2024	133	200488	4526	24777	-	229791
2024/2025	106	144224	3625	25270	-	173119

Quota utilisation by fishers on the Mahé Plateau showed notable variation across species and seasons. In 2021/2022, a total of 140 trips were undertaken, with high utilization recorded for Pentard (84.28%), Prickly redfish (83.53%), and White teatfish (89.47%). In 2022/2023, fishers carried out 132 trips, with Pentard utilisation increasing to 92.82%, Golden sandfish recorded at 11.67%, and Prickly redfish declining to 75.86%.. By 2023/2024, with 133 trips, Pentard dropped slightly to 83.37%, Golden sandfish fell further to 4.53%, and Prickly redfish declined significantly to 55.06%. In 2024/2025, the number of trips fell to 106, the lowest across the period, with Pentard utilization declining sharply to 59.97%, Golden sandfish at only 3.62%, and Prickly redfish stabilizing at 56.16%. (Table 3). Furthermore, midway through every fishing season, quota is redistributed to ensure maximal utilisation at the end of the seasons

Table 3. Overall Quota utilisation by the end of each fishing seasons from the Authorised zones of the Seychelles EEZ for the past 4 seasons. Number of trips undertaken is also included.

Seasons	Number of trips	Pentard (Flower teat)	Golden sandfish	Prickly redfish	White teatfish
2021/2022	140	84.28%	-	83.53%	89.47%
2022/2023	132	92.82%	11.67%	75.86%	-
2023/2024	133	83.37%	4.53%	55.06%	-
2024/2025	106	59.97%	3.62%	56.16%	-

1.2 Stock assessments

The first full-scale stock survey was carried out in 2004 (Aumeeruddy et al., 2005) and focused on assessing the density of sea cucumbers at 246 sites throughout the Amirantes and Mahé Plateau. The survey produced stock estimates for 24 commercial (or potentially commercial) species.

The assessment indicated that Sandfish and Surf redfish were overexploited, whilst White teatfish and Pentard were fully exploited. Recommendations for management included Total Allowable Catch (TAC) for all target species, controls in fishing effort for high value species close to the main islands, minimum size limits and the implementation of continuous periodic surveys (Aumeeruddy et al., 2005). None of the recommendations were subsequently implemented.

A second stock survey of a restricted area of the Mahe Plateau was carried out from 2011 - 2013 (Koike, 2017). It found that the abundance of Lollyfish (*Holothuria atra*) and Black teatfish declined significantly compared to the 2004 survey. However, Blackfish (*Actinopyga miliaris*) had increased.

A stock assessment using fishery dependant (logbook) data was carried out in 2012, based on a spatially disaggregated standardized catch per unit effort (CPUE) time series, and surplus production models to estimate biomass and maximum sustainable yield (MRAG, 2012). This assessment recommended catch limits based on the TACs suggested in 2005.

A subsequent fishery dependent stock assessment was conducted using fishery data from 2002 to 2016 (MRAG, 2017). Evidence of significant population decline was observed especially for Black teatfish in some areas. Based on the analysis, further measures were introduced including reducing the length of the fishing season from 9 months to 8 months, alongside species' specific TACs and quota allocations (Table 1). Fishers could only target three species of sea cucumber: Pentard (Flower teatfish), White teatfish and Prickly redfish.

A new full-scale fishery independent survey was conducted in 2021/2022 to revisit approximately 200 sites on the Mahe Plateau and the Amirantes sampled in 2004. The main objective was to estimate the trends in density and population size since 2004 for a total of 20 commercial (or potentially commercial) species. The results of the survey revealed a significant decrease in the average density of White teatfish, indicating a heavily depleted population. On the other hand, a decline was also observed in Pentard (Flower teatfish) however the population status remained remarkably stable. Despite the ban on its exploitation since 2018, Black teatfish was still in a depleted state. Meanwhile, an increase in Prickly Redfish population was observed between 2004 and 2021 (Skewes, 2022). Some recommendations highlighted in the final report was the immediate cessation of fishing for White Teatfish and to conduct a follow-up survey in three years.

Fishery-independent surveys are valuable tools for collecting data on fish stocks, including abundance, distribution and size that can be used for effective management decisions. Additionally, these surveys can also be used to also gather data on species' habitat which is valuable for spatial management planning (Hilborn and Walters, 1992).

As per the recommendation from the 2021/2022 report, a follow-up survey was undertaken between April and May 2025.However, the survey was scaled down to focus on sites found on the Mahe plateau

only. The goal of the new survey was to assess the abundance and recovery of sea cucumber stocks, with the aim to provide recommendation necessary to effectively manage the resource.

Compared to previous surveys, the 2025 one was conducted solely on the Mahé Plateau, even if there are other areas within the Seychelles EEZ being targeted by the fishery. The focus on the Mahe plateau was due to financial and logistical reasons, however, from the fishery the Mahé Plateau is the area where most harvesting occurs (~60%), supporting the largest concentration of fishing activity and effort compared to other zones . Focusing the survey on the plateau allowed researchers to assess stock status in the main fishing zones, providing direct insight into population trends and the sustainability of the fishery.

1.3 Project objectives

This project aimed to survey sea cucumber populations and their habitats on the Mahé Plateau. The survey consisted of underwater visual census (UVC) carried out by scientific and commercial divers in shallow areas (<30 m) and the use of a Drop Camera in deeper areas (>30 m).

The results from the survey were used to inform the next steps in the development of new management measures for the fishery. This included reviewing the TAC for exploited species (which had not changed since the 2021 stock assessment) so that it reflected the current status of the stock.

Specific Objectives of the Project

1. To conduct a fishery-independent survey to assess the abundance of all sea cucumber resources on the Mahé Plateau.
2. To provide information on the stock status of the main commercial species.
3. To collect biological and ecological information on sea cucumber species.
4. To understand the effect of exploitation on sea cucumber populations and distribution.
5. To provide management advice to guide the future management of the sea cucumber fishery.

1.3.1 Survey Scope and Objectives

- **Geographical extent**
    - The survey included the Mahé Plateau only.
- **Primary species (stock size and trends)**
    - White teatfish (trends – recovery)
    - Pentard (Flower teatfish)

- Prickly redfish

- **Secondary species**
  - Black teatfish (trends – recovery)
  - Sandfish (trends)
  - Other commercial species (trends)
  - Other species (trends)

1.3.2 Survey Outputs

- **Stock size estimates**
  - Population estimates of the three primary species, as well as other secondary species encountered in surveyed habitats were generated.
  - The expected survey precision criterion was 60% CI < ±25%, in order to allow the application of sufficient precaution by using the lower 80th percentile of the population estimate for setting TACs.

- **Stock trends**
  - Trends in species density provided an indication of the effect of exploitation on the target sea cucumber stocks.
  - Estimated changes in species density were calculated relative to 2004 and 2021 (and potentially 2011) with high power (detecting 40% change with >95% power).
  - This was achieved by comparing the density of sea cucumbers at repeated sites from the 2004 and 2021 surveys (i.e. a repeated measure approach).

2 Methods

2.1 Sample design

The 2025 survey was based on a repeated measures design on the Mahe Plateau only, using sites from the 2021 survey. The benefits of this approach include:

- Prior field knowledge: information about the depth and substratum assists with sampling safety and efficiency.
- More statistical power: repeated measures designs are usually more powerful than random designs for detecting change, particularly over time from multiple sampling occasions, because they account for factors that cause variability between new sites.
- Fewer sites: Due to the greater statistical power, a repeated measures design can use fewer sites to detect a desired effect of the population size.
- Further sample size reductions are even possible in future monitoring because each site is involved with multiple surveys.
- Lower probability of site loss: as sites characteristics are largely known, the potential for site loss due to depth or other issues is greatly reduced.
- More efficient logistics: sampling approaches (e.g., ability to utilise divers) can be largely predetermined from previous site sampling data

Potential disadvantages are:

- Order effects: if repeated sampling affects the site in any way, then this can result in biased outputs (e.g., if sea cucumbers are removed during sampling and it impacts the subsequent survey). This is unlikely to be an issue since the previous sampling was in 2021/2022 (and potentially 2025) and sea cucumbers will, in most cases, be returned to the same general area as the sample site.
- GPS accuracy: even with high accuracy it is unlikely that the same area will be resampled. For diving, wind and sea conditions will affect current direction, especially during drift-video-recording whereby these effects can be even more pronounced.
- Spatial scale of habitat heterogeneity can also affect repeated sampling. If changes in habitat occur at a spatial scale less than the length of the transect this can affect how repeated samples match up in terms of habitat. Note, fishing of survey sites does NOT bias the outputs – this outcome is incorporated as part of the overall fishery density change.
- Detecting changes in species distribution: Repeated measures trends may be biased downward if survey sites are chosen partly based on high density. This risk is low when population density is linked to habitat, and habitat is strongly related to depth, since depth does not change much

over time. To minimize any potential bias, exploratory sites should also be included during monitoring surveys.

2.1.1 Fishery area stratification

For the 2021/2022 survey, the fishery habitats on the Mahé Plateau were re-stratified to better represent the true bathymetry of the area. Bathymetry data for Seychelles is publicly available from GEBCO 2021 and the Global Multi-Resolution Topography Data Synthesis (GMRT) (Appendix B). However, GEBCO 2021 contained visually apparent artifacts, particularly in the deeper waters northeast of the Mahé Plateau, which were partially corrected in the GMRT dataset. To assess the reliability of these datasets, field depth data were regressed against both GMRT and GEBCO 2021, but results indicated low accuracy, with the GMRT layer showing only a weak correlation with survey data (R = 0.19).

Additional ship track data collected during the 2004 survey were therefore considered more suitable for classifying plateau habitats in both Mahé and the Amirantes (Appendix C). Using these data, a new stratification schema was developed consisting of a reef stratum (emergent or near-emergent coral reefs and reef edges down to ~20 m) and three plateau depth strata: 0–30 m, 30–60 m, and >60 m. The reef strata were delineated using the Allen Coral Atlas (2020), which matched survey sites and satellite data with high accuracy, while the areas for the three plateau strata were estimated from the 2004/05 bathymetry tracking records (Table 4).

2.1.2 Site selection

Sites were selected based on those sampled during the 2021/22 survey on the Mahé Plateau. During the site selection process, the number of sites was reduced to 131 priority sites while maintaining the ratio of strata sampled in the previous survey. Additionally, the sea cucumber fishing industry provided four new sites to enable a comparison of density between our survey sites and their fishing grounds (Figure 2). However, during the survey, the number of sites were reduced further due to issues encountered with the drop camera. Moreover, during data cleaning, some drop camera sites were also removed from the database because of discrepancies in the GPS coordinates recorded. This ultimately reduced the total number of sites to 117.

When looking at the total number of sites surveyed, there were 194 in 2004, 149 in 2021/22, and 117 in 2025, with most of the effort concentrated in the Mahe 30–60 m stratum, which remained the core habitat for sea cucumber populations. Although this reduction in sites resulted in lower statistical precision shown by the predicted 80% confidence intervals widening from 11.44–25.65% in 2021–22 to

21.60–28.99% in 2025, the increase was not substantial enough to outweigh the main benefit of prioritizing repeated sites. Using repeated sites enhanced the ability to track long-term population trends and ensured consistency in the dataset, even if precision was somewhat reduced compared to earlier surveys (Table 5).

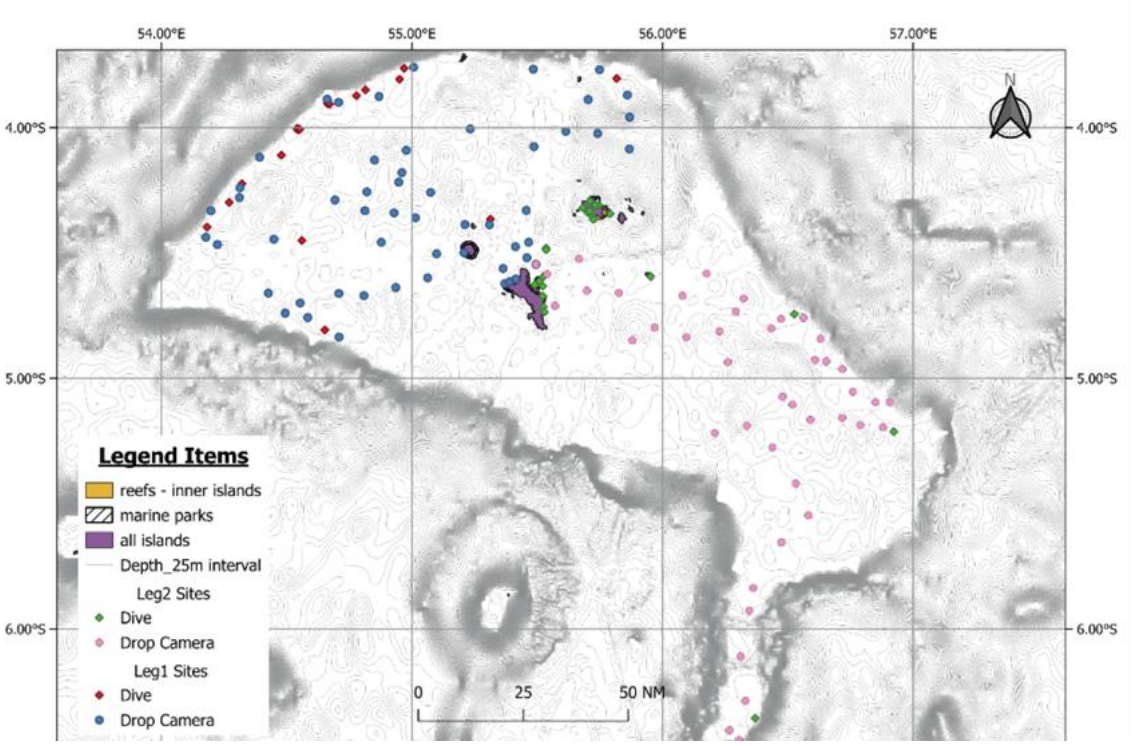


Figure 2. Sites planned to be surveyed for the 2025 survey, by transect type.

Table 4. Strata (depth and plateau based) statistics for 2021/2022 sample sites.

Strata name	Area (ha)	% of fishery area	Hol density (No./Ha)	% of pop	Fishery species density (No./Ha)	% of pop	2021-2022 Sites (%)
Amirantes reef	11,639	0.2	67.5	1.01	10.0	1.53	3.11
Amirantes 0-30m non-reef	148,065	3.1	49.22	9.38	10.71	20.56	7.25
Amirantes 30-60m	286,712	5.9	23.26	13.67	5.28	19.61	8.29
Mahe reef	10,184	0.2	106.73	1.4	7.69	1.01	13.47
Mahe 0-30m non-reef	476,815	9.8	29	17.78	7.03	43.45	16.58
Mahe 30-60m	3,194,050	65.8	15.04	56.74	0.34	13.86	51.3

Mahe >60m	710,935	14.7	0	0	0.00	0.0	5.6
All	**4,838,398**	**100**	**16.06**	**100**	**1.60**	**100**	**100**

Table 5. Number of sample sites in the 2025 survey

Strata name	Opt. All spp.	Opt fishery spp.	2004 sites	2021-22 sites	2025 resample	2025 addition	2025 total
Mahe reef	2	1	32	26	15	0	15
Mahe 0-30m non-reef	32	39	46	32	24	0	24
Mahe 30-60m	159	152	99	87	70	2	72
Mahe >60m	10	0	17	4	6	0	6
TOTAL	203	192	194	149	115	2	117
Predicted precision (80% CI)	9.16	16.68	-	11.44/25.65	21.60/28.99		

2.2 Survey timing and duration

It was recommended that the survey timing be based on logistical, safety (e.g., weather) and personnel availability, not based on aligning with fishery opening. As for survey length, it was recommended that the proposed 4-week cruise is split into two legs. (Appendix A).

2.3 Constraints and issues

Industry involvement in surveys was considered beneficial for several reasons:

- Provides access to trained divers.
- Increases industry acceptance of survey results.
- Facilitates knowledge transfer on sea cucumber biology and distribution.

However, several risks and challenges were identified:

- Participation of non-scientific observers requires targeted training and calibration to minimise survey bias.
- Additional training, as well as health and safety considerations, are necessary.
- Potential chain of command and coordination issues.

It was therefore recommended that industry divers be paired with scientific divers during transects, enabling subsequent validation and, if necessary, adjustment of the collected data.

2.4 Cruise logistics and path analysis

The survey was carried out over two legs. For each leg more than 50 sites were sampled, with a mixture of both UVC (dives) and video sampling. As previously mentioned, each leg began and ended at Mahe Island. Due to constraints in time and distance needed for travelling, an additional third leg was undertaken to cover video sites that could not be covered initially.

2.5 Field sampling

Field approaches were similar to previous surveys. For a full description of the field sampling approach, refer to Appendix H Cruise plan.

2.6 Data entry and storage files

Collected data were entered and stored on an MS Excel data entry and validation workbook linked to an MS Access database. Data is then stored on a cloud-based folder using MS OneDrive synced to a local drive. Mainly, due to the fact that Access, while good for securely storing and summarising data using

SQL is difficult to enter data into, and Excel, while excellent for data entry and validation, is vulnerable to formula corruption.

Therefore, the data stream is to use Excel for the data entry with extensive data validation and quality checks so that data is clean when it is imported (or linked if cloud storage is used) in Access. In the instance that data needs to be corrected or Look-Up-Tables modified, it will be done in the "master" Excel workbook.

For this project, data entry, analysis, spatial visualization and storage were implemented using the following data models:

- MS Excel for data entry and verification
- MS Access for data storage as tables and queries suitable for export as flat tables for analysis and reporting using Excel and other statistical packages
- QGIS for survey design and visualization

2.7 Data analyses

The following analysis were carried out.

1. Density estimates
    a. Stratified approach
    b. Repeated sites only
    c. Paired t test to test for statistical difference between two surveys.
2. Population estimates
    a. Stratified approach
    b. All data
    c. Report 60% CI (such that we are 80% certain that the true estimate is lower than the upper CI)

2.7.1 Density

Density (number per hectare) of sea cucumber species for each site were calculated by dividing the species count by transect area. The whole of fishery average density was then calculated using a stratified analysis approach that considers the heterogeneity of variance between fishery habitats, and the total area within in the fishery area (Cochran, 1977). This is a common and well proven approach that has been used for many fisheries population studies over the past 30 years or more, including for sea cucumbers in Torres Strait (Long et al., 1995, Skewes et al., 2002), the Australian Coral Sea fishery (Skewes and Perrson, 2017), the Cook Islands (Drumm, 2005), PNG (Skewes et al.,2002) and the Seychelles (Aumeeruddy et al., 2004, Skewes, 2022).

Detail of the analytical approach is contained in Appendix I Stratified analysis approach.

Only the repeated sites that were sampled on the Mahe plateau in 2004, 2021 and 2025 were used in the calculation of density.

2.7.2 Stock size

Estimates of standing stock were calculated as the product of estimates of density and stratum area. For stock size, we report the 60% Confidence Interval (60% CI), such that we can report the lower 20th and upper 80th percentile. This is an approach to, risk and certainty that considers, i) the highly variable nature of the survey counts, ii) the level of risk suitable for a small-scale commercial fishery of this nature.

Note that all available data for each survey was used in the calculation of stratified stock size estimates.

2.7.3 Repeated measures paired comparisons.

For comparison between sample years, we used a repeated measures analysis approach where the difference in density was calculated at site level first for all repeated sites. This increases the precision and reduces potential bias between comparisons due to habitat and other considerations. Statistical significance of differences can then be carried out by examining confidence intervals (1-α) of the paired differences for each parameter particularly their zero coverage, to assess whether significant changes in density had occurred between years (with test size α). This type of test is preferable to standard parametric tests due to the zero-inflation of counts and the skew and nonconformity of the distribution of observed densities.

In this case, the principals of stratified design were extended to difference test be weighting the differences from sites within each stratum by the stratum weight.

3 Survey report

The survey team visited a total of 123 sites (Figure 4) out of the original target of 131 sites, with 9 sites abandoned due to issues encountered with the drop camera (Table 6). Out of the 131 priority sites identified in the sampling design, data were collected from 121 sites (repeated sites from 2011 and 2021) along with two additional sites provided by the commercial sea cucumber crew assisting with the survey. Out of the four sites provided by sea cucumber fishers, one overlapped with an already identified survey site and was therefore removed from the list. Additionally, another of the suggested site had invalid coordinates, thus after consultation with the commercial sea cucumber crew assisting with the survey, it was also excluded from the final sample sites list. Moreover, whilst conducting data cleaning, six drop camera sites had to be removed from the database due to discrepancies in the GPS coordinates recorded. A full list of sample sites is included in Appendix D.

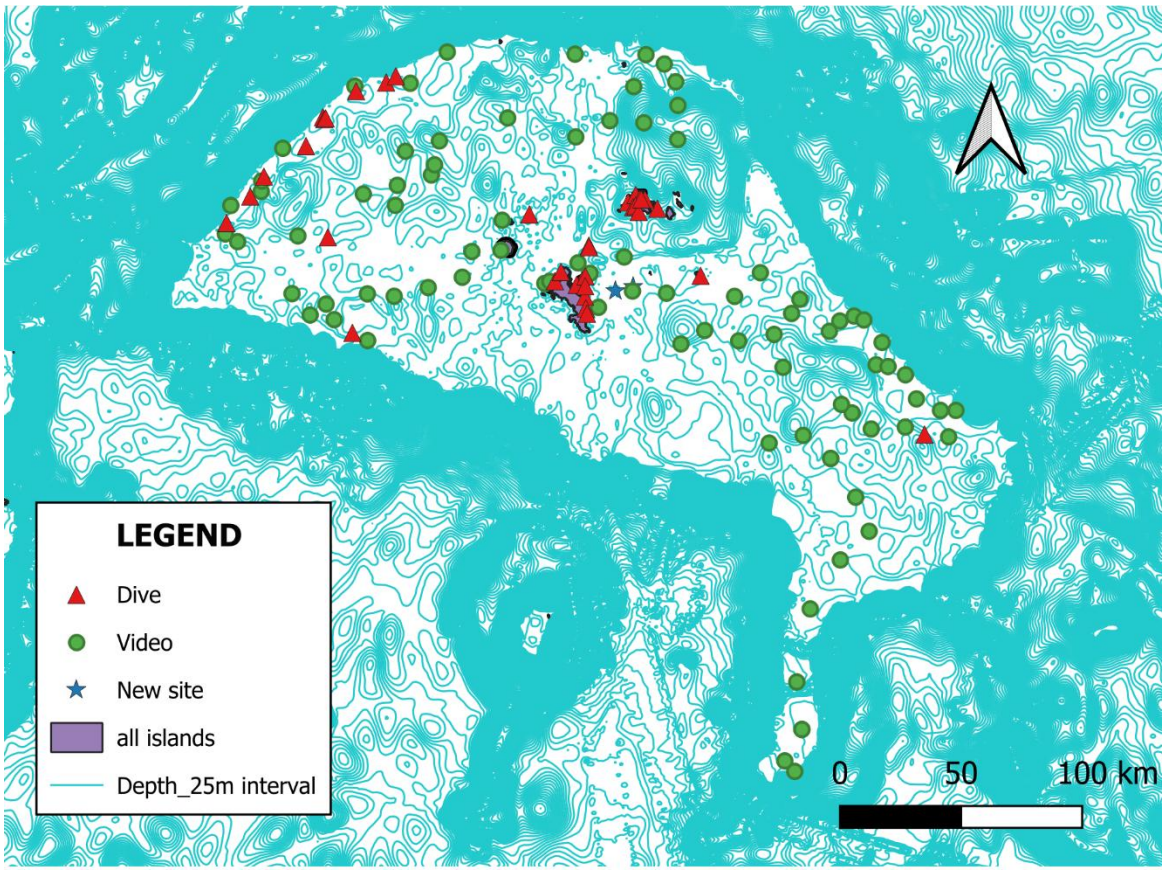


Figure 3. Sites sampled in 2025 survey, by transect type.

Table 6. Sampled Site counts for 2025 survey.

Strata	Reef (0-20 m)	Shallow non-reef (0-30 m)	Intermediate (30-60 m)	Deep (>60 m)	All
Mahe	15	25	76	7	123
All	15	25	76	7	123

3.1 Data Validation

The survey data was entered into the dedicated survey database and included the same fields as the 2004 survey data. Extensive data validation was carried out to correct and validate the data, including a comparison of data sheets, database, size frequency datasheets and size frequency database.

Although there is a high degree of certainty regarding the identification of the high priority species, (Pentard, White teatfish, Prickly redfish and Black teatfish), some lower value species are difficult to distinguish as the common names used during the survey refer to species groups (Table 7; Skewes and Aumeeruddy, 2006), and therefore some results will be combined (see Results).

Table 7. Species observed during surveys in 2004 2021 and 2025.

Scientific Name	Common Name	Local name
Holothuria nobilis	Black teatfish	Kokosye Nwanr
Holothuria fuscogilva	White teatfish	Kokosye Blan
Holothuria spp. (type "Pentard")	Pentard, Flower teatfish	Pentard
Holothuria fuscopunctata	Elephant trunkfish	Safran
Holothuria atra	Lollyfish	Spork, Spork koray, Disan
Holothuria edulis	Pink Fish	
Holothuris scabra	Sandfish	Kokonm
Holothuria lessoni	Golden sandfish	Kokonm
Actinopyga mauritiana	Surf redfish, Yellow surf	Brisan
Actinopyga miliaris	Hairy blackfish	Spork
Actinopyga echinites	Deepwater redfish	Spork
Actinopyga palauensis	Deepwater blackfish	Spork

Bohadschia vitiensis	Brown sandfish	Lakol
Bohadschia atra	Tiger fish	Lakol
Bohadschia subrubra	Bohadschia white belly	Lakol
Pearsonothuria graeffei	Flowerfish	
Thelenota ananas	Prickly redfish	Sanpye
Thelenota anax	Amberfish	
Stichopus herrmanni	Curryfish	
Stichopus chloronotus	Greenfish	

4 Results

4.1 White teatfish (*Holothuria fuscogilva*)

4.1.1 Density

Overall density of White teatfish at repeated sites on the Mahé Plateau in 2025 survey showed a modest increase compared to the 2021 survey, reaching approximately 0.2 individuals per hectare. This slight rebound was primarily driven by higher densities recorded in shallow non-reef areas (0–30 m), which had previously experienced sharp declines. Despite the overall increase in density reef areas was the strata which experience a decline in density. Deeper strata (30–60 m and >60 m) continued to exhibit very low or near-zero abundance (Figure 4).

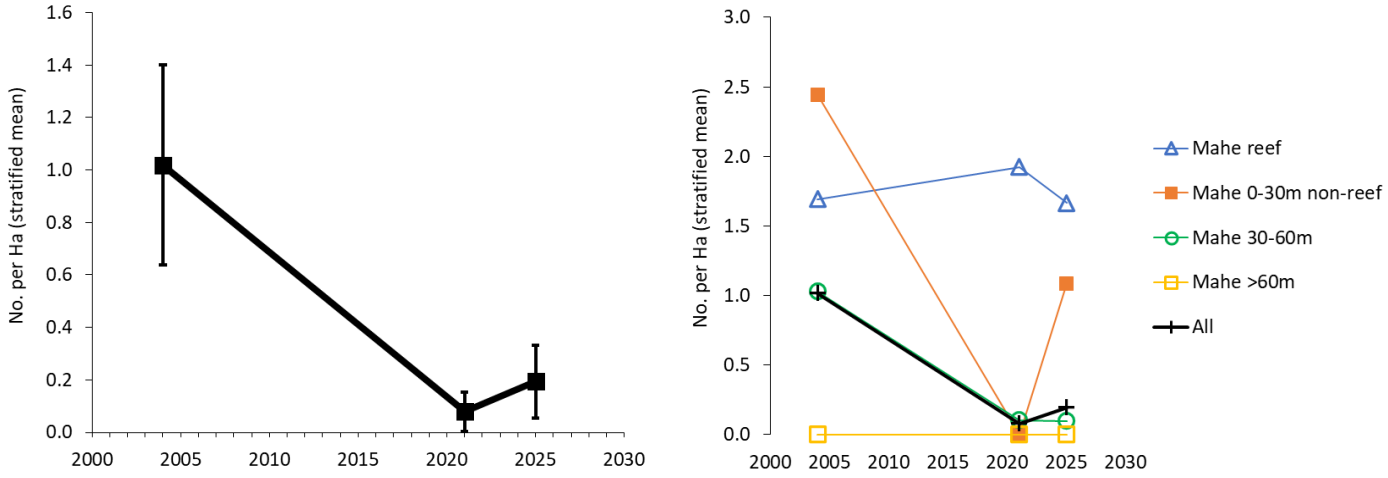


Figure 4. Overall (left) and stratum (right) average (stratified) density (No. per Ha) for White teatfish (*H. fuscogilva*) at repeated sites in 2004, 2021 and 2025 (error bars = 1 s.e.) (n=117).

4.1.2 Stock estimate

The population estimate for White teatfish (*Holothuria fuscogilva*) in 2025 represents 19.1% of the 2004 stock estimate, showing a partial recovery from 2021, when the estimate was only 7.8% of the 2004 baseline (Table 8, Figure 5). In the 2025 survey, the majority of the population was distributed across the Mahe 0–30 m non-reef (60.8%) and 30–60 m (37.2%) strata, while the Mahe reef stratum accounted for only 2.0%, and the Mahe >60 m stratum remained unoccupied. Even when considering the upper 60%

confidence interval, the 2025 population estimate remains at only 30.6% of the 2004 estimate. White teatfish stock on the Mahé Plateau therefore remains significantly reduced compared to historical levels.

Table 8. Stock estimate for White teatfish (*H. fuscogilva*) in 2004 ,2021 and 2025. For each stratum and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117).

Strata	Number 2004	60% CI (%)	Number 2021	60% CI (%)	Number 2025	60% CI (%)
Mahe reef	17,238	63.8	19,584	59.3	16,973	86.6
Mahe 0-30m non-reef	1,166,123	44.0	0	0.0	518,277	85.7
Mahe 30-60m	3,288,423	40.2	329,698	84.6	317,037	84.6
Mahe >60m	0	0.0	0	0.0	0	0.0
All	**4,471,784**	**31.6**	**349,282**	**79.7**	**852,287**	**60.2**

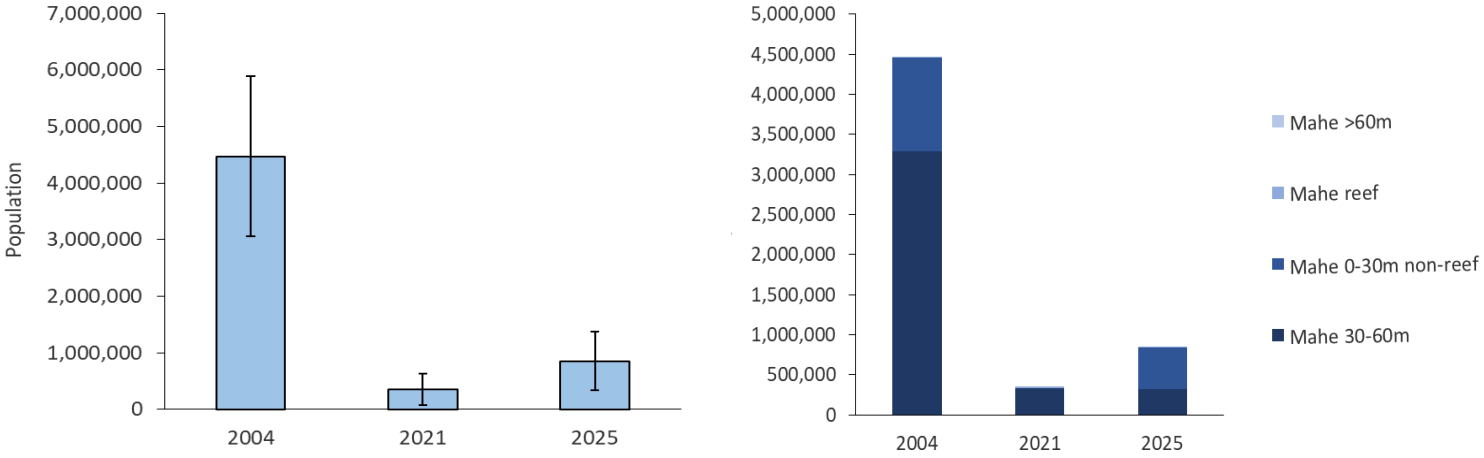


Figure 5. Stock estimate (in numbers of individuals) for White teatfish (*H. fuscogilva*) for the entire fishery (left) and for each stratum (right), for each year surveyed (error bars are 60% CI).

Figure 6 shows a comparison of White Teatfish (*Holothuria fuscogilva*) population estimates across four survey years: 2004, 2011, 2021, and 2025. The population declined significantly from 2004 to 2021, with the 2021 estimate representing the lowest recorded level. The 2011 estimate, although based on a different survey dataset and fishery area (Koike, 2017), indicates a reduction to around half of the 2004 population. A modest increase was observed in 2025 survey, suggesting a partial recovery since 2021. However, the 2025 estimate remains substantially lower than those of both 2004 and 2011, indicating that the stock has yet to return to its historical levels.

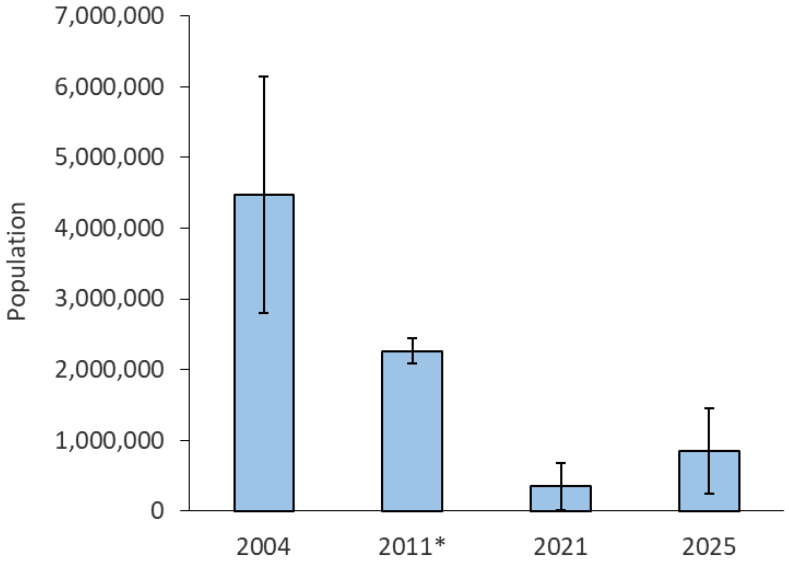


Figure 6. Comparison of 2004 ,2021 and 2025 fishery population estimates of White teatfish with that of 2011 (Koike, 2017) (error bars are 1 s.e.) *2011 survey utilises a different survey dataset and fishery area.

4.1.3 CPUE

Analysis of Catch-per-unit-effort (CPUE) for White teatfish, based on fishery logbook data from 2004 to 2021, shows a clear long-term decline, with 2021 CPUE values less than half of those recorded in 2004. This decline closely mirrors survey-based population estimates, which in 2025 survey is only about 16% of the 2004 level, despite a slight increase compared to 2021 (Figure 7, Figure 8).

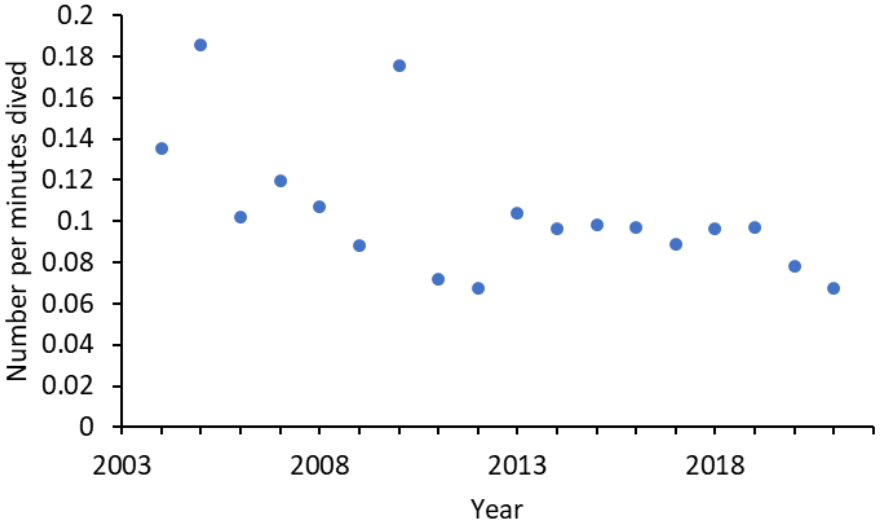


Figure 7. CPUE (number caught per minute dived) of white teatfish for 2004 to 2021 season from available fishery logbook data.

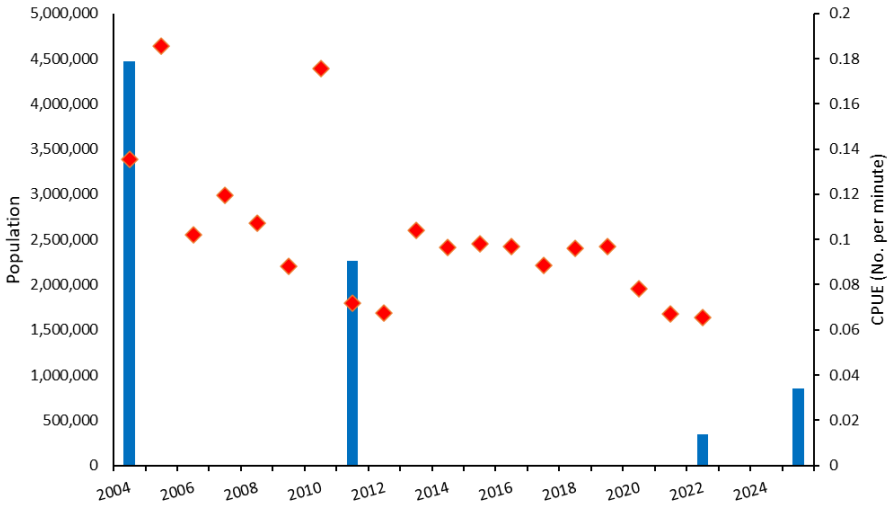


Figure 8. Combined trends in population estimates (blue bars) and catch-per-unit-effort (CPUE; red diamonds) for White teatfish (*H. fuscogilva*) on the Mahé Plateau from 2004 to 2025.

Estimates of density and population is still indicating that the White teatfish population in the Seychelles fishery remains severely depleted even with the slight recovery observed during the past 3 years.

4.1.4 Stock status

Stock status is usually assessed as the populations size or density relative to its virgin (before fishing) size/density (usually referred to as B_0), which is related to the ecological carrying capacity for that species. This can be a difficult parameter to estimate if there is no "before fishery" survey data, and when dealing with species that may have variable recruitment and/or population density over time or have a patchy distribution between or even within fishery habitat areas.

The next source of uncertainty is the stock level reference points where the stock level yield is maximised (B_{MSY}), and the stock level at the point of recruitment impairment (B_{PRI}). These have not been well established for sea cucumber fisheries; however, they are likely to be greater than the "rule of thumb" reference levels set for finfish fisheries of 40% and 20% of B_0 for Maximum Sustainable Yield MSY and Primary Performance Index PRI respectively (MSC, 2018).

In this case, the marked decrease in average density at repeated sites, the sharp reduction in population estimates, and the long-term decline in CPUE for White teatfish all point to a heavily depleted population currently at around 19% of its 2004 level. Given that, the fishery has been operating for several years before the 2004 survey and was already showing signs of depletion then (Aumeeruddy et al., 2005), it is highly likely that the population was well below the default PRI (20% of B_o), even allowing for uncertainty in the population estimates.

No catch quota was allocated for White teatfish on the Mahé Plateau in 2025, as the species was not included in the list of targeted species and therefore was not permitted to be fished in this area. In previous years, the catch quota of 56,250 per annum, equivalent to about 13% of the mean 2021 stock estimate, contributed to depletion of the population, reinforcing findings from other teatfish fisheries in Australia and elsewhere, that sustainable yields for teatfish may be of the order of 5% or less (Uthicke et al., 2004).

In the 2025 survey, the White teatfish stock on the Mahé Plateau was estimated at ~0.85 million individuals, representing approximately 19% of the 2004 estimate and still far below the level that would support sustainable harvesting. Previous stock modelling using CPUE data up to 2011 also indicated that this stock had been consistently overfished, likely resulting in recruitment overfishing (Koike, 2017).

When comparing the density and population estimates of 2025 with that of 2021, there are signs of recovery within the population being observed. This is indicative that the current management measure

of completely removing the species from the fishery is effective in improving the population of White teatfish on the Mahe plateau. However, since the estimated population is still at only 19% of the 2004 estimate and therefore should be given more time for recovery.

4.2 Pentard/Flower teatfish (*Holothuria spp.* (type "Pentard"))

4.2.1 Density

The overall density of Pentard (*Holothuria* spp. type "Pentard") at repeated sites on the Mahé Plateau in 2025 survey was approximately 0.2 individuals per hectare, continuing the declining trend observed since 2004. This represents a sharp reduction from the 2004 density of around 0.85 individuals per hectare, and a slight decrease from 2021 (Figure 9).

At the stratum level, the Mahe 0–30 m non-reef area continuously showed the highest density over the years, with an increase from 2021, though still well below 2004 levels. The estimated density for Mahe 30–60 m stratum declined slightly between 2021 and 2025 survey. In contrast, the Mahe reef stratum recorded very low density, continuing the decline observed since 2004. No individuals were recorded in the Mahe >60 m stratum in any year (Figure 10). These patterns reflect an ongoing depletion of the Pentard population across most habitats, with only limited signs of stratum-specific recovery in the shallow non-reef areas.

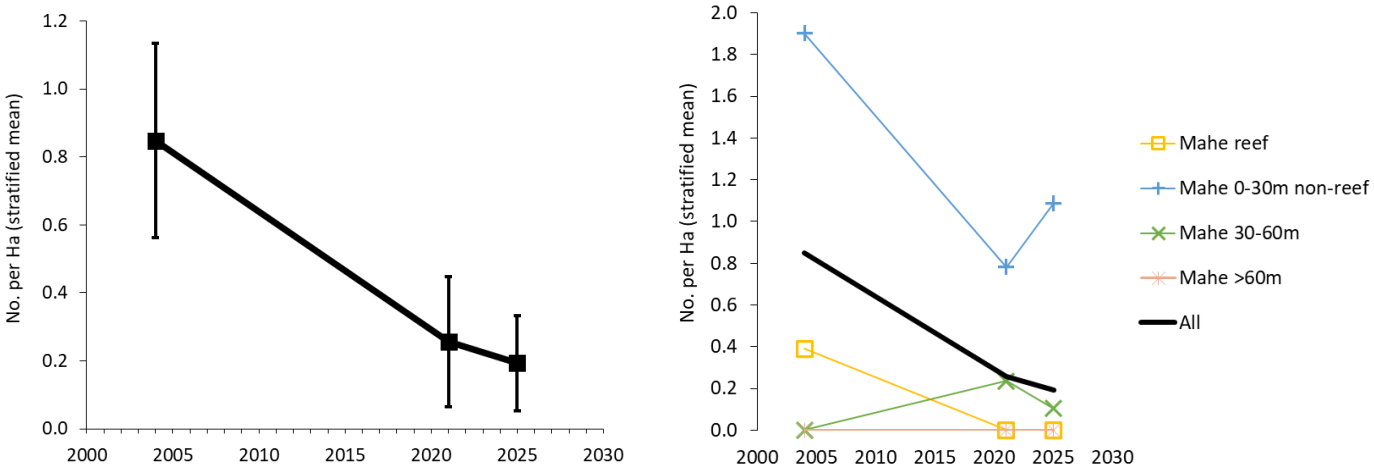


Figure 9. Overall (right) and stratum (left) average (stratified) density (No. per Ha) for Pentard/Flower teatfish (*H. spp.* (type "Pentard")) at repeated sites in 2004,2021 and 2025 (error bars = 1 s.e.) (n=117).

4.2.2 Stock estimate

The population estimate for Pentard in the 2025 survey was 846,878 individuals (± 61.2%, 60% CI), representing about 22.8% of the 2004 stock estimate (Table 9, Figure 10). The population was primarily distributed across the shallow and intermediate non-reef strata on the Mahé Plateau.

Table 9. Stock estimate for Pentard/Flower teatfish (*H. spp.* (type 'Pentard")). For each strata and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117).

Strata	Number 2004	60% CI (%)	Number 2021	60% CI (%)	Number 2025	60% CI (%)
Mahe reef	3,978	85.3	0	0.0	0	0.0
Mahe 0-30m non-reef	906,985	34.6	372,512	85.8	518,277	85.7
Mahe 30-60m	2,810,682	36.1	752,848	84.7	328,601	54.6
Mahe >60m	0	0.0	0	0.0	0	0.0
All	**3,721,645**	**28.5**	**1,125,359**	**63.0**	**846,878**	**61.2**

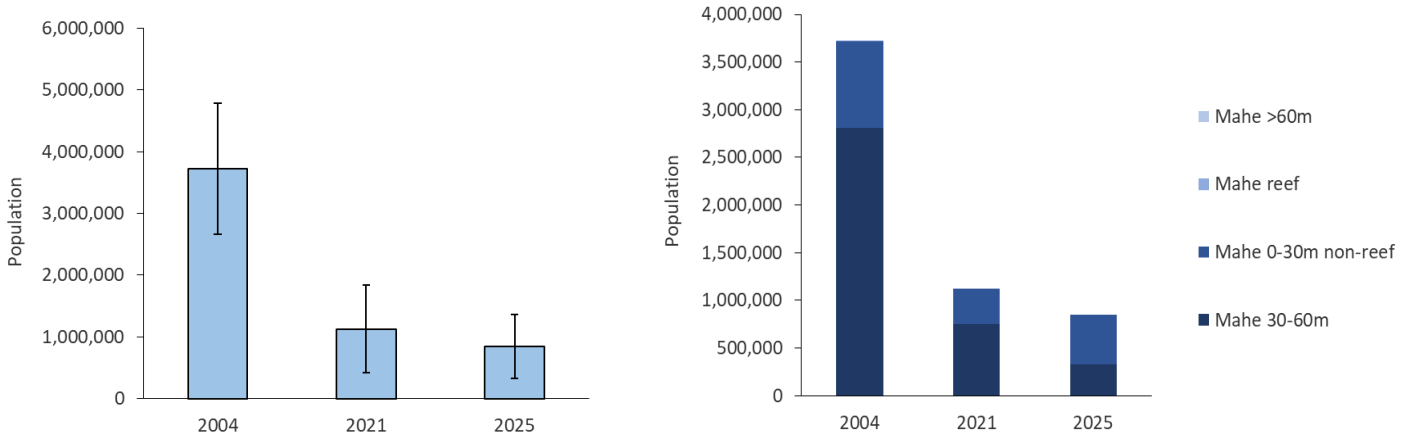


Figure 10. Stock estimate (in numbers of individuals) for Pentard/Flower teatfish (*H. spp.* (type 'Pentard")) for the entire fishery (left) and for each strata (right), for each year surveyed (error bars are 60% CI).

4.2.3 CPUE

An analysis of the catch and effort data from fishery logbooks (2004–2023) for Pentard/Flower teatfish indicate a ~27% decline in catch rates, which is consistent with the depleted stock status shown by the 2025 survey. Although the magnitude of decline in CPUE is less than that observed in survey-based population estimates (~73% since 2004), the convergence of both indicators provides strong evidence of long-term population reduction (Figure 11, Figure 12).

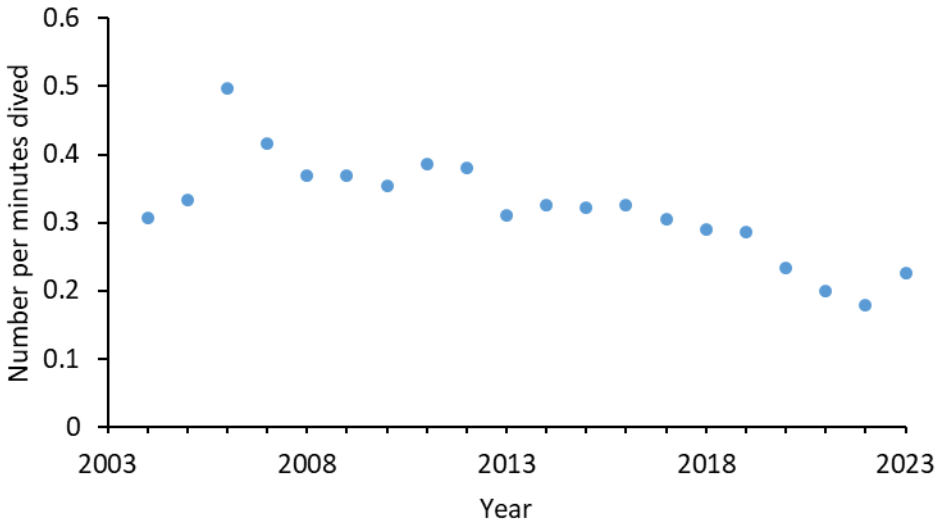


Figure 11. CPUE (number per minutes dived) of Pentard/Flower teatfish for 2004 to 2023 from available fishery logbook data

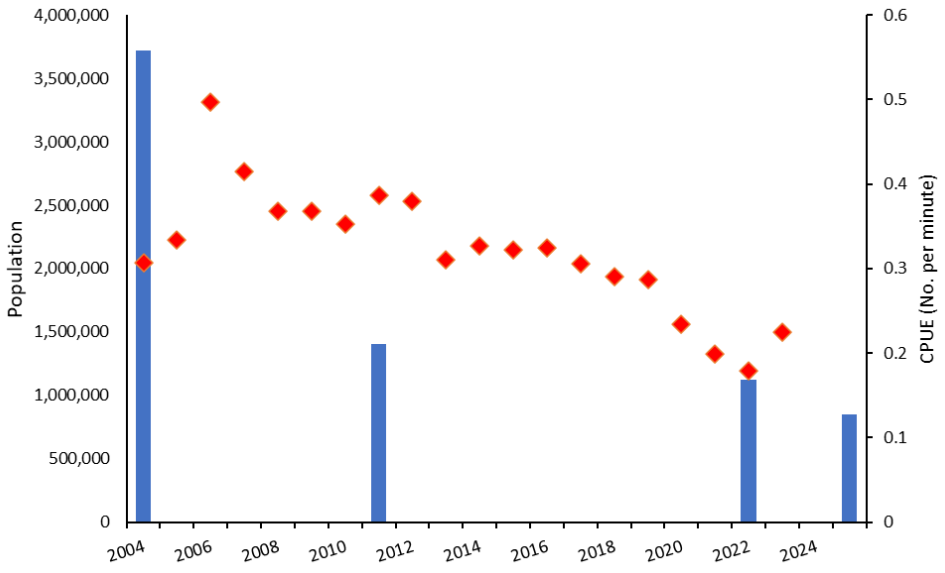


Figure 12. Combined trends in population estimates (blue bars) and catch-per-unit-effort (CPUE; red diamonds) for Pentard/Flower teatfish on the Mahé Plateau from 2004 to 2025.

4.2.4 Stock status

The average density at repeated sites, population size estimates, and CPUE data for Pentard indicate a substantial decline since 2004, with survey results showing a ~73% reduction in population size and CPUE data reflecting a ~27% decline in catch rates. This demonstrates significant depletion, suggesting that the population is less stable than previously reported in the 2021-2022 survey report.

While the stock level may not have reached a level where recruitment impairment is occurring, the downward trajectory of CPUE would indicate that current fishing levels are likely unsustainable.

4.3 Prickly redfish (*Thelenota ananas*)

4.3.1 Density

The overall stratified mean density of Prickly redfish (Thelenota ananas) at repeated sites on the Mahé Plateau increased markedly in 2025 to approximately 1.6 individuals per hectare, representing a statistically significant increase compared to both 2004 and 2021 (Figure 13)

At the stratum level, the Mahe 0–30 m non-reef stratum showed the most notable increase, reaching over 12 individuals per hectare in 2025, more than double the 2021 level. In contrast, the Mahe reef stratum, which had also shown an increase in 2021, declined sharply by 2025. The Mahe 30–60 m and Mahe >60 m strata continued to support very low or near-zero densities across all years (Figure 13).

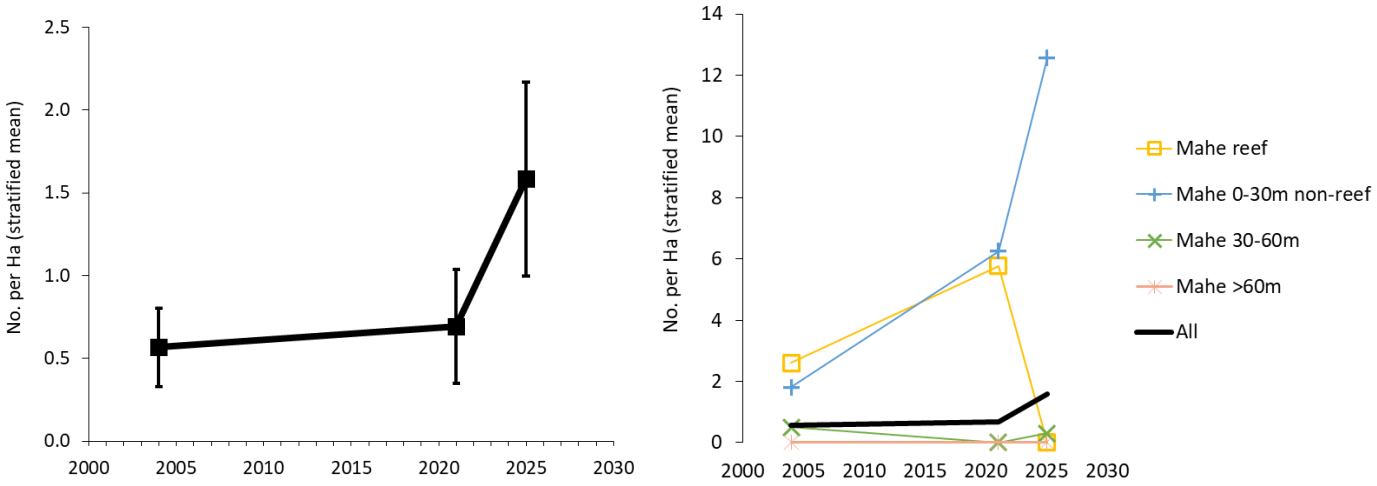


Figure 13. Overall (right) and stratum (left) average (stratified) density (No. per Ha) for Prickly redfish (*T. ananas*) at repeated sites in 2004 , 2021 and 2025 (n=117) (error bars = 1 s.e.).

4.3.2 Stock estimate

The 2025 population estimate for Prickly redfish (*Thelenota ananas*) on the Mahé Plateau was 6,950,500 individuals (± 31.4%, 60% CI), reflecting a substantial and statistically significant increase compared to

the 2021 estimate of 3,038,843 individuals and more than double the 2004 estimate of 2,485,348 individuals (Table 10, Figure 14).

Table 10. Stock estimate for Prickly redfish (*T. ananas*). For each strata and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117).

Strata	Number 2004	60% CI (%)	Number 2021	60% CI (%)	Number 2025	60% CI (%)
Mahe reef	26,520	37.7	58,751	37.4	0	0.0
Mahe 0-30m non-reef	863,564	30.2	2,980,092	43.3	5,989,951	34.3
Mahe 30-60m	1,595,265	52.5	0	0.0	960,549	84.6
Mahe >60m	0	0.0	0	0.0	0	0.0
All	**2,485,348**	**35.2**	**3,038,843**	**42.1**	**6,950,500**	**31.4**

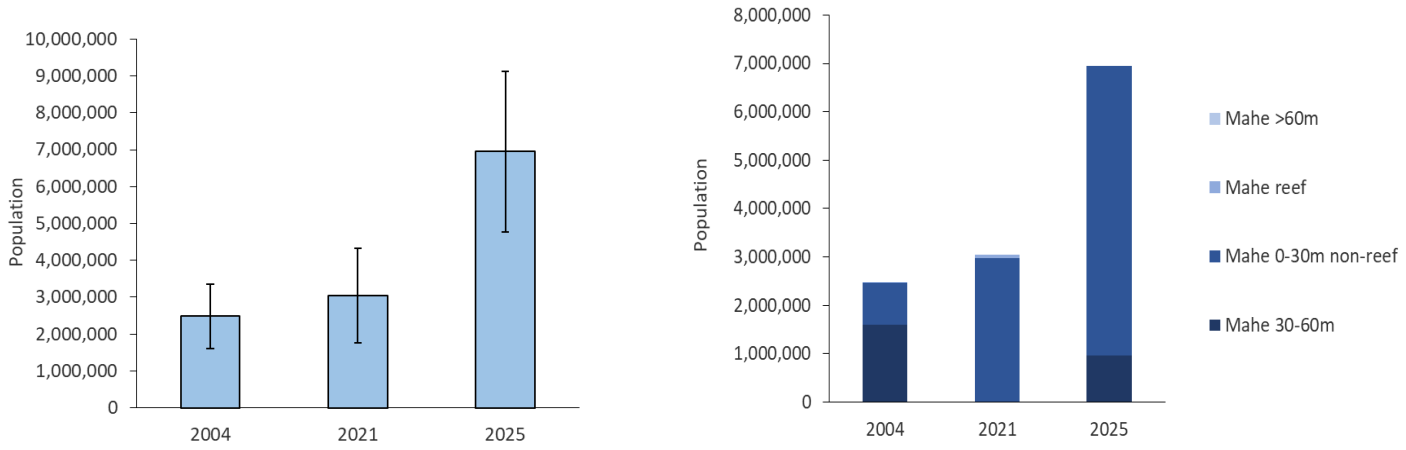


Figure 14. Stock estimate (in numbers of individuals) for Prickly redfish (*T. ananas*) for the entire fishery (left) and for each stratum (right), for each year surveyed (error bars are 60% CI).

A comparison of Prickly redfish (Thelenota ananas) population estimates from 2004, 2011, 2021, and 2025 shows notable trends over time. The 2011 estimate, derived from a different survey dataset and fishery area (Koike, 2017), showed little change from 2004, with overlapping confidence intervals indicating no statistically significant difference between the two periods. A moderate increase was observed in 2021, although the relatively wide confidence interval suggests high variability in the estimate (Figure 15).

In contrast, the 2025 population estimate shows a substantial and statistically significant increase, reaching approximately 7 million individuals the highest recorded across all years (Figure 15).

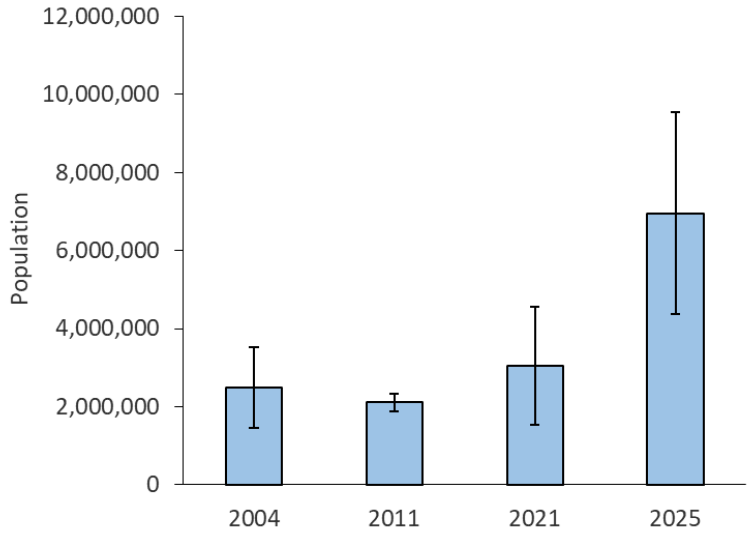


Figure 14. Comparison of 2004, 2021 and 2025 population estimates or Prickly redfish with that of 2011 (Koike, 2017) *2011 survey refers to a different survey dataset and fishery area.

4.3.3 CPUE

An analysis of catch and effort data from fishery logbooks for the period 2004 to 2023 shows a highly variable CPUE for Prickly Redfish, with no consistent long-term trend until a marked decline after 2018. By 2023, CPUE had fallen by approximately 83% compared to 2004, reaching the lowest value in the time series (Figure 16). In contrast, the 2025 fishery-independent survey recorded a substantial increase in the estimated population size to ~7.0 million individuals, more than double the 2021 estimate (Figure 17). This divergence between fishery-dependent and fishery-independent indicators may reflect spatial differences in survey coverage versus fishing effort and shifts in fisher targeting behaviour.

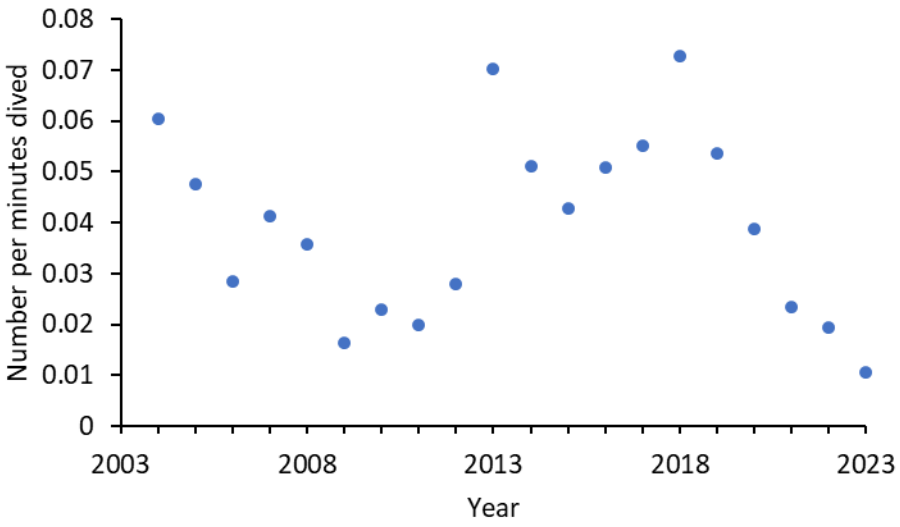


Figure 15. CPUE (number per minutes dived) of Prickly redfish for 2004 to 2023 season from available fishery logbook data

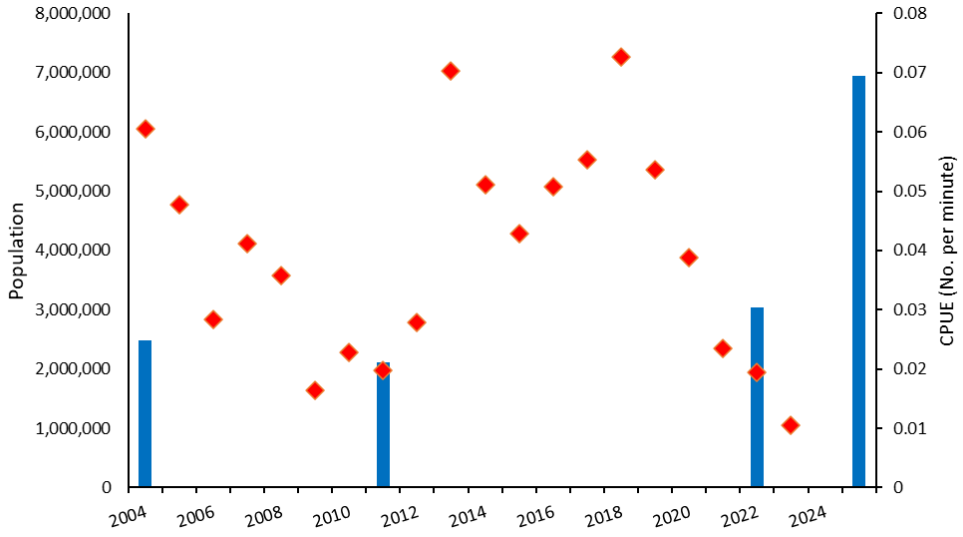


Figure 17. Combined trends in population estimates (blue bars) and catch-per-unit-effort (CPUE; red diamonds) for Prickly redfish on the Mahé Plateau from 2004 to 2025

4.3.4 Stock status

The density, population size, and CPUE data for Prickly Redfish show high variability and considerable uncertainty regarding stock status. Given the generally high observability of this species, the survey results are considered to have relatively high confidence and suggest that the stock is not currently at a depleted level that would warrant a reduction in fishing pressure. However, the divergence between CPUE and survey results highlights the need for further investigation. Additional analysis of fishery-dependent and fishery-independent data may provide a more robust basis for adjusting catch limits, including consideration of whether an increase in catch could be supported without compromising stock sustainability.

4.4 Black teatfish (*Holothuria nobilis*)

4.4.1 Density

The overall density of Black teatfish (*Holothuria nobilis*) at repeated sites on the Mahé Plateau in 2025 was approximately 0.25 individuals per hectare. This represents a slight increase from the 2021 estimate but remains substantially lower than the 2004 density, which exceeded 1.5 individuals per hectare (Figure 18).

At the stratum level, the Mahe reef stratum showed a sharp increase in density in 2025, reaching nearly 10 individuals per hectare. In contrast, the Mahe 0–30 m non-reef and 30–60 m strata showed only modest increases from 2021, and the Mahe >60 m stratum no individual was sighted (Figure 18).

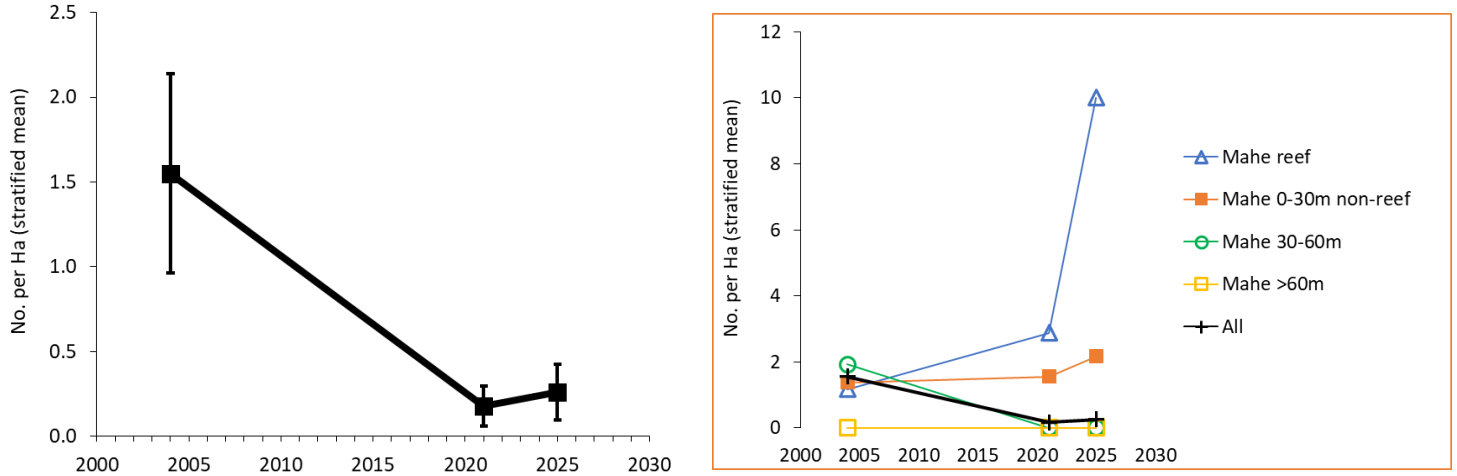


Figure 18. Overall (right) and stratum (left) average (stratified) density (No. per Ha) for Black teatfish (*H. nobilis*) at repeated sites in 2004, 2021 and 2025 (n=117) (error bars = 1 s.e.).

4.4.2 Stock estimate

The population estimate for Black teatfish (*Holothuria nobilis*) on the Mahé Plateau in 2025 was 1,138,389 individuals (± 54.0%, 60% CI), representing an increase from the 2021 estimate of 774,399 individuals, but remaining significantly lower than the 2004 estimate of 6,810,029 individuals. This sustained reduction, exceeding 83% since 2004 (Table 11).

The population in 2025 was primarily distributed within the Mahe 0–30 m non-reef and Mahe reef strata, accounting for 91% and 9% of the estimate, respectively. Notably, the Mahe 30–60 m and >60 m strata,

which collectively supported the majority of the population in 2004 (primarily Mahe 30–60 m), remained unoccupied in both 2021 and 2025 (Figure 19).

Table 11. Stock estimate for Black teatfish (*H. nobilis*) in 2004,2021 and 2025. For each strata and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117).

Strata	Number 2004	60% CI (%)	Number 2021	60% CI (%)	Number 2025	60% CI (%)
Mahe reef	11,934	62.8	29,376	47.4	101,835	86.6
Mahe 0-30m non-reef	656,192	43.5	745,023	59.3	1,036,554	59.2
Mahe 30-60m	6,141,903	35.3	0	0.0	0	0.0
Mahe >60m	0	0.0	0	0.0	0	0.0
All	**6,810,029**	**32.0**	**774,399**	**56.5**	**1,138,389**	**54.0**

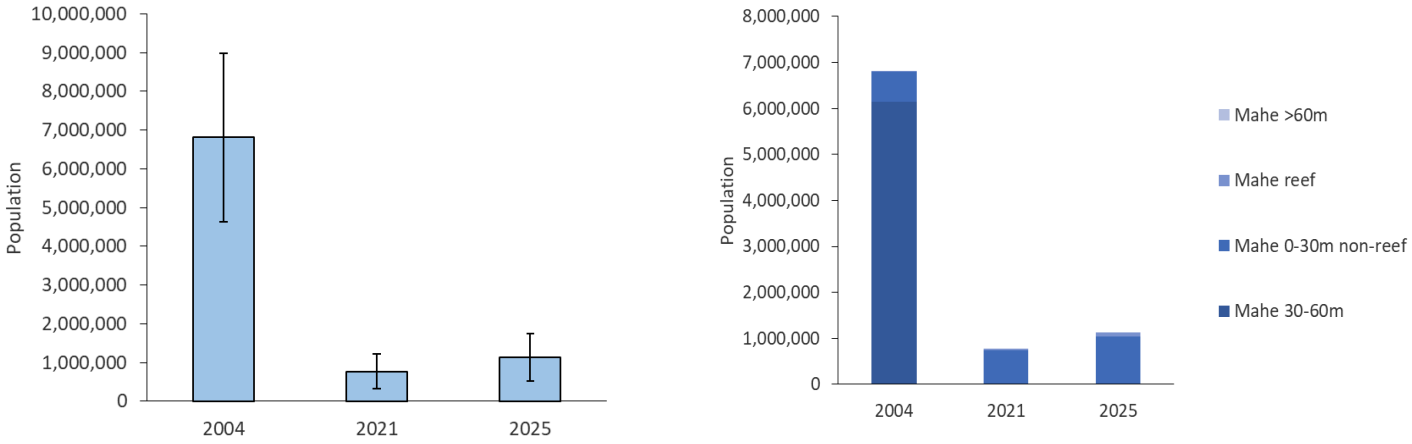


Figure19. Stock estimate (in numbers of individuals) for Black teatfish (*H. nobilis*) for the entire fishery (left) and for each strata (right), for each year surveyed (error bars are 60% CI).

The population estimate from the 2025 survey reflects a continued decline consistent with trends observed in 2011 and 2021 (Figure 20), although the 2011 estimate was derived from a different dataset and fishery area and should be interpreted with caution.

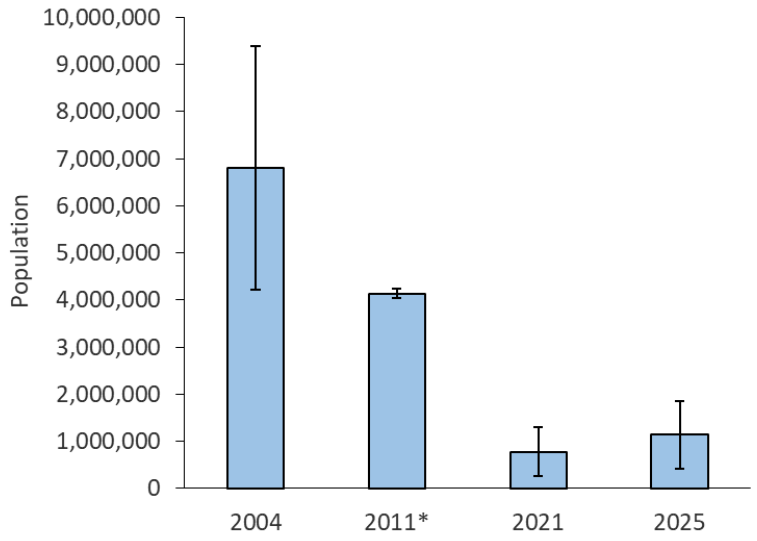


Figure20. Comparison of 2004, 2021 and 2025 population estimates or Black teatfish with that of 2011 (Koike, 2017) *2011 survey refers to a different survey dataset and fishery area.

4.4.3 CPUE

The analysis of CPUE data from 2004–2019 from fishery logbooks shows a sharp decline in Black teatfish catch rates after 2004, with near-zero values recorded from 2008 onwards, consistent with severe stock depletion (Figure 21 and Figure 22).The CPUE modelling from MRAG (2017) closely matched the trajectory of the 2004 and 2021 fishery-independent survey results, including a potential recovery phase following the cessation of fishing (Figure 24).The 2025 survey results, showing an increase in population size to ~1.5 million individuals from ~1.0 million in 2021, are consistent with the modelled recovery trend, although biomass remains far below 2004 levels (Figure 19 left). While the observed 2025 population aligns with the model's predicted direction of recovery under reduced fishing pressure, the magnitude of recovery appears somewhat slower than the model's optimistic scenario (Figure 23).

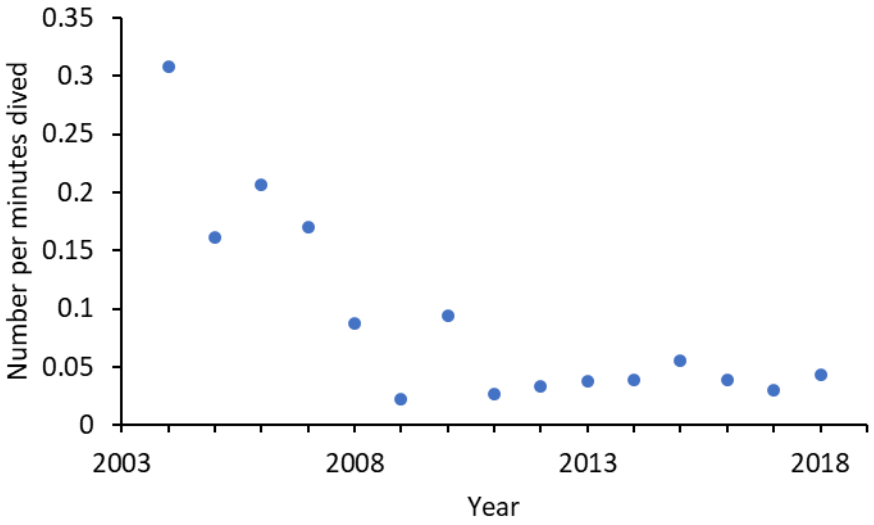


Figure 21. CPUE (number per minutes dived) of Black teatfish for 2004 to 2019 season from available fishery logbook data

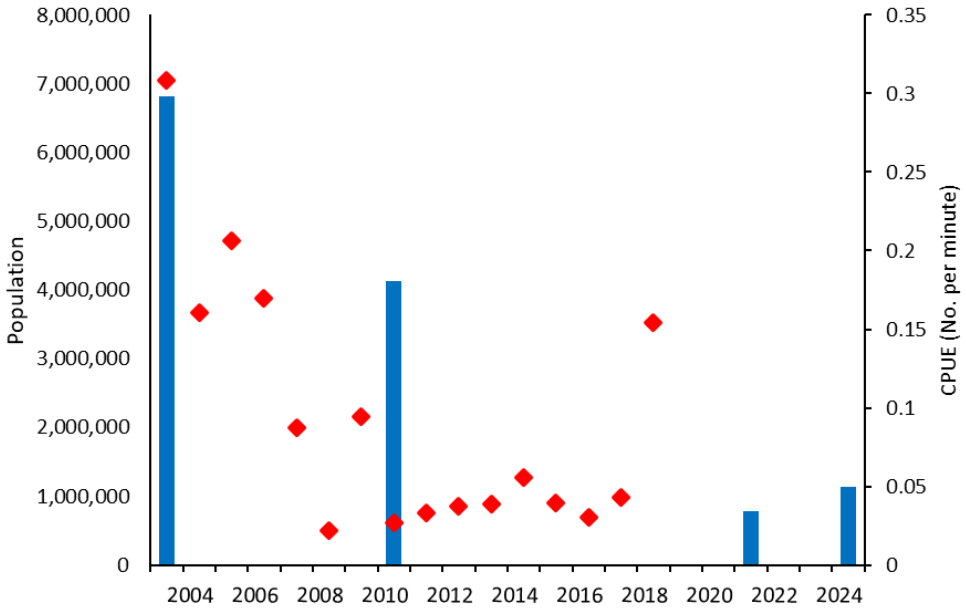


Figure 22. Combined trends in population estimates (blue bars) and catch-per-unit-effort (CPUE; red diamonds) for Black teatfish on the Mahé Plateau from 2004 to 2024

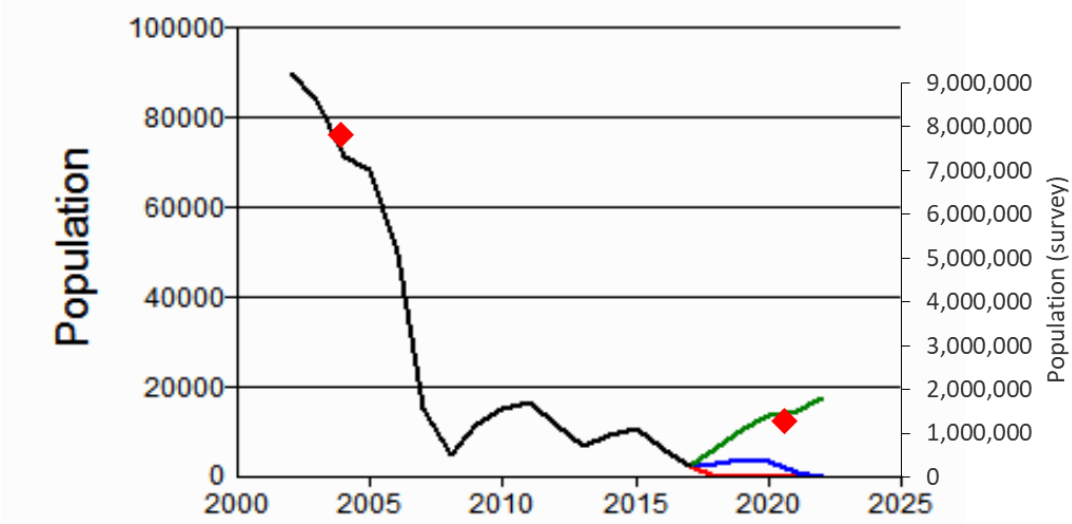


Figure 23. Comparison of a stock reduction model for Black teatfish for statistical area 4 based on logbook data to 2017, and projections of stock recovery under 3 scenarios for future catches (green line represents catch reduction (MRAG, 2017); with the results of the 2004 ,2021 survey for the entire study area (axis different scales)

4.4.4 Stock status

The density and population size data for Black teatfish indicates that this species is still in a depleted state, even though fishery effort on this species ceased in 2018. However, there are indications that recovery is occurring, with higher densities than when the population reached its lowest estimate in 2017.

This population should be monitored with the view of a possible reopening once the stock reaches predetermined levels (at least to those levels consistent with B_{MSY} – MRAG, 2017).

4.5 Golden Sandfish (*Holothuria lessoni*)

4.5.1 Density

The results show that Golden Sandfish (*H. lessoni*) was only recorded in 2004, with a density of 0.39 individuals per hectare on the Mahé reef, while no individuals were found in any other strata. By 2021, the density had dropped to zero across all strata, representing a complete loss of the species from the survey sites. This absence persisted in 2025, confirming the difficulty in assessing the species. Overall, the data and graphs highlight that the Mahé reef was the only habitat where the species occurred historically. (Figure 24).

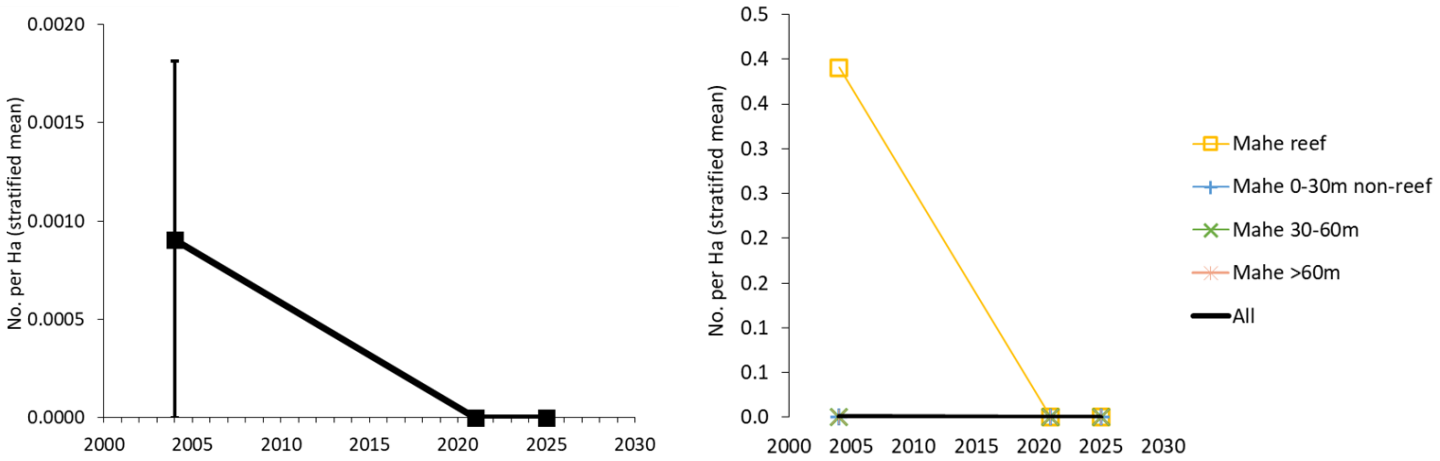


Figure 24. Overall (right) and stratum (left) average (stratified) density (No. per Ha) for Golden Sandfish (*H.lessoni*) at repeated sites in 2004, 2021 and 2025 (n=117) (error bars = 1 s.e.).

4.5.2 Stock estimate

The population estimate in 2004 was 3,978 individuals (± 84.3% CI), all concentrated on the Mahé reef, with no individuals recorded in other strata. In 2021 and 2025, the population could not be estimated and therefore the population estimates remains uncertain. (Table 12, Figure 25).

Table 12. Stock estimate for Golden sandfish (*H. lessoni*) in 2004,2021 and 2025. For each strata and year surveyed, the population stock estimate in numbers and the 60% CI (as a % of the population estimate) (n=117).

Strata	Number 2004	60% CI (%)	Number 2021	60% CI (%)	Number 2025	60% CI (%)
Mahe reef	0	0.0	0	0.0	0	0.0
Mahe 0-30m non-reef	3,978	85.3	0	0.0	0	0.0
Mahe 30-60m	0	0.0	0	0.0	0	0.0
Mahe >60m	0	0.0	0	0.0	0	0.0
All	**3,978**	**84.3**	**0**	**0.0**	**0**	**0.0**

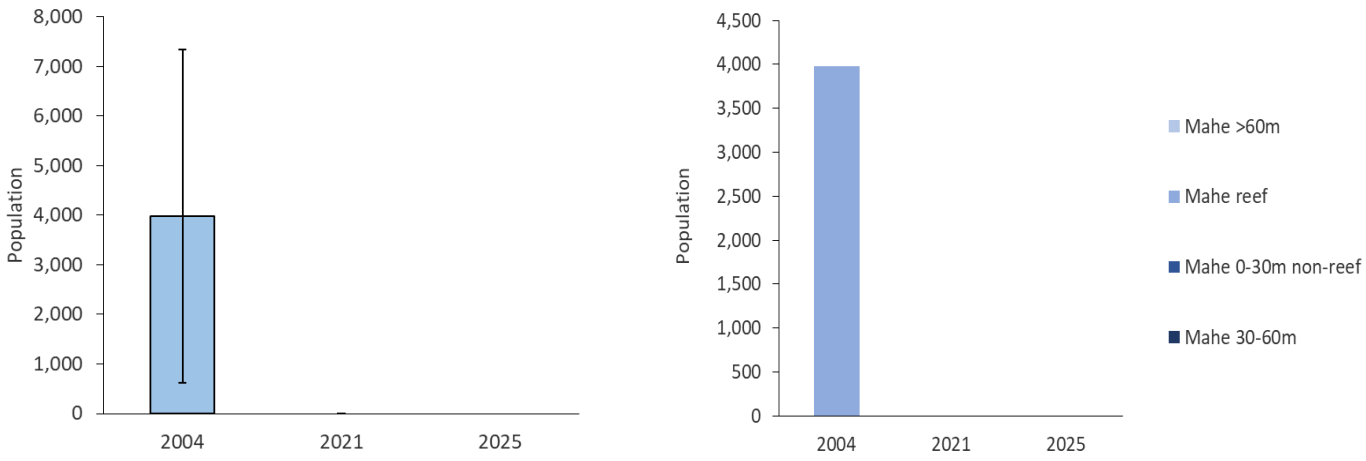


Figure 25. Stock estimate (in numbers of individuals) for Golden sandfish (*H.lessoni*) for the entire fishery (left) and for each strata (right), for each year surveyed (error bars are 60% CI).

4.5.3 CPUE

The analysis of CPUE data shows that from 2004 to 2012, values for sandfish remained close to zero, indicating very low catch rates. In 2013, CPUE spiked sharply, reaching the highest recorded value of about 0.058 per minute. Between 2014 and 2018, CPUE stabilized at moderate levels, fluctuating between approximately 0.033 and 0.041 per minute. From 2018 to 2021, the species was banned from the fishery, resulting in no catches during this period. After its reintroduction in 2021, catch rates remained low at around 0.011–0.012 per minute. It is important to note that up until 2018, CPUE reflects mixed sandfish species, whereas from 2021 onward it represents only Golden sandfish (*H. lessoni*) (Figure 26).

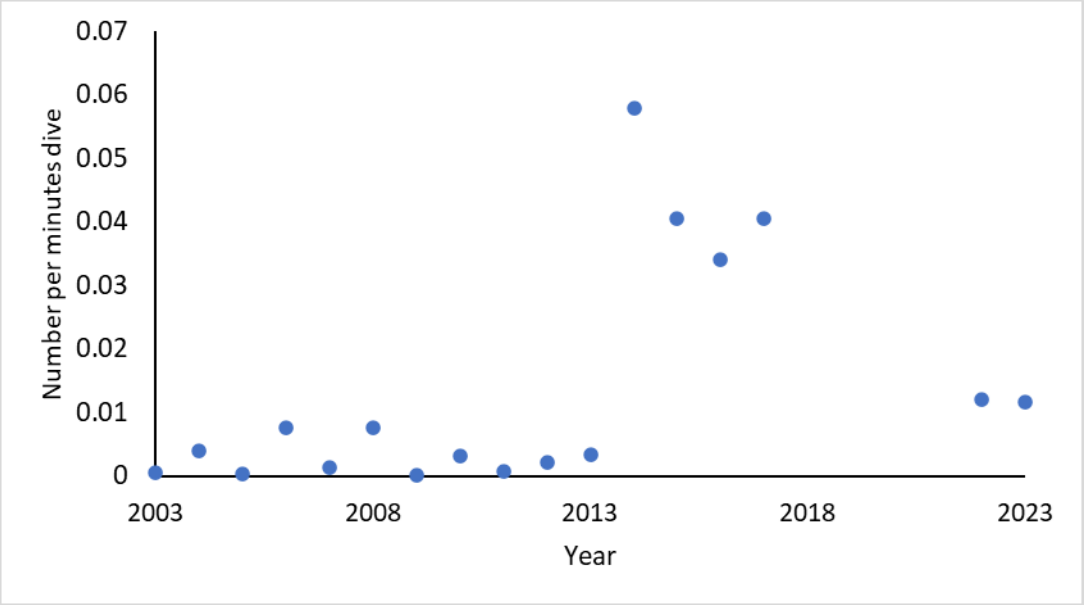


Figure 26. CPUE (number per minute dived). Values before 2021 represent mixed Sandfish species, while from 2021 onward they represent only Golden sandfish (*H. lessoni*).

4.5.4 Stock status

Golden Sandfish (*H. lessoni*) remain at extremely low abundance on the Mahé Plateau. Although reintroduced and currently fished, surveys indicate very low densities and population estimates. CPUE data show high variability, with occasional peaks but generally low values in recent years. The species' cryptic behavior, as it often remains buried in sediment, makes detection difficult during surveys and may lead to underestimation. Additionally, Golden Sandfish is not among the most common species landed, reducing their prominence in the fishery. Overall, the stock status remains uncertain.

4.6 Other species

4.6.1 Density

Density for remaining species at repeated sites in the survey are shown in Figure 27, due to identification issues*, Actinopyga miliaris*, *Actinopyga palauensis* and *Actinopyga echinites* are combined as "Spork"; and *Bohadschia vitiensis*, *Bohadschia atra* and *Bohadschia subrubra* are combined as "Lakol".

Elephant trunkfish (*Holothuria fuscopunctata*) showed a progressive decline across survey years, with densities dropping from ~1.8 individuals/ha in 2004 to ~1.2 individuals/ha in 2021, and further down to ~0.24 individuals/ha in 2025 (Figure 27). The 2025 population estimate was 1,036,554 (± 58.4%, 60% CI) compared to 5,234,203(± 71.9%, 60% CI) and 7,838,550 (± 46.2%, 60% CI) in 2021 and 2004 respectively (Figure 28).

Lollyfish (*Holothuria atra*) densities (~3.8/ha) remained lower than 2004 (~5.6/ha) but higher than 2021 (~2.0/ha) (Figure 27). The population estimate was 16,851,741 (± 22.4%, 60% CI) compared to 9,476,443 (± 31.8%, 60% CI) in 2021 and 24,583,137 (± 23.3%, 60% CI) in 2004 (Figure 28).

Red/Yellow surffish (*Actinopyga mauritiana* complex) remained at extremely low densities, declining from ~0.13/ha in 2004 to ~0.23/ha in 2021, and further to ~0.01/ha in 2025 (Figure 27). The population estimate was 50,918 (± 61.1%, 60% CI) in 2025, 1,019,195 (± 45.4%, 60% CI) in 2021 and 587,904 (± 54.6%, 60% CI) in 2004 (Figure 28).

Spork declined between 2004 and 2021, from ~3.8/ha in 2004 to ~2.7/ha in 2021 but increased to ~6.4/ha in 2025 (Figure 27). The population for 2025 was 28,030,817 (± 74.4%, 60% CI) individuals which is an increase from the 11,963,782 (± 36.8%, 60% CI) in 2021 and 16,824,130 (± 27.6%, 60% CI) in 2004 (Figure 28).

Lakol (*Bohadschia spp.*) increased to ~1.3/ha in 2025 after being much lower in 2021 (~0.6/ha), but below the 2004 densities (~4.0/ha) (Figure 27). The population estimate was 5,811,231 (± 65.4%, 60% CI) in 2025 which is higher than the 2,703,785 (± 42.3%, 60% CI) estimated in 2021 but lower than the 17,374,667 (± 20.6%, 60% CI) estimated in 2004 (Figure 28).

Flowerfish (*Pearsonothuria graeffei*) density decrease between 2021 and 2025, reaching ~0.15/ha in 2025 compared to ~0.25/ha in 2004 and ~1.13/ha in 2021 (Figure 27). The population estimate in 2025 was 637,085 (± 69.3%, 60% CI), with 4,971,173 (± 61.5%, 60% CI) estimated is 2021 and 1,080,311 (±63.6%, 60%CI) estimated in 2004 (Figure 28).

Curryfish (*Stichopus herrmanni*) densities declined from ~1.0/ha in 2004 to ~0.58/ha in 2021 and ~0.12/ha in 2025 (Figure 27). The population estimate in 2025 was 535,249 (± 81.8%, 60% CI), with 2,527,282 (± 56.0%, 60% CI) estimated is 2021 and 4,573,714 (± 54.9%, 60% CI) estimated in 2004 (Figure 28).

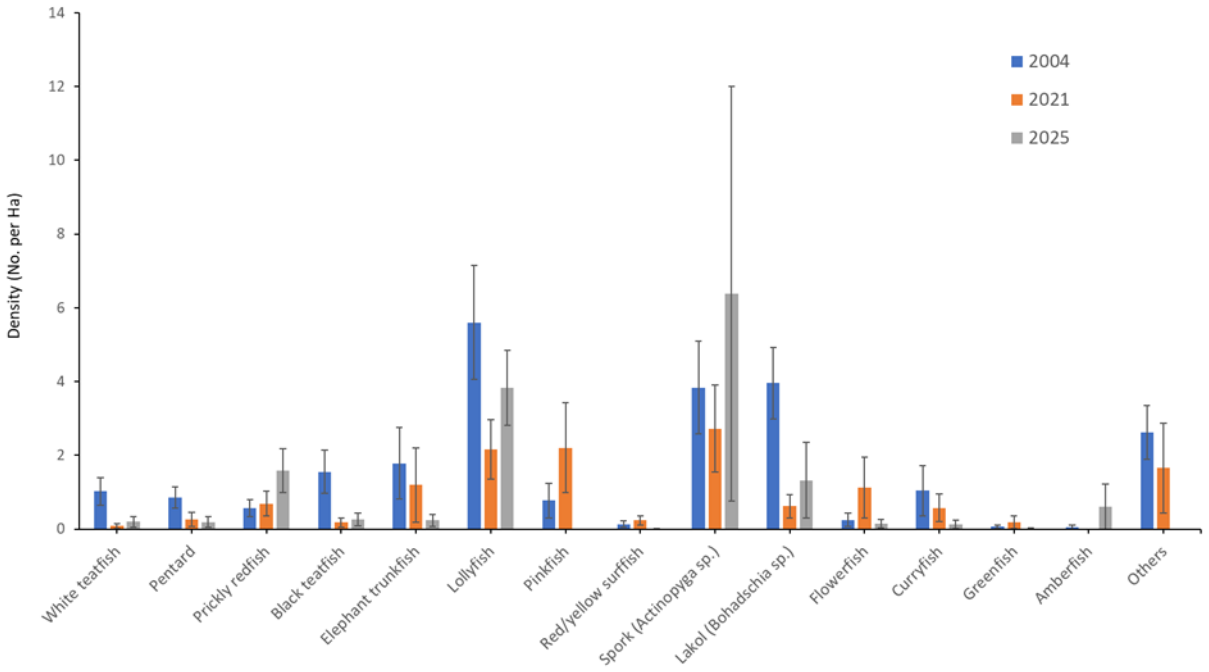


Figure27. Overall average (stratified) density (No. per Ha) for non-priority species at repeated sites in 2004,2021 and 2025 (n=117) (error bars = 1 s.e.).

4.6.2 Stock estimate

The overall sea cucumber population estimate on the Mahé Plateau in 2025 was approximately 65,494,395 individuals (±32.5%, CI 60%), showing a modest increase from the 2021 estimate of 60,951,627 (± 22.7%, 60% CI) individuals, but still ~38% lower than the 2004 estimate of 105,768,910 (± 12.1%, 60% CI) individuals ($P < 0.05$) (Figure 28 and Figure 29).

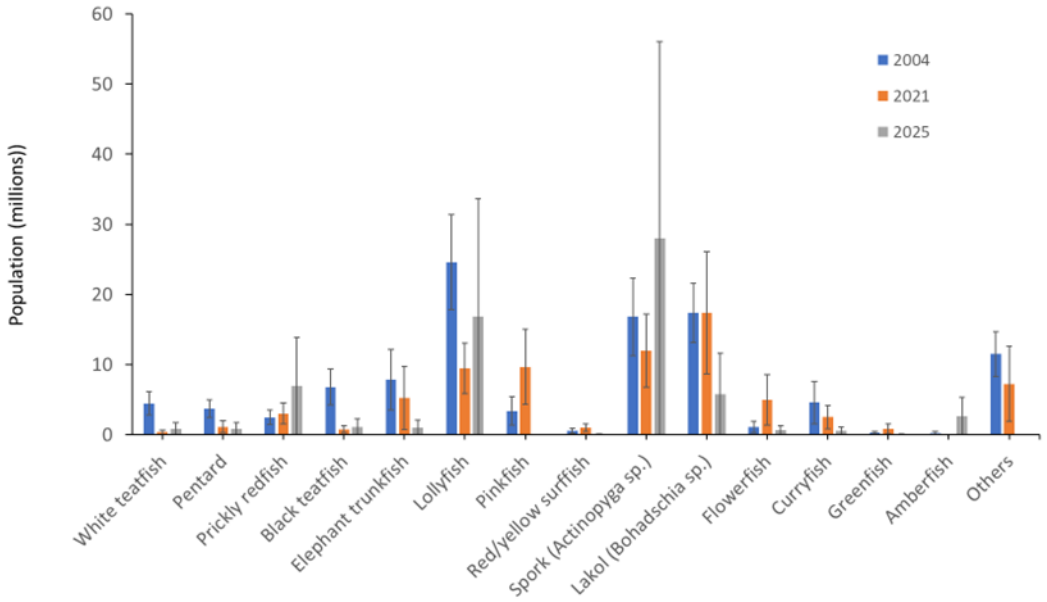


Figure 28. Stock estimates (in numbers of individuals) for all species for the entire fishery.

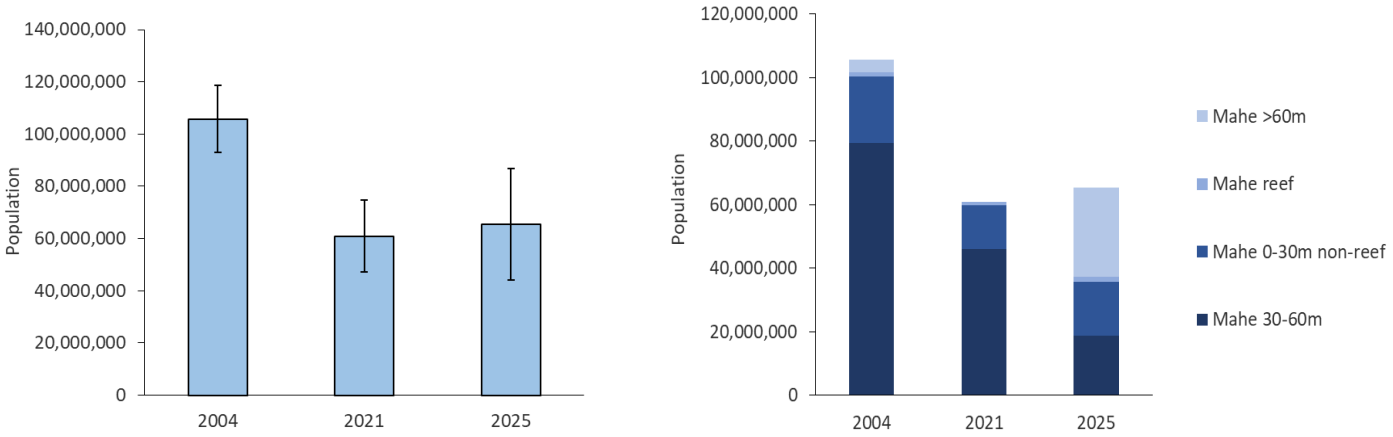


Figure 29. Stock estimate (in numbers of individuals) for all sea cucumbers for the entire fishery (left) and for each strata (right), for each year surveyed (error bars are 1 s.e.).

4.6.3 Stock status

The survey results show that Elephant trunkfish, Curryfish, Flowerfish, and Greenfish have continued to decline over time and remain at very low levels in 2025. Red/Yellow surfish has remained extremely scarce across all survey years, showing little sign of recovery. Lollyfish and Lakol demonstrated some partial recovery in 2025, but their populations are still well below the levels recorded in 2004. In contrast, Spork exhibited a strong rebound in 2025, surpassing its previous population estimates. Sandfish also reappeared in 2025, although only at very low levels, and its overall stock status remains uncertain due to its cryptic nature and tendency to remain buried, making it difficult to assess accurately.

T-test analysis

A t-test analysis comparing the percentage changes in density between 2021, and 2025 for priority species across 115 repeated survey sites was undertaken. The results showed slight changes in the density for Pentard, Black teatfish, White teatfish and all sea cucumbers between the 2021 and 2025 surveys. However, since the 90% confidence intervals includes zero, these changes are not statistically significant (Figure30). In contrast, Prickly redfish, the 90% confidence interval exclude zero, indicating that the observed increase in density is statistically significant.

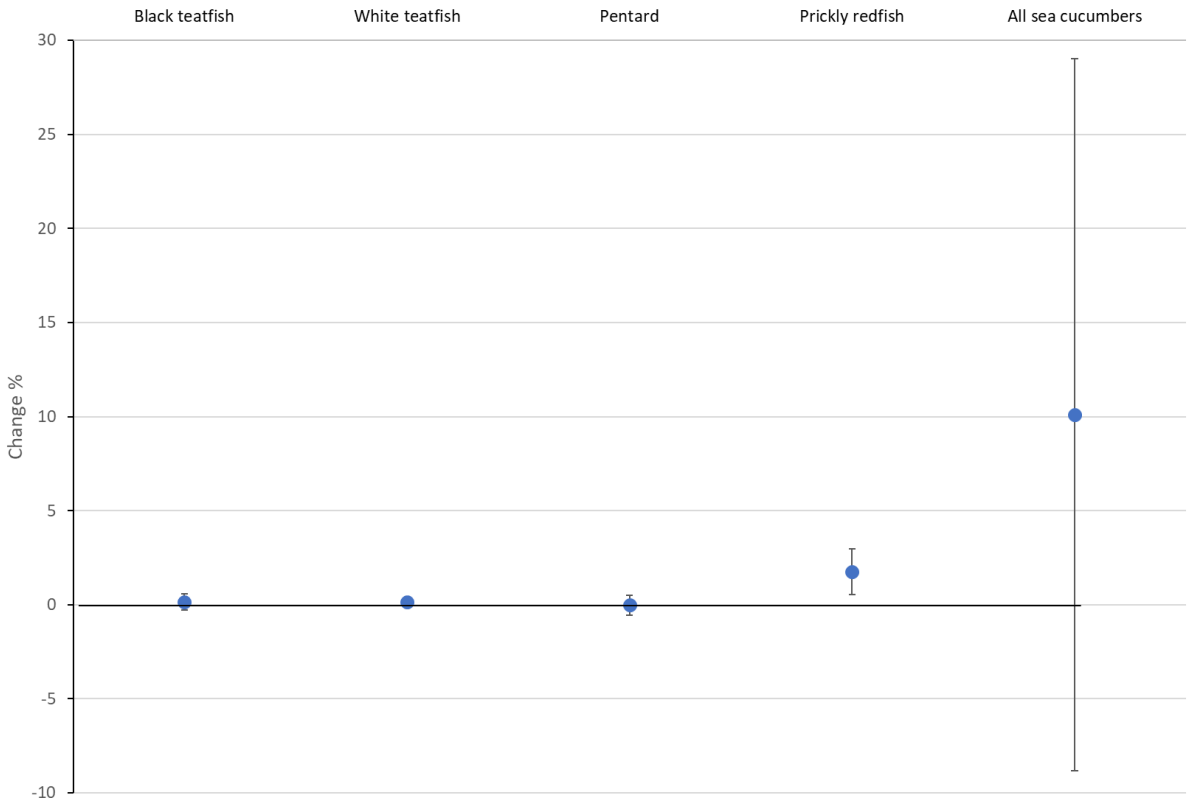


Figure 30. Percentage change in density between 2021and 2025 at 115 repeated survey sites across the Mahe Plateau, sea cucumber fishery for priority species. The change statistics include 90% confidence intervals to determine significance at the 0.05 level (one-tailed test).

5 Discussion

Both survey data (2004 and 2021) and fishery-dependent logbook data was used to assess the size and stock status of the current fishery species, as well as the observed recovery in White teatfish and Black teatfish populations. The 2025 survey results indicate mixed trends across all species on the Mahé Plateau However, stock status for most species remains uncertain, partly due to challenges in species identification, species behaviour and natural variability in sea cucumber counts.

Despite these challenges, the recent survey and other research efforts over the years (Aumeeruddy et al., 2005; MRAG, 2012; Koike, 2017; MRAG, 2017; Skewes, 2022) has provided important information on the status of the stock and recent stock trends, especially for the current target species, Pentard and Prickly redfish and previously targeted species, White teatfish and Black teatfish. These have been used to make management recommendations for each species.

Based on the management recommendations from the 2021-2022 survey report, there remains a need to implement a harvest strategy for the sea cucumber fishery, which would include the following components:

i. A shared vision and objectives (stock, environmental, economic and social) for the fishery for all stakeholders
ii. Indicators (how will the fishery performance be measured?)
iii. Reference levels (what are the target and limit points for the indicators?)
iv. Harvest Control Rules (what are the agreed actions that will be taken if a reference level is reached?)

A harvest strategy will provide the opportunity for the co-design of monitoring and response frameworks that is critical to get industry engaged and united. It would also promote a more “holistic” approach to the fishery.

A rotational harvest strategy has been shown to be a useful management strategy for reducing risk and increasing productivity in the Queensland east coast sea cucumber fishery (Skewes et al., 2014), and this could be an approach worth investigating for the Seychelles sea cucumber fishery. In the Queensland example, fishing is rotated throughout 154 zones on a three-yearly cycle; however, modelling shows that benefits accrue up to a 6-year cycle (Plaganyi et al., 2015). Implementing such a strategy would likely be challenging in the Seychelles with the number of operators and compliance challenges, however, this could be investigated.

A key approach to lower the risk to fisheries generally is to implement a comprehensive and representative (e.g. by fishery zone, depth zone, habitat type) system of closed areas. This provides areas where populations can remain at near natural densities to ensure a consistent supply of fishery recruits. Recent research suggests that a good target would be to protect 30% of each fishery zone as no-take areas (O'Leary et al., 2016).

5.1 Recommendations:

1. Undertake a new survey to assess the stock after 5 years
2. Maintain closure of White teatfish and Black teatfish and monitor recovery after next survey
3. Reduce Flower teatfish TAC by 15%.
4. Maintain current TAC for Prickly redfish
5. Consider the possibility for partial spatial closure. Skewes (2021) recommended the implementation of a comprehensive and representative system of closed areas in deeper non-reef areas throughout the fishery area (target 30% of each fishery area).
6. Two possibilities for golden sandfish (*H.lessoni*) and sandfish (*H.scabra*) either close golden sandfish from the fishery and sandfish remains closed or keep golden sandfish with the current quota and add sandfish as well to the fishery with quota. Identify alternative harvesting methods
7. Undertake a targeted survey for sandfish by the next 3 years
8. Identify alternative harvesting and processing technology for other species not currently being targeted

Table 13: Table of recommendations

Scientific Name	Common Name	Local name	Status	Management recommendation
Holothuria fuscogilva	White teatfish	Kokosye blan	Heavily depleted but showing signs of recovery	Maintain closure monitor recovery after 5 years
Holothuria sp. Type "Pentard"	Flower teatfish	Pentard	Overexploited	Reduced TAC by 15%
Thelenota ananas	Prickly redfish	Sanpye	Uncertain but possibly under-exploited	Maintain current TAC and carry out further stock assessment modelling

Holothuria nobilis	Black teatfish	Kokosye nwanr	Depleted but showing some signs of recovery	Maintain closure monitor recovery after 5 years
Holothuria lessoni	Golden sandfish	Kokonm	Uncertain	Either remove from list of fishery target or maintain the current TAC. Carry out targeted survey after 3 years. Identify harvesting alternatives
Holothuria scabra	Sandfish	Kokonm	Uncertain	Keep closed or allow with TAC Carry out targeted surveys after 3 years. Identify harvesting alternatives
Holothuria fuscopunctata	Elephant trunkfish	Safran	Uncertain but probably near virgin biomass	Allow TAC <2% pop estimate Give recommendation on other alternative for processing
Holothuria atra	Lollyfish	Spork, Spork koray, Disan	Likely under-exploited	Allow TAC <2% pop estimate Give recommendation on other alternative for processing
Holothuria edulis	Pinkfish		Uncertain	Allow TAC <2% pop estimate

				Give recommendation on other alternative for processing
Actinopyga mauritiana (complex)	Surf redfish	Red surf, Yellow surf, Brisan	Uncertain	Allow small experimental quota, collect detailed fishery data and carry out further stock assessment modelling Give recommendation on other alternative for processing
Actinopyga miliaris	Hairy blackfish	Spork	Likely under-exploited	As above
Actinopyga echinites	Deepwater redfish	Spork	Uncertain	As above
Actinopyga palauensis	Deepwater blackfish	Spork	Likely under-exploited	As above
Bohadschia vitiensis	Brown sandfish	Lakol	Likely underestimated	As above
Bohadschia atra	Tigerfish	Lakol	Uncertain. Likely underestimated due to burrowing	As above
Bohadschia subrubra	White belly	Lakol	Uncertain. Likely underestimated due to burrowing	As above
Pearsonothuria graeffei	Flowerfish		Uncertain	Unlikely to be commercially viable in Seychelles
Thelenota anax	Amberfish		Likely at near virgin levels	Unlikely to be commercially viable in Seychelles

Stichopus herrmanni	Curryfish		Uncertain, likely at near virgin levels	Allow TAC <2% pop estimate. Requires specialist processing
Stichopus chloronotus	Greenfish		Uncertain.Likely at near virgin levels	Allow TAC <2% pop estimate. Requires specialist processing

References

Aumeeruddy, R., and R. Payet. 2004. Management of the Seychelles sea cucumber fishery: status and prospects. Rome (Italy) FAO. http://www.fao.org/docrep/007/y5501e/y5501e00.htm.

Aumeeruddy, R., T. Skewes, J. Dorizo, F. Carocci, H. A. de Lion, and M. Cedras. 2005. Resource assessment and management of the Seychelles sea cucumber fishery. Pages 1–37.

Aumeeruddy, R., and C. Conand. 2008. Seychelles: a hotspot of sea cucumber fisheries in Africa and the Indian Ocean region. Sea Cucumbers: A Global Review of Fisheries and trade. Fisheries and Aquaculture Technical Paper 516:195–209.

Becker, J. J., Sandwell, D. T., Smith, W. H. F., Braud, J., Binder, B., Depner, J., & Weatherall, P. (2009). Global bathymetry and elevation data at 30 arc seconds resolution: SRTM30_PLUS. Marine Geodesy, 32(4), 355-371.

Cahuzac, S., C. Conand, R. Govinden, A. Ebrahim, S. Marie, and M. Léopold. 2019. Size at sexual maturity of the Flower teatfish Holothuria (Microthele) sp. in the Seychelles. Beche-de-Mer information bulletin:8.

Cariglia, N., S. K. Wilson, N. A. J. Graham, R. Fisher, J. Robinson, R. Aumeeruddy, R. Quatre, and N. V. C. Polunin. 2013. Sea cucumbers in the Seychelles: effects of marine protected areas on high-value species. Aquatic Conservation: Marine and Freshwater Ecosystems 23:418–428.

Cochran, W. G. (1977). Sampling techniques. 3rd ed. John Wiley & Sons, New York

Koike, H. 2017. Fishery ecology of Seychelles' sea cucumber fishery. Doctor of philosophy in Zoology, University of Hawaii, Manoa. https://scholarspace.manoa.hawaii.edu/bitstream/10125/62829/2017-05-phd-koike.pdf.

Leopold, M. 2017. Estimating sea cucumber resource abundance in the Seychelles using spatially explicit fishery-dependant data. https://symposium.wiomsa.org/wp-content/uploads/2017/10/Leopold-M_Estimating-sea-cucumber-resource-abundance-in-the-Seychelles-using-spatially.pdf.

Leopold, M. 2019. Estimating sea cucumber resource abundance in Seychelles using fishery-dependent data. https://symposium.wiomsa.org/wp-content/uploads/2017/10/Leopold-M_Estimating-sea-cucumber-resource-abundance-in-the-Seychelles-using-spatially.pdf.

MRAG. 2012. Stock Assessment for the Sea Cucumber Fishery of the Seychelles. Page 75. MRAG Ltd, London.

MRAG. 2017. Assessment of Seychelles' Sea Cucumber Fishery. Page 58. MRAG Ltd, London.

MSC. 2018. MSC Fisheries Standard and Guidance v2.01.

Murphy, N., E. Plaganyi, S. Edgar, K. Salee, and T. Skewes. 2021. Stock survey of sea cucumbers in East Torres Strait. Page 138. Final report., CSIRO, Australia.

Murphy, N., M. Fischer, and T. Skewes. 2019. Torres Strait Beche-de-mer (Sea cucumber) species ID guide. Australian Fisheries Management Authority :60.

Muthiga, N.A., and C. Conand. 2014. Sea cucumbers in the western Indian Ocean: Improving management of an important but poorly understood resource. WIOMSA Book Series No. 13.:84.

O'Leary, B. C., M. Winther-Janson, J. M. Bainbridge, J. Aitken, J. P. Hawkins, and C. M. Roberts. 2016. Effective Coverage Targets for Ocean Protection. Conservation Letters 9:398–404.

Oury, N., M. Léopold, and H. Magalon. 2019. Isolation and characterization of microsatellite loci from three widespread tropical sea cucumbers of the genus Holothuria (Echinodermata, Holothuroidea), and cross-amplification among them. Molecular Biology Reports 46:3501–3510.

Plagányi, É. E., T. Skewes, N. Murphy, R. Pascual, and M. Fischer. 2015. Crop rotations in the sea: Increasing returns and reducing risk of collapse in sea cucumber fisheries. Proceedings of the National Academy of Sciences 112:6760–6765.

Purcell, S. W., P. Ngaluafe, G. Wang, and W. Lalavanua. 2017. Market value of flower teatfish ("Pentard"): A highly exploited Indian Ocean holothuroid. Beche-de-mer Bulletin:5.

Purcell, S.W., Y. Samyn, and C. Conand. 2012. Commercially important Sea Cucumbers of the World. FAO, Rome.

SFA. 2021. Economic Impact of the Seychelles Sea Cucumber Fishery and Industry. Page 37. Seychelles Fishing Authority Fisheries Economics. https://www.sfa.sc/index.php/e-library/fisheries-report?task=download.send&id=131&catid=21&m=0.

Skewes, T.D., 2022. Seychelles sea cucumber survey. Draft Final Report for the Seychelles Fishing Authority.

Skewes, T.D., and R. Aumeeruddy. 2006. Seychelles sea cucumber species guide.

Skewes, T., E. Plaganyi, N. Murphy, R. Pascual, and M. Fischer. 2014. Evaluating rotational harvest strategies for sea cucumber fisheries. Fisheries Research and Development Corporation, Brisbane.

Uthicke, S., D. Welch, and J.A.H. Benzie. 2004. Slow Growth and Lack of Recovery in Overfished Holothurians on the Great Barrier Reef: Evidence from DNA Fingerprints and Repeated Large-Scale Surveys. Conservation Biology 18:1395–1404.

Appendix A Timing issues

Reasons to start survey at same time:

- Fisheries that target short lived species where there is a high exploitation rate
- Fisheries where fishing activity may influence stock behaviour
- Where the assessment of status relies on depletion of some kind (i.e. depletion experiments)
- Where the results of the survey could be used to manage the fishing activity later in the season.

Reasons to maintain flexibility:

- Logistical considerations
- Getting industry participation
- Choosing the best weather window
    - Relate issues such as:
    - Safety
    - Efficiency
    - Morale
    - Risk

Table 14. Average catches for the period 2009-2017 and population estimates from surveys in 2004 and 2011-12.

Species	Average catch 2009 -2017	2004 Survey	2011-12 Survey
White teatfish	0.076M	3.045M	2.262M
Pentard/Flower teatfish	0.252M	2.334M	1.402M
Prickly redfish	0.043M	2.529M	2.107M

Appendix B Depth Analysis

The one shown below, Global Multi-Resolution Topography (GMRT) dataset is one of the best available.

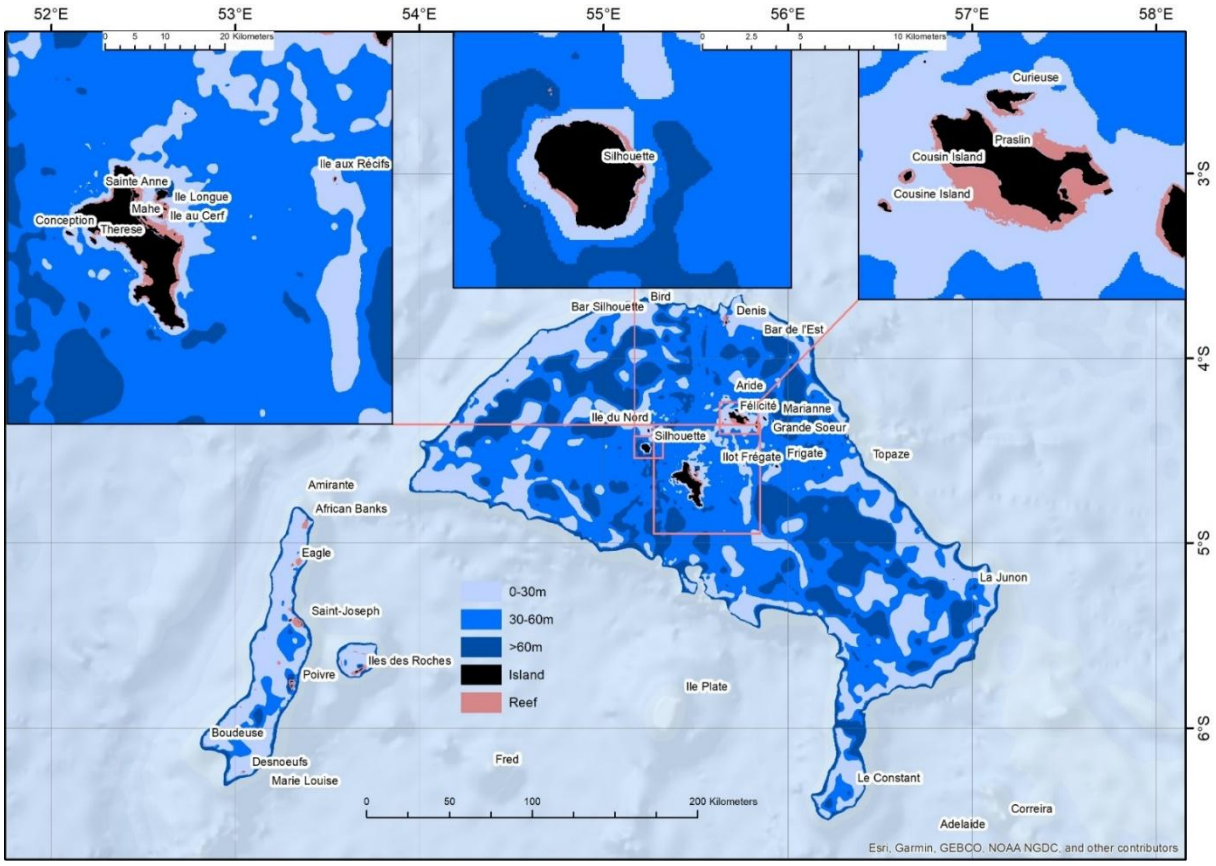


Figure 31. GMRT V3.9 depth map from NOAA.

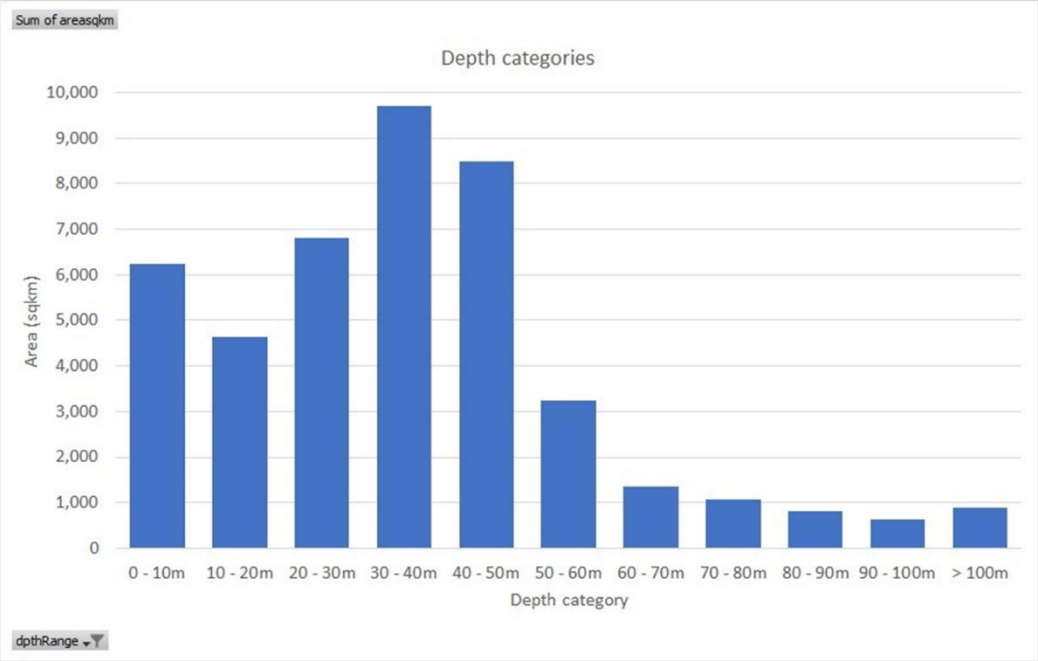


Figure32. Area of depth categories from GMRT.

Depth sounder data collected intermittently during the 2004 survey was regressed against GEBCO2021 and Global Multi-Resolution Topography Data Synthesis (GMRT v3.9) (Figure 33., Figure 34.). The spatial resolution of the GEBCO2021 is 15 arc-second interval grid (approximately 500 m) and the spatial resolution of the GMRT v3.9 is approximately 120 m.

The purpose of the analysis was to test the bathymetry data to determine if it was suitable for creating depth categories 0-30, 30 – 60 and >60m. Area estimates for the depth categories are used for estimating standing stock.

To further explore the relationship between field depth data and publicly available data an analysis was done regressing field depth data against GMRT and GEBCO 2021. Bathymetry of Mahe and Amirantes plateaus, continuous depth profiling during the 2004 survey and stored as log files, was analysed.

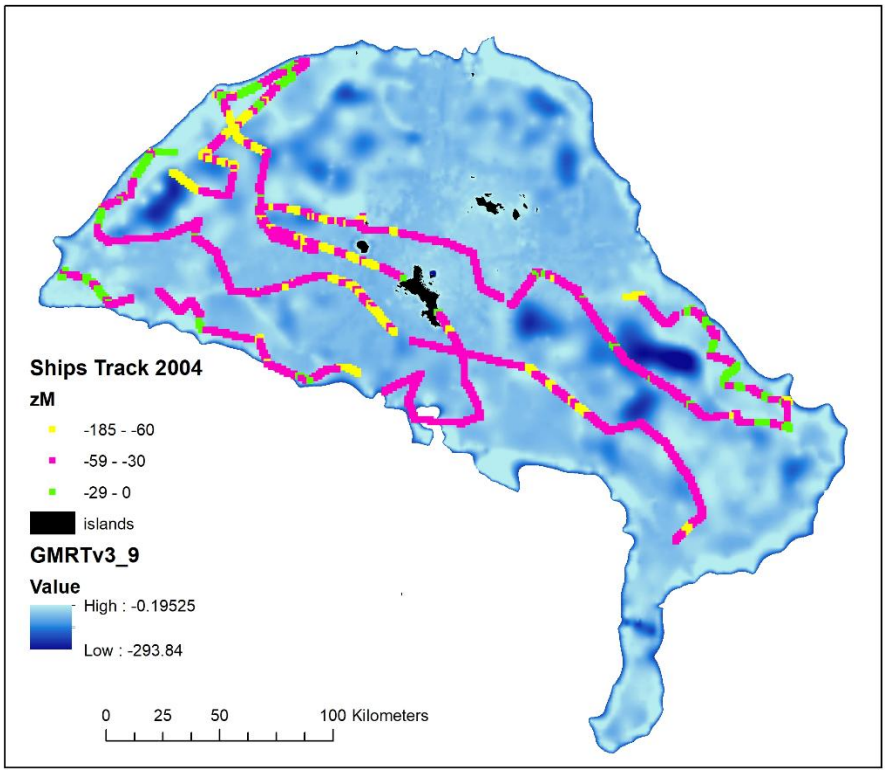


Figure 33. Ships track depth soundings for 2004 survey overlain on GMRT v3.9 bathymetry. Note that Amirante plateau is not shown

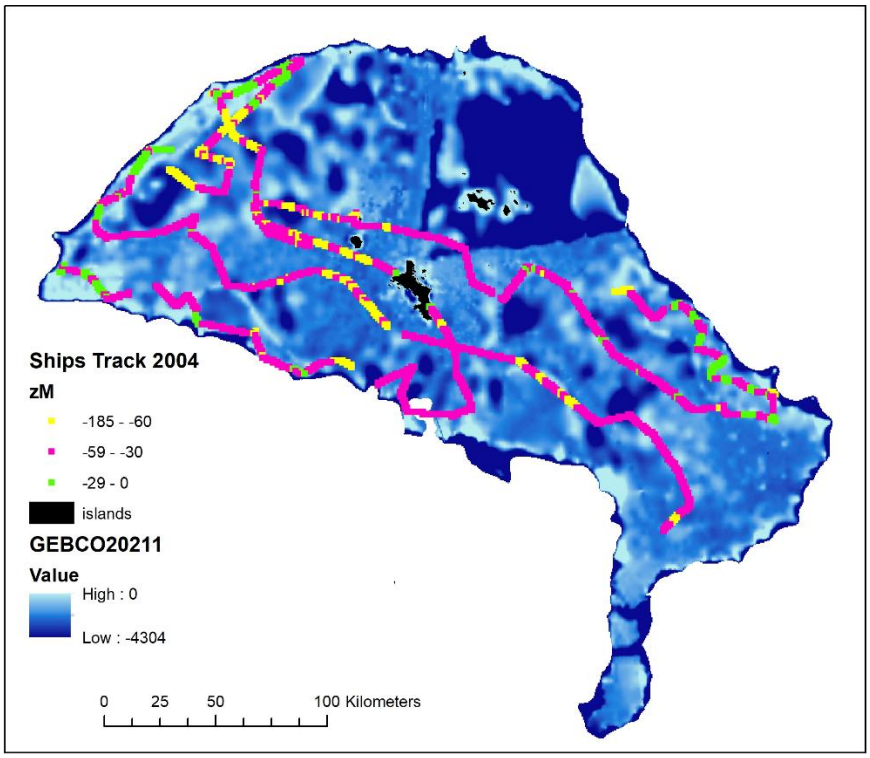


Figure 34. Ships track depth soundings for 2004 survey overlain on GEBCO 2021 bathymetry

The regression of GEBCO 2021 depths against intermittent depth soundings from the 2004 survey indicated that there was a poor fit with an R^2 of 0.14 (Figure x).

Similarly, the regression of GMRT v3.9 depths against intermittent depth soundings from the 2004 survey indicated that there was a poor fit with an R^2 of 0.14

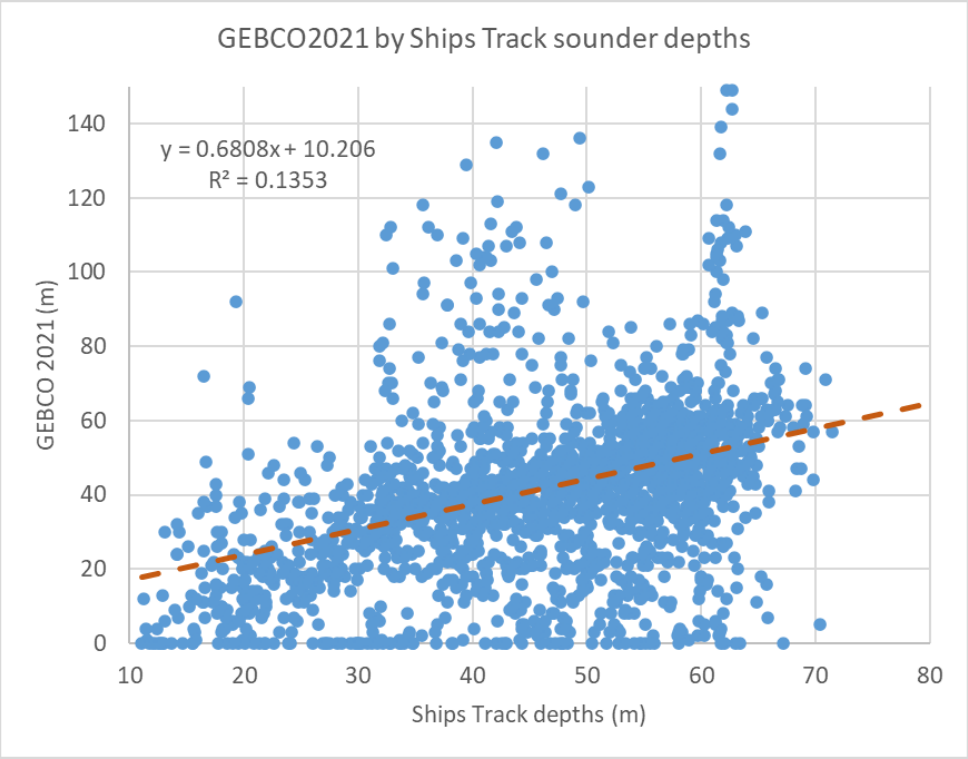


Figure 35. Regression analysis of GEBCO 2021 bathymetry against 2004 survey ship tracks depth soundings

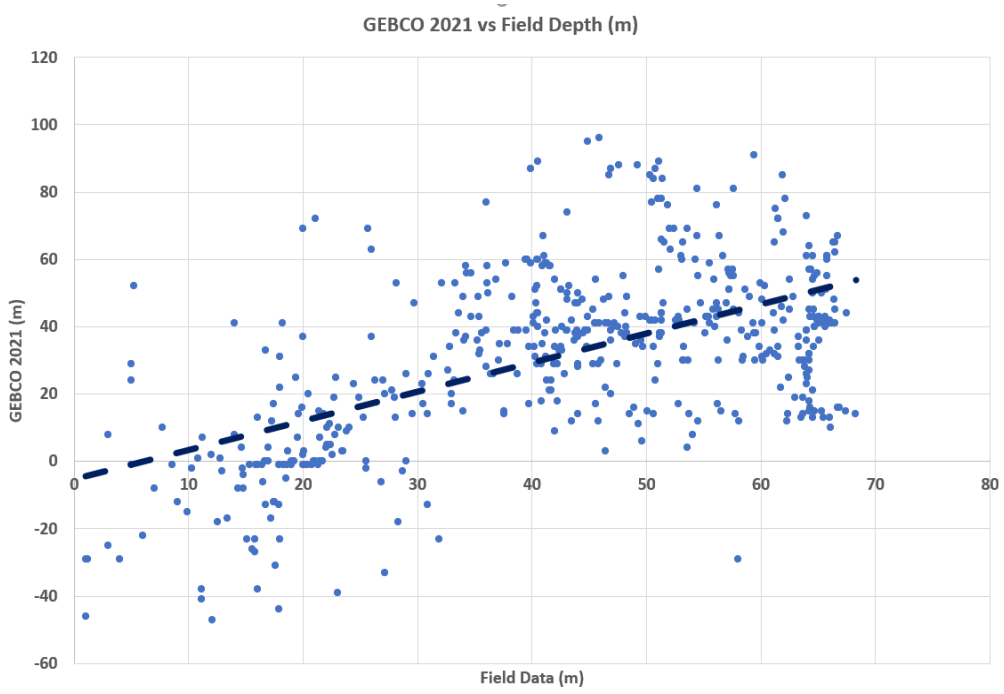


Figure36. Regression of GEBCO2021 bathymetry data against of field data

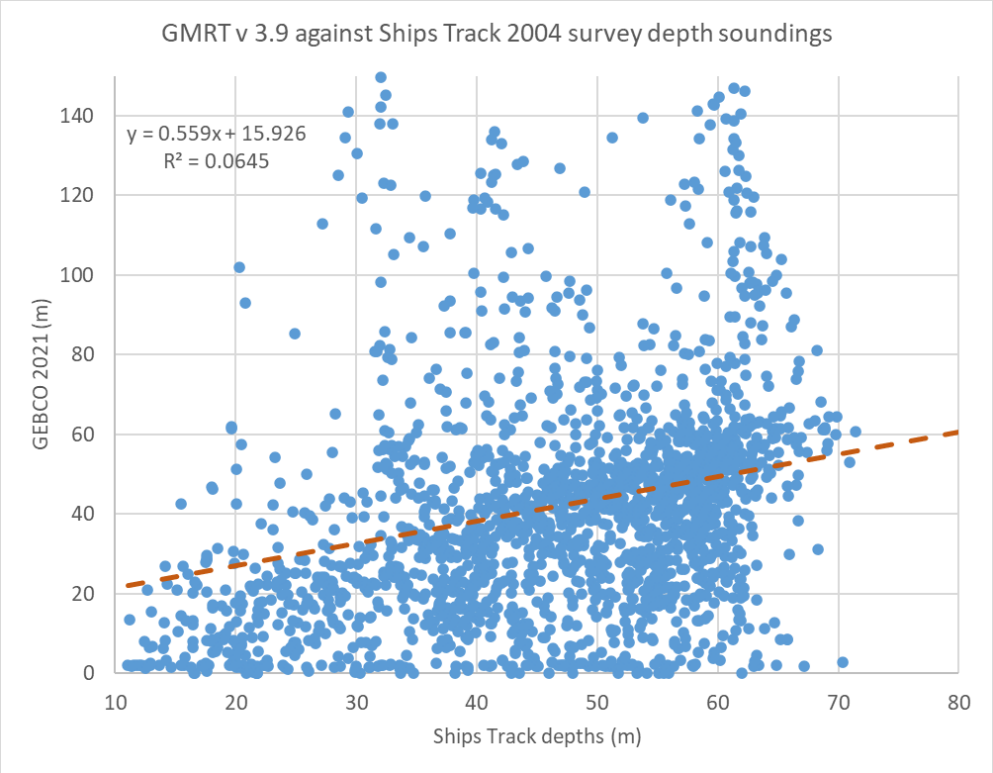


Figure37.Regression analysis of GMRT v 3.9 bathymetry against 2004 survey ship tracks depth soundings

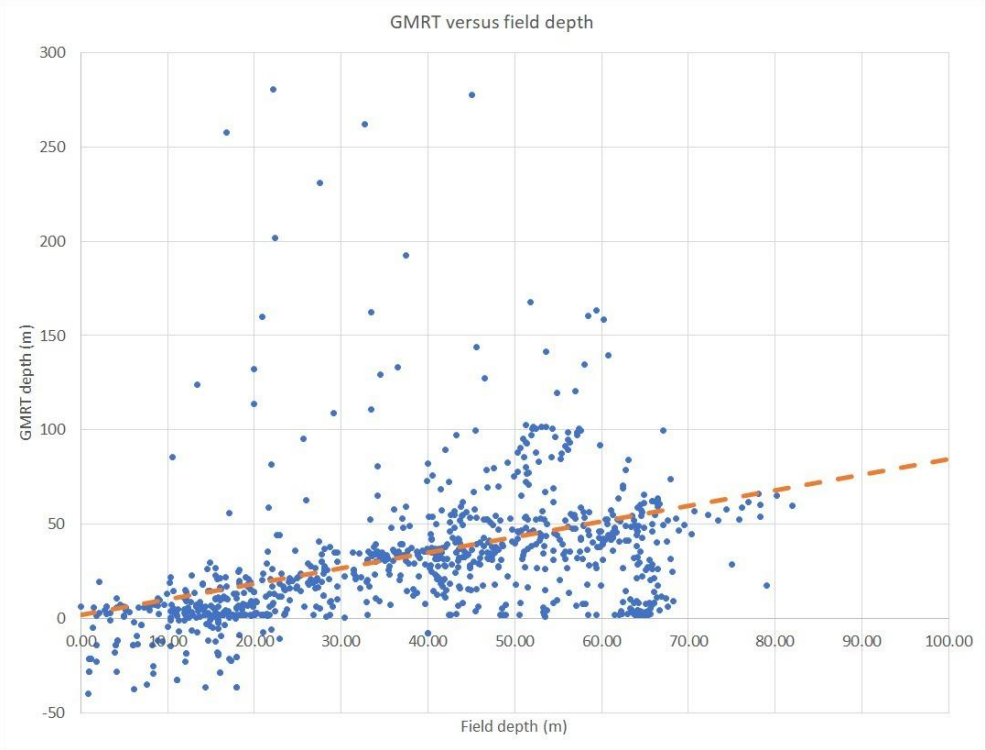


Figure 38. Regression analysis of GMRT v 3.9 bathymetry versus field data depths

Based on these poor fits a decision was made to base area estimates for depth categories on the depth soundings from the ships track. It assumes that the ships track is a representative sample of depths on Mahe plateaus.

Three quarters of the Mahe plateau was located in depths between 30 and 60m (Figure x)

Note that the ship track data can only be applied non-reef benthic areas as ships do not like going into shallow water, but for the deeper areas it is useful, and shows there is a lot of fishing ground in the 50-60 m depth range.

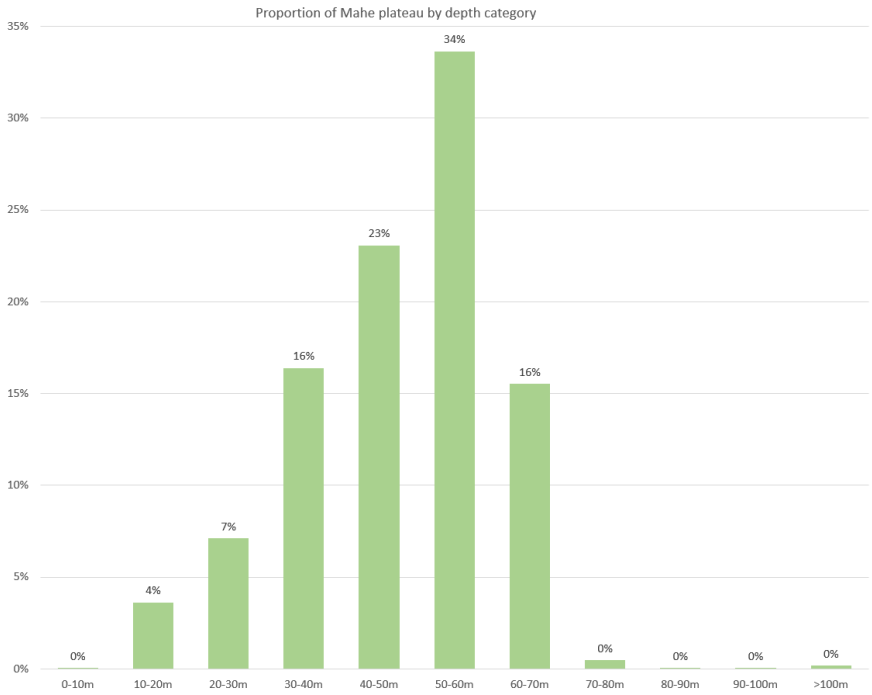
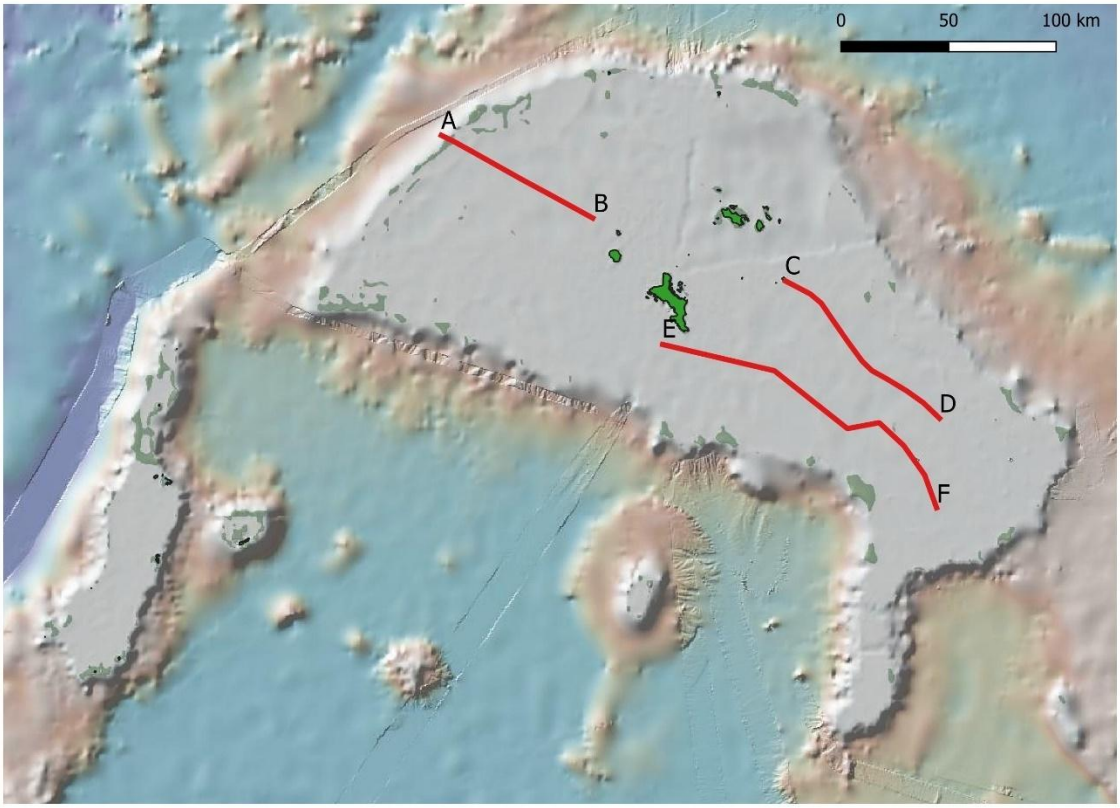


Figure 39. Proportion of Mahe plateau by depth category based on ships depth soundings 2004 survey

Appendix C Bathymetry plots



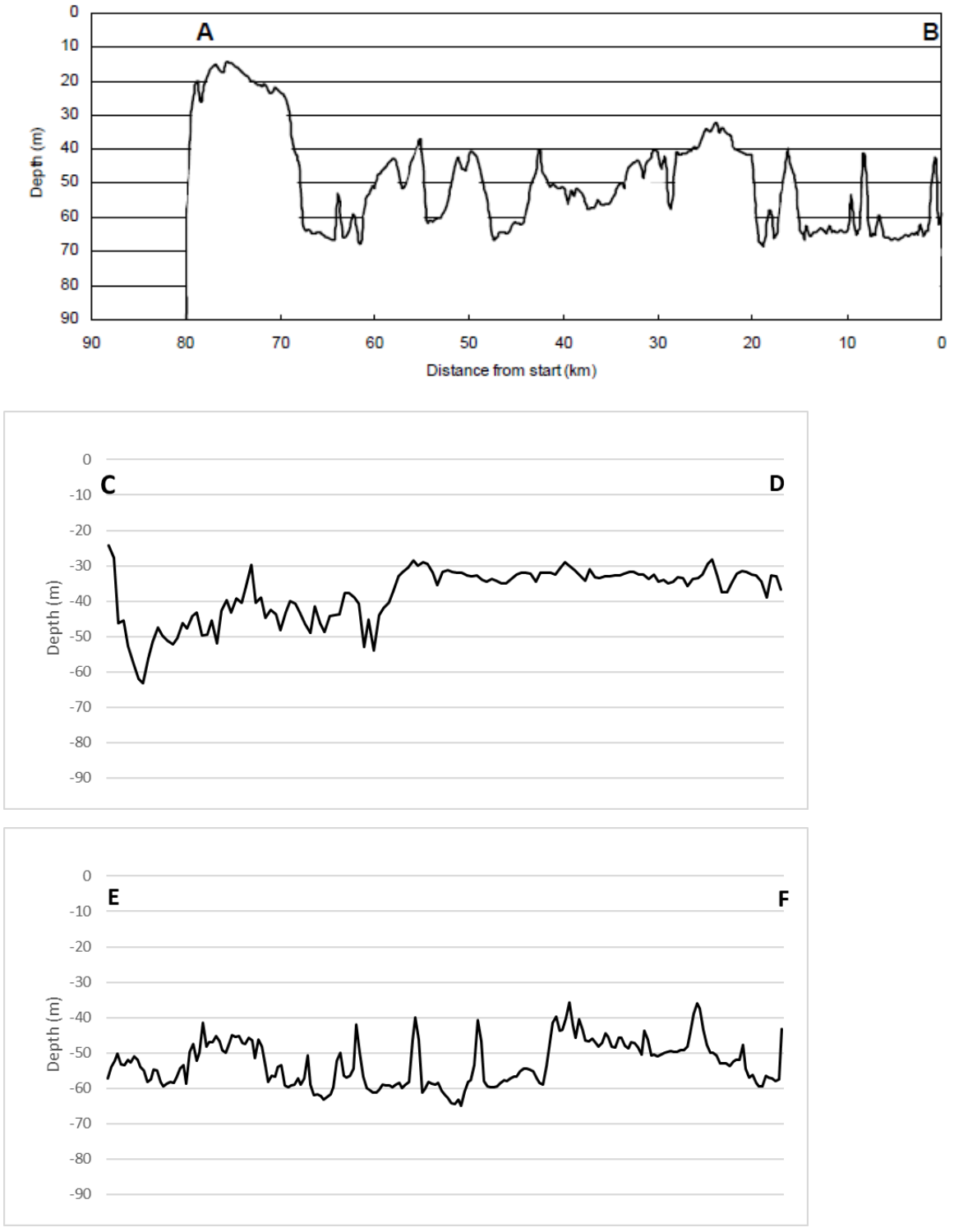


Figure 40. Depth profile from 2004 survey.

Appendix D Survey sites

Site	Latitude (S) (d.ddddd)	Longitude E (d.ddddd)		Type	Depth (m)	Strata name	Leg
S076	-4.66140	54.70798		Video	60.0	Mahe Non-reef >60m	2
S080	-3.76708	55.48387		Video	-	Mahe Non-reef 0-30m	2
S091	-4.80121	56.43350		Video	48.2	Mahe Non-reef 30-60m	1
S093	-4.92606	56.60834		Video	42.5	Mahe Non-reef 30-60m	1
S097	-4.66059	54.42650		Video	53.0	Mahe Non-reef 30-60m	2
S098	-4.69957	54.55366		Video	52.8	Mahe Non-reef 30-60m	2
S101	-4.67025	54.80799		Video	44.1	Mahe Non-reef 30-60m	2
S107	-4.00535	55.23214		Video	-	Mahe Non-reef 30-60m	2
S109	-4.07592	55.48647		Video	-	Mahe Non-reef 0-30m	2
S112	-4.01522	55.61364		Video	-	Mahe Non-reef 30-60m	2
S113	-3.88805	55.70305		Video	-	Mahe Non-reef 30-60m	2
S116	-4.02326	55.74080		Video	53.2	Mahe Non-reef 30-60m	2
S117	-3.76893	55.74850		Video	49.6	Mahe Non-reef 30-60m	2
S119	-4.84839	55.87916		Video	58.0	Mahe Non-reef 30-60m	1
S120	-4.08541	55.86727		Video	51.5	Mahe Non-reef 30-60m	2
S121	-3.95824	55.86797		Video	57.6	Mahe Non-reef 30-60m	2

Site	Latitude (S) (d.ddddd)	Longitude E (d.ddddd)		Type	Depth (m)	Strata name	Leg
S123	-4.79796	55.96767	Video	59.4	Mahe Non-reef >60m		1
S124	-4.67080	56.07963	Video	50.6	Mahe Non-reef 30-60m		1
S128	-5.21822	56.20846	Video	56.4	Mahe Non-reef 30-60m		1
S129	-4.83673	56.09484	Video	30.9	Mahe Non-reef 30-60m		1
S130	-4.58240	56.17582	Video	35.2	Mahe Non-reef 30-60m		1
S134	-5.18954	56.33563	Video	34.8	Mahe Non-reef 30-60m		1
S135	-4.93522	56.26065	Video	32.8	Mahe Non-reef 30-60m		1
S139	-5.27546	56.43854	Video	48.9	Mahe Non-reef 30-60m		1
S142	-5.54721	56.58214	Video	44.7	Mahe Non-reef 30-60m		1
S143	-5.42005	56.53194	Video	55.1	Mahe Non-reef 30-60m		1
S145	-5.16572	56.58995	Video	34.1	Mahe Non-reef 30-60m		1
S150	-5.15831	56.71712	Video	55.9	Mahe Non-reef 30-60m		1
S156	-4.45033	54.56037	Dive	24.9	Mahe Non-reef 0-30m		2
S157	-4.62233	55.37048	Video	44.9	Mahe Non-reef 30-60m		2
S160	-4.61487	55.38938	Video	33.2	Mahe Non-reef 30-60m		2
S162	-4.59602	55.52256	Dive	22.6	Mahe Non-reef 0-30m		1
S163	-4.31965	55.68166	Dive	18.7	Mahe Reef 0-30m		4

Site	Latitude (S) (d.ddddd)	Longitude E (d.ddddd)		Type	Depth (m)	Strata name	Leg
S166	-4.34363	55.79126		Dive	20.0	Mahe Reef 0-30m	1
S167	-3.80403	55.81702		Dive	24.5	Mahe Non-reef 0-30m	2
S179	-4.27910	54.31113		Video	53.6	Mahe Non-reef 30-60m	2
S180	-4.44524	54.44835		Video	55.6	Mahe Non-reef 30-60m	2
S186	-4.28876	54.69263		Video	51.6	Mahe Non-reef 30-60m	2
S189	-4.63791	54.93516		Video	57.4	Mahe Non-reef 30-60m	2
S190	-4.25642	54.81979		Video	37.1	Mahe Non-reef 30-60m	2
S191	-4.12925	54.84996		Video	54.5	Mahe Non-reef 30-60m	2
S194	-4.59933	55.06232		Video	57.2	Mahe Non-reef 30-60m	4
S196	-4.21784	54.94695		Video	36.2	Mahe Non-reef 30-60m	2
S197	-4.09067	54.97712		Video	57.4	Mahe Non-reef 30-60m	2
S206	-4.38684	55.21134		Video	38.7	Mahe Non-reef 30-60m	2
S212	-4.71175	55.57098		Video	41.3	Mahe Non-reef 30-60m	1
S213	-4.58458	55.54000		Video	33.0	Mahe Non-reef 30-60m	1
S216	-4.65104	55.69814		Video	35.4	Mahe Non-reef 30-60m	1
S217	-4.52388	55.66716		Video	37.1	Mahe Non-reef 30-60m	1
S221	-4.65908	55.82531		Video	40.2	Mahe Non-reef 30-60m	1

Site	Latitude (S) (d.ddddd)	Longitude E (d.ddddd)		Type	Depth (m)	Strata name	Leg
S225	-4.59406	55.95247	Dive	11.3	Mahe Non-reef 0-30m		1
S237	-6.44320	56.30436	Video	36.0	Mahe Non-reef 30-60m		1
S242	-4.43761	54.17724	Video	49.3	Mahe Non-reef 30-60m		2
S244	-4.24039	54.31321	Video	46.9	Mahe Non-reef 30-60m		2
S245	-4.74018	54.49403	Video	38.3	Mahe Non-reef 30-60m		2
S246	-4.10970	54.47857	Dive	18.2	Mahe Non-reef 0-30m		2
S248	-4.75774	54.58396	Video	47.2	Mahe Non-reef 30-60m		2
S250	-4.80695	54.65193	Dive	21.6	Mahe Non-reef 0-30m		2
S251	-3.87275	54.77822	Dive	12.9	Mahe Non-reef 0-30m		2
S254	-3.87574	54.86814	Video	46.5	Mahe Non-reef 30-60m		2
S259	-3.75920	55.00620	Video	56.5	Mahe Non-reef 30-60m		2
S273	-4.73449	56.29267	Video	45.5	Mahe Non-reef 30-60m		1
S275	-6.28653	56.33110	Video	32.7	Mahe Non-reef 30-60m		1
S277	-5.83687	56.36222	Video	36.4	Mahe Non-reef 30-60m		1
S280	-4.76269	56.47254	Video	60.3	Mahe Non-reef >60m		1
S281	-4.75865	56.56247	Video	43.8	Mahe Non-reef 30-60m		1
S282	-4.93253	56.65295	Video	46.7	Mahe Non-reef 30-60m		1

Site	Latitude (S) (d.ddddd)	Longitude E (d.ddddd)		Type	Depth (m)	Strata name	Leg
S283	-4.84260	56.63043	Video	40.6	Mahe Non-reef 30-60m		1
S284	-5.05328	56.75895	Video	37.6	Mahe Non-reef 30-60m		1
S285	-4.96335	56.71779	Video	30.4	Mahe Non-reef 30-60m		1
S286	-5.18623	56.78918	Video	53.7	Mahe Non-reef 30-60m		1
S287	-5.09630	56.84889	Video	34.3	Mahe Non-reef 30-60m		1
S289	-5.19487	56.87911	Video	53.2	Mahe Non-reef 30-60m		1
S299	-4.62738	55.48993	Dive	18.0	Mahe Reef 0-30m		1
S301	-4.61123	55.50965	Dive	20.4	Mahe Reef 0-30m		1
S302	-4.29283	55.71010	Dive	11.1	Mahe Reef 0-30m		1
S303	-4.30775	55.72510	Dive	11.1	Mahe Reef 0-30m		1
S305	-4.30961	55.74524	Dive	4.2	Mahe Reef 0-30m		1
S307	-4.46669	54.22312	Video	54.0	Mahe Non-reef 30-60m		2
S308	-4.33179	54.19778	Video	44.1	Mahe Non-reef 30-60m		2
S309	-4.11839	54.39174	Video	58.0	Mahe Non-reef >60m		2
S314	-6.10935	56.31183	Video	40.2	Mahe Non-reef 30-60m		1
S317	-4.68152	56.32349	Video	66.1	Mahe Non-reef >60m		1
S319	-4.74426	56.52584	Dive	19.4	Mahe Non-reef 0-30m		1

Site	Latitude (S) (d.ddddd)	Longitude E (d.ddddd)		Type	Depth (m)	Strata name	Leg
S323	-4.67200	55.52075	Dive	7.0	Mahe Reef 0-30m		1
S324	-4.73566	55.52824	Dive	4.0	Mahe Reef 0-30m		1
S325	-4.71551	55.52394	Dive	6.0	Mahe Reef 0-30m		1
S326	-4.33803	55.70078	Dive	5.0	Mahe Reef 0-30m		1
S328	-4.33312	55.70953	Dive	3.0	Mahe Reef 0-30m		1
S333	-4.63282	55.52153	Dive	16.6	Mahe Non-reef 0-30m		1
S343	-4.61388	55.40873	Dive	17.8	Mahe Non-reef 0-30m		2
S346	-4.57968	55.43097	Dive	13.6	Mahe Reef 0-30m		2
S348	-4.48133	55.53515	Dive	15.4	Mahe Non-reef 0-30m		1
S350	-4.48702	55.53593	Dive	17.4	Mahe Non-reef 0-30m		1
S357	-4.36505	55.31290	Dive	22.7	Mahe Non-reef 0-30m		2
S358	-4.00230	54.54187	Dive	14.8	Mahe Non-reef 0-30m		2
S360	-4.00927	54.54680	Dive	15.9	Mahe Non-reef 0-30m		2
S361	-4.00650	54.55198	Dive	17.4	Mahe Non-reef 0-30m		2
S364	-3.90503	54.66602	Dive	14.8	Mahe Non-reef 0-30m		2
S377	-4.35588	55.72133	Dive	8.6	Mahe Reef 0-30m		1
S378	-4.30848	55.73077	Dive	12.1	Mahe Reef 0-30m		1

Site	Latitude (S) (d.ddddd)	Longitude E (d.ddddd)	Type	Depth (m)	Strata name	Leg
S391	-6.35625	56.36947	Dive	29.0	Mahe Non-reef 0-30m	1
S392	-4.39685	54.18170	Dive	20.1	Mahe Non-reef 0-30m	2
S393	-4.29833	54.27027	Dive	27.8	Mahe Non-reef 0-30m	2
S394	-4.22383	54.32143	Dive	21.4	Mahe Non-reef 0-30m	2
S396	-3.84950	54.81413	Dive	16.5	Mahe Non-reef 0-30m	2
S407	-4.83553	54.70877	Video	49.5	Mahe Non-reef 30-60m	2
S410	-4.81263	56.22740	Video	43.1	Mahe Non-reef 30-60m	1
S411	-5.09623	56.90640	Video	50.1	Mahe Non-reef >60m	1
S412	-5.21300	56.92287	Dive	22.7	Mahe Non-reef 0-30m	1
S413	-5.10582	56.51847	Video	35.5	Mahe Non-reef 30-60m	1
S414	-5.07383	56.47870	Video	36.1	Mahe Non-reef 30-60m	1
S417	-4.50347	55.09817	Video	59.6	Mahe Non-reef >60m	2
S418	-4.49903	55.20703	Video	41.1	Mahe Reef 30-60m	2
S420	-4.54575	55.49475	Video	36.7	Mahe Non-reef 30-60m	1
S421	-3.87033	55.85977	Video	45.9	Mahe Non-reef 30-60m	2
S422	-4.17978	54.95895	Video	41.0	Mahe Non-reef 30-60m	2
S424	-6.40398	56.26725	Video	38.4	Mahe Non-reef 30-60m	1

Site	Latitude (S) (d.ddddd)	Longitude E (d.ddddd)		Type	Depth (m)	Strata name	Leg
S425	-5.65423	56.47467		Video	37.9	Mahe Non-reef 30-60m	1
S426	-3.88655	54.66122		Video	51.1	Mahe Non-reef 30-60m	2
S432	-4.63458	55.70051		New site (Video)	34.0	Mahe Non-reef 30-60m	1
S433	-4.65032	55.63439		New site (Video)	41.1	Mahe None-reef 30-60m	1

Appendix E Provisional Cruise Schedule

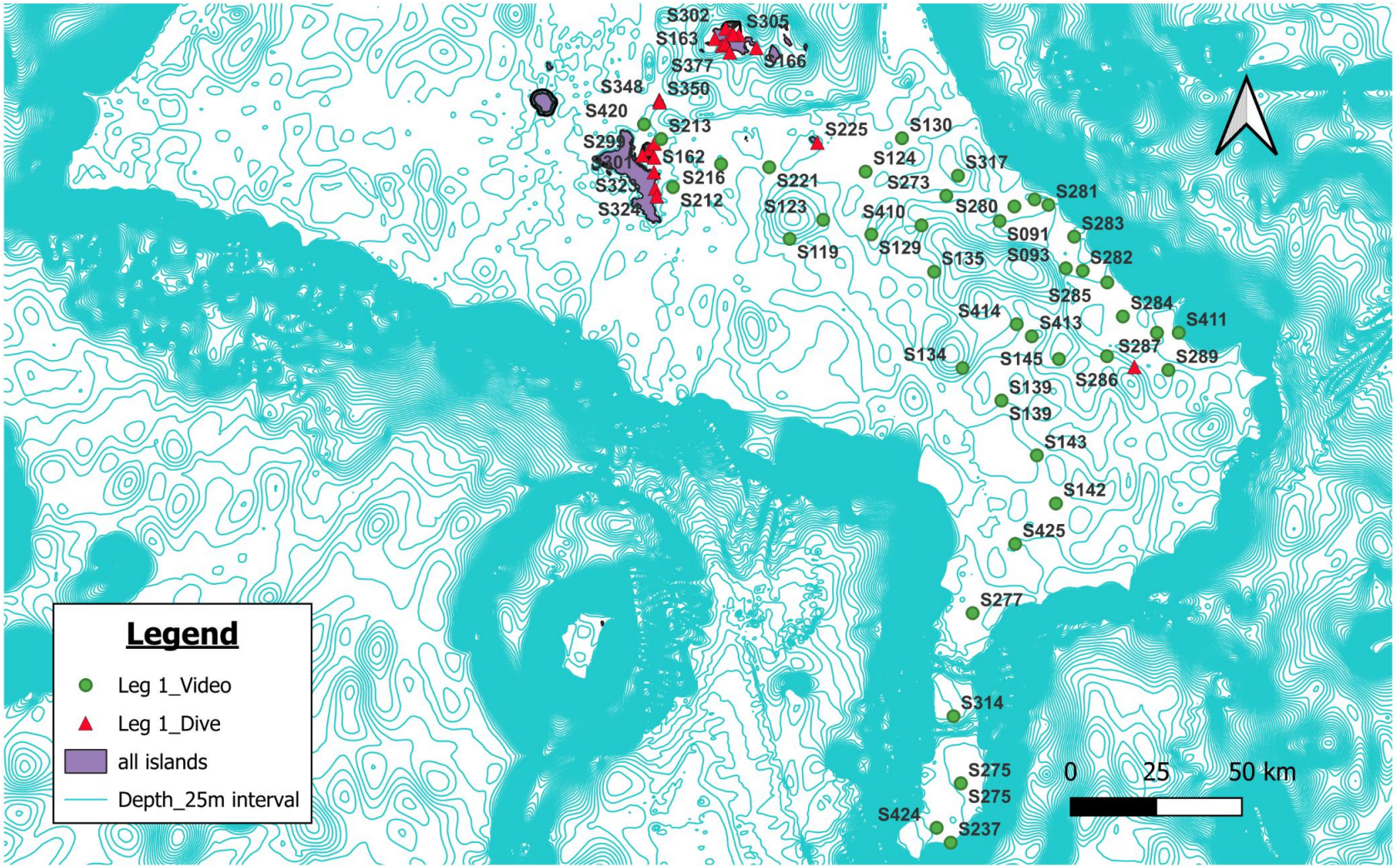
E.1 Cruise: Legs 1 and 2.

Seq.	Date	Day	Activity
1	3/03/2025	Mon	Depart Mahe Island, Leg 1
2	4/03/2025	Tue	DIVE and VIDEO UVC
3	5/03/2025	Wed	DIVE and VIDEO UVC
4	6/03/2025	Thru	DIVE and VIDEO UVC
5	7/03/2025	Fri	DIVE and VIDEO UVC
6	8/03/2025	Sat	DIVE and VIDEO UVC
7	9/03/2025	Sun	DIVE and VIDEO UVC
8	10/03/2025	Mon	DIVE and VIDEO UVC
9	11/03/2025	Tue	DIVE and VIDEO UVC
10	12/03/2025	Wed	DIVE and VIDEO UVC
12	14/03/2025	Thru	Return to Mahe Island, Leg 1
13	14/03/2025 - 6/04/2025		Break from the cruise and restock
14	07/04/2025	Mon	Depart Mahe Island, Leg 2
15	08/04/2025	Tue	DIVE and VIDEO UVC
16	09/04/2025	Wed	DIVE and VIDEO UVC
17	10/04/2025	Thru	DIVE and VIDEO UVC
18	11/04/2025	Fri	DIVE and VIDEO UVC
19	12/04/2025	Sat	DIVE and VIDEO UVC
20	13/04/2025	Sun	DIVE and VIDEO UVC
21	14/04/2025	Mon	DIVE and VIDEO UVC
22	15/04/2025	Tue	DIVE and VIDEO UVC
23	16/04/2025	Wed	DIVE and VIDEO UVC
28	17/04/2025	Thru	Return to Mahe Island, Leg 2

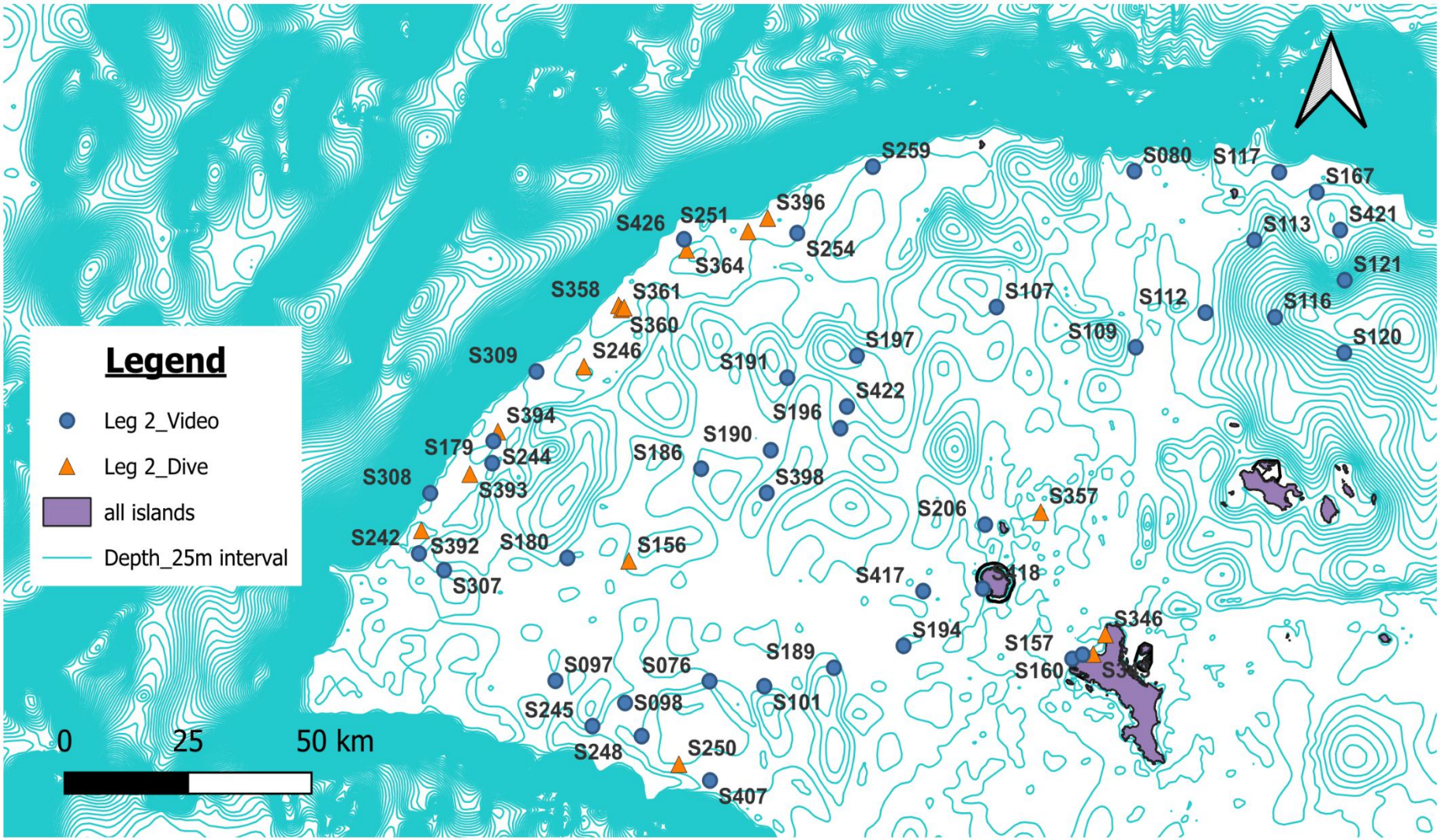
Note: dive rest days will be scheduled where only ROV sites are done..

Appendix F Provisional survey site

F.1 Leg 1



F.2 Leg 2


Legend
Leg 2_Video
Leg 2_Dive
all islands
Depth_25m interval
0
25
50 km
S259
S080
S117
S167
S396
S251
S426
S421
S113
S254
S364
S121
S358
S361
S107
S112
S116
S360
S109
S120
S309
S246
S197
S191
S422
S394
S196
S190
S179
S244
S186
S308
S398
S393
S357
S206
S242
S392
S180
S156
S417
S307
S194
S346
S189
S157
S097
S076
S160
S245
S098
S101
S248
S250
S407

Appendix G Species survey codes

Species survey code will be as follows

Survey Code	Scientific Name	Common Name	Local name
hNobi	*Holothuria nobilis*	Black Teatfish	Kokosye Nwanr
hFusg	*Holothuria fuscogilva*	White Teatfish	Kokosye Blan
hPent	*Holothuria spp.*	Flower Teatfish	Pentard
hFusp	*Holothuria fuscopunctata*	Elephant Trunkfish	Safran
hAtra	*Holothuria atra*	Lollyfish	Spork, Spork koray, Disan
hEdul	*Holothuria edulis*	Pink Fish	
hScab	*Holothuris scabra*	Sandfish	Kokonm
hLess	*Holothuria lessoni*	Golden Sandfish	Kokonm
hAmau	*Actinopyga mauritiana*	Surf Redfish	Brisan
hYsur	*Actinopyga sp.*	Yellow surfish	
hAmil	*Actinopyga miliaris*	Hairy blackfish	Spork
hAech	*Actinopyga echinites*	Deepwater redfish	Spork
hApal	*Actinopyga palauensis*	Deepwater blackfish	Spork
hBvit	*Bohadschia vitiensis*	Brown Sandfish	Lakol
hBarg	*Bohadschia argus*	Tiger Fish	Not found in Sey
hBatr	*Bohadschia atra*	Tiger fish	Lakol
hBsub	*Bohadschia subrubra*	Bohadschia white belly	Lakol
hPgra	*Pearsonothuria graeffei*	Flower Fish	
hAnan	*Thelenota ananas*	Prickly Redfish	Sanpye
hAnax	*Thelenota anax*	Amber Fish	
hHerm	*Stichopus herrmanni*	Curry Fish	
hChlo	*Stichopus chloronotus*	Green Fish	

G.1 List of biota and classification codes

See species identification guide to familiarise yourself with what needs to be observed

Category	Level	Abundance measure
Substratum		% cover

	Soft sediment	
		Mud (M)
		Sandy mud (SM)
		Muddy sand (MS)
		Sand (S)
	Rubble (2 - 30 cm diameter loose particles)	
	Boulders (>30 cm diameter loose particles)	
	Consolidated rubble (rubble concretion fixed to bottom)	
	Hard substrate (general fixed substrate)	
		Carbonate
		Granite
	Limestone pavement (hard substrate eroded flat)	
	Live coral	
	Dead standing coral	
Fungids	All Fungidae	% cover
Soft coral	All Alcyonacea	% cover
Sponges	All Porifera	% cover
Gorgonians	All Gorgonacea	% cover
Seagrass	All species	% cover
	HOV - *Halophila ovalis*	Relative % of All species
	HSP - *Halophila spinulosa*	Relative % of All species
	CYS - *Cymodocea serrulata*	Relative % of All species
	CYR - *Cymodocea rotundata*	Relative % of All species
	HUN - *Halodule uninervis*	Relative % of All species
	TAD - *Thalassodendron ciliatum*	Relative % of All species
	SYR - *Syringodium isoetifolium*	Relative % of All species
Algae	Macro species, all classes	% cover

	HAL - *Halimeda*	
	TOR - *Turbinaria ornata*	
	CAU - *Caulerpa*	
	LAU - *Laurencia*	
	PAD - *Padina*	
	SAR - *Sargassum*	
	GRN - Green	
	BRN - Brown	
	RED - Red	
Holothurians	All species	Counts
	(see sea cucumber species list)	
Clams	All Tridacnids	Counts
	GIGA – *Tridacna gigas*	
	CROC - *Tridacna crocea*	
	SQUA - *Tridacna squamosa*	
	MAXI - *Tridacna maxima*	
	DERA - *Tridacna derasa*	
	HIPH - *Hippopus hippopus*	
Lobsters	All Palinurids	Count
	PEN - *Panulirus penicillatus*	
	VER - *Panulirus versicolor*	
	ORN - *Panulirus ornatus*	
Trochus	TROCH - *Trochus niloticus*	Counts
Starfish (Asteroids)	CULC - *Cucita* sp	Counts
	COT - *Acanthaster planci*	
	OTH - All other species	
Urchins (Echinoids)	All species	% cover

Clam

Substrate

Coral Forms

Clams

Appendix H Cruise plan

2025 Sea Cucumber Resources Assessment Cruise Plan

Introduction

The Seychelles Fisheries Authority (SFA) plans to collaborate with the sea cucumber industry to conduct a fisheries-independent stock survey and assessment aimed at enhancing the management of the Seychelles sea cucumber fishery. The survey will focus specifically on the Mahé Plateau fishery area.

The survey methodology will include an underwater visual census (UCV) conducted by scientists and commercial sea cucumber divers in shallow areas (<30m), complemented by using a drop camera for deeper areas (>30m). The survey aims to evaluate the density and standing stock of all sea cucumber species, with a focus on commercially valuable ones.

To ensure robustness, the survey will employ a repeated measures design, revisiting survey sites previously studied in 2004 and 2021. This approach will facilitate the detection of population change over time.

The results from the fishery-independent survey will guide the next steps in developing new management measures for the fishery. This will involve reviewing the Total Allowable Catch (TAC) quotas for exploited species, with recommendations based on the 2021-2022 stock assessment, ensuring they align with the current status of the stock.

To improve management of the Seychelles sea cucumber fishery, the Seychelles Fishing Authority (SFA) will, in collaboration with the sea cucumber industry, conduct a fisheries-independent stock survey and assessment. The survey will include the fishery area on the Mahé Plateau and Amirantes Bank.

The survey approach will be based on an underwater visual census (UCV) by scientists and sea cucumber commercial divers in shallow areas (<30m) and a remotely operated vehicle (ROV) in deeper areas (>30m). The surveys will assess the density and standing stock of all sea cucumber species and also estimate the stock status for commercial species.

The survey will be based on a repeated measures design, with survey sites being chosen from the same sites surveyed in 2004. This will increase the power to detect change in the populations over time and also allow for better cruise planning.

The results from this study will be used to provide management advice for the fishery going forward and will also provide a useful set of indicator sites that could be used as sustainability measures for the fishery so that it can become more sustainable.

Objectives

1. To assess the abundance of sea cucumber resources on the Mahe plateau.
2. To collect biological and ecological information on sea cucumber species.
3. To understand the effect of exploitation on sea cucumber population and distribution.
4. To provide information on the stock status of the main commercial species.
5. Provide management advice to guide the future management of the sea cucumber fishery.

Aim

- Carry out a UVC on Mahe Plateau sites throughout the study area using divers at sites <30m and Drop Camera at sites >30m, to a maximum depth of 100m.
- Count sea cucumbers and record observations of other biota and habitat along a fixed length and width DIVE transect at all shallow (<30m) sites.
- Collect sea cucumbers on dive transects for measurement of length and weight.
- Count sea cucumbers and record observations of other biota and habitat using a drop camera for deeper (>30m) sites.

Sample sites

There are 134 priority sample sites selected prior to the survey cruise, and they are all mapped across the Mahe Plateau (Figure 1). These different sites are classified into 4 site (types) stratification scheme which were developed for the 2021-2022 survey:

- **Mahe reef 0-30m**
- **Mahe non-reef 0-30m**
- **Mahe non-reef 30-60m**
- **Mahe non-reef >60m**

Site strata were determined based on various factors, including depth, the presence of emergent reef, and characteristics of the plateau itself. For each stratum, the appropriate sampling protocols (DIVE or Drop Camera) have been selected to best suit the conditions and objectives (Table 1).

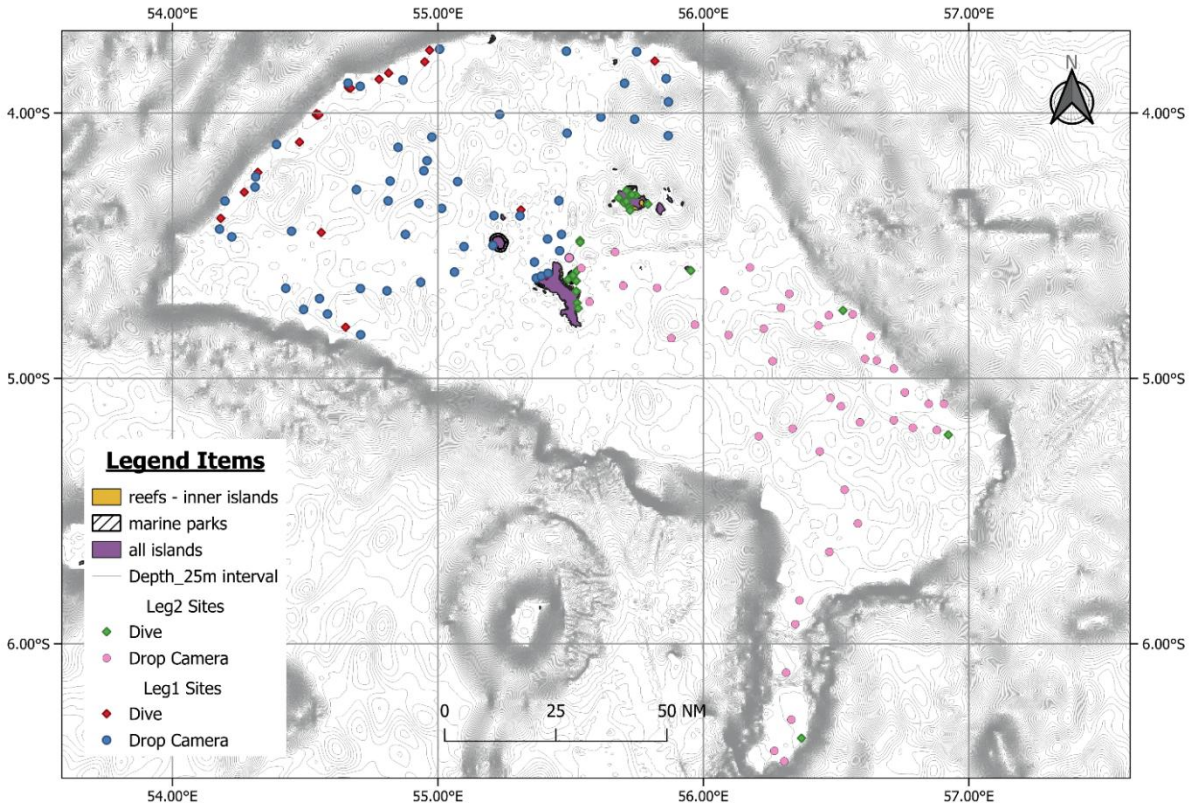


Figure 41. Map of sampling locations for DIVE and Video priority and additional survey sites during the 2025 sea cucumber survey.

Table 15. Sites stratum types and number of sites per strata

Strata name	Method	Number of Sites
Mahe reef 0-30m	Dive	15
Mahe non-reef 0-30m	Dive	25
Mahe non-reef 30-60m	Drop Camera	76
Mahe non-reef >60m	Drop Camera	7

Total Sites		123

Survey Design

The survey design will follow a repeated measures approach, selecting sites that were previously surveyed in 2004 and 2021. This strategy is intended to improve the detection of changes in population dynamics over time and to optimize cruise planning for greater efficiency. The primary goal of these surveys is to assess the density and standing stock of all sea cucumber species, with a particular focus on estimating the stock status of commercially significant species.

- Data Collection techniques:
    - **Shallow Sites (<30m):** An underwater visual census (UVC) will be conducted, where scientific & commercial divers will count sea cucumbers and record observations of other biota and habitat types along fixed length transects.
    - **Deeper Sites (>30m):** Drop cameras will be deployed to count sea cucumbers and record biota and habitat types of along similarly fixed length transects.
- Instrumentation:
    - **Underwater Visual Census (UVC):** Scuba diving equipment, including dive computers, measuring tape, and underwater cameras, will be used to ensure accurate counts and observations along the transects.
    - **Drop Camera:** A high-resolution camera with GPS coordinates, will be used to capture clear images of the sea floor and sea cucumbers.

Sampling Plan

- The sampling plan involves visiting 123 priority sites, split into two legs, with each leg lasting 10 days.
- The expedition will commence and conclude at Mahe Island.
- Two vessels will be employed for the field trip, operating in coordination: the SFA research vessel R/V L'Amitie, and a commercial sea cucumber vessel contracted specifically for the survey.
- Leg 1 will take place in the Eastern part of the Mahe Plateau with a total number of 66 sites (Table 2)

- Leg 2 will take place in the Southern part of the Mahe Plateau with a total number of 57 sites (Table 2).
- The two vessels will travel together, maximizing efficiency by visiting as many sites as possible each day.
- Note: To achieve the project goal of sampling 123 sites, it will be necessary to visit at least a certain number of sites per day.
- The main skipper will determine the final route of the vessel and select anchor sites in consultation with the cruise leader.
- If any sites become inaccessible due to weather or other factors, consider the following contingency ideas in **(Appendix A)**.
- Prior to the survey cruise, a training session on the methodology will be conducted for both the commercial divers and the scientific divers.
- The training will cover survey methods, data collection techniques, habitat data collection, data recording methods, and sea cucumber species identification.

4. Protocol I: Dive Survey Transect

- Dive surveys will only be conducted at sites <30m deep.
- A team of three divers, comprising one commercial and two scientific divers, will conduct the surveys together.
- The length of the transect will be 100m long and 4m wide (2m x 2m) on both sides. At each site, a single transect will be conducted.

Scientific Diver (1):

- Responsible to set out the transect line at the beginning of the survey.
- Responsible to retrieve transect line after survey.

Scientific Diver (2)

- Swim along a 100m length and 4m wide transect, assessing 2 meters on respective side of the transect line.
- Count the number of sea cucumbers observed within the respective side of the transect line to ensure data integrity and reliability.
- Record habitat information.

Commercial Diver

- Swim along a 100m length and 4m wide transect, assessing 2 meters on respective side of the transect line.
- Collect (all) sea cucumbers within his/ her respective side of the transect line.

All Divers

- Should co-operate using established underwater communication to ensure that all sea cucumbers within the transect are counted and collected.

4.4.1. Before each Dive

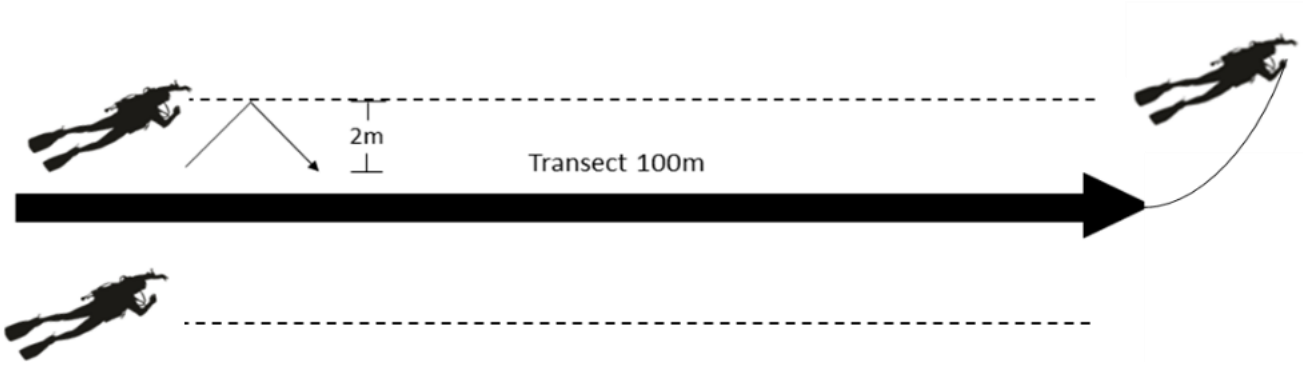
- Check that all diving equipment are in perfect working condition.
- Check that all safety equipment including those onboard R/V L'Amitie are in perfect working condition and within accessible reach in case of an emergency.
- Check that all on-board roles regarding diver safety are established and clear to those involved.

4.4.2. Dive Survey

Before surveying:

- Divers should measure 2 meters using their body length from fingertip to flipper end (or a shorter distance for taller divers). It is essential for the diver to calibrate this measurement on board the vessel before starting the survey.
- All three divers enter the water simultaneously.
- Once submerged**, scientific diver 1** lays out the transect line Infront of the **scientific diver 2** and the **commercial diver** without disturbing the seabed.
- With or without current, **scientific diver 1** maintains a consistent compass bearing/ direction relative to the sun angle, ensuring no deviation from the line.
- Scientific diver 2 and the commercial diver will begin the transect with each focusing on the 2m transect boundary on either side of the l00m line.

- End of transect the dive team retrieves all equipment, including the transect line and follows diving safety protocols to exit the water.



- The Dive transect (UVS) survey layout.

4.4.3. Commercial Diver Protocol

- The commercial diver should try and collect every sea cucumber within the transect, however, if the sea cucumbers are plentiful, collect up to six (6) individuals of each species, and just count the remainder.

- Store the individuals in the provided dive bags and bring them back to R/V L'Amitie for further processing.

- The commercial diver is expected to limit their collection within 2m of the transect line.

- Any deviations could lead to biased collection and counts, rendering the data unusable or misleading. It's permissible for the diver to collect sea cucumbers from outside the 2-meter transect width, but they must note this as "**OUTSIDE"** on the data sheet and swiftly return to the transect line. This data can still be utilized for size frequency and other sampling protocols.

After the dive, on the commercial diver's diving form **(Form I, Appendix E)** should have a following entries:

- Site number
- Diver initials[1]
- the date

- Start time of the transect.
- Maximum depth reached.
- Visibility (estimated distance at which a sea cucumber could be seen),
- Transect width, and the side of the transect tape surveyed.
- Sea cucumber count within transect (including any found outside[2]).

4.4.4 Scientific Diver Protocol

- Swim parallel to one side of the transect tape and record the number of sea cucumbers.
- Observe habitat and biota within a 2m distance from the transect tape.
- To identify unknown sea cucumbers, it's advisable to capture underwater images of the individuals or collect them for later identification on board the boat.

After the dive, on the scientific diver's diving form **(Form II, Appendix F)** should have a following entries:

- site number
- latitude and longitude coordinates corresponding to the entry point into the water.
- Diver initials.
- Date
- Start time of the transect.
- Maximum depth reached.
- Visibility (estimated distance at which a sea cucumber could be seen)
- Transect width, and the side of the transect surveyed.
- Sea cucumber count within transect (including any found outside).

Record the **habitat information** of the transect area. This will include:

- Substratum descriptions
- Benthic flora cover
- Counting fauna other than sea cucumbers.

It is important that divers have a thorough knowledge of sea cucumber species, and the associated codes used for their identification. This is crucial when divers are solely focused on quantifying sea cucumbers without retrieving them to the surface. Underwater photography can be immensely helpful in such situations. For a comprehensive compilation of sea cucumber species codes, please refer to the **(Appendix B)**.

Furthermore, it is imperative for scientific divers to be well-versed in the identification of diverse habitats, including seagrass, algae, and other species, as outlined in the list provided in **(Appendix C).**

For DIVE transects, it is important that the observer (the diver observing from outside the transect) are also well versed in sea cucumber species identification and the different codes used to identify them. See **(Appendix I).**

Additionally, well versed in habitat identification, coral types, seagrass, algae, and other species identification as per the list in **(Appendix C).**

4.4.5. Equipment List

Vessel

1. Dive tender.
2. Oxygen Tank
3. Compressor
4. Sufficient fuel and oil for dive vessel and compressor

Diver

1. Diving Tanks
2. BCD
3. Regulators
4. Snorkel
5. Flippers
6. Diving Computer
7. Weight + Weight Belt
8. Surface Marker Buoys (BSMB)
9. Masks
10. Gloves
11. Underwater flashlight
12. Rings
13. Safety knife

Sampling

1. Handheld GPS to travel to site and record actual position on every dive.
2. Transect tape (must cover at least 100m)

3. Transect width measures (2m long – optional if using body length to measure transect width)
4. Slates (for underwater records/notes)
5. Pencils
6. Collecting bag
7. Camera/GoPro
8. Rope tied to surface buoy.
9. Datasheets (Commercial diver and Scientific diver)

4.5. Protocol II: Onboard sea cucumber sampling.

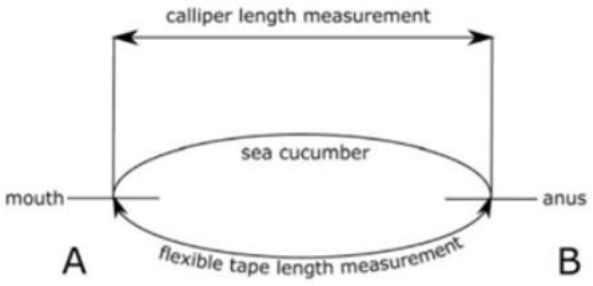
Sea cucumbers collected along the transect will be brought back to R/V L'Amitie for processing:

- Identify and record the individual species of sea cucumber on: **(Form III, Appendix H)** utilizing the sea cucumber species codes provided **in (Appendix I).**

- Allow the sea cucumber to rest on the deck for a duration of 2 minutes.

- Using a digital scale, measure the weight of the sea cucumber to the closest 0.05 kg.

- Measure the total "caliper" length of the sea cucumber by employing a measuring tape on a flat surface, ensuring accuracy to the nearest 0.5 cm (this information will be used for comparison with prior survey length data).



- **Measure the total curve length of the sea cucumber using a measuring tape from mouth to anus to the nearest o.5cm**

- **Measure the circumference of the sea cucumber**

4.5.1 Equipment

1. Measuring tape/board
2. Gloves
3. Pencils and eraser
4. Datasheets
5. Digital Weighting scale

5. Protocol III: Drop Camera survey transects.

- A drop camera will be used to survey in deeper areas (>30m). The surveys will assess the density and standing stock of all sea cucumber species and estimate the stock status for commercial species.

- The drop camera will be slowly deployed by hand or using a hydraulic system and positioned, 1-2 meter above the seafloor.

- Video feed from the Drop Camera will be being surveyed in real time as it drifts with the current for 10 mins.

- If drop camera surveys are conducted from the research vessel, the vessel will position itself as close as possible to the predetermined site location/position.

- Before beginning the transect start location/ position and depth should be recorded on the **Drop Camera video record form (Form IV, Appendix G)**.

- During the transect, record any sea cucumbers and other items of interest and the time stamp – this will allow later review of the drop camera recording.

- Upon completing the 10-minute transect, document the end location and depth. Then, proceed to fill out the remainder of the form, noting the deepest depth reached, visibility conditions, and the effective width of the transect.

Drop Camera deployment.

- Transport vessel to as close to the site location as possible.
- Switch on the Drop Camera.
- Deploy the Drop Camera and lower to within 1-2m from the sea floor.
- Start to record.
- On the Drop Camera video record form **(Form IV, Appendix G)** record the site name, starting time, starting location/ position, water temperature, visibility, and depth.
- Start a timer and allow the vessel to drift with the current for 10 minutes.
- While the one person views the video one person will have control of the tether and line to move the Drop camera up and down based on advice from the person viewing the video regarding the changing sea floor.
- During the 10 minutes drift, observers onboard will count, identify, and record any sea cucumber species observed on the transect, alongside the time stamps for later verification.
- Significant environmental data will also be recorded.
- At the end of the 10 minutes - record the end time, end location/ position, and depth.
- Return the Drop Camera to the surface and collect the Drop Camera and tether.
- Save the video and transfer a copy to an external drive.
- Name the video with the transect label.
- Switch off the Drop Camera and sit in a safe place ready for the next deployment.
- At the end of each dive/day, rinse the Drop Camera with fresh water.
- At the end of each cruise leg (not every day as seals can become worn): disconnect the Drop Camera from the tether. Close the connecting ends with the provided cover.

- Place the Drop Camera for at least 30 minutes in fresh water and allow it to airdry afterwards.
- Rinse the tether with fresh water, allow to dry, collect and store to prevent entanglement.

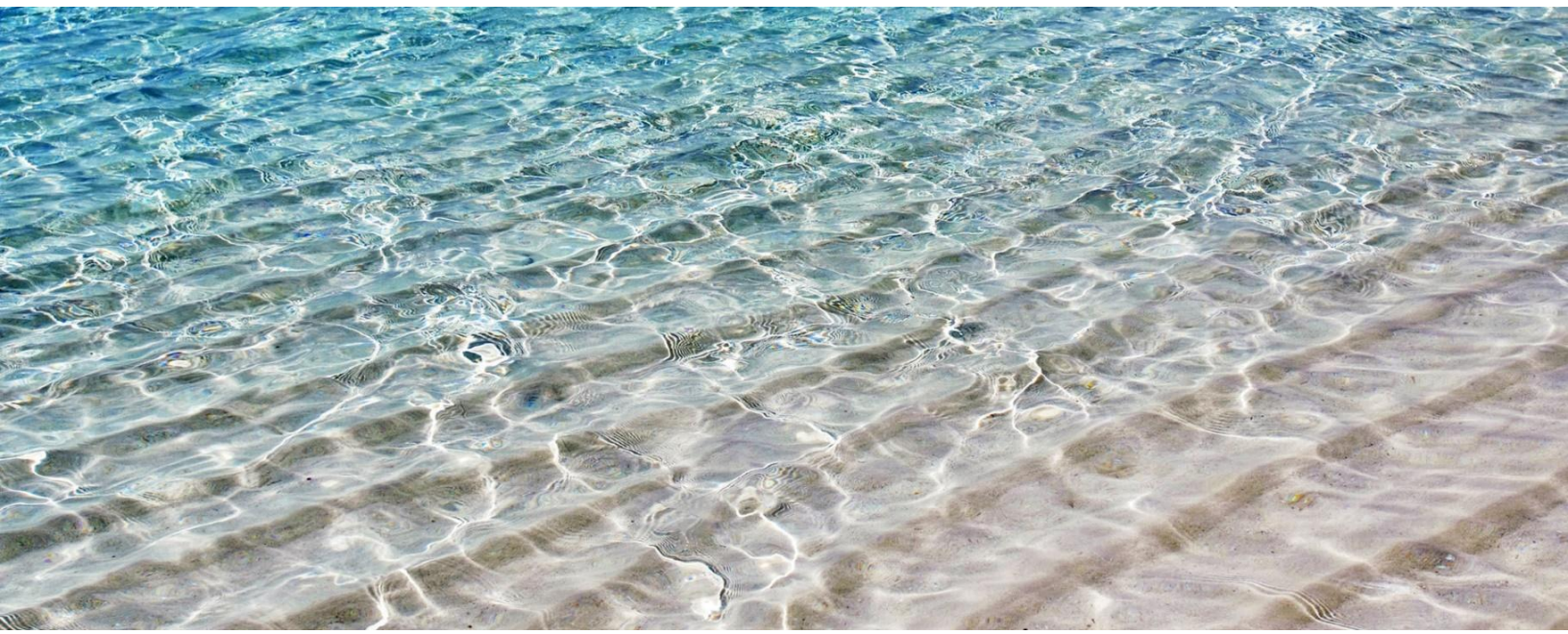
Pre-Drop camera deployment checks

- Visually check that all system is in order and conduct all safety check as per the manual.
- Connect the Drop Camera to the control system.
- Make sure the system is connected to a working power source.
- Turn on the computer and wait for the system to complete the boot up process.
- After the computer has started.
- Test the Drop Camera by turning on.
- Verify the image on the software.

4.5.1 Equipment

1. Drop Camera- high definition (HD) digital Camera with underwater housing and strobes in video mode.
2. GPS
3. Camera Cable
4. Full HD video recorder/Monitor
5. External Hard Drives
6. Drop Camera user manual.
7. Hard gloves (hyper touch gloves)
8. Polyethylene rope- spare is required in case the rope get damaged.
9. Cable ties
10. Battery for drop camera

Appendix I Stratified analysis approach

In stratified sampling the population of N units is divided into subpopulations of N1, N2, N3,... NL units respectively. Estimates of the stratum mean can be obtained by averaging the sites in that stratum. These estimates can then be combined to give a precise estimate for the whole population. The notation of terms used for stratified sampling follows below:

N	total number of possible sampling units in the study area;
N_h	total number of possible sampling units in stratum *h;*
n_h	actual number of samples taken in stratum *h;*
y_{hi}	value obtained from *i*th unit in stratum *h;*
$W_h = \frac{N_h}{N}$	stratum *h* weight;
$f_h = \frac{n_h}{N_h}$	sampling fraction in stratum *h;*
$\overline{y}_h = \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h}$	stratum *h* mean;
$\overline{y}_{st} = \sum_{h=1}^{L} W_h \overline{y}_h$	stratified mean over all strata;
s_h^2	sample estimate of stratum *h* variance;
$v(\overline{y}_{st}) = \sum_{h=1}^{L}\left(\frac{W_h^2 s_h^2}{n_h}\right) - \sum_{h=1}^{L}\left(\frac{W_h s_h^2}{N}\right)$	estimated strata variance.