RECRUITMENT OF A RESEARCH INSTITUTE OR A COMPANY FIRM IN SUPPORT OF THE MINISTRY OF FISHERIES AND AQUACULTURE THE BLUE ECONOMY IN THE STUDY OF FISH STOCKS (FIVE PRIORITY SECTORS: coastal prawns, coastal lobsters, mangrove crabs, sea cucumbers and octopus)

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FINAL REPORT

ABOUT :

SUPPORT FOR THE MINISTRY OF FISHERIES AND THE BLUE ECONOMY IN THE STUDY OF FISH STOCKS (FIVE SECTORS) PRIORITY: coastal prawns, coastal lobsters, mangrove crabs, sea cucumbers and octopus)

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ABBREVIATIONS

AC	Conventional approach
AEP	Ecosystem approach to fisheries
AGR	Income-generating activity
ASH	Fisheries Health Authority
BANACREM	National Database on Malagasy Shrimp Fishing
CCPR	Code of conduct for responsible fishing
CGP	Management Committee for Octopus Fishing
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora extinction
CORDIO	Coastal Oceans Research and Development in the Indian Ocean
CORECRABE	COOPERATION FOR THE DEVELOPMENT OF RESEARCH FOR THE MANAGEMENT OF SMALL-SCALE FISHERIES IN THE MANGROVE IN MADAGASCAR
COS	Certificates of Origin and Healthiness
CPUE	Capture per Unit Effort
DESP	Research, Statistics and Planning Department
DRPEB	Regional Directorate for Fisheries and the Blue Economy
ECN	National Framework Survey
FAO	Food and Agriculture Organisation
SWOT	Strengths, Weaknesses, Opportunities and Threats
GAPCM	Groupement des Aquaculteurs et Pêcheurs de Crevette de Madagascar (Madagascar Shrimp Farmers and Fishermen's Group)
GDM	Generalised Depletion Model
GPS	Global Positioning System
GT	Working Group
ICRI	International Coral Reef Initiative
IH.SM	Institute of Fisheries and Marine Sciences
IRD	Development Research Institute
MAEP	Ministry of Agriculture, Livestock and Fisheries
MPEB	Ministry of Fisheries and the Blue Economy
MSC	Marine Stewardship Council
MSY	Maximum Sustainable Yield (= 'RMD')
ONE	Office National de l'Environnement
NGO	Non-Governmental Organisation
PCI	Industrial shrimp fishing
PCT	Traditional shrimp fishing
PI	Industrial fishing
SMES	Maximum Balanced Intake
PP	Petite Pêche
PPC	Small-scale shrimp fishing
PRL	Reference point Limit
PRS	Reference point Threshold
PUE	Intake per Unit Effort
IQ	Individual quota

QIT	Individual Transferable Quota
RMD	Maximum sustainable yield
SAS	Statistical Analysis System
SPSS	Statistical Package for the Social Sciences
SSP	Fisheries Statistics Service
SWOT	Strengths - Weaknesses - Opportunities - Threats (= SWOT)
TAC	Total Allowable Catch
IUCN	International Union for Conservation of Nature
URL	Lobster Research Unit
USAID	United States Agency for International Development
VPA	Virtual Population Analysis
YPR	Yield per recruit

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 REMINDER OF THE PROJECT

The project focuses on small-scale fishing resources of economic importance to Madagascar. These include coastal prawns, coastal lobsters, mangrove crabs, sea cucumbers and octopus. These fast-growing species each have a relatively short life cycle (from a year to a few years), facilitating the implementation of relatively short management cycles (including stock assessment and the formulation of scientific advice) and offering good opportunities for research, training and capacity building for sustainable socio-economic profitability.

However, the biological, ecological, geographical, technical and socio-economic characteristics of these species, their fisheries and their industries differ, requiring different and adapted management systems. Of the five small-scale fisheries, only the shrimp fishery has been subject to large-scale scientific monitoring, at least in the industrial segment, since it was set up around 1967, with the implementation of a data collection system (catches, effort), However, monitoring of other exploited coastal resources has been neglected (with the notable exception of advances in crab monitoring as part of the IRD/IHSM CORECRABE project[1] , octopus monitoring in south-west Madagascar as part of the programme run by the Comité de Gestion des Poulpes (CGP) and the IHSM with support from the NGO Blue Ventures, and former research on lobsters).[2]

In terms of the adaptive management cycle (data collection, stock assessment, formulation and provision of scientific advice, monitoring of catches and corrective action) and approaches to training and capacity building, shrimp fishing (including its industrial and traditional segments, which has already been the subject of a study in 2019 as part of SWIOFish2[3]) can serve as a reference example to be adapted to other resources, provided that full account is taken of the specific features of each resource.

Overall, the fisheries data available for sectors other than inshore shrimp is limited to the quantities marketed or exported, regional production figures, indirect data on the level of effort (national and local framework censuses), some spatially limited biometric data on crabs, octopus and lobsters, and some data collected in certain areas by non-governmental organisations (NGOs) and seafood collection companies. These gaps pose constraints at several stages in the cycle of sustainable management of these specific fisheries and their development.

This being the case, carrying out data sorting and analysis, stock assessments, scientific advice and planning for the systematic collection of fisheries data as part of targeted training courses for MPEB technicians, in collaboration with national and international scientific institutions, represents an exceptional opportunity for the MPEB and the government of Madagascar to make progress towards national sustainable development objectives and at the same time meet international commitments in terms of the SDGs and international conventions (UNCLOS, CBD, CITES and others) as part of the implementation of a sustainable blue economy .[4]

1 https://corecrabe.ird.fr/novembre-2019-avril-2023
[2] Mara 1993; Rabarison 2000
[3] Resolve/UQAR-ISMER 2019.
[4] Blue Economy Policy Letter, MPEB 2015; National Blue Economy Strategy 2023-2027, MPEB-BAD (2023)

1.2 PROJECT OBJECTIVES AND APPROACH

The main objective of this mission was to support, train and assist the MPEB's scientific team (including the DESP and its regional structures) in determining the state of stocks of fishery resources in the five sectors mentioned above, and in preparing and providing scientific management advice on the same resources. The specific objectives relate to :

- Training for the MPEB's scientific staff in the concepts and methods for assessing stocks (including the determination of health status indicators) ;
- Supporting the MPEB's scientific staff and assisting them in carrying out stock assessments or determining indicators of the state of health of fisheries resources, depending on the data available;
- Training MPEB scientific staff in the provision of scientific management advice;
- Supporting the MPEB and helping them to draw up scientific management advice for the five priority sectors;
- Training and support for MPEB scientific staff and fisheries statistics officers in the sorting, standardisation and planning of scientific data collection on the various fisheries;
- Supporting the MPEB's scientific staff in synthesising the project's achievements, with a view to creating a cohesive, competent and sustainable body of scientific staff within the ministry, capable of ensuring stock assessment, scientific advice and data collection planning in the future, in collaboration with its external scientific partners and stakeholders in the sector.

The project's approach focused on training and capacity building for MPEB staff in the performance of their duties. The project's approach took account of international best practice, including the FAO's Code of Conduct for Responsible Fisheries and the ecosystem approach to fisheries (EAF), as part of an adaptive, inclusive and participatory management approach.

1.3 PURPOSE OF THIS REPORT

This report constitutes the draft final report (or interim final report) for validation and takes into account the achievements and results of activities throughout the project programme:

- Gathering and analysing available data and stock valuation strategies ;
- Training and carrying out stock assessments or resource status indicators ;
- Training and scientific management advice ;
- Training on and analysis of marketing data for the 5 sectors to provide context and corroboration for stock assessments;
- Training on and analysis of data gaps and requirements to ensure and improve assessments and indicators of the state of resources;
- Iterative evaluation with a view to building the capacity of the MPEB's scientific staff stock assessment and scientific advice during and after training courses and projects;
- A description of the achievements, including problems and challenges encountered, recommendations and technical proposals, and a summary of the major results (legacies) of the exercise.

1.4 HOW THE ACTIVITIES TAKE PLACE

1.4.1 Activities calendar

The activities were carried out according to a timetable that underwent two iterations:

- Iteration 1 (designed before the intervention of the pandemic) over 15 months ;

- Iteration 2 (designed to restart the project after the pandemic and with a view to the advanced closure of the SWIOFish2 project in September 2023) (over a period of 11 months).

The updated schedule of activities is presented in Appendix 1.

1.4.2 Analysis of actual versus forecast

The following table summarises the planned and actual training durations.

Table 1: Provisional training timetable

TRAINING TOPICS	Forecast	Duration (days)
Introductory training on stock valuations	One week	5 days
Training on stock valuation models Introductory training on water supply	One week	5 days
Stock valuation session Consolidating skills in stock valuation	One week	5 days
Fisheries management training	One week	5 days
Formulation of scientific management advice	One week	5 days
Presentation of scientific advice + seminar	One week	5 days
Training on the categorisation of data needed/to be collected for fisheries management Sampling and data collection strategy Drawing up a data collection framework	One week One week	5 days 5 days
	8 weeks	**40 days**

Table 2: Schedule of face-to-face training programmes

ACTUAL FACE-TO-FACE TRAINING PROGRAMME	Date	Duration (days)
Introductory training on stock valuations Assistance with crab stock assessment (CORECRABE)	14 to 16 Nov 22 17 and 18 Nov 22	3 days 2 days
Training on stock valuation models Sharing assessment of octopus stocks	20-22 Feb 23 23-24 Feb 23	3 days 2 days
Directed session on stock assessment for the shrimp industry, sea cucumbers, lobsters	27 Feb to 02 March 23	4 days
Fisheries management training	20 to 22 March 23	3 days
Formulation of the ecosystem approach to fisheries management	23 and 24 March 23	2 days
Guided crab stock assessment session	27 to 29 March 23	3 days
Training in fisheries management and the formulation of fisheries advisories fisheries management	10 to 14 April 23	5 days
Directed sessions formulating scientific advice for each sector	17 to 21 April 23	5 days
Seminar on training in stock assessment, fisheries management and management advice Presentation by the trainers and participants of the evaluations and management notice	24 to 26 April 23	3 days
General review session (Clinical) Presentation of data collection methods for the five sectors Presentation of the Ministry's data collection methods Achievement of consistency in data collection methods data for stock valuation purposes (5 sectors)	03 to 08 July 23	6 days
		40 days

Table 3: Details of training courses

PROJECT DETAILS	Date	Duration (days)
Introductory training on stock valuations Assistance with crab stock assessment (CORECRABE workshop)	14 to 16 Nov 2022 17 and 18 Nov 2022	3 days 2 days
Online training for the 5 streams: - On prawns (Haja Razafindrainibe) - On octopuses (Daniel Raberinary) - Jean Claude Brethes course - On lobsters (Daniel Raberinary) - On sea cucumbers (Richard Rasolofonirina) - On sea cucumbers (continued) (Richard Rasolofonirina) - On crabs (Marc Leopold) - On crabs (continued) (Marc Leopold)	 24 Nov 2022 24 Nov 2022 24 Nov 2022 25 Nov 2022 06 Dec 2022 08 Dec 2022 08 Dec 2022 09 Dec 2022	3 days
Training on stock valuation models Sharing assessment of octopus stocks	20 to 25 Feb 2023	6 days
Directed session on stock assessment for the shrimp industry, sea cucumbers, lobsters	27 Feb to 02 March 2023	4 days
Guided crab stock assessment session Directed session for the lobster sector	27 to 31 March 2023	5 days
Fisheries management training Training in the ecosystem approach to fisheries Training in fisheries management and the formulation of fisheries management advice Presentation of the crab industry Directed sessions on formulating scientific advice for the sector lobster	17 to 22 April 2023	6 days
Presentation of the shrimp, lobster, octopus and sea cucumber sector Seminar on training in stock assessment, fisheries management and management advice Presentation by the trainers and participants of the evaluations and management notice	24 to 28 April 2023	5 days
Additional general review session on stock assessment and data requirements, data categorisation, sampling and data collection strategy, different stock assessment models for commodities Sharing information on the Department's data collection strategy Consistency of the data collection strategy and drawing up a data collection manual	03 to 08 July 2023	6 days
		40 days

1.4.2.1 Comments on the table :

- Additional participation in octopus assessment training was carried out with CGP (Comité de Gestion des Poulpes) in Toliara in order to confirm the consistency of the activity with other stakeholders and to obtain further data;
- Participation in the national CORECRABE workshop also enabled activities to be brought into line with each other.
  with other initiatives and provides an additional experience for participants;
- Fisheries management training postponed to take advantage of the experience of expatriate instructors;

- The last practical session was held in Mahajanga for all 5 commodities (finally, practical sessions in Toliara (sea cucumbers) and Taolagnaro (lobsters) in small groups proposed in January could not be held due to the unavailability of data on site and the request of participants to attend all sessions);
- Sea cucumber stock assessment postponed due to data availability ;
- The need for general revision to anchor learners' knowledge;
- The presentation of a summary of what has been learned by the participants themselves was not fully carried out due to the lack of time to prepare the participants, hence the need for a general review;
- The training of the Ministry's surveyors on data collection was not carried out as the MPEB surveyors had already been trained on their data collection system and were already in the field for the applications. This session was replaced by training on the MPEB's data collection system and the drafting of a manual to ensure consistency in data collection;
- There were some delays in preparing the stock assessment reports, which took much longer than expected due to the distance between the parties involved and connection problems (technical disruption);
- Aware of the importance of their knowledge of stock assessment for the 5 commodity chains, and with the aim of sharing it with the MPEB, the participants decided to set up a stock assessment working group, which they presented to the Minister during the last session in Mahajanga, who gave it a positive reception.

1.4.2.2 Conclusion on the duration of activities

We can conclude that the actual duration of activities was well in line with forecasts and sometimes exceeded forecasts. In particular, it can be noted that :

- The total duration of the main training courses was respected (40 working days vs. 8 weeks in the forecast) (not including travel);
- The content of the training courses was enriched with the addition of activities not included in the initial schedule (attendance by learners at the national workshop of the CORECRABE project; pre-training of a trainer and one of the learners in octopus stock assessment in Toliara in collaboration with the CGP and Blue Ventures; guided SWOT analysis session);
- A general review ('clinical') session has been added to the main training courses to address aspects that learners found more difficult to master.

1.4.3 Description of activities

1.4.3.1 Designation and initial assessment of learners

The client was able to nominate 12 instead of the 15 candidates it had hoped for. The Group then evaluated the candidates according to five major criteria (academic level, area of expertise, level of experience, relevance to current position and possession of relevant specific skills). In summary:

- 2 candidates were classified as 'experts' who could play a support role for the others learners in training and work ;
- 8 candidates were classified as 'suitable' for training and work;
- 2 candidates were classified as 'less suitable' and required more substantial support and monitoring;
- No candidate was classified as 'unsuitable'.

It should be noted, however, that three candidates were only partially available for training due to their responsibilities within the Ministry. These candidates were kept informed throughout the project and received copies of all the training materials.

1.4.3.2 Introductory courses

The introductory training sessions on stock valuation were held face-to-face at Hôtel Le Pavé. Antaninarenina on 14, 15 and 16 November 2022, covering the following main routes:

- Introductory training in fisheries management adapted to the Madagascar context;
- An introduction to the Ecosystem Approach to Fisheries (EAF) ;
- A session on the role and value of scientific research in fisheries management;
- Introduction to stock valuation (general module before proceeding with the streams) ;
- The main types of model ;
- Statistical evaluation models ;
- Direct assessment of abundance ;
- Production surplus models ("global models") ;
- Analytical models ;
- Capture per recruit ;
- Sequential population analysis ;
- Other procedures ;
- Traffic lights ;
- The PSA approach ("Productivity and Susceptibility Analysis").

The introductory training course was followed by a two-day workshop (17 and 18 November 2022) organised by CORECRABE at the invitation of the Ministry, during which participants were able to see the management of a commodity chain in action and compare their theoretical training in the context of a dynamic multi-stakeholder commodity chain.

The debriefing session after the five days showed that the learners were active and the participation rate and group dynamism were quite high. And the rather pertinent remark means that, if we collect data, we should give feedback to the fishermen, explaining to them what the data collected will be used for.

Participants were particularly interested in the descriptive training sessions held online (on 24 and 25 November 2022 and on 06, 08 and 09 December 2022), where they stated that they had very little knowledge of certain species, and that examining each course proved very instructive.

After drawing up the list of available data, a table of the types of data by sector still required was drawn up for completion by both experts and participants.

Stock assessment sessions are the major development in the group's activities during the year.
training from 20 February to 02 March and from 27 to 31 March 2023 :

- Training courses on stock assessment for 4 of the 5 sectors (all except sea cucumbers);
- Introduction to R software ;
- Identification and analysis of available data on each resource (except sea cucumbers) ;
- Finalisation of the models for the different sectors (except sea cucumbers).

The particular case of sea cucumbers is worth mentioning. In view of the absence of catch and size data, even for a single region (as, for example, in the case of octopus and lobster in the south-west and south-east), time has been invested in exploring and identifying alternative approaches to resource assessment for presentation in the next series of training courses to be held from 17 to 28 April 2023.

The group's activities from 17 to 28 April 2023 covered :

- Fisheries management ;
- The Ecosystem Approach to Fisheries (EAF) ;
- Stock assessment - continued (finalisation of assessments for the shrimp, crab, lobster and octopus sectors and assessment of sea cucumber resources as a data-deficient resource);
- Formulation of scientific opinions ;
- Holding a seminar to summarise the results of the project, including a joint workshop on octopus with Blue Ventures/CGP.

In addition, a number of ancillary activities were carried out:

- Assessment of learners' level of knowledge following previous training courses;
- Assessment of prior learning (at the end of these courses) ;
- Programming of the final project activities.

The major development of the group's activities during the training period from 03 to 08 July 2023 consists of :

- General review sessions (clinical) ;
- Presentation of data collection methods for the five sectors;
- Presentation of the Ministry's data collection method ;
- Achieving consistency in data collection methods for the purpose of evaluating stocks (5 sectors).

1.4.4 Challenges and problems encountered

Challenges and problems of various kinds were encountered during the course of the project, requiring adaptive action to overcome them. They are presented in Table 4 by category and in chronological order of occurrence.

The major external challenges and problems concerned the COVID pandemic, administrative disruptions within SWIOFish2, the dissolution of para-ministerial structures (CEDP, URL) and the advanced closure of SWIOFish2. The major technical challenges concerned the limited availability of learners, the challenges of ensuring their assimilation of the training, the availability of data for evaluations and the adaptation of the training to small-scale fishing. The communication challenges concerned the need to ensure the flow of technical information to the learners, effective communication between the group and the learners, and communication among the learners themselves. Finally, the logistical and financial challenges concerned the availability of learners and trainers, the unavailability of training rooms at the Ministry, the dilapidated state of the national roads, the sharp rise in air fares and the staggering of payments. Thanks to the adaptability of the learners, the group and the customer, and to the spirit of collaboration between all those involved, we were able to overcome all the challenges and problems encountered.

Table 4: Challenges and problems encountered

CHALLENGES / PROBLEMS ENCOUNTERED	**Issues and action taken**
EXTERNAL CHALLENGES	
Challenges health, administrative, institutional and scheduling challenges	At the start of the project, **the COVID pandemic** hit, requiring all physical movement of people to be halted. All the options for moving the project forward virtually were examined, but it was decided not to go ahead with the project.

	effective suspension of the activities of the SWIOFish2 UG, as well as the blocking of the group's managers and trainers made it difficult to move forward. When the pandemic ended, **the SWIOFish2 UG experienced administrative** and operational **disruption** following the departure of the initial coordinator, followed by the arrival and departure of his replacement, before normal operations did not resume until September 2022. In all, these external factors resulted in a 12-month delay. In addition, the decision taken in 2022 to **dissolve the inter-ministerial structures, including the beneficiaries of the project (CEDP and URL**), and to replace them in part by the creation of a new Directorate of Studies, Statistics and Planning (DESP) has called into question the feasibility of the project. Finally, the decision was taken **to bring forward the closure of the SWIOFish2 project to September 2023**, requiring the timetable to be compressed from 15 to 11 months (see annex for details). A contract amendment is signed to reflect the new arrangements and adjust the timetable.
Reduced project duration	The initial timetable was designed to ensure that the pace of training did not disrupt the work of managers. The narrowing of the timetable following the pandemic and the decision to close the SWIOFish2 project earlier than planned meant that the schedule had to be significantly compressed without compromising the content of the training courses, with the major disadvantages of reducing the number of managers available for training and preventing them from following the full annual cycles of data collection from the various resources.
TECHNICAL CHALLENGES	
Availability of learners for training	**The number of managers within the MPEB available to take part in the training is necessarily limited by their work obligations** in carrying out the Ministry's programmes and functions - a consultation with the Minister at the time of the restart in 2022 emphasised the twofold usefulness of the study - carrying out stock assessments (still a priority for the Ministry) and providing training for their future implementation. This argument led to the designation by the MPEB of 15 managers capable of taking part in the project's training and activities, whereas only 10 had been appointed. were able to follow the course in its entirety.
Challenges assimilation of participants	After the initial assessment of the learners based on the documents available, the trainers monitored the learners' assimilation through interactions during the lessons and technical work sessions. At the beginning of the 2023 training courses, an in-depth evaluation of each individual was carried out by one of the IRD experts, who identified the strengths and weaknesses of each learner in order to better adapt and target the remaining training courses and exercises. At the end of the training courses in May 2023, a second evaluation helped to identify the progress made by the learners and the aspects still to be strengthened. The learners themselves stressed the importance of practical exercises in order to understanding and mastering the different assessment methods. In response to these various findings, the group organised and financed an additional review and training session in Mahajanga on 3-8 July 2023, during which a 'clinic' enabled learners to review aspects that had not been assimilated. The capacity analysis in this report aims to summarise assimilation completed by the end of the project.

Availability of catch data	The availability of quality data over a number of years is essential for carrying out stock or resource status assessments. Different measures have been taken for each sector. Overall, the collection and analysis of marketing statistics for fishery products from the MPEB enabled us to identify overall national and regional trends for each sector. For **prawns**, these marketing data were particularly useful in assessing the state of small-scale fishing. For **crabs**, collaboration with the CORECRABE project through the IRD and the IHSM was crucial in carrying out stock assessments. For **octopus**, the group has established a relationship with Blue Ventures and the CGP du Sud-Ouest to secure access to catch data over several years (2015-2022). This latest collaboration has enriched the analyses for a more robust result on the
	octopus. For **spiny lobsters**, collaboration with key staff at the former URL in Taolagnaro provided access to catch data over several years, helping the project to complete spiny lobster stock assessments for the south-east region. Finally, for **sea cucumbers**, the combination of analysis of marketing data (international, national and regional) from the MPEB and various observations of the state of the resource in the scientific literature and data from exporters enabled an **assessment of the state of this data-deficient resource** to be carried out and, following analysis of the ASH data, to provide guidelines for compliance with the obligations under the Convention on the Conservation of Migratory Species of Wild Animals. CITES.
Adapting training to small-scale fishing (PPE)	It is important to emphasise that this project essentially concerned 5 sectors of importance to small-scale fisheries (SSF). Sustainable SSF is recognised worldwide for its contribution to poverty reduction and food security. Historically, only industrial fishing has had the resources to collect data. **The SWOT analysis of the 5 sectors** helped learners to situate their training in the context of small-scale fishing and its specific challenges in fisheries management, stock assessment, scientific advice and data collection.
COMMUNICATION CHALLENGES	
Communication challenges for training and collaboration	A training and collaboration project of this complexity requires good communication. The group has taken the following steps: • Consultation with communication, IT and training experts on the tools and approaches to be used, including the acquisition of a Zoom licence for online training, the setting up of a website for the project and virtual training techniques; • Recruitment of a communications specialist from Resolve at the launch of the training programme, which helped a great deal in getting the courses off the ground; • Purchase of a TELMA Powerbox with connections for 10 computers to facilitate communication and use of the Internet during training courses; Setting up of chat groups on What's App to facilitate communication between groups and learners. • Creation of a dedicated training web page on the Resolve website to store training materials. • Among themselves, the learners organised themselves to issue collective messages on important issues relating to the implementation of the programme. During the workshops, verbal exchanges also helped to reconcile the learners' expectations with the group's obligations and commitments. One-to-one interviews with learners also allowed questions to be discussed in greater confidence. Overall, communication between learners and the group was good. • The final act of the learners is to create a stock assessment working group as a permanent framework for communication between the learners, who will become future stock assessors.
LOGISTICAL AND FINANCIAL CHALLENGES	

Availability of participants (learners)	Initially, because of the pandemic, some trainers were unavailable and/or obliged by health regulations to travel. Some introductory training courses at the start of the programme were carried out online with Zoom (for which a subscription was obtained by the group), taking into account good practice in online training (distribution of presentations before the session, posting of documents and aids online, etc.). At the end of the pandemic, following requests from learners and budgetary analyses, the remainder of the training was carried out mainly face-to-face by organising multiple training sessions relatively close to each other. to limit the number of trips.
Availability of trainers	The IRD's main trainer, initially based at the IHSM in Toliara, left Madagascar in 2022, limiting his availability for face-to-face training courses. to provide some of its training. The unavailability for health reasons of the
	The unavailability of the national shrimp trainer was offset by the international trainer taking over his modules. The unavailability in 2022 of the 2ème IRD trainer was compensated for by the report of his training in PEA after the stock assessments, but also had advantages by taking advantage of his presence later in the programme to carry out an evaluation of the learners and to conduct a participatory SWOT analysis of small-scale fisheries in as an additional exercise.
Rooms of training and projection facilities	Although the contract provided for the training sessions to be held in the Ministry's rooms, this was not possible due to the lack of electricity in the main meeting room. The Groupement decided to hold the meetings in private establishments in Antananarivo and Mahajanga, on its own account. In In addition, the group's leader has bought an overhead projector with his own funds to ensure projection in the event of default by the establishments.
Transport - dilapidated state of national roads / higher prices and limited availability of Tsaradia flights	As a result of the pandemic, the state of the national roads has become worse than ever, making road travel difficult. While most learners based in Mahajanga were willing to travel by road properly, those further afield (Diego) were forced to travel by bus for very long journeys. To mitigate the impact, meetings were held only in Antananarivo and Mahajanga. At the same time, the availability of domestic flights has diminished and ticket prices have risen sharply, adding to the challenge of providing the necessary transport within budget. Logistical efficiency and prudent budget management have made it possible to activities without compromising the results of the project.
Availability of instalments	The high operational costs of the project limited the ability of the consortium to fund activities prior to receipt of payment for the previous deliverable - the solution was to retain within the consortium a precautionary margin of 20% for trainers' fees and still ensure timely delivery of reports and related invoices. The UG of the SWIOFish2 project was very understanding and cooperative in ensuring the rapid review of deliverables and payment. invoices.

2 TRAINING COURSES HELD

2.1 TRAINING PLAN

Each methodological stage will be supported by theoretical training for MPEB staff, followed by technical training or, as the case may be, practical work sessions involving stakeholders when it comes to making management decisions.

The training plan will begin with the various theoretical courses, which will be presented in virtual form with modules for each theoretical course. Practical training and work sessions will be carried out with a specific number of trainers.

This training project will culminate in an evaluation of what MPEB staff trained in the two-day seminar.

The training courses followed the pre-established plan set out in the table below:

Table 5: Training plan

Phase	Methodological stage	Type of training	Course content	Training methods and concerned
Phase 1: Training cross-disciplinary	Introductory training for fisheries management	Theoretical training for base		
Phase 2: Stock valuation	**1. Assessment of available data and data required for the future**	1. Basic theoretical training	* Basis of stock valuation * Basics of population dynamics * Notion of fishing as a system (elements, interaction, emergent properties) * Types of data to be searched	Virtual CEDP-URL/Trainers
		2. Practical training session explaining the types of information to be search	1. Description of the 5 fisheries sectors * Biological variable (resource) * Environmental variable * Human variable (fishermen as social and economic players, role of markets, role of regulations) * Inventory valuation	Virtual CEDP-URL/Trainers
			2. Inventory valuation * Biological variable (growth-mortality-recretion) * Farming variable (farm dynamics, catch, fishing effort, concept of CPUE)	Virtual CEDP-URL/Trainers
		3. Work session	- Determination of strategies and action plan for acquiring data required	Face-to-face if possible CEDP-URL/Trainers

Phase	Methodological stage	Type of training	Course content	Training methods and concerned
Phase 2: Stock valuation	2. Stock valuation; indicators/points of reference	1. Theoretical training	1. Fishing theory * Biomass/production relationship * Notion of equilibrium * Notion of maximum equilibrium grip (MSY) and maximum grip * Principles of large basic models	Virtual/ or Face-to-face if possible CEDP-URL/Trainers
			2. Concept of the ecosystem approach to fisheries	
			3. Biological and biometric data for target species, ecosystemic data (biotic and abiotic impacts), main fishing areas and periods, fishing gear, production, etc.).	
			4. The main types of stock valuation model: * Production surplus models (global models) * Analytical models: - capture per recruit - sequential population analysis - other procedures: "Traffic lights PSA approach (Susceptibility Analysis)	
		2. Practical work session	- Description of the 5 sectors: * identification of appropriate indicators	CEDP-URL/TRAINERS
			- Validation of values based on available information	
			- Design of a dashboard for each sector * thanks to AEP training: *Identification of areas of application and methods by sector* * Real assessment of the state of resources in each sector	Face-to-face
		3. Analysis session	- Analysis of the models and their limitations in relation to the data available and the biological characteristics of the target species.	CEDP-URL/TRAINERS Face-to-face + economic operators or stakeholders
			- Analysis of data sources, how they are collected and their frequency.	
			- Analysis of their reliability, statistical representativeness and consistency.	
			- Definition of strategies, methodologies and action plans to complete the data for future assessments.	
			- Definition of the system of interviewers to complete the information.	
		4. Practical training	- Revision of models already available and usable in the specific case of each sector on the basis of available data.	CEDP Scientists-URLs/TRAINERS
			- Refinement of models in relation to additional data perspectives to acquire.	On-the-job training.
			- Development of stock valuation models appropriate to the context of the target fisheries.	Face-to-face

Phase	Methodological stage	Type of training	Course content	Training methods and concerned
Phase 3: Formulation and provision of scientific advice	**Formulation and provision of scientific advice**	1. Theoretical training	- General training on fisheries management.	CEDP-URL/trainers Face-to-face
		2. Work session	- Formulation of scientific opinions. * use of assessment results * choice and presentation of data	CEDP-URL-TRAINERS-Stakeholders On-site
			- Decision-making process * basic information-to-decision scheme * the place and role of the different sciences * place and role of stakeholders in the sector * the place and role of decision-makers	
			- Decision-making * management objective * management tools * use of scientific advice	
		3. Analysis session	- Critical diagnosis of historical fisheries management systems and their efficiency.	CEDP-URL Working Group MAEP TRAINERS
			- Critical assessment of current fisheries monitoring.	Face-to-face in the field
Phase 4 - Data acquisition and standardisation	**Data acquisition and standardisation**	Practical training	- Implementation of the information gathering plan, categorisation of data and formulation of questionnaires.	CEDP-URL/Trainers
			- Precautionary approach	
			- Formulation of opinions	
			- Identification of human, technical and financial resources, Design of databases adapted to the profile of each resource and formulation of requirements. analysis framework.	
			- Initiation of data collection in the field with the appointment of interviewers and supervisors to ensure efficient data collection reliable.	
Phase 5: Consolidation of all the achievements and evaluation of the CEDP's capacity and URLs		Technical work session in the field	- Continuation of data collection.	CEDP-URL
			- Entry of the first data collected.	
			- Data verification and standardisation.	With suggestions for Trainers
			- Review of stock assessments and initial scientific advice in the light of new data.	remotely
			- Consolidating achievements in fisheries management.	
			- 2-day seminar presentations on the various activities and products of the project.	CEDP-URL/Trainers

2.2 INTRODUCTORY COURSES ON STOCK VALUATION

The first introductory course focused on several modules, including :

1. Introduction to the concept of fishing in Madagascar;
2. The principles of fisheries biology in Madagascar;
3. Catch, fishing effort, biology and population dynamics;
4. Growth and mortality ;
5. Modelling and its principles ;
6. Classical stock assessment models in Madagascar;
7. Other approaches to stock valuation.

The participation of IRD and IHSM in the CORECRABE workshop was an excellent opportunity for participants to see the management of a priority commodity chain in action, and to put their theoretical training into the context of a real and dynamic commodity chain.

Taking advantage of the large number of participants at the CORECRABE workshop, the consortium (RESOLVE, IRD and IH.SM) organised a debriefing session at the end of the workshop with all the learners and trainers, as well as the mission leader Pr. Jean-Claude Brêthes, to gather feedback from the participants, their overall view of the quality of the training and the areas for improvement, and their opinion of the CORECRABE workshop.

2.3 DESCRIPTIVE TRAINING ON SECTORS

2.3.1 Coastal prawns

Of the more than thirty species of shrimp of commercial interest (continental waters, coastal marine waters or deep waters on Madagascar's continental slope), only the neritic peneid shrimp (6 species) are exploited on a sustained and large scale, with the small Sergestide *Acetes erythraeus* (chevaquine) in coastal waters, which is consumed locally.

Shrimp are amphibiotic, migrating between estuaries (intertidal zone) and the sea: environmental conditions (salinity, temperature, nutrients) determine their spatial and bathymetric distribution, the survival and growth of larvae and juveniles, and their availability to each type of fishery.

The shrimp fishery is reputed to be sequential, with 2 fishing segments: small-scale fishing and industrial fishing, which currently overlap.

The bay of Ambaro, on Madagascar's north-west coast, is certainly the most developed, with the highest concentration of small shrimp fishing villages in Madagascar.

Regulations cover prohibited gear, the characteristics of authorised gear, the registration of pirogues and marking of gear, the closed season, the certificate of origin and healthiness, and the professional fisherman's card.

Inventory valuations concern :

- Species exploited: 5 peneid species + 1 species accessible to PPC ;
- Models used: Schaefer and Fox models (global models) ;
- Data: Assessments based exclusively on industrial fishing data;
- Assessment based solely on PCI (and therefore dubious);

- The "MSY" per development zone calculated previously.

Previous studies on this sector are mainly :

- On PCP**:** Very rare / sporadic: late 60s - early 70s, 80s, 90s, late 90s - early 2000s, 2018
- Mainly on the north-west and west coasts: typological studies of traditional fishing across all sectors (national framework surveys): 1987-88; 2012; regular monitoring in terms of catches and effort using logsheets.

In 1998, a reliable and controlled storage base for the shrimp fleet's activities, BANACREM, was set up within the Fisheries Directorate (Razafindrakoto, 2005).

Madagascar's shrimp stocks have been successively assessed using the Schaefer and Fox models. The assessments were based on industrial fishing data. In fact, small-scale fishing, described as "traditional", was insufficiently identified, with effort and catches not being monitored despite evidence of a clear upward trend in these parameters (1980s; PATMAD, 1996; PNRC, 2008; etc.). In addition, the fishery uses gear that is not very selective. A number of hypotheses have been put forward: a reduction in the trawlable stock linked to low recruitment; a natural and cyclical fluctuation in the biomass; biological over-exploitation linked to the uncontrolled extent of the MDT; significant impacts of the environmental factor linked to exploitation practices (modification of the shrimp beds through continuous trawling and the dumping at sea of a large biomass of secondary catches; impacts of climate change on the physico-chemical characteristics of the environment, etc.).

The PNRC, funded by the AFD and with the support of the IRD and the GAPCM, has had mixed results, but we feel that the overall picture is positive. Studies have been carried out on the biology, population dynamics and assessments of exploitation levels, as well as on the economy.

In the field of the biology of exploited species, the growths of the three main shrimp species have been estimated, mostly by major geographical areas and seasons, based on tens of thousands of shrimp markings carried out with the help of shipowners. The differences highlighted between species, areas and seasons are significant. The absence of major migrations has been confirmed.

Population dynamics studies have reached an unprecedented level, with real cohorts of individuals of the same age group being monitored over several years to study levels of exploitation by sex and overall. Of course, there are still some uncertainties associated with this type of study, and it is regrettable that their evaluation (or rather their direction of evolution) has not been carried out by introducing different values into the range of possibilities.

The bio-economic model, developed fairly early on in the programme, has subsequently been considerably improved. It can now run simulations over 10 years. Whatever the version of the model, it remains demanding in terms of information, both biological and economic, and the effort required to update it regularly should not be underestimated. The use of a bio-economic model, both in carrying out simulations and in analysing them, requires expertise in the various aspects taken into account in the model, and this raises the question of strengthening national capacities, the costs of application, control and monitoring, and the feasibility of measures.

The Ministry of Fisheries is responsible for managing the shrimp fishery. For several years now, the Ministry has been developing a partnership / co-management with fishing operators, particularly those in the shrimp industry, grouped together in the GAPCM. The new regulations issued by the Ministry envisage the inclusion of local communities in this co-management process. In addition, close collaboration with international NGOs has been woven.

Indicators and a scoreboard will be designed in line with the proposed methodology. This methodology guides the search for data and information at the Ministry responsible for fisheries and, where necessary, at landing points. The open cooperation of the stakeholders concerned (fishing companies, collectors, fishermen, etc.) is therefore desirable.

2.3.2 Coastal lobsters

Five species of lobster have been identified in Madagascar: *Panulirus penicillatus, P. ornatus; P. homarus, P. versicolor, P. japonicus* (REMANEVY, 1993), of which the following three are the most exploited in Fort-Dauphin: *P. homarus, P. longipes* and *P. penicillatus* (Dizano, 2021). Spiny lobsters are among the species with a fairly slow growth cycle, and can live for more than 15 years (Phillips et al, in Coombs and Phillips, 1980). Depending on the species, the refuges are diversified according to various substrates: rocks, mud, sand and seagrass.

Morphologically, males can be distinguished from females by three criteria, including the absence of tweezers on the tip of the fifth pair of podia in males. In females, these tweezers are used to scrape off the spermatophore plate deposited by the male during mating.

Lobster fishing has been practised in Madagascar since the early 20th century. The technique most commonly used in Fort Dauphin is trap fishing. The second fishing technique involves using nets to target fishing areas with mini holes or caves, and "Kipa" is also widespread in the Anosy regions. In Tuléar and the northern part of Madagascar, some fishermen practice snorkelling in addition to these three techniques.

The minimum size for catches is 20 cm, according to the regulations, and the national closure has changed: in 2003, it went from 1 October at 00:00 to 31 December at 24:00 throughout the territory and all waters under Malagasy jurisdiction, but in 2017 (modification), it became :

- from 01er January at 00.00 to 31 March at 24.00 each year in the Regions of Androy, Anôsy, Atsimo-Atsinanana and Vatovavy-Fitovinany,
- from 01er October at 00.00 to 31 December at 24.00 each year in the Atsinanana, Analanjirofo, SAVA, DIANA, Sofia, Boeny, Melaky, Menabe and Atsimo Andrefana Regions.

***Note*: Local closure** (Sainte Luce Fort-Dauphin) for 3 to 5 months depending on the community's wishes. and has been in operation since 2014.

Sizes at first sexual maturity (L_{50}) differ from one species to another in the Anosy Fort- Dauphin region.

The results of the study carried out in Fort-Dauphin with the three species (*Panulirus homarus, P. longipes, P. penicillatus*) illustrate a contrast between the peak spawning periods for these three species. Most of the products are destined for export (95%). The main destination countries for lobsters from Madagascar are France, Japan, China and Mauritius.

To study the spiny lobster stock in Madagascar, it is easier to start with the data already available from the DRPEB/URL in Fort Dauphin. Based on the results obtained from the study of one or two species in the region, we could imagine the possibility of replicating the study with other species in the region.

other regions. In addition to the catch monitoring data available from the Ministry, we can work on with production data from companies such as Martin Pêcheur and Madapêche.

Depending on data availability, we consider both the global logistic Schaeffer model and the structured models (rectified VPA and YPR).

2.3.3 Mangrove crabs

The mangrove crab *Scylla serrata* is the largest species of the Portunidae family (up to 28 cm carapace width), the other species of the *Scylla* genus are absent from Madagascar. As with all crustaceans, growth is discontinuous and occurs in successive moults. The mature size of females is estimated at 12cm (between 10cm and 14cm) (Le Reste 1976), which was confirmed by a study by an IH.SM student in the Belo-sur-mer area (Razoanirina, 2015).

After spawning at sea (which explains why very few egg-bearing females are caught), the juveniles settle in the channels and in the mangrove hinterland (tannes). Mating takes place in burrows in the mangrove.

The industry has been developed since the 1990s through the export of frozen crab, and has diversified into the live crab market since 2013. This has led to a sharp increase in fishing pressure and in domestic and exported production, and the need to manage resources and assess them. Exports have fluctuated around 2300t/year to 3100t/year since 2015 after peaking at 3400t in 2014. The proportions have changed considerably recently between the frozen and live markets, and while the live crab market has dominated since 2014 (50% to 75% of exports), it will only account for 24% of exports in 2022. Customers are mainly France, Mauritius (frozen) and China (live and frozen).

Five main techniques are used to exploit the fishery:

1. with a hook (iron or wood) or sometimes by hand or with a small "spade" (angady);
2. Scales with iron or wooden hoops (weighted down with shells), using bait and a racket to remove the crabs from the scales once they have risen to the surface;
3. angling with bait ;
4. Trekking with bait, a technique that is still not very widespread (especially in the Mahajanga area);
5. snowshoeing at night with a torch.

It is estimated that there are nearly 8,000 crab fishermen nationwide, according to censuses. of the CORECRABE project.

The management of the mangrove crab industry in Madagascar is based on the rights of commercialisation (Décret N°2017-352 Arrêté 28239/2019 du MAEP) :

- Individual collection licence (purchase from fishermen and resale to a collection company in the territory) of a Commune): this is the fishmonger's card;
- Collection company & Collection cooperative (buying from fishermen, wholesalers and individual collectors and reselling on the domestic market) known as a collection licence;
- Exporting collection company (buying only from collectors and selling on the export market) export permit) which is an export permit (frozen and/or live crab).

Restrictions apply to collection and export permits. Minimum legal size :

- Before 2006: no regulations on minimum size
- 2006 (decree no. 16365/2006): 10 cm
- 2014 (order no. 32 101/14): 11 cm between the last points of the carapace.

But as we saw at the national workshop, compliance with the minimum size is a real issue, as it is not being respected according to observations made by scientists.

As for the national closure period, it was set from July to the end of October in 2014, then reduced from July to the end of August in 2016, changed from August to the end of September in 2019 and changed from mid-October to mid-December in 2020. The fact that the national annual closure period is stable has been appreciated by the industry, although it still poses socio-economic difficulties for some of the more vulnerable players.

Stock assessment methods will include the estimation of resource status indicators (catch per unit effort or CPUE, sizes, etc.) at appropriate spatial and temporal scales, as well as the modelling of stock dynamics based on a regional case study. The traffic light assessment method will be tested to monitor changes in fishery performance indicators.

In order to generalise the above approach so that fish stocks and indicators can be assessed in different regions of Madagascar and at sector level, the data collection systems for monitoring catches and fishing effort implemented by several organisations (NGOs, research institutions) and the Ministry in their respective areas of intervention should be standardised. Approaches and methods should be considered with a view to finding ways of harmonising and coordinating them at national level. By way of example, updated monitoring sheets were proposed during the training session, as well as data sharing methods.

2.3.4 Octopus

Three species of octopus have been identified in south-west Madagascar: *Octopus aegina, O. macropus and O. cyanea.*

In southern Madagascar, *Octopus cyanea* is very coastal (0-3 metres) with most of its abundance on coral flats, but it can still be found above 10 metres. According to a tagging study in the southern part of Toliara, this species can travel up to 5km.

In south-west Madagascar, three techniques have been used to date, including fishing on foot, fishing from a pirogue and diving. The minimum size of individuals caught in the Tuléar area in 2012 was 50g, while the maximum size recorded was 9,700g. The lifespan of female *Octopus cyanea*, which is determined according to the time of spawning, has been estimated at 12 to 15 months after settling on the seabed. At Tuléar, the weight at the age of first sexual maturity is 300g for males and 600g for females.

In Madagascar, where octopus fishing is considered less developed, a 35% increase in octopus exports to Europe was reported between 2002 and 2003 (FAO 2005). The main countries receiving octopus from Madagascar are France, Portugal, South Korea and Mauritius.

To manage this industry, two nationwide management measures have been in place since 2005: a minimum catch size of 350g, and the closure of octopus fishing between 15 December and 31 January in the western part of the island and from 1er June to 15 July in the east.

In addition to this national closure, several associations and platforms of committed fishermen have created a temporary closure of the octopus fishing area for 2 or 3 months. This local closure to octopus fishing aims to increase catches and individual weights.

The study of stock trends is based primarily on biological data and catch data for the species under consideration. It is therefore very important to understand the biology and catch structure of the species under consideration. Before understanding the true distribution of populations, we should consider a unit based on geographical barriers or biological characteristics.

Octopus is one of the country's strategic resources, and one that deserves to be managed properly. Annual catch data already show a disproportion between catches in Tuléar and the total tonnage recorded in Madagascar. It is possible that the *O. cyanea* species in Madagascar is made up of several populations (stocks).

The data required for stock assessment are catch data on fishing effort, catch per unit effort (CPUE) and also data on the distribution of individual weights. Catch data are available from export companies such as COPEFRITO and Murex in Toliara, and from DRPEB. With regard to fishing effort, individual size distribution and catch per unit effort data, we are going to use the data already available from the NGO Blue Ventures.

For the stock assessment itself, we will use both the global model and the structural models:

- The global model proposed in relation to the available data is the depletion model or GDM (Generalized Depletion Models), which is a statistical model, and is based on catch data series, CPUE and fishing effort, with estimates of other parameters such as natural mortality (Roa-Ureta, 2015).
- The structural model relies on cohort analysis (VPA) which is based on age-structured data grouped by sampling month (Raberinary, 2015). In addition to the size-structured data at NGO level, we also need to consider the total catch of the DRPEB using extrapolation factors to convert them into size-structured sample data (Modou, 2010). The VPA results will be used as input data for estimating stock status (MSY), based on the YPR model. The results obtained with YPR can be compared with changes in spawning biomass or other factors.

2.3.5 Holothurians

Sea cucumbers are vermiform or serpentine marine animals, shaped like cucumbers or buns. Sea cucumbers have long been exploited as a coastal marine resource, and are of major socio-economic interest. The trepang or bêche-de-mer is the dry product obtained after processing.

In Madagascar, the Hindus have been exploiting and exporting sea cucumbers to Asian countries since 1920 (Petit G., 1930). Despite the heavy exploitation of these resources, no serious study has been carried out to manage them, and changes need to be made to current regulations.

In south-west Madagascar, fishermen exploit holothurians, either on coral reef flats or in lagoons or post-reef channels. Although some species can be found below boulders or in the crevices of coral reef flats, they live mainly in soft bottoms, on the surface or buried in the sediment. Sea cucumbers move slowly along the seabed, burrowing into the sediment.

feeding mainly on detritus. Most species reproduce by sexual multiplication; the sexes are separated and the male and female gametes are released freely into the sea where fertilisation takes place. Some species can also reproduce by scissiparity.

A research project entitled "Study of sea cucumber fishing and management measures", financed by the World Bank and managed by ONE (Office National de l'Environnement), was carried out by a team at IH.SM (Institut Halieutique et des Sciences Marines de Toliara) as part of Environmental Action Plan I (1991-1997), to lay the foundations for sustainable development.

In the short term, three objectives have been defined:
- Presentation of the current state of exploitation in south-west Madagascar;
- Study of the marketing of these products;
- Proposed development strategy.

The long-term objective of this study will be to perpetuate these resources for sustainable development. It is therefore necessary to approach the "holothurian fishing system" (Conand. C, 1988), which takes socio-economic aspects into account, if we are to assess the resources and propose a sustainable development plan. To this end, we have :
- identification of all the species of sea cucumbers encountered;
- an eco-biological study of the main species of commercial interest ;
- the study of the exploitation and marketing of these products.

Stock assessment must take account of the complexity of the holothurian situation, with around twenty species to study, the behaviour of certain species (burrowing, nocturnal), the variability of morphometric parameters (length, weight, soft body, etc.), the biology of holothurians (long life span) and the variability of habitats or biotopes. It was therefore initially proposed to start with the global model, i.e. based on the following parameters:
- CPUE ;
- Fishing effort ;
- Monthly change over at least one year in the production of a village ;
- Annual production ;
- Trend in annual production for a region based on data available at the national level ministries or regional fisheries directorates.

Analysis of the structural model would then be considered at the end of the study to obtain more precise values. reliable. As with other resources, this would require monitoring or studying the following parameters:
- Structure of the population studied: individual weight, individual length of each individual in the population ;
- Population density by biotope ;
- The surface area of each biotope in the study site.

The traffic light assessment method would be implemented and would make it possible to monitor changes in the fishery's performance indicators. It is suggested that this assessment be limited geographically to a clearly defined management area. The process could be repeated for other areas.

However, it is recognised that the lack of systematic collection of catch and effort data in holothurian fishing regions may require assessment approaches adapted to **deficient data** resources.

2.4 TRAINING ON DATA COLLECTION, RELIABILITY AND ACQUISITION

2.4.1 Data availability

It is crucial to have as complete a picture as possible of existing data on the various sectors. The group has drawn up a list of what is currently available, either directly or after examining databases.

The head of Mission drew up a table of types of data per commodity for the experts to fill in. The experts identified the data available for each sector by filling in the data available by sector form for the following fields:

- Biological data
- Ecological and environmental data
- Statistical data on fishing, marketing, etc.

2.4.2 Data reliability

Data on production by type of resource are recorded in national databases maintained by the ministry responsible for fisheries. Initial data are collected and sent to the central level by its regional services (pers. com.). In addition, the statistics department has already recruited field investigators two years ago (pers. com.); the concordance and complementarity between the data they collect and those supplied by the regional services should be checked.

Generally speaking, the national catch data recorded in the databases of the Ministry's statistics department are checked and collated from the various sources available: exports, certificates of origin and healthiness (COS), declarations by operators and/or collectors, before being considered validated (pers. com.). At this stage, we can say that the industrial fishing data are reliable, while the small-scale fishing data raise a number of questions regarding the following points:

- As far as shrimp are concerned, the wide range of small-scale fishing gear, the low selectivity of some gear and the fact that the use of some gear is prohibited raise doubts about the accuracy of catch data from small-scale fishing, especially as very small shrimp are not always collected;
- Crabs below the legal commercial size are not officially collected. Furthermore, live crabs are systematically seen on markets in the capital, and certainly in other major towns, throughout the closed season, a production that is not accounted for in the statistics;
- Sea cucumbers statistics do not distinguish between all species, given their sheer numbers. Collection and export data relate to trepang; however, dry weight can be transformed into live weight;
- The "self-consumed" fraction is not formally quantified, while the statistics
  The traditional fishing methods include collection.

The issue of coverage of all production areas, through the existence of regular collectors
/ There is also the question of the accessibility of certain areas for surveyors from the statistical service or regional fisheries departments. Nevertheless, data from certain regions are considered to be more reliable, depending on the resources of commercial importance; this is the case of the Anosy-Androy zone for lobsters, and Atsimo-Andrefana for sea cucumbers and octopus,

probably the Boeny region for crabs. Data from these regions could therefore be used for an initial stock assessment.

The assessment of neritic shrimp stocks will be somewhat hampered by the lack of small-scale data. fishing in some regions.

Small-scale fishing effort is estimated separately from production data.

The initial evaluations carried out as part of this project will enable the participants to envisage the future. following the collection of reliable data and to replicate the assessments in the various other regions.

2.4.3 Strategies and action plans for acquiring data for each sector

With the aim of ensuring that scientists are trained in the fisheries biology approach, capable of setting up collection protocols and monitoring databases, and that scientists are in a position to continue assessing resources.

As a result, the strategy adopted for data collection would be based on several levels: "Global"

approach: (Madagascar scale)

- Compile the data available to the statistics department, i.e. production data by product and by district ;
- Analyse and "clean up" the data series to obtain the main production trends over time by "region". These results should be put into perspective with economic trends (market development, etc.).

Regional" approach (local data by sector)

- Compile the data available to the statistics department of the regional services, in particular production data by product and by district, identifying the source of the information (origin and accessibility);
- Group the data according to a practical geographical scale (administrative region, biogeographical area, etc.). Give the main production trends over time by "region";
- Obtain sharing agreements and consolidate data in a common database.

Local" approach (local data by sector)

- Identify existing biological data and their time series ;
- Identify existing fishing data and their time series;
- Evaluate possible models and approaches for assessing resources and obtaining sharing agreements, and consolidate data in a common database;
- Make a precise (or empirical) assessment of the resources to obtain the potential (productivity) of each of the target species for one (or more) regions;
- Define the relevant indicators for monitoring resources, and create a "dashboard" based on the indicators, which will be a basic document that can be used in the future to monitor resources.

The definition of ecoregions (ecosystems) for each species or group of species will require the use of ecosystem mapping as a "proxy" for missing data and extrapolate the local potential to the whole territory to obtain a rough idea of the national potential of the different resources under study.

2.5 TRAINING ON THE DIFFERENT STOCK VALUATION MODELS

2.5.1 Reminder of the concept of stock valuation

To begin the training session proper, a few brief reminders were given. The biologists needed to be asked a few questions, such as :

- What is the state of the resource (in relation to a reference level) ;
- How much can you get out of it (without affecting its long-term viability);
- How quickly can the resource "regenerate"?
- What impact will fishing have on the ecosystem in which the resources are exploited?

Reminders of the general approach were also covered, as well as "signals" or indicators, more specifically the indicators used in resource evaluation. These indicators include :

- Fishing yield ;
- Biomass measurements ;
- Growth ;
- Mortality.

A reminder was also given of the useful indicators in the ecosystem approach to fisheries. In this sequence, the speaker focused on parameter estimation by memorising the basic rules, such as :

- The importance of time series ;
- It is often better to have a long series of data, even if approximate, than a few precise but specific pieces of data;
- It is better to be "generally true" than "precisely false".

It's also important to remember how to use pruning frequencies.

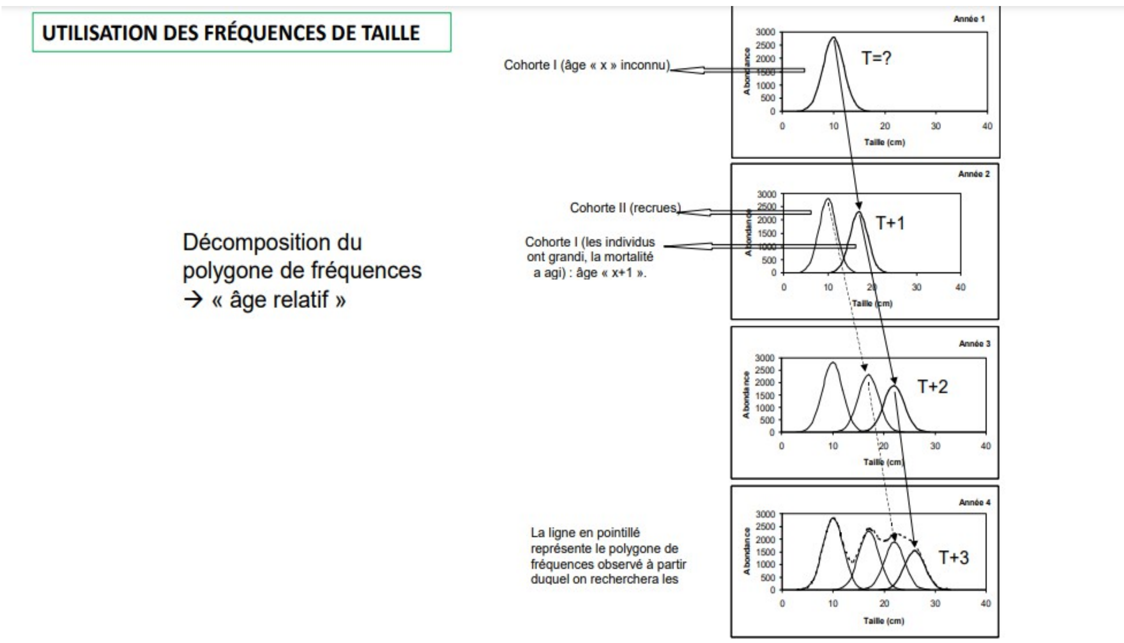


Figure 1: Use of size frequencies

2.5.2 Stock valuation models

Stock assessment models are mathematical (quantitative) models that provide a mechanical description of fishing dynamics and are applicable with quantitative fishing data (total catch, fishing effort, average weight, total weight, etc.).

2.5.2.1 Model types

There are two main groups of stock valuation models:

- Global models: such as the Generalised Depletion Model (GDM).
  generalized), Schaefer logistic model ;
- Analytical models: VPA (Virtual Population Analysis), YPR (Yield per Recruit).

Global models are based on the relationship between fishing effort and total catch weight, using fishing statistics collected over several years. In this way, the assessment of the fishery can be traced, and its current situation described in relation to a fishing effort corresponding to maximum production.

Analytical models quantify the processes governing the dynamics of exploited populations: growth, recruitment, natural or fishing mortality. Knowing the structure of catches as a function of their size (or age), it is possible to reconstruct the fishing mortality suffered by individuals over the course of their lives, and to assess production in relation to the stock's potential. More demanding in terms of biological knowledge, this approach can be used to study the impact of changes in stock exploitation strategies.

Global and analytical models can be used alone or in combination, depending on the data available.

2.5.2.2 GDM model

The GDM (General Depletion Model) is a global model like the logistic model. The GDM model requires data with disturbances during the catching seasons. The GDM is not a population assessment model as such, but rather a catch dynamics model. This model produces results that can be used to assess the state of the stock on the basis of the biomass trend and the exploitation rate.

Input data for GDM :

- Total catch
- Total effort
- Capture sample
- Average weight of individuals (per week or per month ... depending on data availability)
- Initial parameters

GDM output data :

- Biomass (annual)
- Natural mortality
- Fishing mortality
- Exploitation rate (possibility of calculating quota/TAC).

2.5.3 Introduction to 'R' software

R is a very popular open source software environment used in statistical analysis and data science. It is developed and maintained by the R Project for Statistical Computing, a worldwide community of developers. The 'R' software represents a reliable resource that will always be freely available to stock evaluators in Madagascar for future studies.

R is widely used by statisticians to develop statistical routines and analyse data. This tool is an integrated environment for data manipulation, calculation and graph preparation. However, it is not just 'another' statistical environment (like SPSS or SAS, for example), but also a complete, stand-alone programming language.

Data analysis is the process of examining and interpreting data in order to develop answers to questions. The main steps in the analysis process are identifying the topics for analysis, determining the availability of appropriate data, deciding which methods to use to answer the questions of interest, applying the methods, and evaluating, summarising and communicating the results.

Data analysis is essential for understanding the results of surveys, administrative sources and pilot studies, for obtaining information on data gaps, for designing and redesigning surveys, for planning new statistical activities and for formulating quality objectives. Hence the need to introduce learners to the use of R so that the objectives set at the start of the project can be achieved, and so that effective and efficient results can be obtained in this training course in "stock assessment on the five main sectors".
octopus, lobsters, crabs, prawns and sea cucumbers".

To reinforce what had been learned during the theoretical part, this introductory session was followed by a practical R session and tutorials on the second and third day with the data available in octopus with all the learners. Specifically, an actual execution of the R code (script) to transform the 2021 season data from the original standard databases provided by Blue Ventures and the total regional landings for South West Madagascar. This was followed by practical, real-world modelling of the new 2021 season data to perform an assessment of the octopus stock in south-west Madagascar.

2.5.4 Summary of the different steps involved in carrying out a stock valuation

Stock valuation is carried out using the 6 steps and questions/actions summarised below:

STEP 1 - Data identification

Questions to ask :

- What data and information is available?
  Where is the available data and information (service, organisations, content, etc.)?

Actions to be taken :

- Gathering data

STEP 2 - Classifying/sorting data

- Identify and classify the types of data to be analysed:
  - Capture, effort
  - Biological and ecological data
- Identify data coverage, chronology and completeness
  - Geographical scope and spatial scale

  - Time series - beginning and end
  - Completeness - is the entire fishery included?

STEP 3 - Determine the analysis strategy
- Identify analysis options
- Determining whether and which model can be used
- If there is a lack of data, identify alternatives:
  - Empirical model
  - Ecological models
  - Use of proxies

STEP 4 - Data analysis
- Data processing / analysis
- Assess uncertainties (measure of confidence in results)

STEP 5 - Data collection plan
- Taking stock of missing data
- Determine how the data can be obtained
  - Cost-benefit assessment
- Strategy for filling data gaps

STEP 6 - Scientific advice
- Drafting the scientific opinion following the stock assessment

2.5.5 Arrangement and processing of data (Stage 4)

Data to be compiled: The database is rectified and arranged

Several stages have been adopted:

1. **Examine the database** :
   - Check the types of data available;
   - Check the time series (continuous, one-off);
   - Check the consistency of the data (same units of measurement; same types of data; same units of measurement; same method of presentation, etc.);
   - Select the data relevant **to the objective being pursued**:
     - If we are looking for major inter-annual trends → we keep only the years;
     - If we want to study what happens on a small spatial scale → statistical squares are relevant;
     - If we want to analyse variations over the fishing season → we need to keep the months.

2. **Extract relevant data**:
   - Select data;
   - Copy and paste into a new file.
     - ***NEVER MODIFY THE ORIGINAL BASE***

3. **Examine the data** :
   - Check for missing data;
   - Check for outliers;

- Check for duplication or redundancy;
- Eliminate or correct (if possible) these questionable values;
    - ***ENSURING THAT THIS PROCEDURE DOES NOT HINDER INTERPRETATION FINAL***

      Examples:
        - Major breaks in the time series;
        - Too little data for interpretation or analysis mathematics.
- Check whether the remaining data allows the planned analyses (mathematical model, statistical analyses), taking into account the constraints of these analyses;
- Save the final file.

4. **Interpreting the data** :
- Perform the necessary calculations prior to analysis (e.g. calculation of PUE, etc.);
- Drawing graphs :
    - Continuous" values (e.g. time variables) → Continuous lines (never use EXCEL's "smoothing" function);
    - Discrete" values (e.g. catches per village) → Histograms;
    - Proportions (% of species in the catches) → Histograms or "Camemberts";
    - Avoid "pseudo perspectives" that are too difficult to interpret;
    - Avoid overloaded graphics.
- Examine trends and variations;
- Formulate hypotheses to explain these trends and variations;
    - Ex: The increase in catches appears to be linked to an increase in effort
        - Can be tested using statistical regression
            - Look for additional information to explain these trends and variations:
                - Change in the dynamics of the operation (e.g.: shift in the effort of fishing);
    - Changes to the regulations;
    - Regional differences in marketing channels;
    - Modification in the markets (eg: decrease/increase of increase in demand; emergence of new players);
    - Changes to the natural environment (e.g. weather conditions that have made fishing difficult);

      water temperature; mangrove area...).
- Be imaginative and creative.
    - ***MORE THAN JUST NUMBERS***

2.6 FISHERIES MANAGEMENT TRAINING

Fisheries management mainly consists of controlling human activity, which is a predatory activity (i.e. managing fishermen and their activities). It usually involves preventing fishermen from catching too many fish from their stocks, using destructive fishing methods (to ensure the resilience of the resource and preserve habitats), and preventing fishermen from damaging the marine environment (to preserve habitats).

To achieve this, resource managers need to ask themselves a number of questions in order to identify useful and necessary management approaches and measures. In the case of Madagascar, this manager is the Ministry responsible for fisheries, and its decentralised departments in the regions and/or communes.

In

In other countries, management may be private or carried out by fishermen's cooperatives or shipping groups.

The main objectives of management are to ensure sustainable exploitation through the maintenance or perpetuation of the resources exploited and the use of seafood products for the benefit of the managing State or Collectivities for their social and environmental achievements and for the operators and consumers (markets), therefore for the interest of several stakeholders.

Several approaches have been adopted to ensure the sustainability of resources:

1. **the traditional approach**, which links biology and fishing activities and uses models that incorporate other social, economic and environmental parameters as analyses progress;
2. **the ecosystem approach**, which links biology and fishing activities, and integrates ecology after 1972 following the Rio Earth Summit and in 2010 following AICHI and the Convention on Biological Diversity; and
3. As fishing is considered as a system, **the systemic approach** links biology and fishing activities, and integrates socio-economic elements, ecosystem elements, policy (the FAO's precautionary approach) and regulatory texts.

Overall, this course is intended to be technical and practical, providing the main elements needed to manage a fishery:

1. The categories of **management strategy**, from a biological point of view, each with its advantages and disadvantages:
    - **Constant catches**: maximum level of catches as a function of time ;
    - **Mortality due to constant fishing**: effort fixed at a defined level ;
    - **Constant escapement**: maintenance of minimum stock biomass, and therefore spawning stock biomass;
    - **Constant yield**: allocation of quotas to different species according to their condition.

2. **Management tools** :
    - **Control of production factors** :
        - Indirect control: **Royalties** or **taxes** on catches or effort = Rent for access to the resource ;
        - Direct control: **Licences** or **permits** limiting the number of people involved.

These tools are not used on their own, but are complemented by limitations on capture capacity (e.g. the ability to capture a large number of images).
size/power of vessels, number of fishing gears...).

- **Production control**: e.g. TAC (Total Allowable Catch); Quota and Allocation (division of the TAC) including Individual Quota (IQ) or Allocation by Company, Transferable IQ (ITQ), Community Quota.

3. **Technical measures** :
    - **Gear restrictions**: e.g. Gear selectivity = Reduce gear capacity to reduce catches of target species or protect juveniles and non-target species;
    - **Restrictions on fishing periods**: during vulnerable stages of the target species or reproduction or spawning periods, to reduce fishing activities in relation to the weather and therefore reduce fishing effort;
    - Permanent/total/restricted **closure of marine areas** for certain types of gear, for example.

4. **Decision-making**: all decisions are taken on the basis of available information, starting with **stock assessments**, and must meet the objectives of the manager, i.e. the public authorities. These objectives depend on the role that the government wishes to give to fisheries in the national economy:
    - **The biological objective** is to maintain the resource at an optimal level while protecting the "reproductive" stock through various approaches:
        - Rapid but costly or slow reconstruction with risk of stagnation
        - What threshold value should be maintained?

The Biological Objective is not always respected. There is a duality/incompatibility between the weight given to biological information and that given to economic and social information (e.g. **maintaining jobs** in the face of an **overexploited stock**, so **maximising jobs** vs. **optimum profitability for businesses**).

- **Economic objective** to ensure the viability of industries : Development of exports of products with high commercial value with a view to increasing income and foreign currency vs. Development of local and national markets for food self-sufficiency.

- **Social objective**: maintain jobs, maintain rural communities, meet people's vital needs.

- More recently, with the Rio/AICHI/Conservation of Biological Diversity **environmental objective**, the protection of habitats is taken into account in decision-making.

Decisions are taken in the form of regulations on catches or on the profitability of companies. It is up to the biologists to assess the impact of the regulations on the stock according to the management scenarios proposed to them.

2.7 TRAINING ON THE ECOSYSTEM APPROACH TO FISHERIES

2.7.1 Ecosystem approach to fisheries

The ecosystem approach to fisheries (EAF) draws its key principles from international conventions such as the Convention on Biological Diversity (https://www.cbd.int/) and the FAO Code of Conduct for Responsible Fisheries (FAO Code of Conduct for Responsible Fisheries). This CCPR code highlights the concepts of sustainability, which are in fact extensions of the EAF approach to the conventional approach to fisheries management.

Reminder: Summary of the major objectives of the two types of approach (conventional approach, CA, and ecosystem approach to fisheries).

Table 6: Summary of the main objectives of the two types of approach

Conventional approach (CA)	Ecosystem approach (EPA)
Simple fisheries management objectives (MSY for example)	Expanded scope of fisheries management taking explicitly takes into account the ecosystem and socio-economic dimensions
Sectoral - Focused on fisheries issues	Combines more explicitly the interactions between the fisheries sector and other sectors that may be affected by space planning.
Target species	Explore the impact of fishing on other species and habitats, biodiversity, …
Basics of one-level stock/fishery development	Addresses key issues at appropriate spatial and temporal levels with overlaps between local, national and regional levels, etc.

Predictive - Decision-making based on information results of valuation models	Given the uncertainty associated with multiple questions, the data limitations and lack of knowledge about various processes, adoption of strategies.
Knowledge scientific considered as "only" valid	Knowledge scientific sometimes limited, alternative and/or additional knowledge (e.g. traditional knowledge) used as a basis for decision-making
Works with regulations and penalties for non-compliance	Encourages compliance with management decisions through measures incentives
Decision and control follow a approach descendant	Participative approach, collaborative decision-making
Targets the interests of the fishing industry	Targets the interests and wishes of a broad community of stakeholders. stakeholders

Implementing an ecosystem approach to fisheries (EAF) is possible for all types of fisheries, including subsistence fisheries, small-scale fisheries which often lack data and formal management methods, and industrial fisheries which are often well documented.

Different options have been identified to meet different stages of the EPA to cover the range of resources and capabilities that may be encountered.

A variety of tools and methodologies have been developed to meet the various stages of the PEA objectives. It is important to select the most effective tools and methods for a given situation. For example, when a resource is not limiting, the most complex tool or the most expensive to implement may not be the best choice.

To assist in the selection of tools, a set of criteria has been developed to help users choose between various possibilities. However, it is also recognised that in addition to these criteria, other techniques and socio-economic factors may influence the choice of method and so the criteria are informative and not prescriptive.

These criteria for choosing the proposed methods include :

- How difficult is it to implement this tool?
- What are the potential financial, human and time costs of implementing a methodology?
- What might be the technical and academic knowledge requirements for the implementation of a given methodology?
- What levels of basic knowledge, data volume and preparatory work are needed to make a tool effective?
- What degree of involvement is possible or expected for the application of a given method?
- How long does it take to apply a method in a given situation?

The following points were covered during the course:

- What is the ecosystem approach to fisheries (EAF) and what are the benefits?
- What data and information are needed (or desirable) to build up a decision? EAF-based decisions (fisheries policy and management plans)?
- Ensuring that the PEA is operational (broad objectives, operational objectives with choice of relevant indicators, performance monitoring and evaluation) - Example with an analysis of the strengths, weaknesses, opportunities and threats for the 5 sectors studied.

- Ecosystem management measures (technical measures such as gear regulation, temporal spatial controls on uses, control measures on an input variable = effort or output = catches), ecosystem manipulation, rights-based measures).
- The role of incentives in the water supply sector
- AEP: the costs and benefits of setting it up
- The effectiveness of essential actions: Monitoring, Control and Surveillance (MCS)
- Research and knowledge requirements for the implementation of AEP
- Obstacles to the implementation of AEP

2.7.2 Strengths, Weaknesses, Opportunities and Threats (SWOT) method

This simple method is presented in the form of a 4 entry table with 2 rows representing the internal and surrounding context of the object under study and 2 columns for the strengths and weaknesses. It is a method of choice for preliminary assessment of a situation that will need to be addressed in order to undertake planning for a WSP or to implement development measures within the framework of a WSP.

Applying this method to the planning of a PEA is useful because it will help to identify what could affect the success of the PEA. In practical terms, the SWOT method will identify what is good or bad about a proposal based on the internal properties (strengths and weaknesses) and external properties (opportunities and threats) of the system under study.

For example, here are some typical questions that may be encountered under the 4 headings:

Table 7: Types of questions asked under the 4 headings

Forces	**Weaknesses**
+ Benefits of the proposal + Available human, financial and skills resources + Experience, knowledge, data + Innovative aspect + Institutional and political enthusiasm + Processes, systems, telecommunications + Employee culture, attitudes and behaviour	- Disadvantages of the proposal - Gaps in capacity - Lack of time, pressure from management - Lack of resources - Data reliability, predictive capacity of the plan - Institutional morality, stakeholder commitment, leadership - Processes and systems
Opportunities	**Threats**
+ Financial support or co-financing + Improved way of life for the industry and its stakeholders + Technological development and innovation + General influences, new market or niche market that could emerge + New information and research + Partnership including institutions	- Political impact - Legislative effects - Environmental effects - Market demand - Vital partners - Maintaining internal capacity - Loss of personnel - Sustainability of financial support - Scale of economic impact

2.7.3 Application of the SWOT analysis to the context of the 5 sectors' operations

The group of learners taking part in the training course on the management of coastal resources in 5 fishing sectors - crab, octopus, lobster, inshore shrimp and sea cucumbers - undertook an analysis of the strengths, weaknesses, opportunities and threats for each of them. This type of analysis is traditionally used to plan a process for sharing and gathering information with stakeholders.

stakeholders, then analysing the information that will lead to the assessment of stocks and the drafting of scientific advice for the preparation of management advice as part of the ecosystem approach to fisheries.

The list of species exploited and the fishing methods used for these exploitations concerned by this approach are listed in the table below:

Table 8: List of species exploited and fishing method used

Channel	Fishing gear - Fishing technique	Species (Scientific name)	Species (Malagasy malagasy, commercial name)
CREVETTES	Dam (Valakira) Purse seines (kaokobe) Gillnets (Periky) Trawls	*Penaeus indicus* *Panaeus semisulcatus* *Penaeus japonicus* *Penaeus monodon* *Metapenaeus monoceros* *Metapenaeus stebbingi*	White Tiger, Flower, Calendar or Brown Kuruma Tiger, Camaron or King Pink or Brown Long live
CRABS	Hook Balance Net Line Bare hand	*Scylla serrata*	Drakaka, mud crab
POULPES	Fishing on foot (with harpoon), Diving fishing (with harpoon), Fishing from a pirogue (with harpoon), Angling (with harpoon)	*Octopus aegina* *Octopus macropus* *Octopus cyanea*	Horita sariboka (Dwarf octopus) Horitandolo (Night octopus) Horitambato (Large blue octopus)
LANGOUSTES	Trap fishing, Kipa (fuzzy), Net fishing, Diving	*Panulirus homarus* *Panulirus penicillatus* *Panulirus longipes* *Panulirus ornatus*	Oramena (Red lobster) Oramainty (Fork lobster) Tsitsibato (Imp lobster) Tsitsibola (Golden lobster)
HOLOTHURIES	Low tide fishing on reef flats and coastal habitats Snorkelling or freediving in the lagoons Night fishing with torch	*List of species exploited and provided in the presentations on honlothurians* ***in Appendix 2*** *of this document.*	List of species exploited and their vernacular names in the presentations on sea cucumbers **in appendix 2** of this document.

To carry out this analysis, 4 headings were considered for the various criteria, namely :

- ☞ Resources and habitat ;
- ☞ Regulations ;
- ☞ Knowledge (scientific and local) ;
- ☞ Social, economic and market.

For all of these sectors, it was noted that Madagascar's fishing regulations were based on the FAO's Code of Conduct for Responsible Fisheries, so this strength will not be repeated in the "Strengths" section for each sector.

FFOM analyses for the 5 waste streams are presented in Appendix 3 of this document.

2.7.4 Brief summary of the SWOT analysis

While each sector has its own specific characteristics, the SWOT analysis shows that there are more similarities between sectors than major differences.

The main strength of small-scale fishing is the fact that it has put in place harvesting regulations based on the FAO's Code of Conduct for Responsible Fisheries, but its major weakness is the lack of compliance with these regulations due to the absence of any means of control.

Another important strength is the existence of dina and/or the transfer of management, enabling management to take place on a local scale, as part of an LMMA (Locally Managed Marine Areas) approach. Although biological data exist (Strengths), they are rather old (Weaknesses) and the absence of a proactive policy to improve biological knowledge could be detrimental (Threats) and undermine the sustainability of farms for stocks that all represent resources with high to very high added value.

As far as habitats are concerned, there is an opportunity to put in place a policy to restore mangroves if responsible exploitation measures are associated with it.

2.7.5 Conclusion on SWOT analysis

In short, with regard to the objectives of this project, the SWOT analysis reinforces the importance of promoting, in addition to the catch data needed for quantitative stock assessment, the availability of data and biological knowledge of the ecosystems of importance to the 5 sectors (mangroves, reefs, etc.).

2.8 TRAINING IN THE FORMULATION OF SCIENTIFIC ADVICE

Scientific advice is part of the decision-making process. It is a fundamental part of the decision-making process. in a management process.

2.8.1 Management decision-making process :

The management process works as follows:

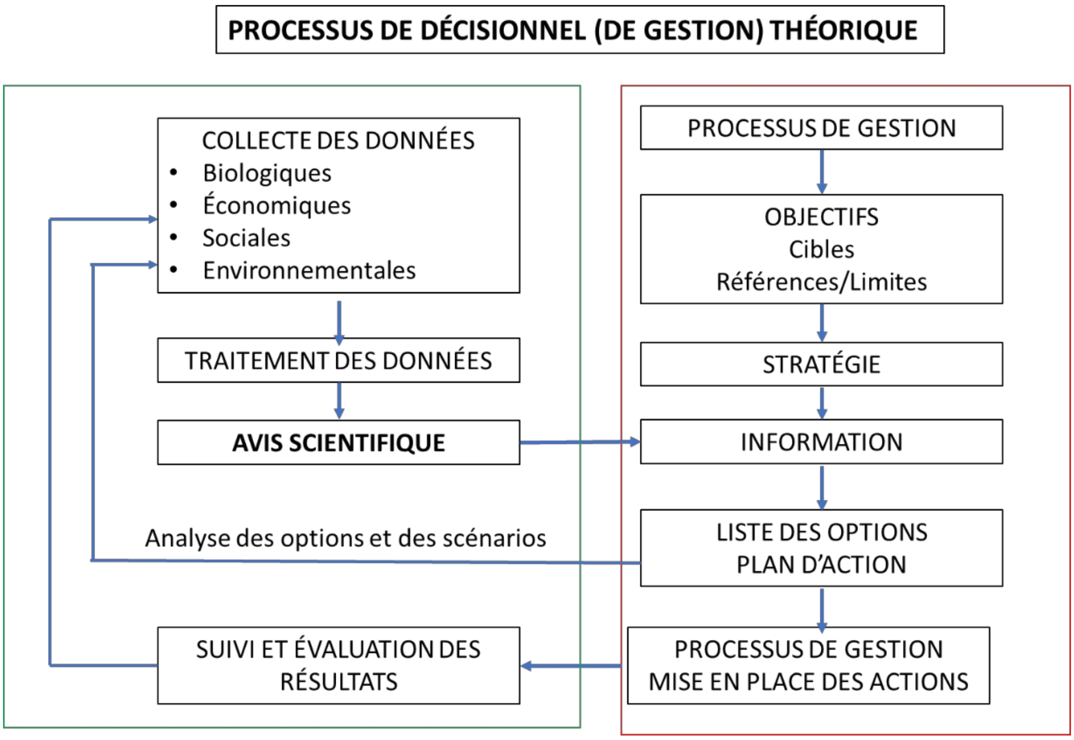


Figure 2: How the management process works

- It is an opinion/decision resulting from reflection and deliberation on a specific question or problem, and intended to be communicated;
- It is written to support public decision-making and is the result of an approach based on the current state of knowledge and on explicit principles and methods adapted to the subject of the research, the context in which it is produced and the level of evidence required;
- It means sharing scientific understanding of the state of resources and the ecosystem in order to to achieve management, conservation and sustainability objectives, and aimed at a non-expert audience.

Scientific advice is used to :
Guide managers in their decision-making (Inform on the scientific results concerning the state of resources and their potential, and possible actions);
Provide information on the scientific basis used (describe and explain objectively and concretely the context, the choice of methods and the problems);
Enable the process to be followed and reproduced if necessary (Analysing: relating facts);
Justify the conclusions reached (make a clear link between the results of the research and the conclusions).

2.8.2 Process for formulating scientific advice :

The process of formulating the scientific opinion can be summarised as follows:

Table 9: Process for formulating scientific advice

PREPARATION (Synthesis of knowledge)	PEER REVIEW (Discussion of methods, analyses and results) results)	REDACTION OF THE NOTICE
1. Inventory of available data 2. Data assessment (quality, reliability, relevance) 3. Data analysis for information 4. Structuring information 5. Information analysis • Reliability of methodology and results • Consistency of results • Emerging ideas • Logical conclusions 6. Formatting (choice of graphs, choice of tables, structuring the text, drafting of dashboard if applicable)	Workshop / discussion between scientific experts on the approach, analysis and results: • Ensuring the scientific validity of the methodological approach • Ensuring the soundness of analyses and conclusions • Detecting possible weaknesses and biases • Suggest changes and improvements	Ensuring the quality of the notice (the text must be understood by all, legible, clear, concise, sober, intelligible, rigorous and precise) The report contains "classically": 1. Summary 2. Context 3. Evaluation 4. Uncertainties 5. Conclusion

2.9 TRAINING ON DATA ACQUISITION AND STANDARDISATION

It is crucial to have as complete a picture as possible of existing data on the various sectors. The group has drawn up a list of what is currently available, either directly or after examining databases.

The Head of Mission drew up a table of types of data per commodity for the experts to fill in. The experts identified the data available for each commodity by filling in the commodity data sheet (see Appendix 4).

2.9.1 Data reliability

Data on production by type of resource are recorded in national databases maintained by the ministry responsible for fisheries. Initial data are collected and sent to the central level by its regional services (pers. com.). In addition, the statistics department has already recruited field investigators two years ago (pers. com.); the concordance and complementarity between the data they collect and those supplied by the regional services should be checked.

Generally speaking, the national production data (collection, marketing) recorded in the databases of the Ministry's statistical service are checked and collated from the various sources available: exports, certificates of origin and healthiness (COS), declarations by operators and/or collectors, before being considered validated (pers. com.). At this stage, we can say that the industrial fishing data are reliable, while the small-scale fishing data raise a number of questions regarding the following points:

- As far as shrimp are concerned, the wide range of small-scale fishing gear, the low selectivity of some gear and the fact that the use of some gear is prohibited cast doubt on the accuracy of catch data from small-scale fishing, especially as very small shrimp are not always collected;
- Crabs below a certain size escape the formal collection circuit (to small local markets and self-consumption) and are not officially counted. Live crabs are also seen on markets in the capital, and certainly in other major towns, during the national closure period, and this production is not counted in the statistics either. Post-capture losses are estimated as a percentage of the volume based on collection statistics (i.e. 15% for the last ten years);
- In the case of sea cucumbers, the statistics do not distinguish between all the species, given their large numbers and the difficulty of identifying processed products. Collection and export data relate to trepang; the transformation of dry weight into live weight can however be carried out, but with a high degree of imprecision given that this transformation coefficient can vary by a factor of five depending on the species;
- The "self-consumed" fraction is not formally quantified (with the exception of sea cucumbers, for which it is close to 0 in Madagascar) and varies according to the sectors concerned.

The question of coverage of all production areas, through the existence of regular collectors
/ There is also the question of the accessibility of certain areas for surveyors from the statistical service or regional fisheries departments. Nevertheless, data from certain regions are considered more reliable, depending on the resources of commercial importance; this is the case of the Anosy-Androy area for lobsters; Atsimo Andrefana for sea cucumbers and octopus, and the Atsimo Andrefana, Menabe, Boeny and Diana regions for crab. Data from these regions could therefore be used for an initial stock assessment.

The assessment of neritic shrimp stocks will be somewhat hampered by the lack of small-scale data.
fishing in some regions.

Small-scale fishing effort is estimated separately from production data, using census data on fisheries, gear and boats.

The first evaluations carried out as part of this project will enable participants to consider
Following the collection of reliable data, the assessments will be replicated in the other regions.

The analysis of the statistical reliability of the available data, carried out by the group's experts, highlighted the statistical reliability of certain data (industrial shrimp fishing) and the general reliability of the overall production data collected by the MPEB's Fisheries Statistical Service (SSP).

However, the small-scale fisheries data raise a number of issues that need to be examined by the work during the next phase and addressed in the data collection plans for the final phase of the project.

2.9.2 Strategies and action plans for acquiring data for each sector

2.9.2.1 Initial global strategy

With the aim of ensuring that scientists are trained in fisheries biology, are able to set up data collection protocols and monitor databases, and are able to continue assessing resources, the strategy adopted for data collection will be based on several levels:

Global" approach: (Madagascar scale)

- Compile the data available to the statistical service, i.e. production data by product and by district;
- Analyse and "clean up" the data series to obtain the main production trends over time by "region". These results should be put into perspective with economic trends (market development, etc.).

Regional" approach (local data by sector)

- Compile the data available to the statistics department of the regional services, in particular production data by product and by district, identifying the source of the information (origin and accessibility).
- Group data according to a practical geographical scale (administrative region, biogeographical area, etc.). Give the main production trends over time by "region".
- Obtain sharing agreements and group data in a common database, taking care over data sources (capture or compliance visa, etc.).

Local" approach (local data by sector)

- Identify existing biological data and their time series,
- Identify existing fishing data and their time series,
- Evaluate possible models and approaches for assessing resources and obtaining sharing agreements and consolidating data in a common database, specifying the sources (NGOs, fishermen, others).
- Make a precise (or empirical) assessment of the resources to obtain the potential (productivity) of each of the target species for one (or more) regions.
- Define the relevant indicators for monitoring resources, and create a "dashboard" based on the indicators, which will be a basic document that can be used in the future to monitor resources.

The definition of ecoregions (ecosystems) for each species or group of species will require the use of ecosystem mapping as a "proxy" for missing data and extrapolate the local potential to the whole territory to obtain a rough idea of the national potential of the different resources under study.

The data acquisition strategy is summarised in the table below:

Table 10: Data acquisition strategy

Elements of strategy		Action points	
Training researchers			
Objective		*Approach*	*Expected results*
Having a competent scientific team to monitor the state of the environment resources on a long-term basis.		Organise theoretical training sessions for based on inventory valuation	Scientists are trained in the fisheries biology approach
A team capable of providing scientifically based management advice		Involving scientists in collecting and formatting databases	Scientists are able to set up collection protocols and monitor databases.
To achieve a form of "institutionalisation" of the activities of research into the state of resources.		Involving scientists in the sessions resource evaluation	Scientists are in a position to continue the assessment resources.
Assessment of resources			
Data scale	Approach	*Approach*	*Expected results*
Global" approach (Madagascar scale)	Compile the data available to the statistics department: production data by product and by district	Analyse and "clean up" the data series	Give the main trends over time in production by "region". To be put into perspective with economic trends (market development, etc.).
Approach "Regional (data by sector)	Compile the data available to the statistics department: production data by product and by district Identify the source of information; origin and accessibility.	Group data according to a practical geographical scale (administrative region, biogeographical group: to be defined) Obtain sharing agreements and consolidate data in a common database.	Give the main trends over time in production by "region". To be put into perspective with economic trends (development of markets, etc.) Integrated database
Local" approach (data by sector)	Identify existing biological data and their time series	Obtain sharing agreements and consolidate data in a common database. Make a precise (or empirical) assessment of resources	Integrated database Obtaining the potential (productivity) of each of the target species for one or more regions
	Identify existing fishing data and their time series		
	Evaluate possible models and approaches for assessing resources		
	Define the relevant indicators for monitoring resources	Create a "dashboard" based on indicators	A basic document that can be used in the future to monitor resources
	Define ecoregions (ecosystems) to each species or group of species	Use ecosystem mapping to "a proxy for missing data, and Extrapolate local potential to the whole area	Obtain a rough idea of the national potential of the various resources under study.
	Defining comparable ecosystems on the Madagascan coast		

2.9.2.2 *Specific strategies for each sector*

Each sector will follow the general data collection strategy, but there are a few points to bear in mind need to be highlighted.

Prawns

Extension of industrial fishery assessments from 2019 with the addition of BANACREM data until 2022, but analysis of the sizes of shrimp caught (source OPCA or GAPCM) should be added for a better indication of the state of the resource.

The evaluation of small-scale fishing should not be neglected, and information should be gathered through various means
data sources :

- PCT Resolve UQAR'ISMER survey in 2019
- Shrimp production data for small-scale fishing MPEB
- Data on effort (e.g. updated data from the framework survey on the number of pirogues, etc.).
- Shrimp export data

As part of the ecosystem approach to fisheries (EAF), assessment of by-catches (fish) should also be taken into consideration.

Lobsters

The quantitative assessment of *P. homarus* stocks in the south-east (regional approach using an analytical model) will be based on available data. However, the previous assessment of 1998-2004 (Rabarison) will be taken into account.

In addition, as part of the scientific advice, we are compiling and analysing marketing data from the MPEB to give an overall picture of the lobster fishery, taking all species together.

Crabs

The quantitative assessment of *Scylla serrata* crab stocks will be based on fisheries data made available by CORECRABE project scientists, updated from 2020 to 2022.

Other data should also be taken into account:

- Blue Ventures data on Belo sur Mer used by IH.SM for the USAID study;
- Evaluation of stocks in Boeny by the private sector in 2007 ;
- Former evaluation of the SWIOP project in 1990 (report Bautil, B.R.R., and J.D. Ardill 1991, Actes du séminaire sur l'aménagement de la pêcherie de craes des mangroves *(Scylla serrata*) du nord-ouest de Madagascar.

In addition, as part of the scientific advice, the compilation and analysis of marketing data from the MPEB will enable some generalisation to all crab fishing areas.

Octopus

The quantitative assessment of south-western stocks will be based on the Blue Ventures study for the years 2015-2020, with the addition of data for 2021 and 2022.

In addition, as part of the scientific advice, data on octopus sales around Madagascar could be taken into account to extrapolate the national resource situation.

Holothurians
In view of the absence of catch and effort data that can be used to apply the mathematical models, the assessment adopts a global approach based on national and regional MPEB production and marketing data (including export data by species submitted to the ASH), corroborated by international import data from importing countries. The overall analysis will then be compared with case studies of specific sites, mainly in the Atsimo-Andrefana region (south-west).

Subsequently, consideration of the evaluations of the IUCN and CITES expert groups (with reference to the situation in Madagascar) could help us in a preliminary determination of detriment/non-detriment for the 4 species listed in appendix 2 of CITES and which are fished in Madagascar (*Thelenota ananas, T. anax* (effective from May 2024); *Holothuria nobilis, H. fuscogilva*) (already effective).

3 STOCK VALUATION PROCESS

3.1 GENERAL INTRODUCTION

3.1.1 Selection of specific strategies by sector

Before carrying out the actual stock assessment, the strategy to be adopted for each sector had to be identified on the basis of the data available and the characteristics of the resource. The selection is determined by the trainers and presented with explanations to the learners.

3.1.2 Dashboard

The dashboard is a qualitative visual way of presenting the situation of a fishery that brings together a number of useful parameters to inform management decisions.

Dashboards are usually used to assess data-deficient fisheries for which quantitative models are not available (e.g. sea cucumbers in the case of Madagascar). However, the use of dashboards makes it possible to introduce different variables that complement the main stock assessment as part of the scientific advice: CPUE trends, effort trends, environmental criteria (if available), market trends (which can put pressure on fishing effort) etc. to give a more complete view of the state of the fisheries and not just the stock.

The indicator values (status and trends) in the dashboard are classified into three categories using a three-colour scheme:

Estimated situation	🟢	The situation is considered healthy. If data are available quantitative: the value is higher than the Upper Reference Point (URP).
	🟡	The situation is considered to be in the caution zone If quantitative data are available: the value is above the Limit Reference Point (LRP) but below the SRP.
	🔴	The situation is considered to be in the danger zone If there are quantitative data: the value is lower than the PRL.
	⚪	An uncertain situation

Trajectory (TR)	↑	The trend shows growth. This can be a positive sign (captures, PUE, biomass) or negative (effort)
	↓	The trend is downward
	↔	No trend has been observed. The situation is stable.

3.2 INSHORE PRAWNS

3.2.1 Consideration of available data

The following data were available for assessing shrimp stocks:

- Industrial fishing
    - Trawler logbooks (BANACREM) from 2007 to 2022;
    - Catch and effort (number of hauls), per day and per statistical square ;
    - Catches broken down by species; after discussion, it appeared that the lists of species provided by the logbooks were unreliable: confusion between names, little uniformity between records, confusion between species; it was therefore decided to consider only total catches.
- Small-scale fishing
    - Sales data recorded by the MPEB ;
    - Volumes marketed by district and administrative region ;
    - As these are commercial transactions, these data only imperfectly reflect the volumes actually caught, so they can only be used to define trends.

These data do not allow a quantitative model to be used:

- Biomass production models require a good assessment of all the catches made; moreover, it is not certain that the CPUE of industrial fishing can be a good indicator of abundance;
- Analytical models (catch per recruit or sequential population analysis) require a time series of catches by age (or, at the very least, by size); such data is currently non-existent.

3.2.2 Choice of empirical method

Given the types of data available, instead of a mathematical model, we have retained the "traffic light" method used in the previous shrimp stock assessment (Resolve- UQAR/ISMER, 2019).

This is a qualitative "empirical" approach based on indicators. The level of the indicators is indicated by "traffic lights". This level is indicated by reference points (if quantitative data over a long series (effort, catch) and by a trend analysis. The results are summarised in the form of a "dashboard".

The scorecard and benchmarks agreed in the previous assessment have been retained. The 2022 assessment has been added to the 2019 assessment in order to examine trends. In addition, we have added two elements:

- Catch (sales) trend data for small-scale fishing; as the statistics relate to administrative regions, they do not correspond exactly with the management areas for industrial fishing; we have considered the regions that are geographically closest to these areas, in order to detect regional trends.
- A biomass depletion model (Leslie's "depletion model") that calculates an estimate of the biomass available to trawlers at the start of the season. This data has replaced the CPUE of industrial fishing as an indicator of stock abundance.

Leslie's model is based on the decrease in biomass during the fishing season. It is acceptable if :

- The stock is well located;
- There is no immigration or emigration;
- There will be no recruitment during the season.

The first two hypotheses are acceptable. The third is more questionable, as historically there has been a peak in recruitment during the season. However, recent catch-per-unit-effort (CPUE) data do not show a significant contribution during the fishing season. We therefore felt that the model could be used.

Principle of the Leslie model :

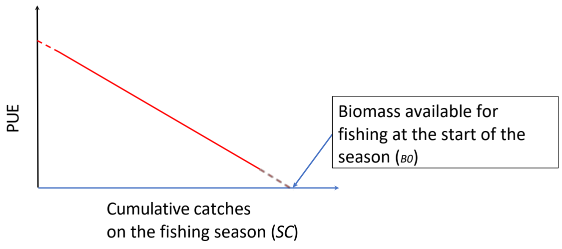
We know the relationship *PUE = q*Biomass*, where *q* = instantaneous catchability coefficient ;
For each fishing activity, abundance is reduced by the catch *Ct* ;
Over time, the initial abundance B_0 is reduced by the sum of the *SC* catches; Using the relationship with CPUE

$$PUE = q*B_0 - q*SC$$

The intersection of the straight line with the *SC* axis (*PUE* = 0) gives B_0 (Figure 2).

We can then calculate an estimate of the exploitation rate, which is the fraction of the available stock that has was caught during the season: $E = SC/B_0$

The catches used are total monthly catches. Calculations are made by region (A, B, C) from 2009 to 2020.



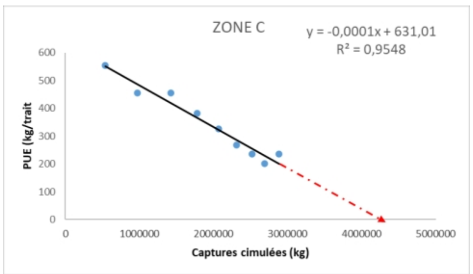


Figure 3: Illustration of Leslie's depletion method (left) and illustration of the method (right).

3.2.3 Dashboard :

The dashboard summarises information on the fishery. This fishery is defined according t o characteristics that are classically :

- Performance of the fishery;
- Abundance of resources;

- Resource productivity (sex ratio, fecundity, size distribution); these data are not available for shrimp.

Each characteristic is defined by indicators. These indicators correspond to a method of measuring the time series of an attribute; the indicators must make it possible to monitor changes in the fishery. The indicators used here are :

- Fishery performance :
  - Capturing IP
  - IP effort
  - PP sales
- Abundance of resources
  - Biomass accessible to trawlers (Leslie method)

The dashboard includes the various indicators, their value in relation to the reference points and their trajectory (positive, negative or neutral direction).

It provides a diagnosis of the fishery (visual, open to discussion, interpreted according to pre-established references and criteria).

Quantitative indicators used and accepted in 2019 :

Indicator	Suggested value
Total landings	average 1986 to 2004 (7598 t) PRS = 80% of reference (6078 t) PRL = 30% of the reference (2279 t)
Landings Zone A	average 1971 to 2004 (1391 t) PRS = 80% of reference (1113 t) PRL = 30% of reference (417 t)
Landings Zone B	average 1969-2003 (1252 t) PRS = 80% of the reference (1001 t) PRL = 30% of the reference (376 t)
Landings Zone C	average 1986-2006 (4720 t) PRS = 80% of the reference (3776 t) PRL = 30% of the reference (1416 t)

The results of this process for shrimp stocks are included in the scientific advice presented below.
low.

3.3 INSHORE LOBSTERS

3.3.1 Data taken into account for lobsters

The data available for lobsters concerns :

- Catch and effort data per week ;
- Average weight data per sample ;
- Data over 8 years (period 2015-2022) in two blocks 2015-2020 and 2021-2022 ;
- Geographical coverage - several sites in south-west Madagascar;
- Official annual octopus marketing statistics for the south-west (used to extrapolate results to the entire south-west region).

With these data, an analytical model of the 'General Depletion Model' or GDM type was used. The Blue Ventures assessment for the period 2015-2020 is updated with the addition of data for 2020 and 2022 (joint assessment between CGP/BV and this project).

3.3.2 Models used for lobsters

In order to strengthen the capacity of the learners with different possibilities of stock assessment models, we proposed two types of models to be applied for lobsters. The first is the logistic Schaefer model based on CPUE and catch, while the second is the structural model based on rectified VPA based on individual size, fishing effort, natural mortality and catch.

During the training course, we worked with the lobster data available from the ex-URL of Fort-Dauphin. With this data, only the data in the northern zone (from the urban commune of Fort-Dauphin to the rural commune of Manantenina) could be used for analysis. The analysis focused on *Panulirus homarus*, which is the most dominant species in the catch.

For lobster, we worked with both models and the results were similar (Schaefer logistic model and rectified VPA structural model followed by the yield per recruit model). These parameters were therefore used with both models:

- Schaefer logistic model (CPUE and capture)
- Rectified VPA model (Individual size, fishing effort, natural mortality, catch)

3.3.2.1 Global model

Schaefer's logistics model does not require a lot of data. It has been applied to understand the level of exploitation. This model is based mainly on a series of annual catch and CPUE data and can be applied to any species if the data are available. We applied this model with a six-year data series (2015-2020), mainly to demonstrate the principle and results of this method. In this way, we can estimate the MSY (RMD) situation with changes in biomass.

To understand the stock situation, we looked at the relationship between F/F_{MSY} and B/B_{MSY} using a KOBE plot to present the results.

3.3.2.2 Analytical model

For the study of the spiny lobster stock, we should consider an annual time step. The structural analysis could be carried out using the rectified VPA or pseudo-cohort analysis, as we only had data for a few years (from 2014 to 2020), which does not yet correspond to the maximum age of the species studied (10 years). The analysis is based on catch data and individual size data, to be supplemented with recruitment indices and fishing effort indices. During this analysis, we worked with data from the ex-URL, which is the only data available for the structural analysis. We also chose the species *P. homarus* because it is the most dominant in the Fort-dauphin area.

Using the formulas (R script), after several iteration processes, we can obtain the catchabilities for each age class, the fishing mortalities and the numbers at each age.

The rectified VPA results will therefore be used as input data to estimate the state of the stock.
(RMD), with the yield per recruit (YPR) model.

3.4 MANGROVE CRABS

3.4.1 Data taken into account for crabs

As mentioned above, for the collection of data on crab catches, the same approach has been adopted as that developed during the CORECRABE project, updated to 2023, in order to continue the time series initiated in 2021. From these data, indicators based on the size and level of catches can be estimated, and stock assessment models can be developed.

The results were compared with data collected in 1989-1990 in the Boeny region (see Bautil and Ardill report, 1991), and with regional marketing data from the MPEB.

3.4.2 Models used for crabs

3.4.2.1 Direct estimation of abundance by in situ observation

GPS tracking of the movements of crab fishermen has been tried out on a voluntary basis with fishermen on foot (hook fishing). It is used to measure a range of variables that are useful for assessing crab abundance: the distance travelled throughout the trip, the time taken to search for crabs (on foot), the time taken to catch crabs (to extract them from the burrow), the speed at which the angler travels on foot through the mangrove to reach the next burrow (this speed depends on the density of burrows and the conditions of travel through the mangrove forest), fishing yields (number of crabs or kg per hour of fishing), the total number of burrows visited (occupied or not), the burrow filling rate (i.e. the proportion of burrows occupied by a crab).

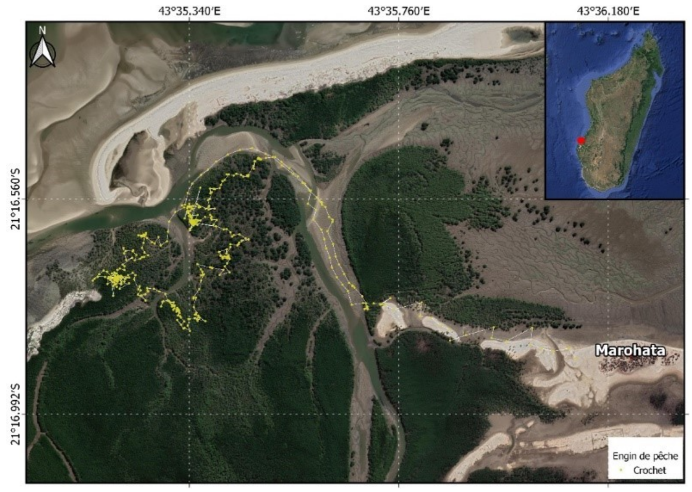


Figure 4: Example of an angler's route based on GPS tracking of a fishing trip (1 point = 1 position every 30 seconds)

If we make an assumption about the width of the "mangrove corridor" visited during a fishing trip (for example 5 m to the right and left of the fisherman during his walk, i.e. 10 m wide) and the catchability of the crabs detected, it is possible to estimate the "surface area exploited" during this trip and therefore, ultimately, the density of crabs (number or kg of crabs per ha of mangrove):

Area farmed (in ha) = Distance travelled (in m) X width of corridor (in m)

Crab density (in number or kg per ha) = Number or weight of crabs caught / area farmed (in ha)
if the catchability of a crab is set at 1 in the corridor used.

It is then possible to estimate the total abundance of the crab population *in the mangrove* by extrapolating the density to the extent of the mangrove cover. However, as the density of crabs varies according to the type of mangrove, this extrapolation must be spatially stratified:

Stock estimate (in t or number) = Sum {Area (km^2) x Crab density (number or t / km^2) per mangrove type}.

However, this method has the following limitations:

- only the fraction of the stock present in the mangrove forest is estimated: the crabs frequenting the mangrove channels are not accessible to fishing on foot and are therefore not taken into account. This method therefore provides an index of *relative* abundance, for comparing changes in the stock over time, for example.
- GPS tracking of fishermen can be costly to set up if the scale of the study is large, and requires the cooperation of fishermen.

3.4.2.2 Estimation of indices of abundance (CPUE) from fishing data

First of all, it should be remembered that catches alone are not an indicator of resource biomass, since the level of catches also depends on the fishing effort exerted on the stock (i.e. fishing mortality), as explained in previous sessions. So while it is not possible to deduce a crab stock level from the production statistics provided by the MPEB, the estimated catch level for a unit of fishing effort (or CPUE) means that we do not need to know the *total* fishing effort deployed in the fishery. The data used to estimate CPUE are therefore easy to collect. CPUE is often used as an index of abundance in data-poor fisheries.

It should be remembered that for a nominal unit of effort (e.g. a fishing trip), fishing mortality is equal to catchability, and the corresponding catch is therefore CPUE = Catchability (q) X Biomass of the resource. In equilibrium, CPUE is theoretically proportional to abundance, if the catchability of crabs is constant (see comments on this below): a change in CPUE then represents the same proportional change in resource abundance, which is unknown.

Again, this is a *relative index*, as catchability is not estimated: a fall in CPUE means that the abundance of the fish population is falling (as a result of harvesting and/or external events), while an increase in CPUE may mean that a fish stock is recovering.

However, several factors can vary catchability and therefore skew the proportional relationship between CPUE and resource abundance: changes in gear efficiency, fishing effort (number of gears) or gear selectivity and the availability of the stock at the time and place where fishing takes place. In these cases, CPUE can be misleading because CPUE can remain high while the stock declines more or less rapidly.

A more realistic relationship between CPUE and stock abundance would be of the form :

CPUE = Capturability X Abundance$^{\beta}$

where the coefficient β may be less than or greater than 1 depending on the resource and/or region.

Learners are given an example of a mangrove crab fishery in New Caledonia where the coefficient β is less than 1, i.e. the CPUE varies little when the abundance of crabs is greater than one

A certain threshold: this means that fishermen (hook fishermen in this case) increase their catches more quickly when abundance is low than when abundance is higher, because of the travel time in mangroves and because they cannot multiply the number of gears used (unlike the scales, for example).

To carry out such a calibration, data on resource abundance in the same area at the same time must exist for comparison with CPUE values. In practice, these data are lacking in Madagascar, so the actual relationship between CPUE and abundance is often unknown.

3.4.2.3 Analytical model

For comparison with previous indices of abundance (CPUE), a virtual population analysis (VPA) and a Thompson and Bell age-structured model (with a monthly time step) were developed with the 2021 and 2022 data from the CORECRABE project using the same method described for the assessment of the octopus stock (see below).

In order to use the structural model based on the VPA, age-structured catch data (converted from the size structure of the total catches of the fishery estimated by month and the crab growth curve estimated by the CORECRABE project), and the following parameters are required: Age, Fishing mortality (F) (from VPA), natural mortality, length-weight relationship $W=a L^b$ and L_∞ of *Scylla serrata*.

The crab stock was assessed using an index of abundance (CPUE) and an age-structured model based on catch data collected in 2021 and 2022 as part of the CORECRABE project. These results were compared with historical data collected in 1989-1990 in the Boeny region, which justified the choice of this target region for the assessment.

The results obtained can be used to estimate the current status of the stock in relation to maximum sustainable yield (MSY) according to the Thompson and Bell model. The estimated catchability of each gear by VPA was considered identical between fishing gears so that an overall fishing effort multiplier could be estimated as a first approximation and for the sake of simplification: this leads to an underestimate of the fishing effort actually applied at present without calling into question the general trend and the interpretation of the results.

3.5 POULPES

3.5.1 Data taken into account for octopus

The *Octopus cyanea* octopus exists almost everywhere on the coasts of Madagascar, only the data collected by Blue Ventures with communities in south-west Madagascar is, for the moment, available and usable for stock assessment. Blue Ventures has worked with 22 of the 176 villages in south-west Madagascar since 2003, but only the data from 2015 matches well with the criteria of the models used. In addition to the data sampled from fishing villages, we also have total catch data available from the Direction Régionale de la Pêche et de l'Économie Blue (DRPEB) in Toliara.

3.5.2 Assessment models for octopus

Two groups of stock assessment models have been used for octopus, namely the
Generalised Depletion Model (GDM) and structural models (= analytical models).

3.5.2.1 Global model

An octopus stock assessment training seminar was held at the IH.SM from 16 to 20 January 2023. After their preliminary training in octopus stock assessment at the IH.SM, Toliara, in partnership with Blue Ventures and the Comité de Gestion des Poulpes (CGP), Herimamy Razafindrakoto and Daniel Raberinary shared with the 10 learners what they had learned during the training seminar they attended.

A presentation on conceptual issues concerning the scientific assessment of stocks fished by small-scale and data-limited fisheries was given and discussed with the participants. Following this, our two speakers gave a demonstration of the implementation of stock assessment using GDM with the CatDyn library, and as an example the 2021 octopus fishing season in south-west Madagascar.

Introductory courses focus on :

- Explanation of the basis of the GDM model, followed by the steps for using this model, and the results obtained from octopus data from BV 2021 (Powerpoint by Mr Mamy),
- Explanation of scripts, octopus biology and how models work (GDM),
- The application of these Blue Ventures data by each learner to obtain the result, followed by a discussion on the significance of these results for resource management (octopus),
- The distribution validation steps used before keeping the typical distribution of octopus stock / or octopus capture,
- Results: Biomass and exploitation rate.

3.5.2.2 Analytical model

In addition to this generalised depletion model (GDM), we worked with the same data from the NGO Blue Ventures for the analytical model based on the VPA (Pope Cohort Analysis) and the yield per recruit model (YPR) with monthly time steps. With this structural analysis, the results obtained were to be used to estimate the current status of the stock in relation to maximum sustainable yield (MSY). In order to understand the current state of the octopus stock in south-west Madagascar, data from three years (2020, 2021, 2022) were considered.

In order to use the structural model based on VPA, we need age-structured catch data, natural mortality and terminal fishing mortality.

Since cohort analysis is the method for estimating instantaneous fishing mortality rates and stock numbers, the model estimates these parameters with corresponding age classes. In this analysis, the time step is in months, taking into account the life span of the species (which is very short) and its rapid growth. It is estimated that the stock can be renewed after one month, depending on the biology of the animal.

The yield-per-recruit model is used if we have age-structured data, including fishing mortalities in each age class. If the biological parameters of the species are known, the yield per recruit (Y/R) can be calculated for any level of fishing effort and at any exploitation diagram.

Conventionally, reasoning by recruit is carried out for a cohort whose recruitment is equal to 1. The result will therefore be expressed per unit of production per recruit (gram/recruit).

With this model, we can estimate the stock situation in relation to the MSY position on the basis of simulations of fishing effort. By multiplying the fishing mortality values with the multiplier effort, from 0 to 2 in our case, we should obtain the current yield per recruit compared with the RMD situation.

The GDM was used with Blue Ventures data based on fishing effort, CPUE, average individual weight and total catch. This depletion model is dependent on seasonal catch disturbance. The monthly time step was considered for octopus, which is fast-growing and short-lived. In the case of octopus, we chose a time step of one week to run the model.

3.6 HOLOTHURIES

3.6.1 Approach for a data-deficient resource

In view of the lack of temporal catch and size data for sea cucumbers, it became clear that an alternative approach adapted to data deficiency resources would be needed for this sector, for example by exploiting marketing and export data, making comparative analyses by region of Madagascar and between Madagascar and importing countries.

3.6.2 Data taken into account for sea cucumbers

Following the strategy outlined above, the data taken into account was production and marketing data available at international, national, regional and sometimes local level, supplemented by data from specific studies.

3.6.3 Valuation method used

In view of the lack of catch and size data, the sea cucumber stock assessment method adopts an alternative assessment adapted to a data-deficient resource. Given the limited time available since the receipt of marketing data from the MPEB on 20 February 2023 and the scheduled stock assessment sessions, the assessment of sea cucumbers stocks has been postponed until March 2023.

In the meantime, initial analyses of the data have identified the main sources of data of interest to be analysed as part of an alternative approach prior to the next series of training courses:

- Imports of holothurians from Madagascar by Asian countries (notably Hong Kong);
- National exports of sea cucumbers (MPEB data) ;
- Production by region of Madagascar (MPEB data) ;
- Data from exporters submitted to ASH (exports by species by around fifteen exporters) ;
- Specific data from various scientific studies (including CPUE, species diversity, etc.)

The alternative assessment was carried out before and during the next training courses (18 to 28 April 2023) in relation to production and marketing data from the MPEB and other data or indicators yet to be collected. The overall analysis is then compared with the case studies, taking into account the requirements of the CITES Convention for the inclusion of four species of holothurian existing in Madagascar (*Thelenota ananas* (EN), *T. anax* (DD), *Holothuria nobilis* (EN) and *H. fuscogilva* (VU)) in Appendix II.

4 SCIENTIFIC ADVICE

4.1 BASED ON SCIENTIFIC ADVICE

Scientific advice is used to :

- **Guide** managers in their decision-making (Inform on scientific results, etc.)
  on the state of resources and their potential, and possible actions)
- **Inform** about the science used (describe and explain objectively and concretely the context, the choice of methods, the problems)
- **Enabling** the process to be followed and reproduced if necessary (Analysing: relating facts)
- **Justify** the conclusions reached (make a clear link between the results of the research and the conclusions).

4.2 CONTENT OF SCIENTIFIC ADVICE

During the course of the study, a variety of nomenclature was used for scientific advice. The main thing to remember is that it is always scientific advice, and not simply management advice.

Scientific advice typically contains the following elements (e.g. advice under the IMO or ICES/CIEM):

- Summary
- Context
- Evaluation
- Uncertainties
- Conclusion

In this report, we follow this structure, adapting it to the context and by resource, with the following variations:

- Recommendations are added at the end of each section. In the context, we insert
  analysis of MPEB marketing data.
- For the lobster, crab and octopus sectors, the scoreboard in
  as a complement to the assessment.
- For shrimp and sea cucumbers, the scoreboard is used as an assessment, and is at the level of evaluation.

4.3 CREVETTES

4.3.1 Summary

The lack of reliable data on small-scale fishing prevents a quantitative assessment of the state of shrimp stocks. It was therefore decided to carry out a qualitative, empirical analysis in the form of a
A "dashboard", where information is classified according to three levels: healthy zone, caution zone, danger zone. The characteristics used are: fishery performance (catch, fishing effort, IP exploitation rate), and stock abundance (CPUE and accessible biomass for IP).

The overall balance for the whole of the west coast indicates that fisheries (small-scale and industrial) are in the cautious zone. This assessment varies from region to region. Zones A and B are in the danger zone and remain critical but have not worsened recently. Area C, currently the most productive, is in the caution zone, with catches stable at an average level.

The main uncertainties stem from the absence of reliable data for CP and the lack of
biological data.

It is recommended that the activities of the PP be fully monitored and controlled, if necessary by introducing a minimum size for shrimp. It is also recommended that the biological data on the various species present be monitored.

4.3.2 Context

More than thirty species of shrimp have been recorded (in all environments) along Madagascar's coasts, including six species of neritic peneids that are exploited on a large scale (Table 11).

They are demersal species (living close to the seabed) and amphibiotic (changing environment during their lifetime): they reproduce at sea, the larvae migrate to coastal lagoons and the juveniles then migrate to the open sea, where they reproduce (Figure 5).

Table 11. The different shrimp species exploited in Madagascar

Scientific names	Trade names
Penaeus indicus	White
Panaeus semisulcatus	Tiger, Flower, Calendar or Brown
Penaeus japonicus	Tiger
Penaeus monodon	Tiger, Camaron or King
Metapenaeus monoceros	Pink or Brown
Metapenaeus stebbingi	Brown

The same stock is exploited by two types of fishery (Figure 5):

- The industrial trawl fishery, which operates off the coast;
- Small-scale fishing, which operates in coastal areas (mangroves) but can also operate further offshore and uses a wide variety of gear. The survey published by RESOLVE in 2019 identified a dozen types of fishing gear: straight nets (gillnets, dormant nets, portable nets, jarifa, periky); mosquito nets; beach seines; weirs (valakiro, poto-poto, vonosaha); trawls (kipiko); pots.

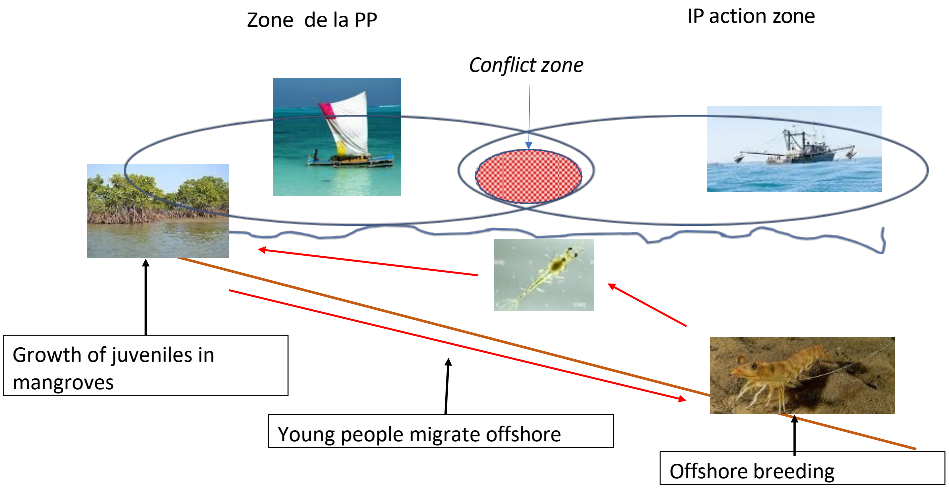


Figure 5. Diagram illustrating the life cycle of exploited shrimp and the areas of action of the two types of fishery.

The fishery is divided into four fishing zones. There are three on the west coast: A, B, C1 and C2 (merged into Area C before 2021). There is a single zone on the east coast (zone D).

Control of industrial fishing includes :

- Number of licences per fishing area (licence limited to a single area) ;
- Limit of 50 boats
- Length limitation (< 40m)
- Power limitation (<500 hp)
- Quota per vessel
- Restrictions on fishing gear (size and mesh size)
- Fishing season (seasonal closure)
- Ban on night fishing
- Compulsory logbook
- Electronic position and speed control (VMS)

Small-scale fishing is not subject to any specific regulations:

- Open access: We don't really know how many fishing units target this resource.
- Appears to be distributed throughout the coastline
- Fishing season like that of trawlers
- There are no effective controls on small-scale fishing. For example, valakira is officially is banned but is still used, as are mosquito nets.

4.3.3 History of fisheries performance

4.3.3.1 Industrial fishing (IP)

The IP has gone through several phases (Figure 6). The first period (1) corresponds to the development of the fishery from the early 1960s to the late 1980s. The second period (2) was marked by very high catches of up to 9,000 tonnes. The year 2005 was marked by a sharp drop in landings (3), which was observed in all areas (Figure 6). This was followed by a phase of stabilisation at low levels (4), which continues to this day.

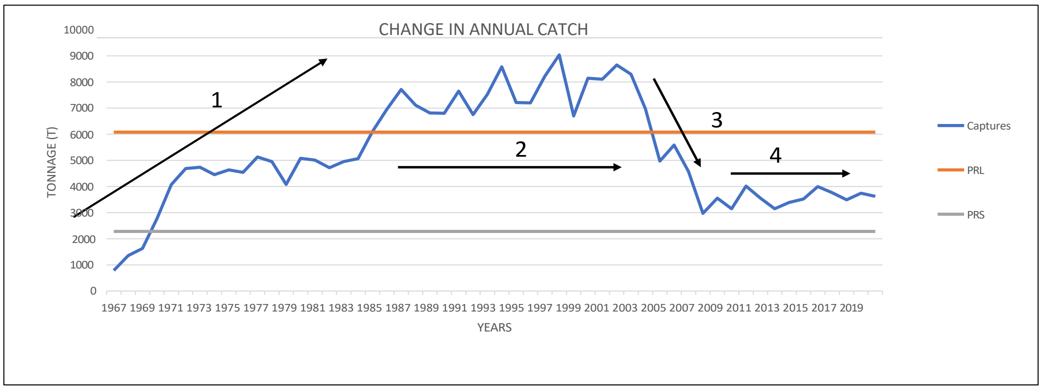


Figure 6 Trend in annual IP catches for the west coast as a whole. The upper line (red) shows the upper reference point, the lower line (green) the lower reference point. The figures indicate the different phases in the evolution of the fishery (explanations in the text).

This general trend is found in the different zones (Figure 7), with a few differences. Area A has long been the traditional fishing region. It expanded rapidly and enjoyed a period of prosperity, with catches fluctuating between 1,000 and almost 2,000 tonnes a year. This period lasted from the early 1970s until the sharp decline in 2005, and current landings are less than 500 tonnes. Area B follows much the same pattern as Area A. The period of expansion of the fishery in Area C was more marked than in Area A.

This was due to the gradual movement of fleets southwards. It became the most productive area, with catches of around 5,000 tonnes from the mid-1990s until the collapse in 2005. It remains the most important region, with catches in this sector stabilising at around 3,000 tonnes.

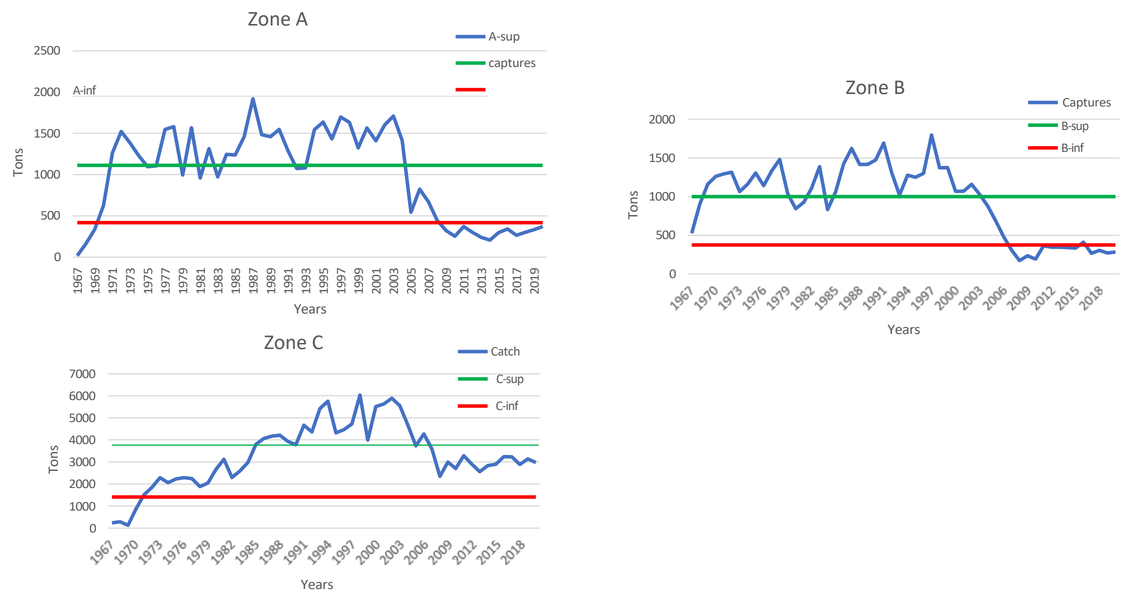


Figure 7. Catch trends for different regions of the west coast. The upper line (green) represents the upper reference point, the lower line (red) the limit reference point.

For the west coast as a whole, fishing effort followed general catch trends until 2010 (Figure 8). It then increased. Recent years have seen a marked fall in effort due to the radical control measures that have been put in place.

The increase in overall effort is due to zones B and C (Figure 8), while effort in zone A has remained relatively stable. Effort has been considerably reduced in all zones in recent years and is currently at an all-time low.

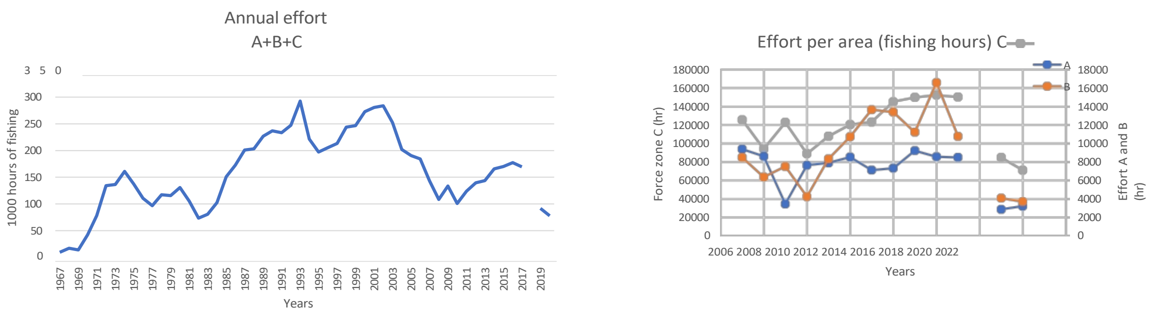


Figure 8. Temporal trends in fishing effort for the west coast as a whole, on the left, and by zone, on the right.

Catch per unit effort (CPUE) for the west coast as a whole increased from 2007 to 2011 (Figure 9) and then gradually declined until 2018. The 2020 CPUE shows a marked increase, but this value is questionable. In fact, there is no increase for any of the zones. Indeed, There is no marked trend in CPUE (Figure 9), apart from a peak in zone B. Maximum CPUE is observed in zone A, followed by zone B. Zone C has the lowest CPUE.

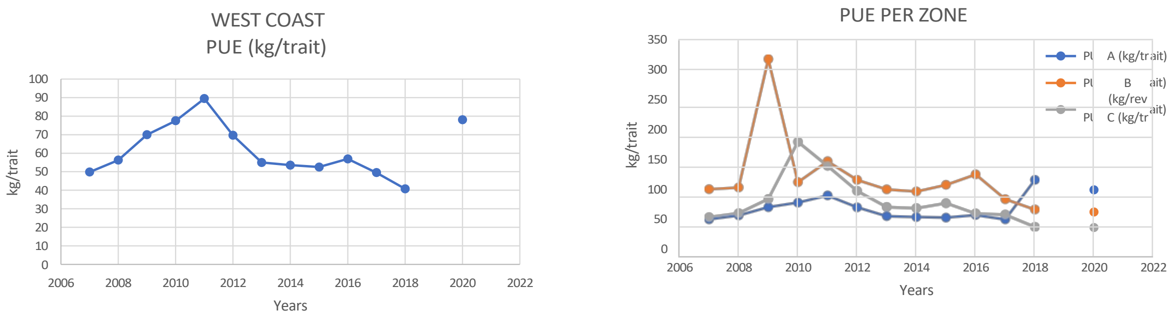


Figure 9. Catch per unit effort (CPUE) for the west coast as a whole, right, and by zone, right.

The biomass available to IP for the whole of the west coast (Figure 10) shows no trend over the period, fluctuating around 5,000 tonnes, with an exploitation rate of around 75%. However, there is an inverse relationship between the two parameters: an increase in the exploitation rate results in a decrease in biomass.

In zone A, biomass fell significantly between 2007 and 2010 (the model cannot be applied to 2009). An increase was noted thereafter, but it now appears to be declining and currently stands at around 400 tonnes. The exploitation rate is particularly high, regularly exceeding 80%.

In zone B, biomass increased from 2007 to 2016, rising from 300 to 700 tonnes. It is currently down to around 350 tonnes. Here too, the exploitation rate is very high, exceeding 80%. It decreased between 2013 and 2016 but is currently increasing.

For zone C, neither the biomass nor the exploitation rate show any clear trend. The biomass varies from 3,500 to 4,000 tonnes and the exploitation rates from 70 to 80%.

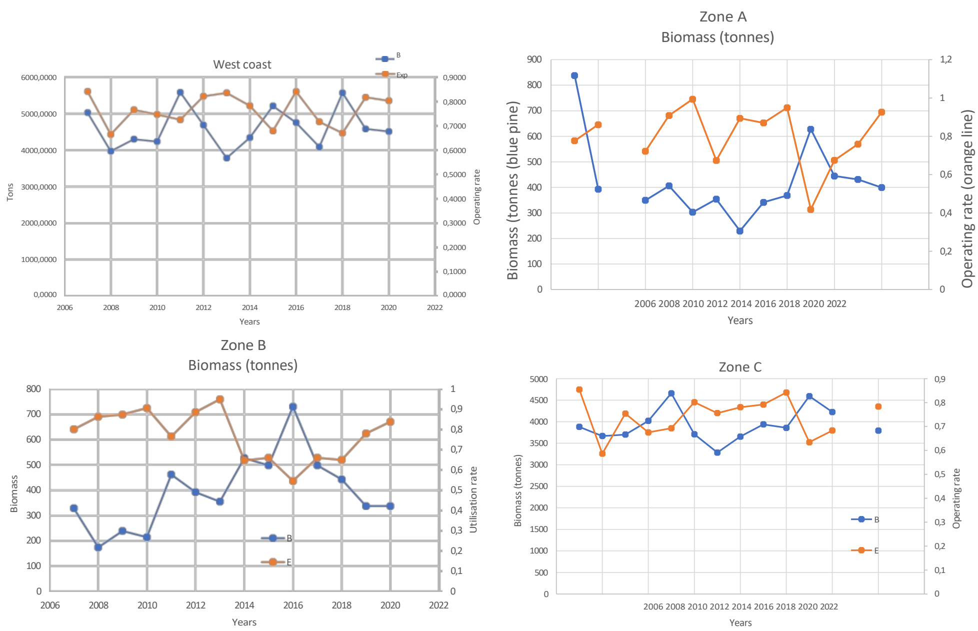


Figure 10. Biomass accessible to IP at the start of the season (B, in blue) and exploitation rate (E, in orange), for the whole of the west coast and by zone. The model is inapplicable in zone A for the year

4.3.3.2 Small-scale fishing (PP)

Figure 11. Recorded shrimp sales in small-scale fishing for the whole of Madagascar (Source: MPEB).

Shrimp fishing can be found all along Madagascar's west coast, at
With the exception of the southernmost region of Atsimo-Andrefana.

All the regions considered show major inter-annual fluctuations (Figure 12). The Menabe and Diana regions stand out, showing an almost regular progression over the time series.

The Sofia region, which was very productive in the years 2014 to 2016, with sales of over 200 tonnes, has seen its production fall to less than 30 tonnes in 2021 and 2022.

The most productive region, on average, is Boeny, with sales exceeding 400 tonnes from 2014 to 2016. The subsequent decline has been reversed, with sales reaching 1,600 tonnes in 2021. It is followed by Diana, with sales reaching 1,500 tonnes in 2021.

Production in the Melaky region rose to 120 tonnes in 2016, before declining thereafter.

Sales in the Menabe region hovered below 200 tonnes until 2021. They will exceed 300 tonnes in 2022. This relatively low production is somewhat surprising given that this is currently the main area for industrial fishing.

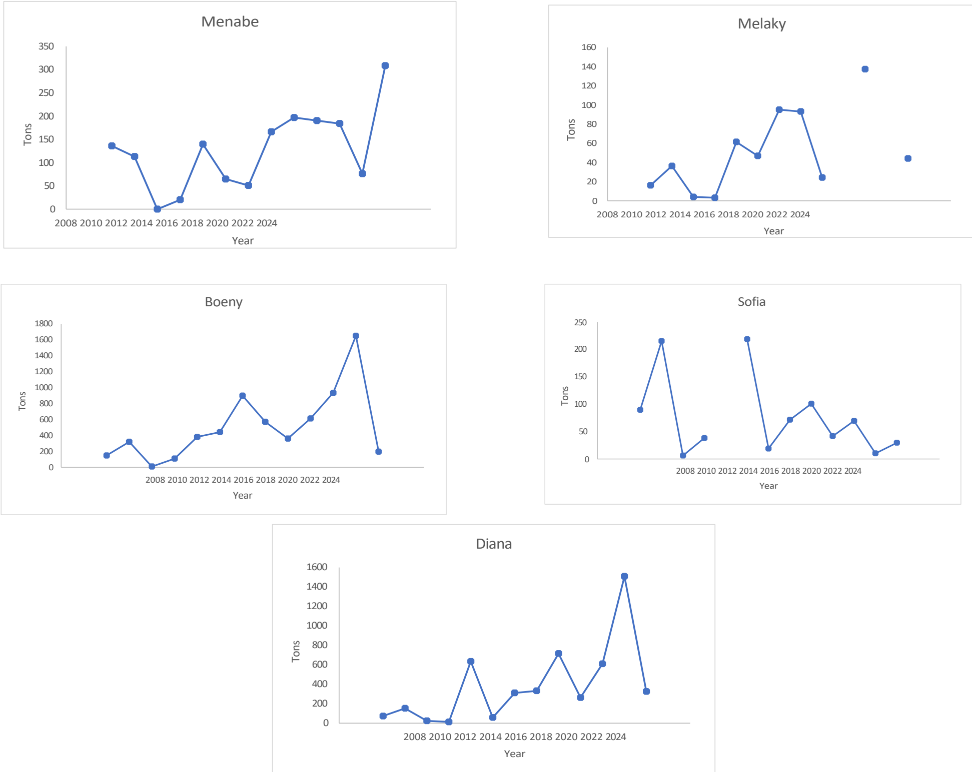


Figure 12: Regional trends in small-scale shrimp production

An attempt was made to compare catches from industrial fishing with declarations from small-scale fishing (Figure 13). The management zones for industrial fishing do not coincide exactly with the administrative regions. An approximation was therefore made. Zone A corresponds fairly well with zone A, as does, in part, the Sofia region with zone B. For zone C (the subdivision between C1 and C2 is too recent to make comparisons), the Melaky, Boeny and Menabe regions have been grouped together.

As observed for Madagascar as a whole, there is no correlation between the data for small-scale fishing and those for industrial fishing (Figure 13). The two fisheries appear to be developing independently. If confirmed, this observation could call into question the idea of sequential fisheries, with the two fisheries exploiting the same resource at successive phases in the life of the shrimp. This would need to be analysed in greater detail using data that are more detailed in time and space.

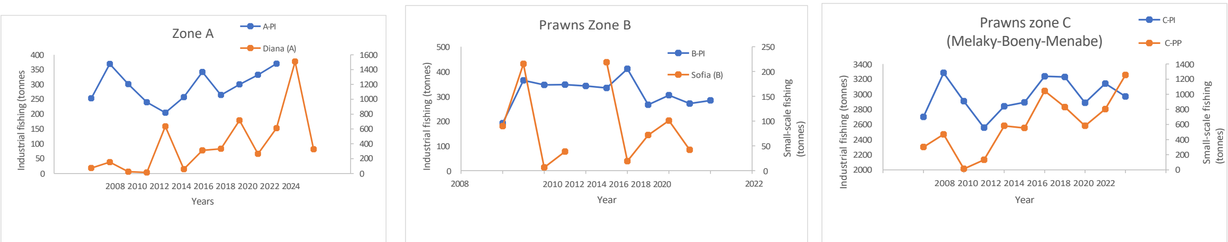


Figure 13: Comparison between catches from industrial fishing (in blue) and recorded sales from small-scale fishing (in orange) for the three IP management areas. The IP legend has been amplified for area C.

4.3.4 Evaluation (scorecard)

All the available data has led to the assessment of the state of the resource, which is summarised in the table below. on the following page.

Table 12. Summary of shrimp stock situation.

FEATURE	**INDICATOR**	**VALUE / REF**	**OBSERVATION**	**COTE 2019**	**COTE 2022**	**TR**
Performance of the western fishery	Capture	2020 = 3623 t In the middle between the PRS and the PRL	Catches stabilised at around 3500 t since 2009			↔
	Effort fishing		Effort at down sharply. Currently à 30% of the average 1998-2004			↓
	Rates operating		No analysis in 2019. Stable operating rate			↔
	Spatial distribution of the effort		Not analysis by 2020			
	Spatial distribution of catches		Not analysis by 2020			
Fishery performance A	Capture	2020 = 369 t Below than PRL (417 t)	Catches up slightly since 2017 (from 264 t to 370 t)			↑
	Effort fishing		Effort a considerably. Currently at 40 % over the period 2005-2017			↔
	Rates operating		Operating rate up since 2017. Currently from on the order of 90%.			↑
Fishery performance B	Capture	2020 = 283 t lower than PRL (375 t)	Catches stable at low levels.			↔

	Effort fishing		Significant decline since 2016			
	Rates operating		Rates operating increase since 2016. Very high (>85%)			
Fishery performance C	Capture	2020 = 2970, lower than the PRS (3776 t) but higher than the PRL (1416 t)				
	Effort fishing		Very sharp fall in the last three years			
	Rates operating		Significant fluctuations of the operating rate around 75% but without trend			
CP performance	Volume marketed		Sharp increase over the last 10 years. Currently: volumes = capture PI			
	Volume marketed by region		No trend can be defined with the data available			

FEATURE	INDICATOR	VALUE / REF	OBSERVATION	COTE 2019	COTE 2022	TR
Abundance of Western resources	PUE		Recent increase (2018 = 40kg/trait; 2020 = 78 kg/trait			
	Accessible biomass		No data for 2019. No trends.			
Abundance of resources A	PUE		PUE has doubled since 2017 (49 kg and 98 kg)			

	Accessible biomass		In decrease since 2017 (from 627 t to 399 t)			
Abundance of resource B	PUE		Slight decline since 2012			
	Accessible biomass		Steady decline since 2016 (from 730 t to 330 t)			
Abundance of C resources	PUE		Declining since the peak in 2010 (178 kg/trait); lowest value in the series (36kg/trait)			
	Accessible biomass		Sharp fluctuations with no clear trend, currently in decrease			

Conclusions

1. **According to IP data, no significant change in the state of the resource since the 2019 assessment**

- The relative stability of the biomass accessible to trawlers in zone C is a positive sign
- The very significant reduction in fishing effort in all areas is also a very positive sign.
- The fall in biomass in zones A and B is a cause for concern
- The situation in zones A and B remains very critical, but has not deteriorated significantly. It must be monitored
- The overall situation is not deteriorating
- But it remains, at best, in the cautious zone

2. **The role of small-scale fishing in shrimp exploitation is growing and currently accounts for (at least) half of national fishery landings.**

4.3.5 Uncertainties

- While data on industrial fishing appears reliable, the same cannot be said for small-scale fishing. The only data available are sales records. So we have the results of commercial transactions. Not everything is necessarily recorded. Exchanges between buyers and transfers from one region to another for commercial reasons are likely. So we don't have a true picture of CP catches on a fine enough spatial scale.
- Data by species for IP is unreliable and non-existent for CP. This is important information. For example, stable catches may correspond to the replacement of a species in difficulty by another.
- Shrimp are sensitive to environmental conditions (state of mangroves, salinity, etc.). In the context of global change, it is difficult to anticipate the future of these shrimp stocks in the medium and long term.

4.3.6 Ecosystem approach

4.3.6.1 Impact of industrial fishing on the ecosystem

Given its nature, shrimp trawling catches a large number of by-catch species (not directly targeted). These catches, which used to be discarded, are now landed. We can see that

that fish landings have been rising steadily for a decade and currently exceed shrimp landings (Figure 14).

These catches have a definite impact on demersal communities. It is therefore important to document and to study the biological dynamics of these species.

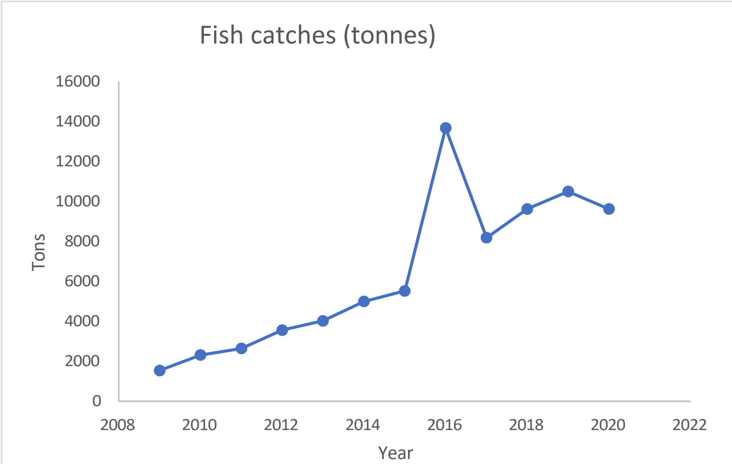


Figure 14. Fish catches recorded by industrial fishing.

It is also recognised that bottom trawling alters benthic habitats. An analysis of the spatial distribution of the fishing effort shows that it is highly concentrated geographically (Figure 15). In fact, 70% of the effort is spread over 10 statistical squares, and 50% over just five squares.

The impact therefore appears to be spatially limited, compared with the whole of Madagascar's coastal zone. A more detailed analysis (using VMS data, for example) would be interesting, as would a comparative study of affected and unaffected benthic habitats.

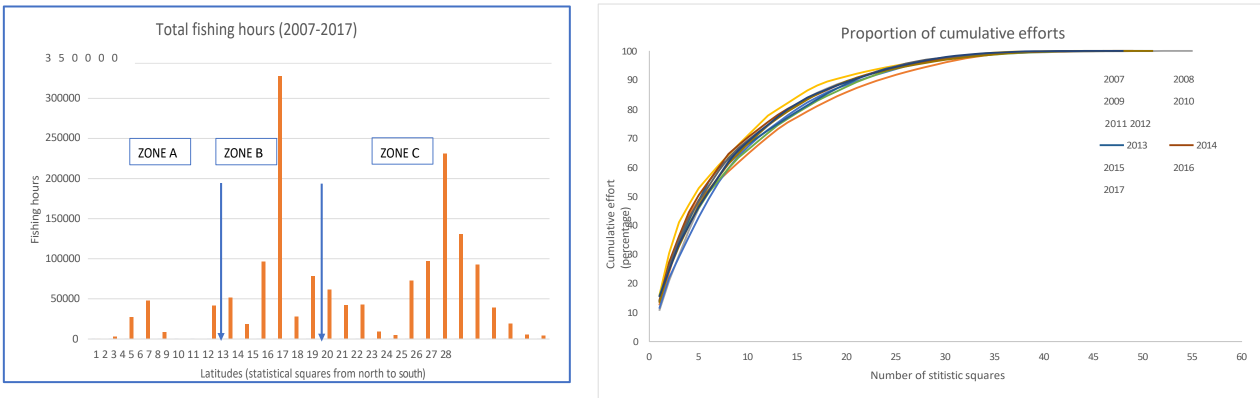


Figure 15. Spatial dynamics of fishing effort from 2007 to 2017. Left: total fishing hours per latitude statistical square. Right: Proportion of cumulative effort by number of statistical squares surveyed.

4.3.6.2 Impact of small-scale fishing on the ecosystem

Small-scale fishing uses a wide range of gear, most of which is non-selective. In fact, this is usually a multi-species fishery, and catches of species other than shrimp can exceed 50% of the total catch (RESOLVE survey, 2019).

These non-selective machines work in coastal areas where juvenile fish grow.
(shrimps, fish, etc.). They are therefore likely to affect the life cycle of many species.

As there are no data on actual catches in small-scale fishing, it would appear that this is also the case here, rigorous monitoring of small-scale fishing activities.

As it is very difficult, if not impossible, to limit the fishing effort and the gear used, one measure for indirectly controlling the activity would be to set a minimum size for the species caught, particularly shrimp.

4.3.7 Recommendations:

For the shrimp industry, our recommendations are:

- Serious monitoring of CP activities (gear, effort, catches) seems more necessary than ever.
- As an indirect measure of activity control, a minimum size should be introduced.
- In order to have a global and real view of the state of the resource, it would seem imperative to set up a programme to monitor small-scale fishing activities.
- More rigorous monitoring of fish catches in the IP is needed.
- The lack of biological data needs to be compensated for by hiring scientific observers (at on land and on boats).

4.4 INSHORE LOBSTERS

4.4.1 Summary

In relation to the data available on lobster in the northern part of Fort-Dauphin, we were able to work with the species *Panulirus homarus*, which is the most represented in the catch, to begin the stock assessment. The two models used (Schaefer logistic model and rectified VPA) indicate that the current situation of the spiny lobster stock in the northern area of Fort Dauphin is still fully exploited but slightly shifted towards overexploitation.

4.4.2 Context

Madagascar has 5 major spiny lobster species of importance to fishing, one of which, the south-eastern *Panulirus homarus*, is the only one to be the subject of stock assessment studies.

Commercial data analysis

Around 2015, the southern regions dominated major national lobster production (Figure 16). Their production then collapsed. The Anosy region, which grew until 2018, saw its production fall in 2022. Only the Sava region, in the north-east, is showing growth in production.

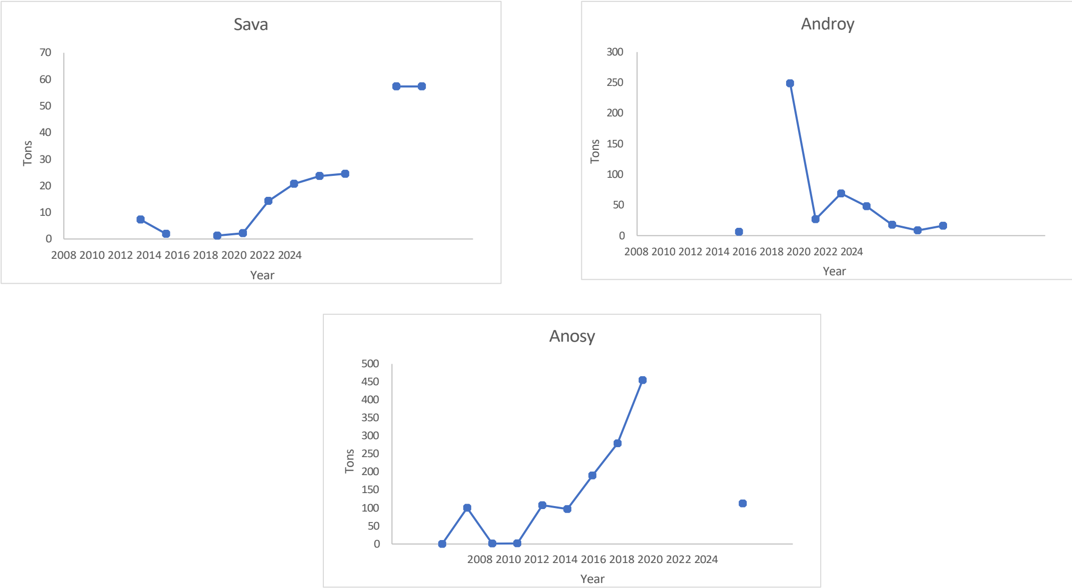


Figure 16: Lobster sales on Madagascar's east and south coasts

The peak in production then moved westwards. The Atsimo-Andrefana region saw very high production in 2014, but this has declined rapidly in recent years (Figure 17). In 2021 and
In 2022, it is the Boeny region that clearly dominates sales.

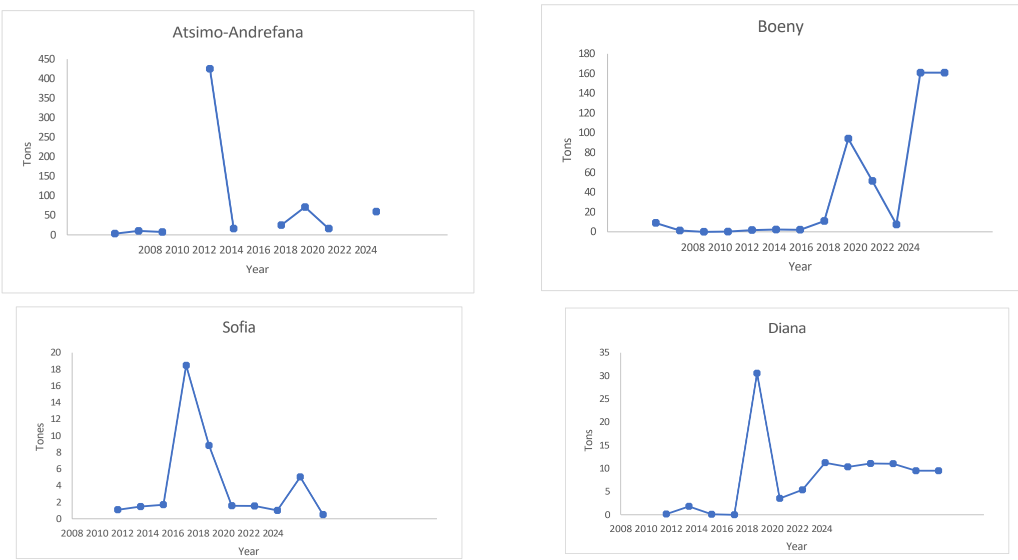


Figure 17: Lobster sales for the regions on Madagascar's west coast

The Sofia region shows a pattern similar to that of the southern regions, while production in Diana remains stable. It should be noted that there are different species and that the data should be analysed species by species.

4.4.3 Evaluation

4.4.3.1 Global model

The result of the analysis presented in this table, with an MSY value of 230.9 tonnes, is still in line with overall annual catches. This situation is also confirmed by the found on the B/Bmsy. To confirm the results with these parameters, we used the solver function to calibrate the observed CPUE and the predicted CPUE.

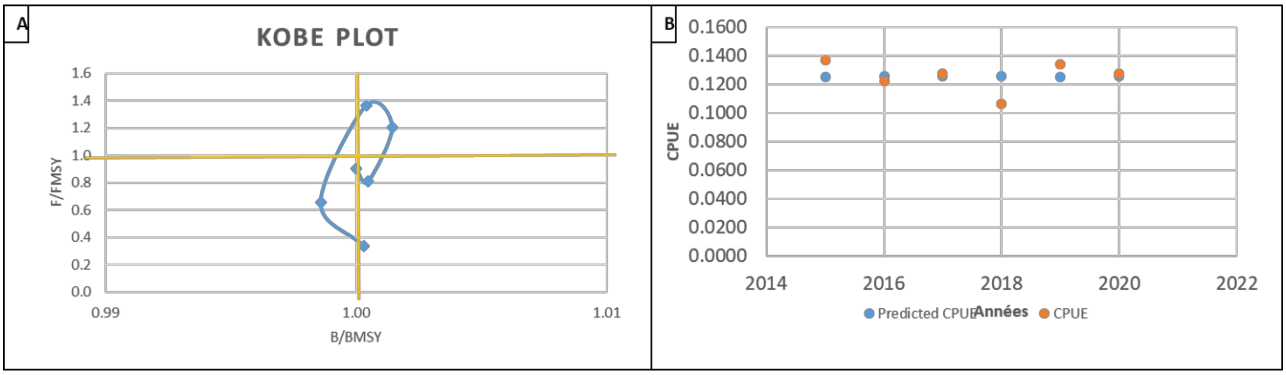


Figure 18: Presentation of results with KOBE Plot

The presentation in this figure confirms that the current situation of the lobster stock at Fort-Dauphin is still being fully exploited, as the shape of the curve revolves around the value 1 of the relationship between these indices. It is also interesting to note that the situation in 2020 and 2016 is still within the safety zone (under-exploited or fully exploited), which confirms the current situation of this stock.

4.4.3.2 Analytical model

Apart from the variation in fishing effort and fluctuations in numbers at different ages, analysis of the yield per recruit has shown us that the lobster stock in this region is still sustainable. The following figure shows changes in biomass and yield per recruit in relation to changes in the fishing effort multiplier (mF).

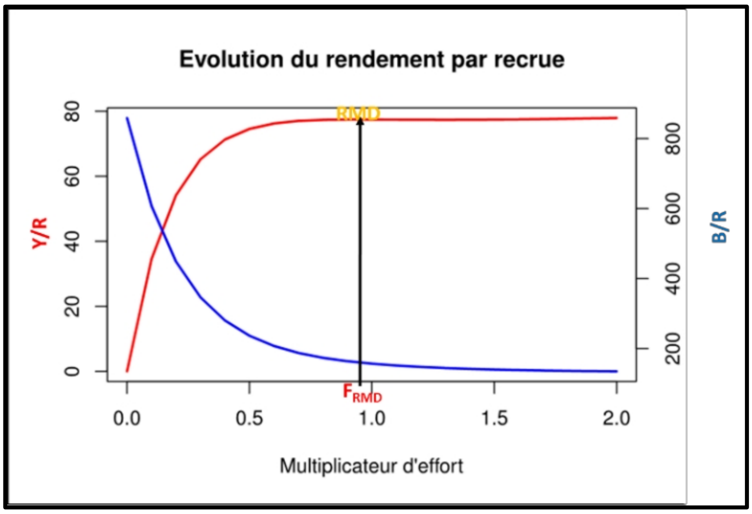


Figure 19: Evolution of yield per recruit with biomass

Legend: Y/R: Yield per recruit; B/R: Biomass per recruit; MSY: Fishing effort corresponding to the Maximum Sustainable Yield.

4.4.3.3 Schaefer logistic model

For this logistic model, the analysis results were interpreted using the relationship between biomass over biomass at MSY (B/Bmsy) and fishing mortality over fishing mortality at MSY (F/Fmsy). In practice, we look for the value of B/Bmsy and F/Fmsy to be able to present and interpret the situation of the stock. If B/Bmsy > 1, this tells us that our population is still larger than the biomass corresponding to MSY, so the stock is not yet overexploited. If F/Fmsy < 1, the fishing mortality rate is lower than the mortality rate corresponding to the MSY, so overexploitation has not yet been reached.

Table 13: Results of Schaefer logistic model with lobster

Years	Biomass	F	Capture(T)	CPUE	Predicted CPUE	Negative Log Likelihood	B/Bmsy	F/Frmsy
2015	46181.1888	0.0045	208.0539	0.1373	0.1256	-0.9780	1.0000	0.9010
2016	46204.0408	0.0040	186.9357	0.1226	0.1256	-1.3287	1.0005	0.8092
2017	46248.0110	0.0060	278.6109	0.1278	0.1257	-1.3448	1.0014	1.2049
2018	46200.3056	0.0068	315.0318	0.1066	0.1256	-0.0832	1.0004	1.3638
2019	46116.1797	0.0033	151.3675	0.1343	0.1254	-1.1337	0.9986	0.6565
2020	46195.7176	0.0017	77.3115	0.1274	0.1256	-1.3481	1.0003	0.3347
	r	0.01	**sig**	0.102656	**SE**	-6.2164487	**Fmsy**	0.005
	K	92362	**q**	2.72E-06	**msy**	230.90594	**Bmsy**	46181.19

The result of the analysis presented in this table, with the value of MSY equal to 230.9 tonnes, is still in line with the total annual catches. This situation is also confirmed by the values found in the B/Bmsy column. Only one value of B/Bmsy (0.9986) in 2019 is less than 1. For the F/Fmsy column too, the two values in 2017 and 2018 which are greater than 1 and the remainders still confirm the sustainability of this stock. To confirm the results with these parameters used, we used the solver function to calibrate the observed CPUE and the predicted CPUE.

The presentation in Figure 19 confirms that the current situation of the lobster stock at Fort-Dauphin is still under full exploitation, as the curve curves around the value 1 of the relationship between these indices. It is also interesting to note that the situation in 2020 and 2016 is still in the secure zone (under-exploited or fully exploited), which confirms the current situation of this stock.

4.4.3.4 Pseudo-cohort analysis or rectified VPA and Yield per recruit (YPR)

The rectified Virtual Population Analyses (rectified VPA) is recommended if the available data do not yet correspond with the maximum age of the species studied. After transforming the individual size into the corresponding age, we found 10 lobster age classes with an annual time step. Figure 20 shows the distribution of individuals according to their age classes. Individuals aged 2 and 3 dominate the catch. It is always possible that small individuals are less retained by the fishing gear, while large individuals become rare at the fishing site.

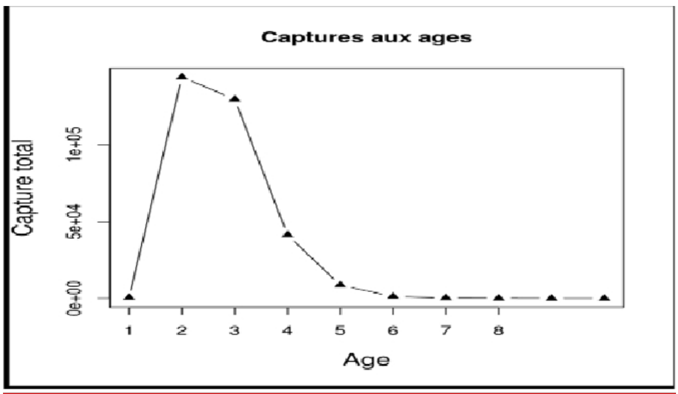


Figure 20: Variation in catches at different ages of spiny lobster

The numbers of individuals per age class are not necessarily proportional to the fishing mortality rates. In Figure 21, the highest fishing mortality is also observed with individuals in the 2 to 3 year age class, but fishing mortality is highest with individuals aged 3 years. As observed with the distribution of catches, fishing mortality is lower for young and older individuals.

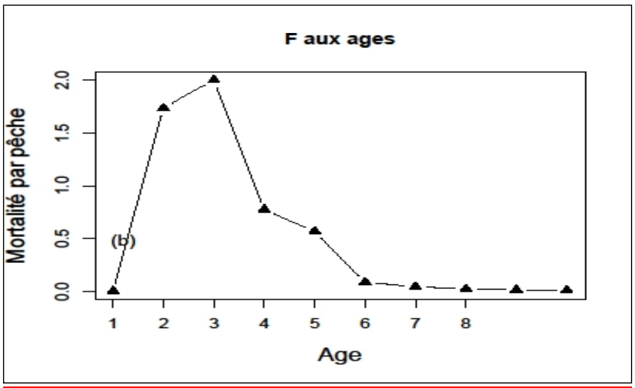


Figure 21: Lobster fishing mortality (F)

In terms of numbers at different ages, we have always seen a decline in the numbers of individuals from recruitment to maximum age. It may be that large individuals are poorly represented in the fishing site accessible to anglers. It is mainly individuals under the age of sexual maturity (5 years) that are the most abundant in the fishing site.

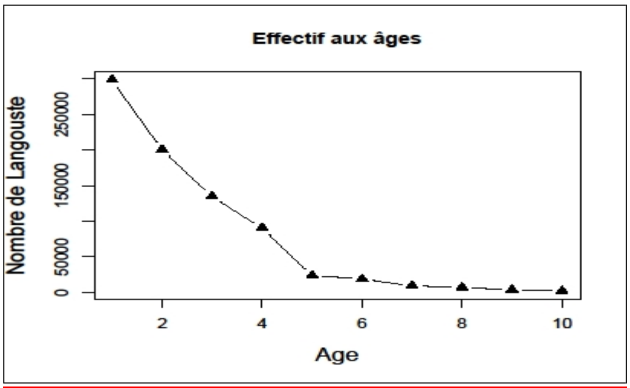


Figure 22: Number of lobster at different ages

Based on variations in fishing effort and fluctuations in numbers at age, analysis of the yield per recruit (YPR) showed us that the lobster stock in this region is still sustainable. Figure 23 below shows how yield per recruit changes with biomass.

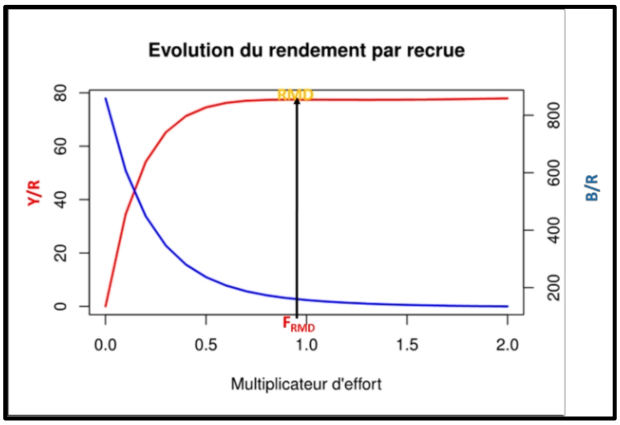


Figure 23: Yield per recruit of Norway lobster

The evolution of the yield in relation to the effort multiplier shows that the position of F_{RMD} (F equivalent to the Maximum Sustainable Yield) is right next to the current effort because the value of the current effort is equivalent to the effort multiplier equal to 1. The MSY situation is at 0.9 of the effort multiplier. This situation shows us that the current level of exploitation is still in full exploitation, but slightly shifted towards overexploitation.

The analysis was carried out using the data available from the ex-URL of Fort-Dauphin in order to be able to assess the current state of the stocks. After analysing the available data on individual size, CPUE and fishing effort, we found that *the Panulirus homarus* spiny lobster stock in the Fort-Dauphin area is still being fully exploited, but management measures need to be put in place to ensure the sustainability of this strategic resource in Madagascar.

Panulirus homarus is the species most represented in the catches at Fort-dauphin, and it is for this reason that the stock assessment began with this species. In Madagascar, lobster production in the Anosy region is higher than in other regions. However, production in the region is in second place and deserves to be closely monitored. There is currently a downward trend in lobster catches in the Anosy region, especially since 2018. Based on the distribution of individuals caught according to age, we have noticed a dominance of young individuals in the catch. The result of the yield per recruit analysis confirms that the current situation is one of full exploitation and slightly shifted towards overexploitation in relation to the maximum balanced yield. The situation of the lobster stock is fairly dubious, so we need to reduce the fishing effort to 30% of the reference point in order to be able to exploit this resource sustainably.

With the six-year data series (2014 to 2020), we cannot yet be sure of the reliability of the results of the Schaefer logistic model, as analysis using this biomass model requires at least 10 years of catch and CPUE data series. We still had to start with the rectified VPA in order to be able to continue the study of lobster stocks on all the coasts of Madagascar.

4.4.4 Uncertainties

Lobster fishing is subject to several sources of uncertainty:

- Studies carried out in Anosy, only with very limited fishing villages
- Missing data for some years (data structure)
- Percentage of species in the catch that changes according to the season
- Post-capture loss
- Use of a stalling tank
- Different individual sizes for different species
- Need to study stock by gender
- Distribution of individuals according to depth

4.4.5 Dashboard

The stakeholders met to draw up the scorecard during the project's final workshop (12 and 13 September 2023). Only observations from the Fort Dauphin region were available. Overall, favourable or cautious indicators dominate over risk indicators. The main risk concerns the high exploitation rate in 2020, associated with an increase in fishing mortality recorded for 2022. Overall, the scorecard supports the conclusions of the main assessment.

Table 14: Trend chart summarising the state of lobster stocks

FEATURE	INDICATOR	VALUE / REF	OBSERVATION			TR
Fort-Dauphin	Volume marketed	2013 = 123,03 t 2020= 77,31 t	Reduction in catches observed (37%)			
Fort-Dauphin	Operating rate (F/Z)	2020=64%	Already above 30%, the situation is tending to become unsustainable			
Fort-Dauphin	CPUE	2014 : 0,80 kg/Fisher 2020 : 0,78 kg/Fisher				
Fort-Dauphin	F	2014: 0.54/year 2022: 0.59/year	Slight increase in mortality from fishing			
Fort-Dauphin	Situation Yield % RMD	Situation Yiel d> to 0.13 of RMD	Situation in full operation			

4.4.6 Conclusion

Panulirus homarus is the species most represented in the catches at Fort-dauphin, and it is for this reason that we began the stock assessment with this species.Since 2018, we have observed a downward trend in lobster catches in the Anosy region. From the distribution of individuals caught according to age, we have noticed a dominance of young individuals in the catch.

After analysing the available data on individual size, CPUE and fishing effort, we found that the *Panulirus homarus* spiny lobster stock in the Fort-Dauphin area was still being fully exploited.

The results of the performance analysis per recruit confirm that the current situation is in full swing and shifted slightly towards overexploitation in relation to the maximum balanced yield.

The situation of the lobster stock is dubious enough to reduce the fishing effort to 30% of the current level. in order to exploit this resource sustainably.

4.4.7 Recommendations

Management measures must be put in place to ensure the sustainability of this strategic resource for Madagascar.

4.4.7.1 National and local closures

Even if our proposal is normally to reduce the current effort to 30%, we think it is preferable to leave the national closure period as it is, because the last decision to change in 2017 is still recent in relation to the growth and lifespan of the lobster. On should encourage local closures in all villages, based on the model already initiated by the fishermen of Sainte Luce.

4.4.7.2 Minimum catch size

We should insist on updating the legislation on minimum catch sizes. We need to think about the specific minimum size for each species (minimum size of 20 cm to be discussed).

4.4.7.3 Reducing post-capture losses

Export companies have noticed an increase in post-harvest losses. It is interesting to study the cause of this phenomenon.

4.4.7.4 Monitoring catches

We should continue monitoring lobster catches (Anosy and Androy, Diana) and also initiate monitoring in other regions in order to assess lobster stocks in Madagascar.

4.5 MANGROVE CRABS

4.5.1 Summary

The assessment of mangrove resources was carried out using fishing data collected by the CORECRABE project in the Boeny region from 2020 to 2022. These data were used to estimate standardised indices of abundance (CPUE), which were compared with the historical estimates available (1990) in the region, and to feed a VPA study and an analytical model that established the level of exploitation of the resources in this region.

The results showed that the mangrove crab fishery in the Boeny region is in a state of severe overexploitation, with a greatly reduced abundance of crabs. Exploitation has increased by a factor of around 7 since 1990 following the strong development of the industry since 2013, with a fishing effort 2 times greater than the effort corresponding to the maximum sustainable yield. Fishing is not selective and small crabs are also intensively exploited. This result calls for the effective implementation of restrictions on fishing pressure to ensure the sustainability of resources and the socio-economic spin-offs of the industry in the region.

This assessment should be repeated in Madagascar's other main mangrove crab production regions to support this country-wide diagnosis.

4.5.2 Context

4.5.2.1 Developing the live crab sector

In 2013, Madagascar set up a new live crab export channel to China. Exports of live crabs by air reached 580 t in the first year and 2,400 t in the second year, 2014. Between 2013 and 2017, this growth in exports of live crabs by air freight occurred at the same time as a significant drop in exports of frozen crabs. One plausible explanation for this is the competition in collection between the two export channels, sometimes within the same company. Over the last period, from 2018 to 2021, export growth is driven more by frozen crab exports than by live crab exports by air.

4.5.2.2 Review of marketing data

The two most productive regions for crab are i) the Boeny region (historically the region where the leading mangrove crab export companies), between 1500 t and 3000 t per year, but in decline since 2020, and ii) the Menabe region, which has grown steadily over the last five years to reach the same level of production as the Boeny region since 2021 (between around 1,500 t and 2,000 t),

Production has been significant over the last decade in the Atsimo-Andrefana region (varying between 300 t and 1000 t per year) and the Diana region (between 500 t and 1200 t per year, but declining steadily since 2019). Production in these two regions has been comparable since 2020 (912 t and 734 t respectively in 2022).

The Melaky region, which showed periods of relatively good production in 2011 and 2014, now appears negligible in total production. It is the only region that has not seen an increase in recent years. However, it is likely that some of the production recorded in the Menabe region (particularly in recent years) is in practice fished further north, in the Melaky region, then transported and marketed by export companies based in Morondava. This hypothesis could explain the upward trend described above in the Menabe region.

The Sofia region enjoyed a period of good production in 2014, with more than 700 tonnes. This was followed by a long period of decline. Recent years show a slight recovery, with 227 tonnes in 2022.

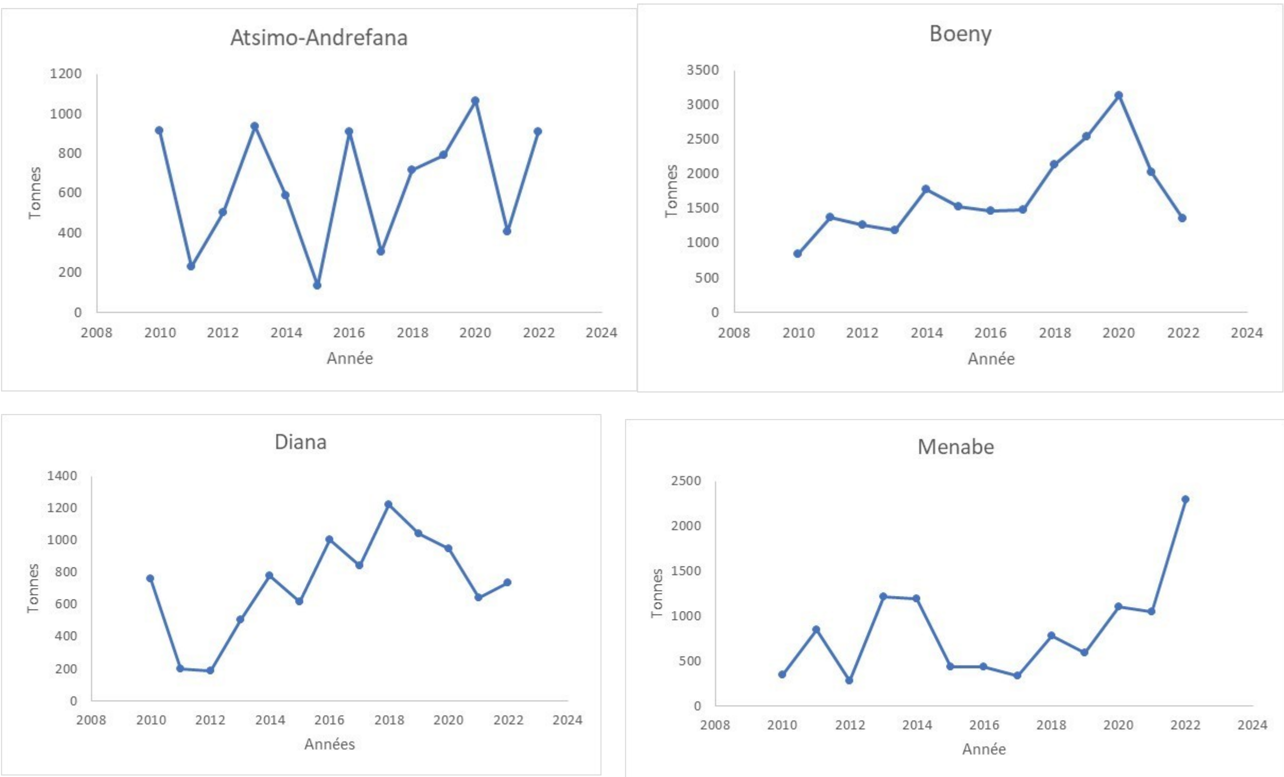


Figure 24: Regional trends in crab production

4.5.3 Evaluation

4.5.3.1 The first assessment of mangrove crab resources in Madagascar was carried out in the Boeny area in 1988-1989 (Bautil report, 1990). Data on catches per trip and per gear were collected from the landings of commercial fishermen in five bays (Baly, Narambitsy, Namakia, Boeny and Boeny).

Marosakoa) between April 1988 and March 1989. These monthly data were analysed by the trainees on a regional scale and for each bay sampled to estimate the average CPUE overall and by size class, in order to show i) the historical level of this index of abundance around 30 years ago, ii) the spatial and temporal variations in this index, and iii) the variation in the index as a function of the gear considered.

The above historical data did not make it possible to analyse the interactions between the above factors influencing CPUE. For comparison, the CPUE was therefore also estimated using more comprehensive recent data, collected continuously in 2021 and 2022 in several villages in the southern region of Mahajanga as part of the CORECRABE project. The data collected (fishing effort during the trip, number of gears, size of 30 crabs per landing, weight of the catch and destination) and the landing monitoring form were explained to the learners. The data is archived in an online database called the Collaborative Fisheries Information System (Figure 25). The group was given a login and password to access the CORECRABE project data.

The CPUE were standardised using GLM (General Linear Model) or GLMM (General Linear Mixed Model) statistical models. The aim was i) to understand how CPUE is affected by temporal factors (months), spatial factors (villages) and fishery factors (type and number of gear), and ii) to compare these with explanatory variables in order to determine the factors influencing the distribution and abundance of the population studied. Another objective is to predict the parameters of interest over the entire study area and monitor changes over time. The standardised CPUEs were then interpreted using the traffic light approach, in relation to a reference state.

$\mathrm{CPUE} = imois + jengin + kmois\ x\ engin + uengin * nombre\ engin + uvillage + \varepsilon residus$ (fish law) in order to explain the variation in CPUE in the villages studied

ln(CPUE)= $imois + jengin + lmois * engin + mengin * nombre\ d'engins + 1/uvillage + \varepsilon résidus$ where the variable "Village" is a random effect used to predict CPUE at the scale of the southern zone of Mahajanga.

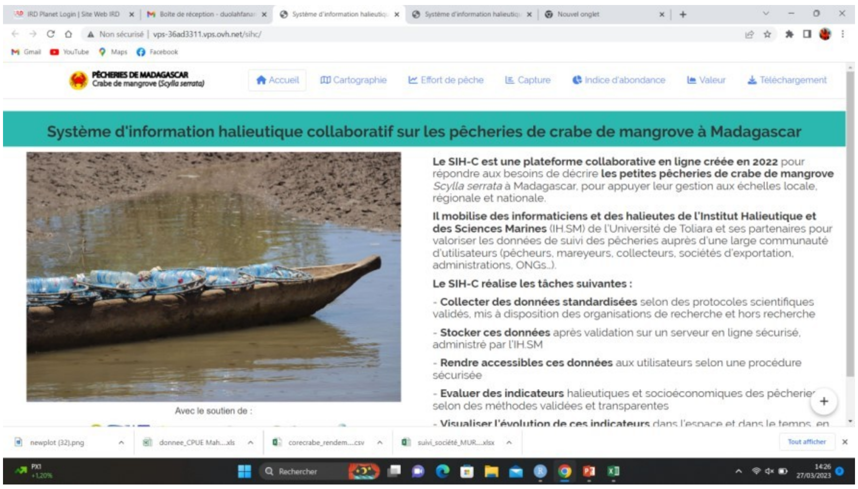


Figure 25: Portal and access to the online Collaborative Fisheries Information System (SIH-C)

4.5.3.2 Thompson and Bell analytical model

For comparison with previous indices of abundance (CPUE), a virtual population analysis (VPA) and a Thompson and Bell age-structured model (with a monthly time step) were developed with the 2021 and 2022 data from the CORECRABE project using the same method described for the assessment of the octopus stock (see below).

In order to use the structural model based on the VPA, age-structured catch data are required (converted from the size structure of the total catches of the fishery estimated by month and the crab growth curve estimated by the CORECRABE project), and the following parameters: Age, Fishing mortality F (from VPA), natural mortality, length-weight relationship $W = a\,L^b$ and L_∞ of *Scylla serrata*.

The results obtained can be used to estimate the current status of the stock in relation to maximum sustainable yield (MSY) according to the Thompson and Bell model. The catchability of each gear estimated by VPA was considered identical between fishing gears so that an overall fishing effort multiplier could be estimated as a first approximation and for the sake of simplification: this leads to an underestimate of the fishing effort actually applied at present without calling into question the general trend and the interpretation of the results.

4.5.3.3 Comparison of average monthly crab yields (CPUE) between 1990 and 2022

In 1989-1990, average catches using hooks and scales (which were not widely used at the time) were comparable: they ranged from 8 kg/trip to 14 kg/trip (and occasionally even 16 kg/trip). Thirty years later, yields are different between these two gears: hook catches are now systematically 2 to 4 kg less per trip than scale catches, and vary between 4 kg per trip and 10-12 kg per trip. However, since scale fishing has changed considerably over this period (e.g. in terms of the number of scales per fisherman), it is difficult to compare the yields of this gear, unlike hook fishing, where the efficiency has probably not increased much over time.

Thus, the average overall yield of the hook suggests that the abundance of crabs in the southern region of Mahajanga would have decreased by a factor of around 2 between 1990 and 2022, except after the opening of the fishery in mid-December, which also altered the seasonality of fishing yields.

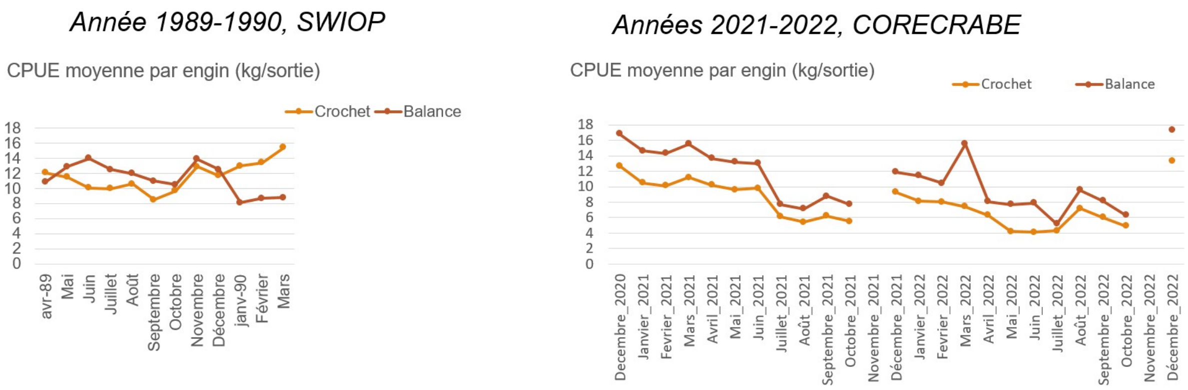


Figure 26: Trends in average monthly crab CPUE for two gears (hook and scale) between 1989-1990 and 2021-2022

4.5.3.4 Index of abundance (CPUE standardised by GLMM)

The results of the statistical model (GLMM) make it possible to estimate standardised CPUEs for the various fishing gears in 2021 and 2022. For the hook in particular, whose data are probably little biased by changes in fishing efficiency, the results confirm and clarify the above findings. The abundance of crab resources remains high in 2021 and 2022 at the time of and shortly after the opening of the fishery, at the beginning of the year, compared with yields in 1990. But it then falls sharply to a minimum during the cold season, when abundance is divided by a factor of around 3 compared with the warm period.

As a result, the seasonality of resources (and therefore yields) is much more marked today than it was in 1990, when crab abundance remained average to high throughout the year, even though yields were already lower in winter than in summer. This seasonality is very marked by the closure of fishing from 15 October to 15 December, which seems to reinforce the biological process of natural recruitment.
In addition, there is a strong variation in abundance between 2021 and 2022, suggesting the effects of fishing. (e.g. increased fishing pressure following the end of the covid-19 epidemic) and/or environmental factors.

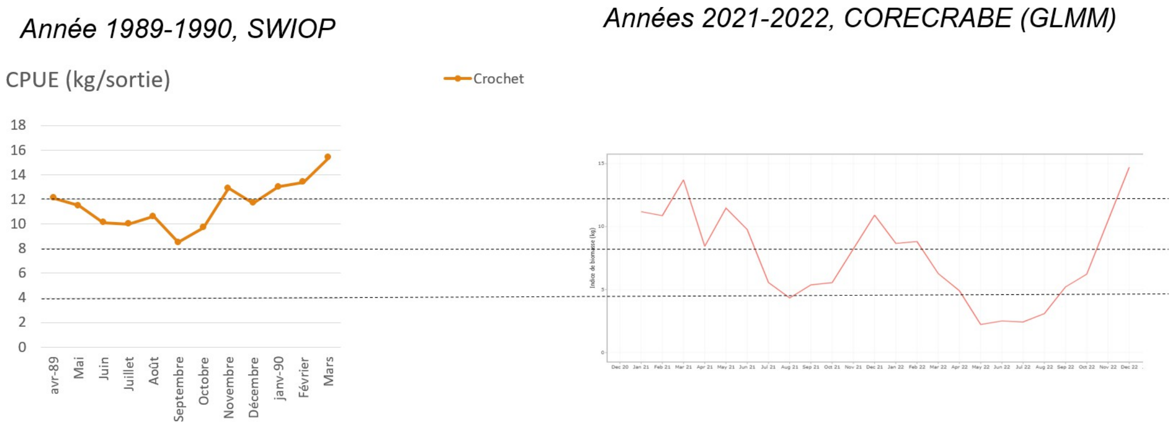


Figure 27: Change in average monthly CPUE on the hook between 1989-1990 (average yield) and 2021-2022 (CPUE predicted by GLMM). The dotted horizontal lines have been added to facilitate visual comparison.

If we distinguish between catches according to the size of the crabs (for example, in "very small <7cm" sizes), we will be able to see the size of the crabs,
"In the case of small crabs (7-10 cm) and medium crabs (>10 cm), it can be seen that the abundance of medium crabs (i) has fallen sharply, although they are still in the majority, and (ii) shows strong seasonal variation compared with smaller crabs (Figure 28).

In addition, the abundance of crabs <10 cm now seems higher than in 1990, which is probably explained by the fact that fishermen did not always land catches of these small crabs in 1990: the average yield of crabs <10 cm in 1990 would therefore be a biased estimator of the abundance of this size, i.e. it underestimated the abundance of this fraction of the crab population, due to discards.

This hypothesis is reminiscent of the fact that discarding catches (live in our case) affects the reliability of CPUE as an index of abundance. Paradoxically, the fact that fishermen no longer discard small crabs caught today has reduced this source of bias and therefore the robustness of this indicator.

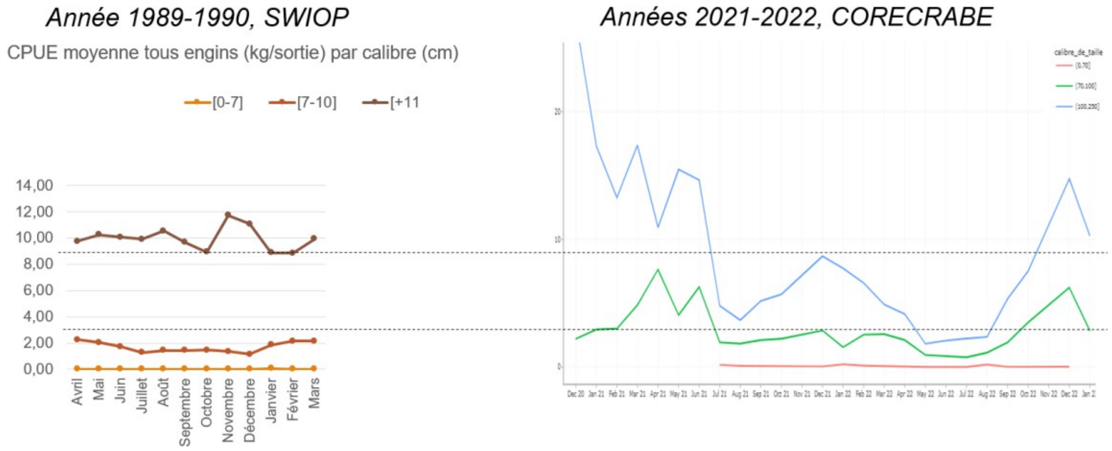


Figure 28: Trends in average monthly CPUE by crab size (in cm) for the hook-and-line fishery between 1989-1990 (average yield) and 2021-2022 (CPUE predicted by GLMM). The dotted horizontal lines have been added to facilitate visual comparison.

4.5.3.5 Crab stock assessment (VPA and Thompson and Bell model)

Recruitment (i.e. the arrival of 5-month-old young crabs in the fishery) is estimated at between 500,000 and 700,000 crabs per month: according to these results, there is continuous recruitment throughout the year (and therefore continuous crab reproduction), with a seasonal increase (+20% to +40%) in very young crabs, especially between April and June.

Furthermore, the evolution of the numbers of a virtual monthly cohort (in yellow in the table below) after its recruitment (age = 5 months), shows that the number of crabs fell by 90% from the age of 12 months because of the strong fishing pressure on juvenile crabs. As a result, large crabs (e.g. >13 cm) have become rare in the natural population.

Table 15: Estimate of catches and the size of the crab stock (in numbers) and the stock biomass (in tonnes) by monthly age class in the Boeny region in 2022 using virtual cohort analysis (VPA) based on data from the CORECRABE project.

Captures aux âges - C (en nombre de crabes)											
Age	déc-21	janv-22	févr-22	mars-22	avr-22	mai-22	juin-22	juil-22	août-22	sept-22	oct-22
5	3814	13770	7128	7624	2321	572	5508	9940	17229	176	129
6	5301	18835	11717	35509	32120	33788	42245	58227	101415	18220	13371
7	31426	36843	34481	42943	54572	48678	56152	51859	95392	56260	36083
8	70058	47627	67967	67112	77690	68024	62657	44820	78109	61772	58692
9	153767	138960	121581	111508	105452	70325	78659	68056	115116	100169	84695
10	148006	149458	105190	93679	96128	68049	81639	79133	119413	126766	111033
11	136974	160756	114372	75666	90085	79834	81851	52506	79049	106810	119322
12	117837	100420	92779	48362	66481	60057	68167	46946	74730	77995	52202
13	18093	16229	13899	5241	3611	4980	11601	1243	11421	13123	24786
14	14193	14433	16030	4087	6842	1912	7561	250	2780	1408	1468
15	885	1585	5492	1888	1008	145	1996	209	544	1043	1087

Effectif (N) du stock/âge											
Age	déc-21	janv-22	févr-22	mars-22	avr-22	mai-22	juin-22	juil-22	août-22	sept-22	oct-22
5	521 404	523 526	600 412	639 474	662 482	703 852	694 704	557 437	548 958	574 538	580 856
6	542 261	500 559	492 821	573 718	611 012	638 481	680 215	666 512	529 386	514 016	555 530
7	511 697	519 271	465 624	465 140	519 987	559 392	584 319	616 368	587 397	412 292	479 246
8	509 562	464 015	466 013	416 448	407 658	449 270	493 179	509 939	545 159	474 325	343 445
9	501 102	423 957	401 964	383 891	336 793	317 887	367 642	415 389	449 141	450 468	398 023
10	434 347	333 449	273 394	269 214	261 641	222 042	238 303	278 230	334 840	321 203	337 187
11	265 715	274 547	175 529	160 980	168 258	158 524	147 839	150 201	191 283	206 424	186 002
12	156 422	122 295	107 448	57 292	81 287	74 146	74 813	62 494	93 639	107 269	94 612
13	39 539	35 405	19 525	12 680	7 851	13 239	12 651	5 320	14 275	17 074	27 047
14	16 098	20 449	18 284	5 215	7 110	4 042	7 908	827	3 923	2 575	3 608
15	900	1 611	5 584	1 920	1 025	148	2 029	212	553	1 060	1 106

Note: The yellow boxes indicate the number of crabs in a virtual cohort as it grows from recruitment (age = 5 months) to age 15 months.

Stock biomass (tonnes)											
Age (months)	Dec. 21	Jan-22	Feb-22	March 22	Apr-22	May 22	June-22	Jul-22	august-22	sept-22	Oct-22
5	12,09	12,13	13,92	14,82	15,36	16,31	16,10	12,92	12,72	13,32	13,46
6	25,56	23,60	23,23	27,04	28,80	30,10	32,06	31,42	24,95	24,23	26,19
7	41,75	42,36	37,99	37,95	42,42	45,64	47,67	50,29	47,92	33,64	39,10
8	64,46	58,70	58,95	52,68	51,57	56,84	62,39	64,51	68,97	60,01	43,45
9	90,71	76,75	72,77	69,49	60,97	57,55	66,55	75,20	81,31	81,55	72,05
10	105,45	80,96	66,38	65,36	63,52	53,91	57,86	67,55	81,29	77,98	81,86
11	82,39	85,13	54,42	49,91	52,17	49,15	45,84	46,57	59,31	64,00	57,67
12	59,48	46,50	40,86	21,79	30,91	28,19	28,45	23,76	35,61	40,79	35,98
13	17,81	15,95	8,80	5,71	3,54	5,96	5,70	2,40	6,43	7,69	12,19
14	8,32	10,57	9,45	2,70	3,67	2,09	4,09	0,43	2,03	1,33	1,86
15	0,55	0,98	3,39	1,16	0,62	0,09	1,23	0,13	0,34	0,64	0,67
Monthly total	**509**	**454**	**390**	**349**	**354**	**346**	**368**	**375**	**421**	**405**	**384**

The cumulative monthly biomass of the stock would be in the order of 350 t to 500 t. The results indicate that the resource is overexploited (catch per recruit = 180 g compared with 240 g at maximum sustainable yield (MSY)). According to the results, MSY could be achieved by reducing the current fishing effort by a factor of 2, representing a 25% increase in the fishery's yield. However, monthly fishing effort is estimated to have increased by a factor of around 7 between 1990 and 2021-2022 (Figure 29). The stock was therefore highly underexploited in 1990 (effort multiplier ~0.15), but if the trend towards increased effort continues in the Boeny region, the results suggest that the fishery's balanced yield will also continue to decline.

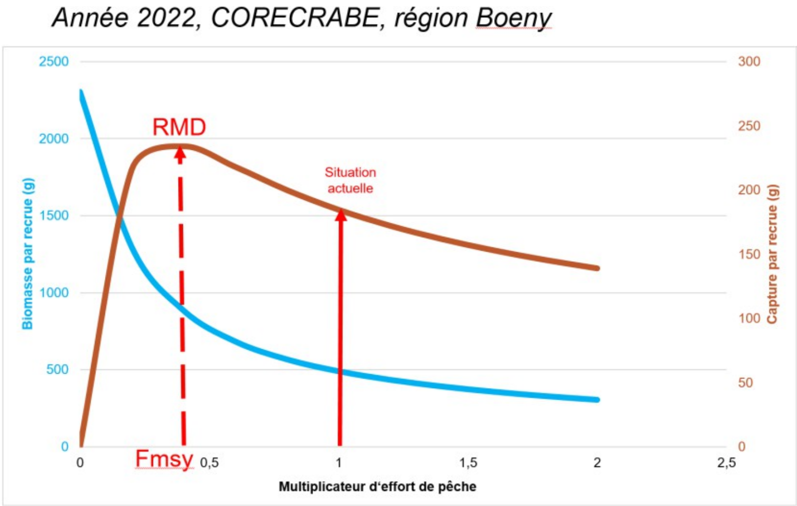


Figure 29: Yield per recruit and biomass per recruit as a function of fishing effort according to the Thompson and Bell model. applied to 2022 data from the Boeny region (CORECRABE project).

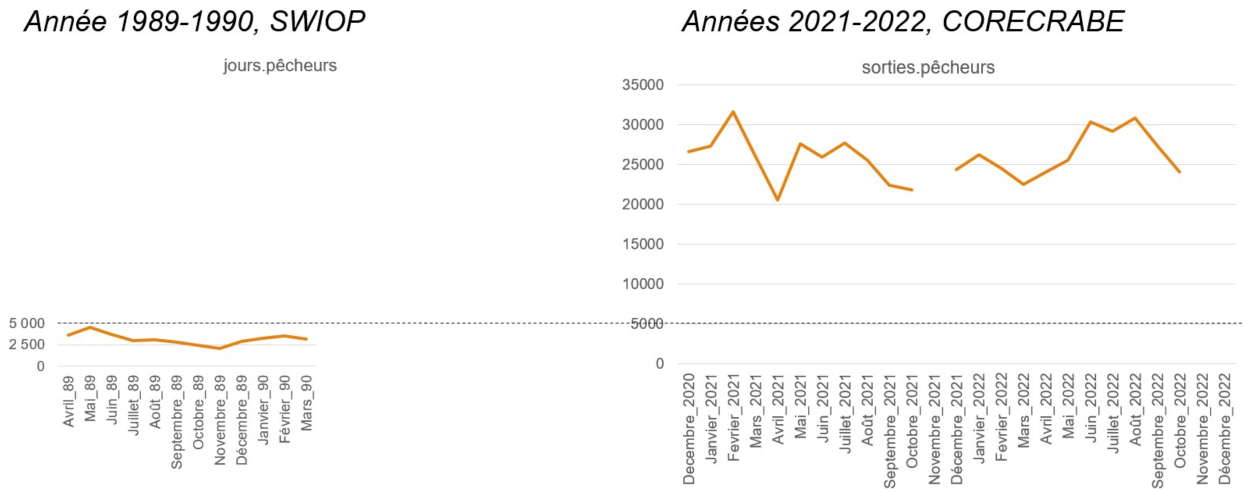


Figure 30: Change in monthly fishing effort between 1989-1990 (hook-equivalent angler-days) and 2021-2022 (trips with all gears). The dotted horizontal line has been added to facilitate visual comparison.

The results converge to indicate that exploitation has increased by a factor of around 7 since 1990. Observations now show that the minimum size for catching and marketing crabs (11 cm) is not being respected, and that the proportion of crabs caught before they reach maturity is a cause for concern for the renewal of resources and weakens the profitability of fisheries. The first-catch size is around 5 cm, which is well below the recommended size. In the Boeny region, the resource is said to be overexploited, with fishing effort 2 times greater than the MSY (Maximum Sustainable Yield). If pressure continues to increase, overexploitation will increase. The current national annual closure must therefore be respected. The 2-month closed season is effective in temporarily increasing stock biomass, but not in preventing overfishing.

4.5.4 Uncertainties

Crab fishing is subject to the following sources of uncertainty:

- The CPUE of crabs <10 cm appears to be higher today than in 1990, which would mean that their abundance has increased if the CPUE is interpreted as an index of abundance. This is contradictory with the other exploitation indicators. A likely hypothesis would be that fishermen did not systematically land catches of these small crabs in 1990, and targeted preferentially the largest individuals sought by companies: the average yield of crabs <10 cm in 1990 would therefore be a biased estimator of the abundance of this size, i.e. it would underestimate the real (unknown) abundance of this fraction of the crab population, due to the discarding of small crabs (in the live state in our case). Discards of crab catches at sea affect the proportionality of CPUE with resource abundance.

- According to this hypothesis, the decline in abundance observed between 1990 and 2021 would in fact be even greater.
- Paradoxically, the fact that fishermen no longer throw back the small crabs they catch today has reduced this source of bias and therefore increased the robustness of this indicator.
- Similarly, the practice of scale fishing has probably changed considerably over this long period (e.g. the number of scales per fisherman), so that the yields of this gear *per fishing trip* are difficult to compare between 1990 and 2021, unlike traditional hook fishing, the efficiency of which has probably changed little over time. This means that the CPUE data for hook fishing is probably little affected by changes in fishing efficiency and can be compared.
- In order to use the structural model based on the VPA, age-structured catch data (converted from the size structure of the total fishery catch estimated by month and the crab growth curve), and the following parameters estimated: fishing mortality from the VPA), natural mortality, length-weight relationship $W = a\ L^b$ and L_∞ of *Scylla serrata*. The uncertainty i) on the biological parameters estimated from the literature and ii) on the fishery data estimated from a sample of fishermen in a small number of villages in the region has not been taken into account in the model. A sensitivity analysis should be carried out to assess the effect of these uncertainties on the diagnosis.
- The catchability estimated for each gear by the VPA was considered to be identical between fishing gears so as to be able to estimate an overall fishing effort multiplier as a first approximation and for the sake of simplification: this leads to an *underestimate* of the fishing effort actually applied in the fishery, because the fishing power (or efficiency) of the scale has become greater than that of the hook, as highlighted. This approximation does not call into question the general trend and the diagnosis of overexploitation, but it does underestimate the current effective effort: the fishery is therefore probably in a state of greater overexploitation than that estimated by the model.
- The diagnosis was established for the Mahajanga region and cannot be generalised to other regions. It is likely that environmental factors (e.g. climate, extent and nature of mangroves) and fishery factors (e.g. history of exploitation) will modify the parameters of the model used.

4.5.5 Dashboard

The stakeholders met during the project's final workshop (12-13 September 2023) to compile a dashboard for the crab with a view to the various analyses carried out. The observations compiled concern only the Boeny region. The indicators point to three main risks for the fishery:

- A high level of over-exploitation (over-exploitation margin of more than 30%)
- Fishing mortality more than twice that corresponding to maximum sustainable yield (MSY)
- A 37% reduction in catch per unit effort (CPUE) between 1989 and 2022

These observations support the conclusion of the main assessment that the crab resource in Boeny is heavily overexploited.

Table 16: Overview of mangrove crab stocks

FEATURE	INDICATOR	VALUE / REF	OBSERVATION		2022	TR
Boeny	Volume marketed	2009:516t (MRHP/DSP/SCE STAT, 2015) 2022 : 2101 t (CORECRABE, 2022)	Increase of 75% of crabs sold	green	yellow	↑
Boeny	Effort of fishing - (number of of anglers)	2015: 4608 fishermen (data from MRHP/DSP/SCE STAT/PACP, 2015) 2022: 3765 fishermen (excluding creel fishermen) (CORECRABE data, 2022)	Trend from numbers of anglers stable	yellow	yellow	↔
Boeny	Effort of fishing - (number of outlets)	2022 :824500 Output (CORECRABE data, 2022)	No comparative historical data		white	
Boeny	Operating rate (F/Z)	2022 : 66 % (CORECRABE, 2022)	No comparative historical data, but trend greater than than 30%, stock not sustainable	white	red	↓
Boeny	CPUE	1989 : 11 kg/output (SWIOP, 1990) 2022: 6.9 kg per output (CORECRABE, 2022)	Decrease in CPUE à height of 37%.	green	yellow	↓
Boeny	F	2022: 0.68 (Data CORECRABE, 2022)	Mortality by fishing greater than à 0,5		white	
Boeny	Situation Yield % RMD	2022: current situation is higher than the MSY value	Fishing mortality twice as high as MSY, so the stock is very low overexploited	white	red	↓

4.5.6 Conclusion

The crab fishery in the Boeny region is in a state of severe overexploitation, with a greatly reduced abundance of crabs. Exploitation has increased by a factor of around 7 since 1990, with fishing effort 2 times greater than the maximum sustainable yield. Fishing is no longer selective for large crabs, and small crabs are also intensively exploited. The fishery is no longer sustainable following the strong development of the industry since 2013.

4.5.7 Recommendations

The following recommendations were made and discussed:

- Proposal for a longer closure period (e.g. 4 months) in regions where biomass has fallen the most, with the creation of IGAs to compensate, as this measure will have a high social cost if economic alternatives are not available;
- Proposal to reduce the catchability of the most effective gear wherever possible (for example, the use of large-mesh scales would reduce the catchability of very small individuals by this gear);
- Biological and socio-economic studies of the sector for the other regions, in order to obtain an overall assessment of the fisheries on the scale of Madagascar. It should be noted that data from the CORECRABE project covers three other regions from 2021 to 2023 and could be used for this purpose. Data from NGOs could also be used;
- Transferring the results of assessments and/or research to stakeholders (particularly local communities) so that they can be taken into account

4.6 POULPES

4.6.1 Summary

The analysis of the octopus stock in south-west Madagascar was carried out using data from the NGO Blue Ventures. Although they have had data since 2015, during this assessment we worked with data from the years 2020, 2021 and 2022 to gain a better understanding of the current situation. For the two models used (the generalised exhaustion model and the sequential model), we worked with the same data in order to be able to compare the results and show the analysis choices to the learners. The models show that octopus exploitation in this region is still sustainable, but that the stock is being fully exploited.

Of the 3 species identified in Madagascar, *Octopus cyanea* is the most widely caught and exportable. The fishing technique is still traditional and fishing is concentrated on the inner coral reef. Several collectors and explorers in Madagascar send their products to Europe and Asia. Production by region shows that the DIANA and Atsimo-Andrefana regions have great potential for octopus. Analyses carried out using data available from the NGO Blue Ventures in south-west Madagascar show that the current state of the octopus stock is being fully exploited. To ensure the sustainability of this resource, the fishing effort needs to be reduced by up to 25%.

4.6.2 Context

4.6.2.1 O. cyanae the only marketable species

The octopus *Octopus cyanea* is the only species that is marketable and exported abroad to date. Most of the fishing takes place in south-west Madagascar and the Diana region. The study on the state of octopus stocks in south-west Madagascar in 2005 showed us that the stock was still being exploited in a sustainable manner (fully exploited and slightly shifted towards under-exploitation).

4.6.2.2 Opportunity presented by Blue Ventures' work in south-western

Madagascar The *Octopus cyanea* octopus exists almost everywhere on Madagascar's coasts, but only Blue Ventures' data collected with communities in south-western Madagascar is currently available and usable for stock assessment. Blue Ventures has worked with 22 of the 176 villages in south-west Madagascar since 2003, but only data from 2015 is available.

correspond well with the criteria of the models used. In addition to the data sampled from fishing villages, we also have total catch data available from the Direction Régionale de la Pêche et de l'Economie Blue (DRPEB) in Toliara. For this assessment, we used the Blue Ventures data with the global model and the analytical model.

To capitalise on the opportunity presented, the project supported the participation of an already experienced learner (Herimamy Razafindrakoto) and an IHSM trainer (Daniel Raberinary) in an octopus stock assessment training seminar held at the IH.SM from 16 to 20 January 2023. After their preliminary training in octopus stock assessment at the IH.SM, Toliara, in partnership with Blue Ventures and the Comité de Gestion des Poulpes (CGP), the learner and the trainer shared their knowledge with the 9 other learners during the training seminar they attended.

4.6.2.3 Analysis of marketing data

Octopus can be found almost all along Madagascar's west coast (Figure 31), with the exception of the following regions
Melaky and Sofia (not shown) where recordings are sporadic and marginal.

For the regions concerned, there was an upward trend in sales over the period under review. The main region is Diana, with an average of 316 tonnes annually, followed by Atsimo-Andrefana, with average registrations of almost 260 tonnes. A remarkable fact is the explosion of registrations in 2022, where records were reached: Atsimo-Andrefana (8747.8 t), Menabe (1097 t), Diana (904 t) and Sava (928 t).

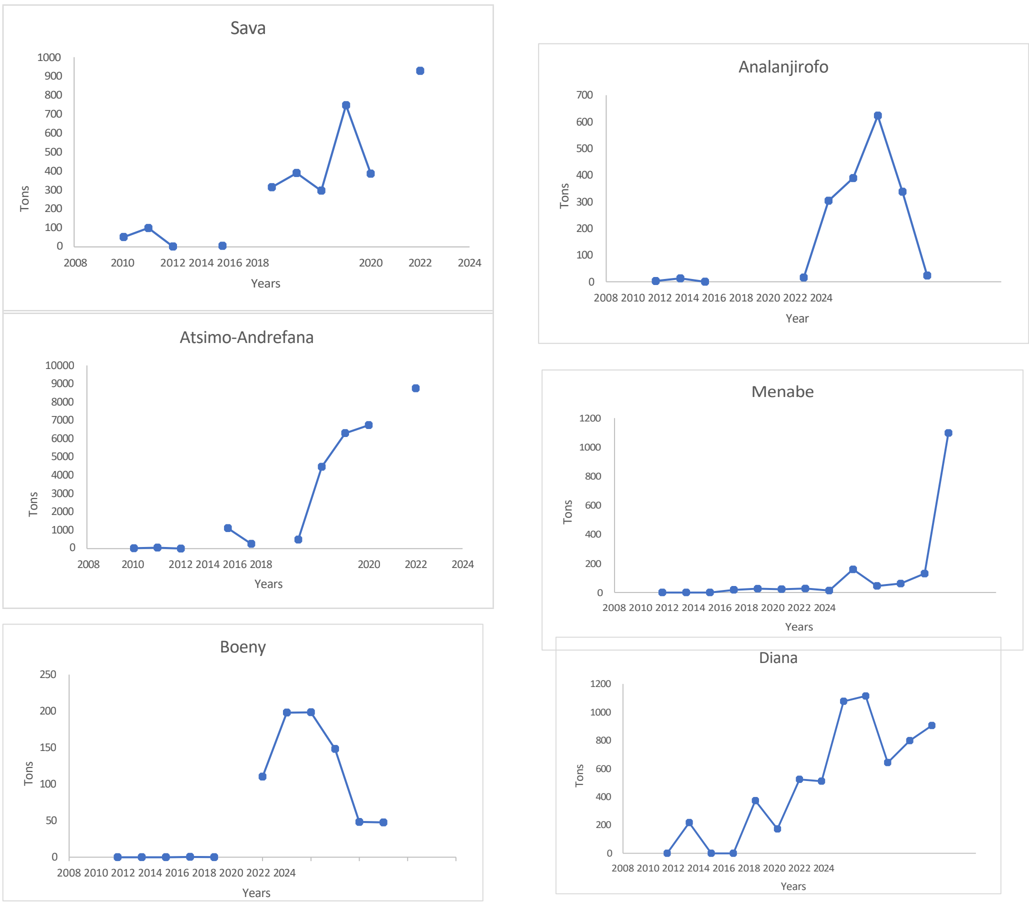


Figure 31: Record sales of octopus in various regions of Madagascar

4.6.3 Evaluation

4.6.3.1 Generalised exhaustion model (GDM)

The main results obtained with the generalised depletion model (GDM) are changes in abundance (population size N and biomass B), natural mortality (M) and fishing mortality (F). These results can also be used to analyse the instantaneous exploitation rate (E), which is one of the main indicators of the state of the resource.

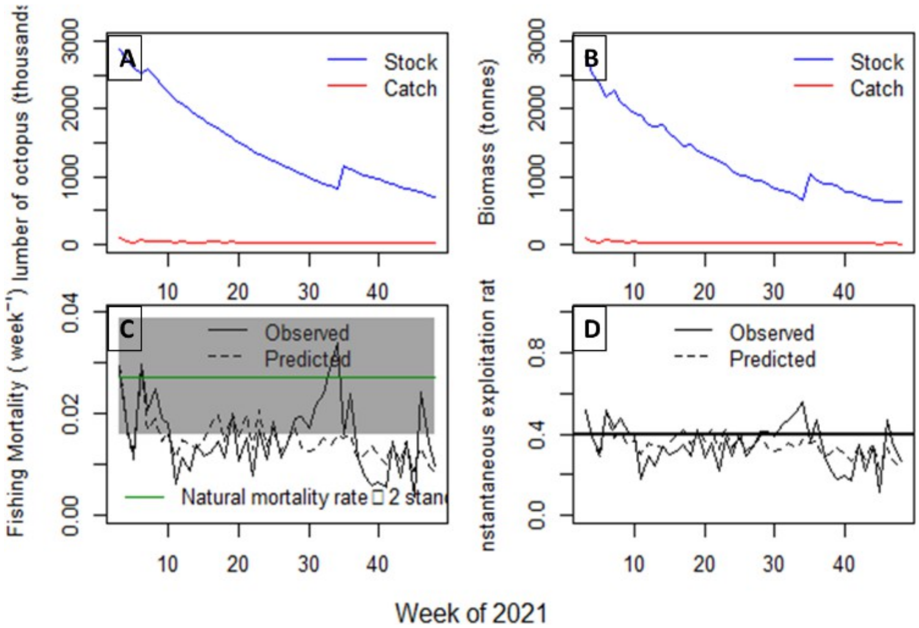


Figure 32: Instantaneous operating rate situation

The analysis showed that the value is equal to 40% and does not yet exceed 30% (the threshold considered for short-lived species such as small pelagics). We can therefore say that exploitation of the octopus stock in south-west Madagascar is still sustainable.

4.6.3.2 Structural models

Sequential analysis is based mainly on individual size data from the sampling years. In our case, the individual size data are available mainly for the last three years and should correspond to the current stock situation. After converting individual lengths into corresponding ages using the growth equation, we obtained 17 age classes from 2 months to 18 months. In addition to the variation in catches at different ages, Pope's VPA also gave us the variation in fishing mortalities, variations in numbers at different ages and the estimated biomass.

From the results of the VPA (Pope cohort analysis), we can deduce the current stock situation using the predictive analysis of yield per recruit. With data for three years (2020, 2021, 2023), the yield-per-recruit diagnosis from these three years of data shows that the current fishing effort still corresponds to F_{RMD} . In other words, the level of catches with the current fishing effort does not yet exceed the critical threshold.

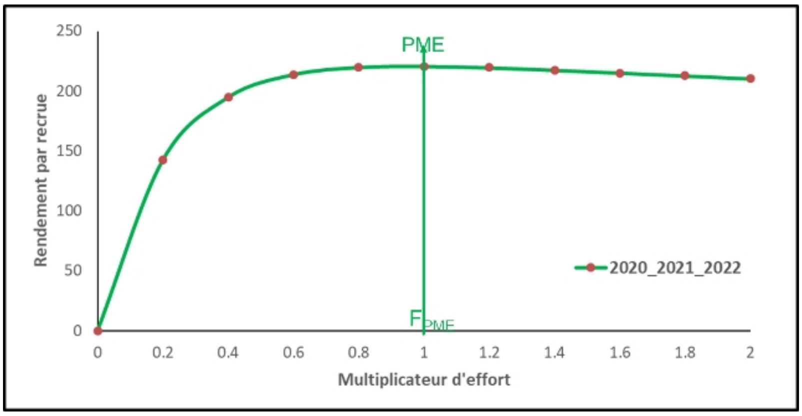


Figure 33: Yield per octopus recruit

4.6.3.3 Analytical models

In addition to the depletion model (GDM), we worked with the same data from the NGO Blue Ventures for the analytical model based on the VPA (Pope Cohort Analysis) and the yield per recruit (YPR) model with monthly time steps. With this structural analysis, the results obtained were to be used to estimate the current status of the stock in relation to maximum sustainable yield (MSY). In order to understand the current state of the octopus stock in south-west Madagascar, data from three years (2020, 2021, 2022) were considered.

In order to use the structural model based on VPA, we need age-structured catch data, natural mortality and terminal fishing mortality.

Since cohort analysis is the method for estimating instantaneous fishing mortality rates and stock numbers, the model estimates these parameters with corresponding age classes. In this analysis, the time step is in months, taking into account the life span of the species (which is very short) and its rapid growth. It is estimated that the stock can be renewed after one month, depending on the biology of the animal.

4.6.3.4 Performance model per recruit

The yield-per-recruit model is used if we have age-structured data, including fishing mortalities in each age class. If the biological parameters of the species are known, the yield per recruit (Y/R) can be calculated for any level of fishing effort and at any exploitation diagram.

Conventionally, reasoning by recruit is carried out for a cohort whose recruitment is equal to 1. The result will therefore be expressed per unit of production per recruit (gram/recruit).

Using this model, we can estimate the status of the stock relative to the MSY position from simulations of fishing effort. By multiplying the fishing mortality values with the effort multiplier, from 0 to 2 in our case, we should obtain the current yield-per-recruit situation relative to the MSY situation.

4.6.4 Uncertainties

There are 2 main sources of uncertainty surrounding stock assessments in the south-western octopus sector:

- Insufficient number of villages sampled in the south-west
- Confusion of the 2 species (*O. cyanea* and *O. aegina*) in the catch

4.6.5 Dashboard

The scoreboard shows that the only positive trend in the fishery is the marketed yield. The major negative trend is maximum sustainable yield, which is reached in 2022. The other trends are balanced.

Table 17: Summary of octopus stocks

FEATURE	INDICATOR	VALUE / REF	OBSERVATION	2014	2022	TR
SW	Volume marketed	2014 = 622,655 t 2022= 989,059 t		●	●	↑
SW (Tul)	Effort of fishing (SIP/ Tul)	2012 : 2022 :				
	Rates operating (F/Z)	2014 : 27% 2022 : 29 %		●	●	↔
SW	CPUE	2014 : 1.8 kg/Fisher 2022 : 1.9 kg/Fisher	Stable situation	●	●	↔
	Accessible biomass	2014 : 2022 :				↔
	F	2014: 0.54/year 2022: 0.59/year		●	●	↔
	Situation Yield % RMD	2014: Yield situation < 26.6 t of RMD 2022: Situation Yield = RMD		●	●	↓

4.6.6 Conclusion

During our present analysis with data from south-west Madagascar, we observed that the current situation of the octopus stock is at MSY level. This indicates that the octopus stock in south-west Madagascar is still being fully exploited but is getting closer and closer to the limit.

On the basis of the results obtained in south-west Madagascar, it is important to also begin studying the state of stocks in other regions, particularly in the Diana region, where octopus exploitation has become significant in recent years.

4.6.7 Recommendations

4.6.7.1 Data collection and sharing by NGOs

NGOs working on octopus in the south-west and in other regions (notably Diana) should increase their collection efforts and should share their data to enable a more accurate assessment of stocks.

4.6.7.2 National closure

As a precautionary approach, the duration of the national fishing closure should be increased instead of reducing the number of fishermen. An increase in the duration of the national closure to 2.5 months instead of 1.5 months is therefore suggested.

4.6.7.3 Conservation measures

In view of the current stock situation, it is necessary to convince fishing communities to introduce conservation measures such as increasing the number of local closures. At present, some villages in the south-west and north have familiarised themselves with this temporary closure (in addition to the national seasonal closure).

4.6.7.4 Octopus research

We should also continue research into the use of octopus pots and artificial reefs, which are still in the experimental phase at the IH.SM.

4.7 HOLOTHURIES

4.7.1 Summary

Sea cucumber fishing has been practised in Madagascar since the 1920s. Initially, 2 species were involved, but since then the number of species exploited has risen steadily and now stands at around fifty. Sea cucumber fisheries are generally found on the west coast of Madagascar. Since the 1980s, there has been chronic over-exploitation of this resource, with a fall in production and product quality, a scarcity of species with a high commercial value and the exploitation of species with a low commercial value. In addition, the weight of evidence points to exploitation to the detriment of populations of 3 of the 4 species listed in appendix 2 of CITES that are present in Madagascar. Several management measures appear to be necessary, including the establishment of monitoring and management zones, the production of a species identification guide, the regulation of catch sizes, fishing closures and the promotion of holothurics.

4.7.2 Context

4.7.2.1 A resource multi-specific highly commercialised for for export

Sea cucumbers are a highly commercialised multi-species resource with a well-defined hierarchy of value. However, species determination appears to be difficult, especially of dried specimens, which complicates monitoring and management at all levels. In addition, species composition and diversity vary between different regions, ecosystems and depths.

At the start of the fishery, fishermen give priority to the most valuable, abundant and accessible species and specimens. Over time, fishing diversifies towards less valuable species, intensifies and extends to greater depths (with illegal diving gear). Exploitation takes on a cascading, area-by-area rhythm, with intensive operations that fish everything up to a bio-economic limit, then move on to another area. Finally, diversity in the fishery decreases as less resilient species are extirpated.

4.7.2.2 Hong Kong imports of holothurians from Madagascar 2013-2019

Internationally, the largest volume of tripangs passes through Hong Kong, whose imports of different categories of holothurians (fresh, dry, smoked, etc.) by country of origin are recorded (Louw and Burgener 2020). The significance for this study is that :

- During the years 2013-2019, Madagascar is the most important country in the African region in terms of trepang imports through Hong Kong.
- However, Hong Kong's imports of Madagascar have been declining rapidly since 2018, suggesting a decline in production and/or the redirection of exports to other importing countries.

Table 18: Hong Kong imports of trephangs 2012-2019 from the top 5 African countries

TABLE 5

A comparison of Hong Kong's total import records for the top African exporting countries between UN Comtrade and Hong Kong Bureau of Statistics, 2012–2019. Source: UN Comtrade and Hong Kong Bureau of Statistics..

HONG KONG TOTAL DRIED IMPORTS FROM TOP AFRICAN COUNTRIES	UN COMTRADE (KG)	HONG KONG BUREAU OF STATISTICS (KG)
Madagascar	1,499,256	1,526,911
Seychelles	474,208	518,534
Tanzania	444,998	472,564
Mozambique	324,960	408,331
Mauritania	312,284	339,646
TOTAL	3,059,593	3,270,318

The trend in exports from Madagascar to Hong Kong has been almost continuous decline since 2012 (Table 19 and Figure 34). The decline in imports of holothurians between 2012 and 2019 is very marked for the last 2 consecutive years (2018 and 2019) of only 47.6 tonnes of imports, suggesting that Hong Kong has become disadvantaged by Madagascar's exporters.

Table 19: Hong Kong imports of sea cucumbers from African countries (Source: Louw&Bergener 2020)

	2012	2013	2014	2015	2016	2017	2018	2019
Madagascar	311,664	293,857	259,616	197,569	216,300	123,710	48,971	47,569
Seychelles	100,671	72,797	66,533	73,357	52,396	51,820	4,665	51,969
Tanzania	74,297	33,605	61,907	108,119	82,444	54,865	2,007	27,754
Mozambique	14,493	12,239	22,693	39,017	54,440	119,675	5,371	57,032
Mauritania	38,451	39,151	35,784	37,757	52,708	31,636	31,076	45,721
TOTAL	539,576	451,649	446,533	455,819	458,288	381,706	92,090	230,045

TABLE 4

The total mass (kg) of dried sea cucumbers reported by Hong Kong as imported from the top five African exporting countries between 2012 and 2019. Source: UN Comtrade.

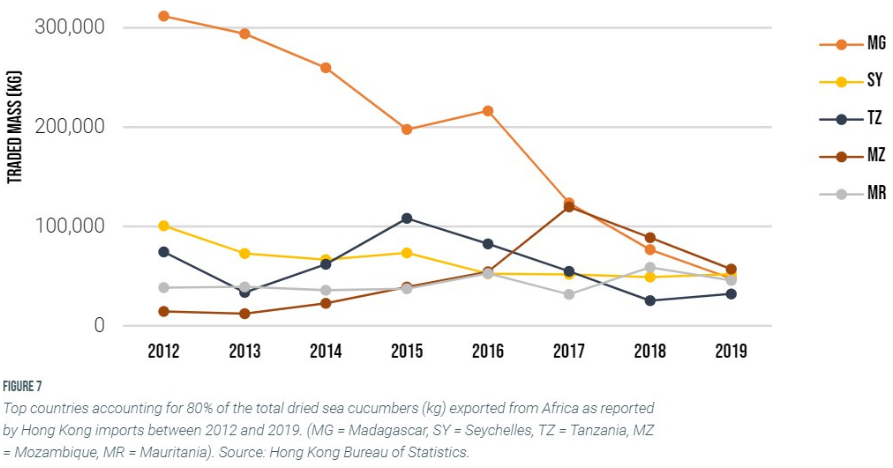


Figure 34: Export trends for the top 5 African countries 2012-2019 (Source: Louw&Bergener 2020)

4.7.2.3 Analysis of MPEB export data from 1987 to 2021

Following the analysis of Hong Kong imports, we have compiled export data from 1987-2021 provided by MPEB for this study (Figure 35). Since 2011, national exports have followed the same trend as the Hong Kong data, with a very marked drop in production since 2011. There have been up-and-down cycles of around 10 years (peaks in 1994, between 2001 and 2005, and in 2011). The temporary drop in 1993 can be explained by the 1993 ban on the use of scuba gear for sea cucumber fishing. It should be noted that data for the years 2001 and 2005 were missing from the data supplied to the project by the MPEB, potentially due to the effects of the political crisis of 2002 and/or the reliability of the data during this period.

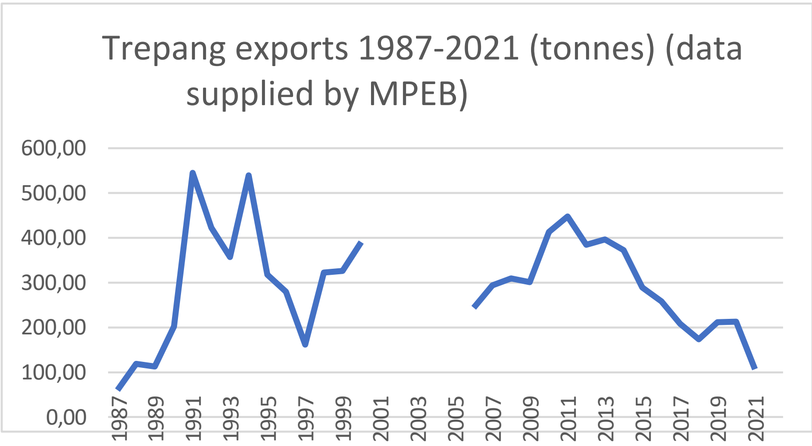


Figure 35: Madagascar trepang exports 1987-2021 (data supplied by MPEB)

On the other hand, it is interesting to compare exports by Madagascar for the same period with Hong Kong's import data (Figure 36). This latter analysis indicates that there has been a change in exporters' strategy in 2018 and 2019, which puts Hong Kong at a disadvantage as an importing country.

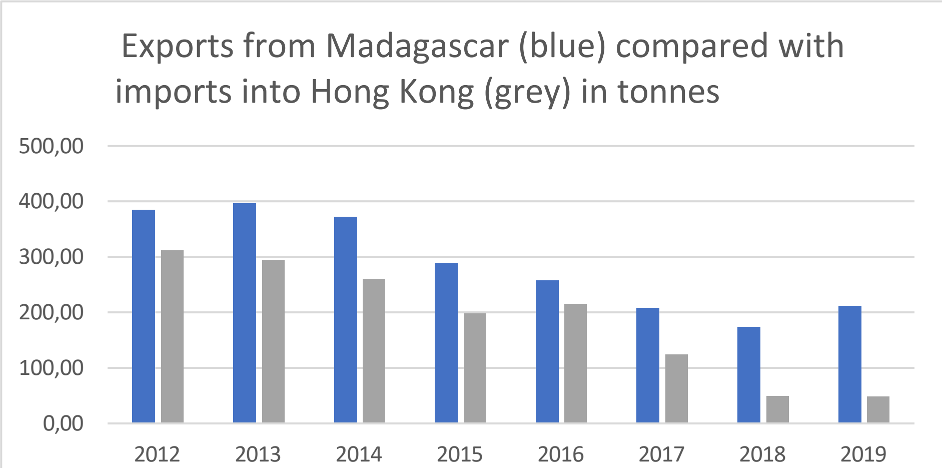


Figure 36: Domestic exports and imports from Hong Kong (MPEB/Traffic)

4.7.2.4 Analysis of regional marketing data at national level

Following the analysis of international marketing data, we turn to the analysis of regional data provided by the MPEB as part of this study. As with several other sectors, sea cucumbers are sold all along Madagascar's west coast, in varying volumes (Figure 37). Production is highly variable, with no notable trend. Records of over 500 tonnes were reached for Boeny in 2020, and for Diana in 2014 and 2022. These oscillations in production may be attributable to the successive exploitation of different species or regions.

Figure 37: Recorded holothurian sales for different regions of Madagascar (Source: MPEB data).

As part of a previous study, the IHSM obtained holothurian production data from the regional directorate of the MPEB for the Atsimo-Andrefana region (south-west). The data are consistent with those obtained at central level, but more complete. These data illustrate the particular situation of this region, with peaks in 2003 and 2011, and a very significant peak in 2014 followed by a decline.

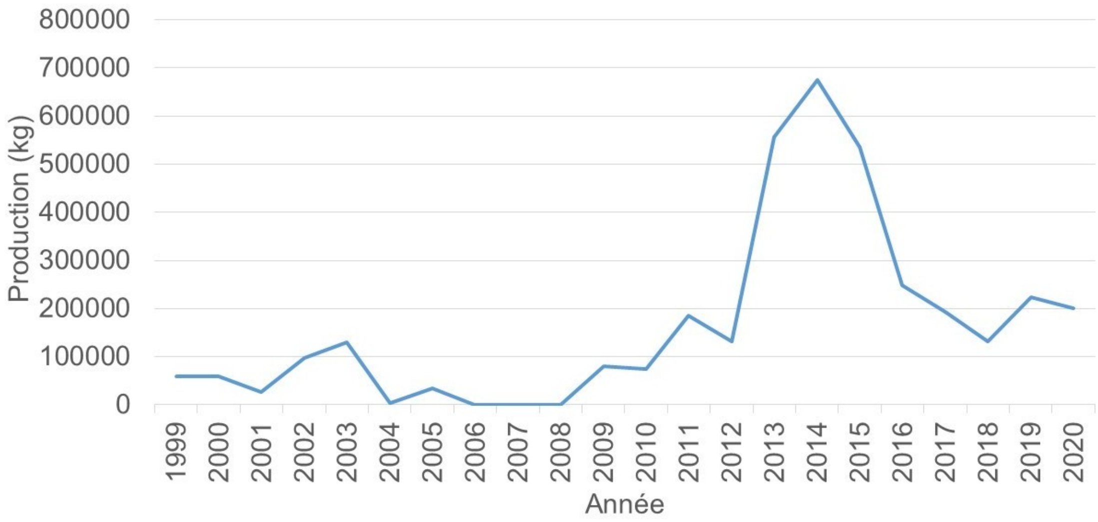


Figure 38: Trends in trepang exploitation in south-west Madagascar (Source: DRPEB, 2021)

4.7.2.5 Analysis of data on species diversity in exports

One source of uncertainty is the frequent use by exporters of '*sp*' in determinations, making them imprecise. This practice is used for the genera *Holothuria* (which includes at least 7 species), *Bohadschia* (which includes at least 3 species) and *Apostichopus* (which may in fact be a single species). There are probably differences in species determination. For example, of the 12 species listed in the south-western fishery by Maka et al (2019), only 5 with the same specific name are recorded by exporters at national level, representing a significant margin of imprecision.

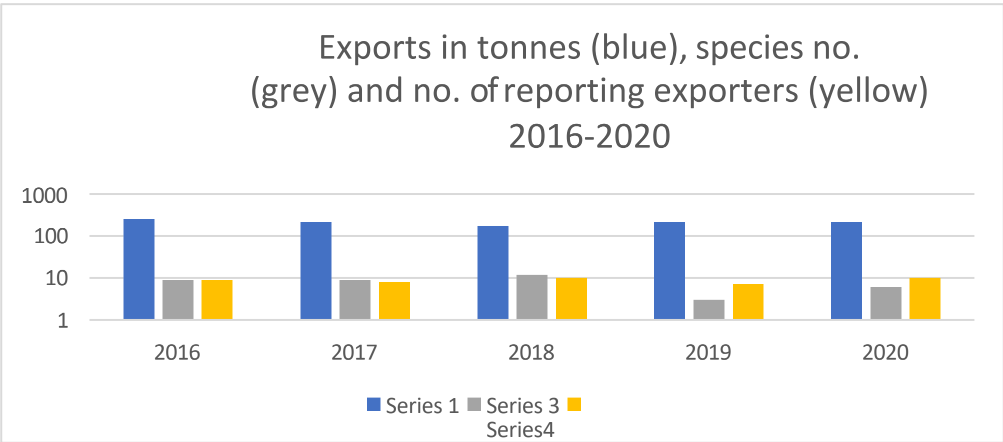


Figure 39: Exports in tonnes, # of species reported and # of exporters reporting 2016-2020 (logarithmic scale) (Source: ASH)

4.7.3 Evaluation

4.7.3.1 Valuation approaches considered

The general aim of the study is to assess stocks (or determine indicators of the state of health) of fishery resources in the five priority sectors, based on available data and scientific advice. In addition, the technical staff of the MPEB who will benefit from the training must be trained in stock assessment methods (or in the determination of indicators of the state of health of stocks), in particular those in data-deficient situations.

The case of sea cucumbers is special in that it lacks the temporal or spatial catch and effort data needed for a conventional stock assessment: in this sense, sea cucumbers are data deficient. However, there are considerable marketing data over several decades and a large number of one-off studies that could provide a qualitative or semi-quantitative assessment of the state of the resource.

Madagascar is also a signatory to the CITES convention. Following the 2022 Panama CoP, six species of sea cucumbers are listed in Appendix 2 of the Convention, 4 of which are species exploited in Madagascar. For species in Appendix 2 that are exploited, the convention requires a "non-detriment finding" as a precondition for export.

The FAO recognises three hierarchical levels of stock assessment:

- **Level 1 traditional approach -** Stocks for which traditional stock assessments are available and considered reliable. Official results are used as reported by management agencies.
- **Level 2 - alternative approaches** - Stocks for which no formal assessment is available, **but for which alternative approaches (such as Sraplus) are viable** because information, such as external landings data with indices of abundance or expert depletion preliminaries, is available to calculate the status of the particular stock.
- **Level 3 weight-of-evidence approach** - If data are insufficient for either the Level 1 or Level 2 approaches, a weight-of-evidence approach to categorising stock status based on qualitative/semi-quantitative information will be used. A working group has been established at FAO Area 51 level to develop protocols, which will meet in May 2023.

For holothurians, it would seem appropriate to adhere to **level 2** (given the availability of marketing data and the fact that the protocols for level 3 have yet to be defined).

4.7.4 Dashboard

4.7.4.1 Overall assessment by scorecard

In the absence of catch and effort data series that could be used in a global or analytical model, sea cucumber resources were assessed by compiling data in a dashboard. The results are presented in the table below.

The data gathered show that the state of the indicators and the trends are negative for all the parameters considered, with the exception of some marketing data, which leads us to the conclusion, on the weight of evidence, that the resource is systematically overexploited.

The following indicators are particularly noteworthy:

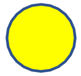
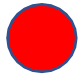
- Madagascar's exports to Hong Kong to fall by 85% between 2012 and 2019
- National production down by more than 75% since 2011
- A ban on diving suits in 1993 was followed by a significant temporary drop in production.

- Gradual reduction in catches, CPUE and effort observed in fisheries at several locations
- Trend of peak and fall in one region, followed by movement to neighbouring regions
- Gradual decline in the diversity of species exploited in fisheries
- Reduction in quality (size and calibre; replacement of high-value species by low-value species)
- Decline in biomass per hectare for most target species
- Increasing scarcity of species of high commercial value
- Decline in the health of coral reefs in all coastal regions

.

Table 20: Dashboard summarising the state of sea cucumber stocks

FEATURE	INDICATOR	VALUE / REF (source)	OBSERVATION	COTE 2010	COTE 2020	TREND
PERFORMANCE						
Performance of fishery of à **International**	Imports from trepang (Hong Kong) 2012-2019	Louw & Burgener 2020	Decline from 311 to 48 tonnes (85%) in 7 years	🟡	🔴	↓
Performance of **national** fisheries	Exports of trepang 2012-2019	MPEB data 1990-2019	Decline from 384 to 212 tonnes in 7 years Boom-and-bust trend Significant but temporary decline following the ban on diving suits in 1993	🟡	🔴	↓
Marketing **regional**	Weight of trepang by region	MPEB data 2010-2022 (JCB analysis)	High variability with a slight upward trend (from 575 to 983 t) Contradiction between international/national and regional data	🟡	🟡	↑
Marketing **regional** (5 regions west)	Weight of trepang marketed	MPEB data 2010-2022 (JCB analysis)	Wide fluctuations but a slight upward trend	🟡	🟡	↑
Performance fisheries **local** (Atsimo Andrefana)	Catch per unit effort	Data IHSM 1996-2021.	A remarkable decrease to 1/5 of catches between 1996 and 2021	🔴	🔴	↓
EFFORT						
National fishing effort	Total fishing effort (no. of pirogues)	FAO 1980 ICRI 1996 ECN 2013	1980 : 5000; 1996 : 25000; 2012 : 48000 No data available since 2012 Extrapolation of the slope gives >60000 pirogues in 2023	🔴	🔴	↑
Regional fishing effort	Effort 5 regions main sea cucumbers	IHSM 2022	A remarkable decline between 1996 and 2021 in Atsimo Andrefana	🟡	🔴	↓
Local fishing effort	CPUE at fishing sites	IHSM data	Decline in CPUE for villages Ankiembe and Ankilibe 1996-2021	🟡	🔴	↓

Distribution of effort **national**	Capture relationship reef area and other ecosystems (muddy bottoms)	UNEP data MPEB data 2013-2022	The Diana and Atsimo Andrefana regions (reef) and Boeny (muddy) dominate holothurian production - downward trend Boeny dominates exports (port of exports to China)			

INDICES OF ABUNDANCE (all species)	Abundance studies	Studies Local ad hoc studies (IHSM data)	Average biomass around 1kg per ha in 1995, except for two very abundant species			↓
	Captures per day (empirical)	Scarffe 2019 (Nosy Be)	Reduction in catches per day between 2000 (300/d) and 2019 (10-20/d)			↓
	Depth de pth	Scarffe 2019 (Nosy Be)	Initially without diving suit, depth progression up to 60 m			↓
INDICES OF ABUNDANCE (CITES species)	No. of species in fisheries	Local studies (Atsimo Andrefana)	28 species in 1997; 14 in 2007; 10 in 2006 2019; 8 in 2021			↓
INDICES FRO M BIODIVERSITY	Diversity of species exported at national	ASH data for 2016-2020	Minimum of 13-19 species in 7 genera No clear trend of decline in the number of species between 2016-2020			↔
CANCELLATION						
Ecosystem health at **national** level	The state of health of coral reefs	CORDIO data (Obura et al 2017)	Between 1998 and 2016: Live coral reduced from 50% to 30% Macro-algae increased from 15% to 35%. % of herbivorous fish rises to 80%.			↓
Ecosystem health by **region**	The state of health of coral reefs	IUCN Evaluation 2019	Average condition except in Atsimo-Andrefana (which is an endangered ecosystem)			↓
Ecosystem health at local level	The state of health of coral reefs	Studies local on Atsimo-Andrefana	Vasseur et al 1988 Harris et al 2010			↓

4.7.4.2 Evaluation under CITES

Following CITES CoP19 in Panama in November 2022, six species of sea cucumbers have been placed on Appendix 2
of CITES (and one on Appendix 3). These are :

- **All 3 species of the genus *Thelenota*** in the family Stichopodidae (including 3 recognised species), namely : *T. ananas*, *T. anax* and *T. rubralineata* (which is restricted to the eastern Pacific)
- **3 species of** teatfish (*Holothuria fuscogilva, H. nobilis and H. whitmaei*)

Data provided to ASH by Madagascar exporters show that 4 of the species listed in the
CITES are exported from Madagascar (Figure 40).

Of these 6 species, 4 (four) exist in Madagascar, all of which are listed by the IUCN:

- ***Thelenota ananas* (EN)**
- *Thelenota anax* (DD)
- ***Holothuria nobilis* (EN)**
- *Holothuria fuscogilva* (VU)

T. ananas, H. fuscogilva and H. nobilis are of high value (and are intensively exploited in Madagascar),
T. anax is of medium value (Conand & Muthiga 2007). These species, with the exception of *T. anax*, appear in the available data on exports of holothurians from Madagascar (Figure 40).

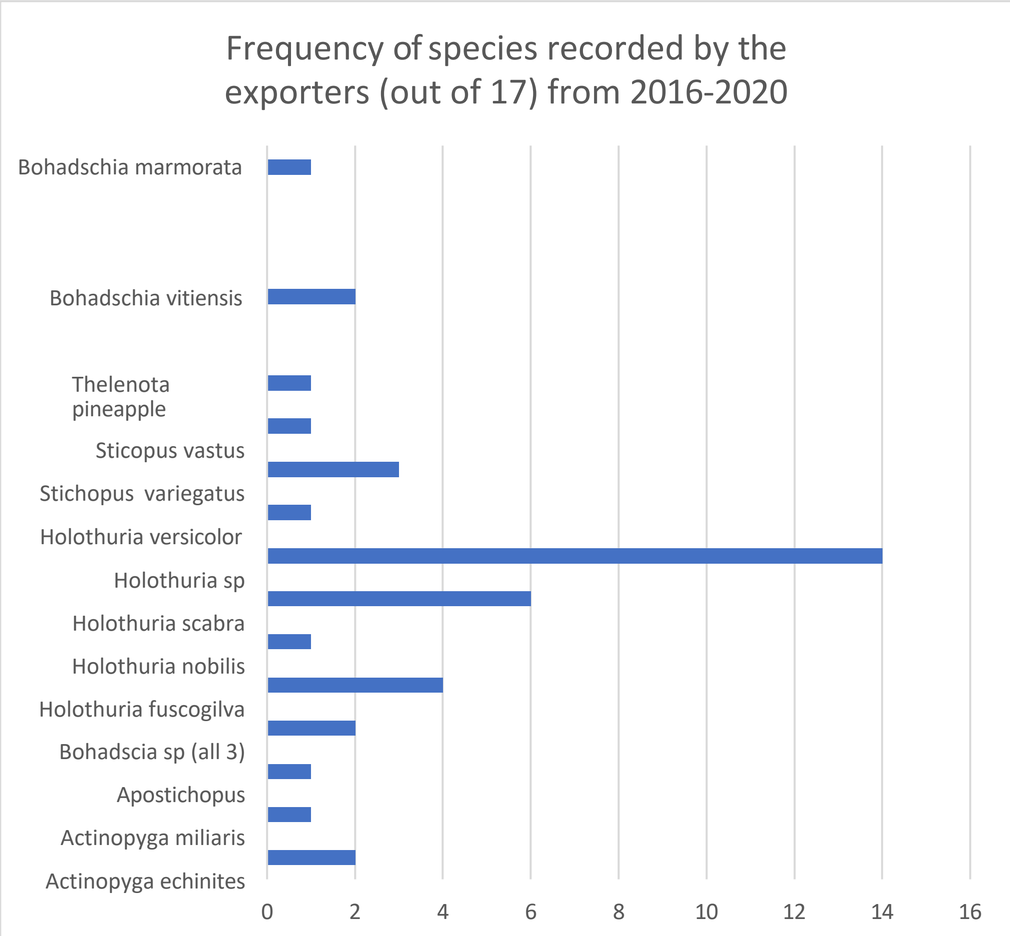


Figure 40: Species reported by the 17 exporters reporting to ASH (2016-2020)

For listed species, a "non-detriment finding" (NDF) is required, allowing the species to persist and continue to play their role in the ecosystems in which they live (Rosser and Heywood, 2002).

In view of the information gathered, the weight of evidence affirms that the sea cucumber trade is detrimental to the populations of at least 3 of the 4 species listed in Appendix II of CITES. This means that Madagascar must put in place monitoring and management systems for the species listed in order to reverse overexploitation and demonstrate sustainable exploitation.

4.7.5 Uncertainties

The major sources of uncertainty in the case of sea cucumbers concern :

- Error linked to the alternation of dry and fresh product weights (conversion coefficient)
- Species identification (often using the abbreviation '*sp.*' in export data)
- Diversification of product presentation. The products are generally presented in dried form (trepang), but can sometimes be found in other forms: salted or boiled.

4.7.6 Conclusion

Madagascar's sea cucumber resources are in decline due to chronic over-exploitation.

4.7.7 Recommendations

Discussion of options

In the case of sea cucumbers, scientific knowledge tends to confirm that sea cucumbers have no specific life cycle and that age/size favours reproduction. Setting a minimum size is therefore a management measure that is often proposed.

One option would therefore be to set and enforce a minimum live size for each species.
greater than the existing one (11 cm) for this resource, which would help to restore the stock.

Another management option is a spatial approach (e.g. protected areas, rotational closures) that allows stocks to recover in a given space and to bring greater resilience to the population of the area. This approach has been used in New Caledonia.

Finally, the strict ban on bottle fishing serves to protect animals and species living at greater depths, which could serve as a source of larvae for the repopulation of shallower biotopes.

With the listing of sea cucumber species in Appendix II of CITES, Party countries are now obliged within 18 months (before 25 May 2024) to build on their existing fisheries management strategies in order to be compatible with the provisions of Articles IV and X of CITES for a species listed in Appendix II. These strategies include:

- Determining population status by assessing stocks
- Setting and monitoring catch quotas, and
- The use of spatial and temporal closures.

In view of the above, we recommend :

Setting up data collection for stock assessment at pilot sites

It is recommended that stock assessments be carried out using the modified or improved VPA model in pilot study areas and sub-areas, with permanent data collection.

Produce an identification guide for sea cucumbers
Given that holothurians are a multi-species resource (more than fifty species are exploited) and in view of the requirements of CITES, the creation of an identification guide for Malagasy species is necessary. This guide should cover the identification of fresh holothurians and sea cucumbers.

Review legislation on sea cucumbers (minimum catch size)
Madagascar's legislation on sea cucumber harvesting needs to be revised, in particular to limit the minimum authorised catch sizes and restrict exports. This concerns all species taken together, but the different species exploited are not of the same size at maturity. Ideally, a minimum catch size should be set for each identifiable species or group of species.

Implement a spatial approach with fishing closures
Several countries practice temporal or spatial closures on sea cucumber fishing. In the case of temporal closures, the results of scientific studies carried out in several regions of Madagascar show a summer reproduction period. An annual closure period of two months in January and February is therefore suggested for the management of this resource. For spatial closures, appropriate schemes could be put in place for managed areas (protected area, LMMA, PAP or other).

Developing holothuriculture
Holothuric farming in Madagascar concerns the species *Holothuria scabra* by the company IOT, whose exports already reach 6 to 8 tonnes per year or around 3-4% of total holothurian exports (Source: ASH data). The expansion of sea cucumber farming could become a substitute industry to reduce the pressure on wild stocks.

5 CAPACITY ANALYSIS

5.1 INTRODUCTION

The Terms of Reference call for an analysis of the capacity of the CEDP and the URL (in effect the MPEB) to evaluate stocks after training.

In this analysis, we distinguish between three levels of capacity:

- Individual capabilities
- Collective (team) skills
- Institutional capacity

5.2 INDIVIDUAL CAPABILITIES

As far as individual skills are concerned, there are three stages in any training process: knowledge acquisition, knowledge transfer and knowledge application.

Learners were assessed at three stages in the process:

- Initial assessment of candidates based on their CVs, qualifications and professional experience

- Assessment after theoretical and introductory stock valuation training courses
- Evaluation after application training and guided sessions in stock valuation and scientific advice

The results of our initial assessment are shown in the table below. In conclusion, all candidates were considered at least suitable for training, with no 'unsuitable' candidates.

Table 21: Results of initial assessments of candidates

Learner status	Number
Expert	2
Suitable for training	8
Less suitable for training	2
Unsuitable for training	0
Total	**14**

After the start-up, four candidates had to withdraw from the course for reasons of obligation professional reasons preventing them from continuing their training.

The second assessment was carried out at the start of the practical stock assessment sessions and applied training (fisheries management, ecosystem approach to fisheries). At this stage, it was found that five candidates could be considered to have acquired knowledge of the issue of resource assessment and the tools to be used, three candidates had acquired knowledge that they were able to pass on, but only one was able to apply the methods.

By the end of the stock assessments, which the learners considered to have been completed because they were based more on practical teaching methods, almost all of them had acquired knowledge of resource assessment and the tools to be used (even if it was still difficult for some of them to explain what they had learnt), and half of them were able to pass it on.

Table 22: Table showing changes in learners' abilities following training

Learner status	No. at start of stock assessments	No. after assessment stocks and scientific advice	Estimated no. at end of course
Fully capable of implementing implementing methods	1	1	**3**
Having acquired the knowledge they were able to return	3	4	**4**
Having acquired knowledge on the issue of resource evaluation and the tools to be used (but not yet able to return them)	5	5	**3**
No knowledge yet of how to evaluate resources and tools	1	0	**0**
	10	**10**	**10**

At the end of the guided stock assessment sessions, the learners all contributed to the preparation and presentation of stock assessments and scientific opinions for the five sectors, further reinforcing their technical mastery of the subject.

Following the guided stock assessment and scientific advice sessions, additional stock assessment sessions were scheduled on crabs and sea cucumbers, held in Mahajanga in March 2023. During these sessions, learners were interviewed to determine their remaining training needs. This guided a final training session held in Mahajanga in July 2023 at the same time as the data acquisition training (in cooperation with the fisheries statistics service). Additional practical sessions, known as 'clinics', further strengthened their ability to implement stock assessment tools.

Finally, for the project's closing workshop in September 2023, the learners were asked to present the stock assessments and scientific opinions in pairs at a plenary session, further reinforcing their mastery of the subject. Following these final presentations, training certificates were distributed to all learners.

While the final stage was not systematically evaluated, it can be said that their capacities have been individually strengthened since the evaluation carried out at the end of the stock assessments, which we have estimated in the last column of the table above. As a final result, we estimate that three learners are fully able to implement the methods, four are able to restitute the methods and three have fully acquired the knowledge of stock assessment and scientific advice and application tools.

5.3 COLLECTIVE CAPACITIES

In accordance with the approach adopted, stock valuation requires the following elements:

- Knowledge of target sectors
- Ability to sort and check data quality
- Formulation of an appropriate stock valuation strategy
- Knowledge of valuation principles and the models to be used (global, analytical, etc.)
- Knowledge and possession of supporting IT tools (such as 'R')
- Assessment of fisheries management (including traditional and ecosystem approaches, SWOT, etc.)
- Knowledge of data collection, acquisition and standardisation
- Competence in formulating and presenting scientific advice

These skills are certainly possessed collectively by the group of ten technicians trained following the training given and the practical work carried out (stock assessment, scientific advice and data collection plan for the five commodities).

The work carried out as part of this project has shown that stock assessment, the formulation of scientific advice and the planning of data collection are first and foremost **the work of a team with proven experience**.

In this respect, it is important to stress that at no time did the trainees work without the on-site support of at least one of the trainers or researchers from one of the institutes. For this reason, even if the team possessed all the necessary skills, it cannot be said that the team could carry out the stock evaluations in the complete absence of external scientific expertise.

It was with this in mind that, at the last training session on planning and data collection, the learners, aware of the importance of their role in the Ministry, agreed and declared their intention to organise themselves into a stock assessment working group for the MPEB, and that this group of

The work could be supported, as required, by external experts, such as stakeholders and scientific experts from research institutions.

5.4 INSTITUTIONAL CAPACITIES

As they are all permanent staff of the Ministry of Fisheries and the Blue Economy, it can be said that the collective capacities of the working group are owned by the Ministry.

To this we could add a certain reinforcement, following the involvement of the head of the fisheries statistics unit in the last phase of the project. Together with this specialist, the team developed a data collection manual adapted to the five sectors.

However, we must be realistic and recognise that at the end of this training course, the Ministry of Fisheries would still not have a team of experts fully capable of evaluating the resources exploited without some external support, for example from national research institutes. Learning these methods requires several months of practice, and applying them and interpreting the results can take 1 to 3 years to master satisfactorily, which was beyond the scope of this training course.

Furthermore, the involvement of scientists in stock assessment is common practice in most countries. In Europe, for example, fisheries administrations play little or no part in the resource assessment process itself. Their skills are often based on average to solid knowledge of fisheries, but they are not involved in implementing the mathematical and statistical assessment methods themselves. Experts from various specialist institutes are called upon to carry out this task. In Canada, on the other hand, stock assessment (and other) research is an integral part of the mandate of the Department of Fisheries and Oceans, but assessment reports, and possibly ad hoc workshops, include external researchers and experts. This also increases the independence of the assessment process from potential conflicts of interest.

In the case of Madagascar, it should be noted that the research institutes (CNRO, IHSM) have their own research interests, have no explicit stock assessment mandate and are not accountable to the ministry responsible for fisheries for their activities. It is for this reason that the group believes that the MPEB should create a department dedicated to assessment (to avoid dispersion), which would work in partnership with the relevant Malagasy research institutions, as previously existed with the CEDP and the URL. This department could be based within the DESP, building on the newly-formed Stock Assessment Working Group.

At the same time, it would be interesting to set up a mixed group of experts from Madagascar, the MPEB and research institutes, to draw up an age pyramid for this pool so as to be able to project human resource requirements for the coming years, and to complement the teaching given on these fisheries aspects (at the IH-SM, for example), to set up specific training courses run by Madagascan and external experts, using dedicated funding if necessary.

On the other hand, subject to the support of the Ministry, the availability of data (see recommendations below), the possession of IT tools, the necessary external support and above all the will and determination of the managers concerned, the MPEB will have the necessary capacity to evaluate stocks and scientific advice.

6 CONCLUSION, MAIN ACHIEVEMENTS, RECOMMENDATIONS AND MAJOR RESULTS (LEGACY)

6.1 CONCLUSION

The main aim of this mission was to support and train the MPEB's scientific team (including the DESP and its regional structures) in determining the state of stocks of fishery resources in the five priority sectors and in preparing and providing scientific management advice on the same resources. The specific objectives were to

- Supporting the MPEB's scientific staff in carrying out stock assessments or determining indicators of the state of health of fisheries resources, depending on the data available;
- Training MPEB scientific staff in the concepts and methods of stock assessment and determining indicators of the state of health of fishery resources;
- Support for the MPEB in drawing up scientific management advice for priority stocks;
- Training MPEB scientific staff in the provision of scientific management advice.

The project focused on small-scale fishery resources of economic importance to Madagascar. These fast-growing species each have a relatively short life cycle, facilitating the implementation of relatively short management cycles (including stock assessment and the formulation of scientific advice) and offering good opportunities for research, training and capacity building.

However, the biological, ecological, geographical, technical and socio-economic aspects of these species, their fisheries and their industries are all very different, requiring different and adapted management systems.

Overall, the fisheries data available for sectors other than inshore prawns is limited to the quantities exported, regional production figures, indirect data on the level of effort (national and local censuses), some spatially limited biometric data on crabs, octopus and lobsters, and some data collected in certain areas by non-governmental organisations (NGOs) and seafood collection companies. These gaps pose constraints at several stages in the cycle of sustainable management of these specific fisheries and their development.

The SWOT analysis identified as strengths the implementation of exploitation regulations based on the FAO Code of Conduct for Responsible Fisheries, the existence of community *dinas* for local fisheries governance and the practice of mangrove conservation. However, the lack of compliance with regulations and the lack of up-to-date fishing data are major weaknesses. The lack of control would probably become even more serious if fishing licences for certain resources were granted to foreign operators. In addition to catch data, it would be advisable to further promote the application of dina and the collection of ecological data on the ecosystems that support the target species.

Overall, the project's objectives have been achieved, and a capacity for stock assessment, scientific advice and data collection planning has been put in place. The results of the assessments show that the 5 sectors are all close to their sustainable exploitation limits or are overexploited. Crab and sea cucumber resources, in particular, appear to be in need of significant effort reduction, while the fishing effort for shrimp, lobster and octopus needs to be brought under control.

6.2 MAIN ACHIEVEMENTS

6.2.1 Learning several stock valuation models

The main objective of stock assessment is to determine the stock's status in relation to MSY (Maximum Sustainable Yield), which can be obtained from the various models. Generally speaking, the choice of models used depends above all on the biology of the animal (longevity and growth) and the fishery data available.

Basically, stock assessment models can be grouped into two main groups, such as analytical models and holistic models (global models). In parallel with these two groups of models, we can also check stock status using statistical models (based on the index of abundance and traffic lights).

For the global models (global approach), we were able to work with the learners on the Schaefer logistic model and the generalised depletion model (GDM). The data required for Schaefer's global model are CPUE/fishing effort and catches over at least 10 years of monitoring, while the GDM works with averages of individual weights, CPUE, fishing effort and total catch. The GDM model is able to estimate annual biomass and natural mortality even with one year's worth of data.

Unlike global models, analytical models (structural approach) depend on the availability of size-structured data. During the course, we were able to work with Pope's VPA (Pope cohort analysis), the rectified VPA (pseudo cohort analysis) and Thompson and Bell's predictive model (YPR).

During the last training session, we took the opportunity to point out the major differences between Pope's VPA and the classic VPA. Pope's VPA still requires long series of data proportional to the animal's lifespan, whereas the rectified VPA can be used even with a year's worth of data. We have also worked hard on the choice of terminal fishing mortality (Ft) for these two models (calibration procedure). In addition to these two models, the predictive model is very important for estimating the status of the stock in relation to MSY.

At present, most stock valuation models work with R software, which is why we have reinforced the explanation of R software and the necessary packages. Before using the valuation models with R (rectified VPA and GDM), it is important to start with an explanation of the formulas involved and the statistical bases. In addition to the mathematical formulas, we were able to reinforce the explanations of how the R scripts work.

Analysis of the results of the various parameters studied will enable advice to be given for the proper management of this multi-specific resource. For the current situation of the holothurian resource, the available data (production) have only made it possible to determine trends in a few parameters such as production, export, diversity of holothurians exploited, ... This has enabled an initial assessment to be made of the state of the resource.

6.2.2 The relationship between industrial fishing and small-scale fishing in coastal shrimp

The situation of shrimp fisheries, and in particular the state of small-scale fishing and the interactions between
industrial and small-scale fishing are finally in the spotlight.

As one of Madagascar's most important fisheries, and the subject of numerous management and improvement initiatives, the case of shrimp and its two segments (industrial and small-scale) deserves particular consideration.

According to industrial fishing data, there has been no significant change in the state of the resource since the 2019 assessment :

- ✓ The relative stability of the biomass accessible to trawlers in zone C is a positive sign;
- ✓ The very significant reduction in fishing effort in all areas is also a very positive sign;
- ✓ The fall in biomass in zones A and B is a cause for concern;
- ✓ The situation in zones A and B remains very critical, but has not deteriorated significantly. It needs to be monitored.
- ✓ The overall situation is not deteriorating but remains, at best, in the cautious zone.
- ✓ The lack of biological data on shrimp (species, size frequencies, sex ratios, etc.) remains a major problem.
  a problem that precludes any comprehensive assessment of the shrimp population.

The role of small-scale fishing in shrimp farming is growing and currently represents
(at least) half of national fishery landings.

But CP data is uncertain. Only records of trade flows are available and not everything is necessarily recorded, and transfers from one region to another for commercial reasons are likely.

The significant increase in PP's contribution to shrimp intake can be seen as a positive sign.

However, the signals given by the IP, which show no improvement in the overall situation, are prompting caution.

Serious monitoring of PF activities (gear, effort, catches) seems more necessary than ever. If we are to have a real, global view of the state of the resource, we need to set up a programme to monitor small-scale fishing activities.

As an indirect measure of activity control, a minimum size should be introduced.

The lack of biological data must be compensated for by the involvement of scientific observers (on land and at sea).
on board the boats).

6.2.3 The need to extend the closure on crab fishing

The state of mangrove crab stocks has been a major concern at national level for almost 10 years. Building on the data collected as part of the CORECRABE project (2020-2023), this project finally identifies the measures needed to ensure the sustainability of this exploitation.

6.2.4 The state of lobster stocks in the SE is back in the spotlight

There has been no assessment of lobster stocks in the south-east for 10 years. This study has finally made it possible to recover the monitoring of spiny lobsters from obscurity and to lay the foundations for ongoing monitoring and assessment at national level.

6.2.5 The condition of south-western octopus is accurately determined

The octopus fishery in the south-west has been the focus of management efforts for over 15 years, and new fisheries have been established around the country, while the state of stocks was still unknown. The fact that similar conclusions were reached with different models means that the results are robust.

6.2.6 Sea cucumbers - assessment of a data-deficient fishery

Sea cucumbers have never been the subject of a proper stock assessment, due to a lack of data, whereas Madagascar will soon be obliged to justify the maintenance of the fishery under the CITES convention.

6.3 RECOMMENDATIONS

6.3.1 Recommendation fields

The overall recommendations arising from the project are grouped around the following themes:

- Training / capacity building / additional human resources required
- Institutional arrangements for better resource management
- Regulatory measures and governance of small-scale fishing
- Interaction with PAPs, LMMAs and AMPs
- Improving stock valuations
- Data collection (Recommendations for fisheries statistics)
- Recommendations for data deficient resources / weight of evidence approach
- Specific recommendations for shrimp fishing (industrial and small-scale)
- CITES compliance for fish products
- Conservation and restoration of ecosystems to support fisheries resources
- Ecological monitoring of ecosystems hosting fish stocks

The recommendations specific to each sector are grouped together at the end of the corresponding scientific opinions in this report.

6.3.2 Training / capacity building / additional human resources required

Assessments of the trainees found that most lacked the sense of self-confidence needed to carry out their duties without hesitation and to insist on their scientific opinions. In addition to technical training, advocacy training is also very necessary.

6.3.3 Institutional arrangements for better resource management

The project demonstrated the effectiveness of collaboration between academic scientists and Ministry technicians, underlining the importance of an institutional arrangement linking the Ministry with research institutions. Indeed, it would be a mistake to assume that DESP or its equivalent could carry out stock assessments on its own. Furthermore, to internalise stock assessment within the Ministry would lack the transparency desired for good fisheries management. It is recommended that collaboration with research institutions be maintained.

The aim of this study is also to re-establish as far as possible the skills and activities of former specialist institutions such as the URL and the CEDP, which already have the necessary equipment and facilities, if only to house ongoing research.

6.3.4 Regulatory measures and governance of small-scale fishing

The SWOT analysis highlighted the major weakness of the lack of enforcement of existing regulations, as well as the great opportunity to develop *dina* for the management of small-scale fisheries. It is recommended that the stock assessment process and scientific advice be used to develop appropriate regulations, supported by the *dina* for implementing the regulations on the ground.

6.3.5 Interaction with PAPs, LMMAs (including management transfers) and MPAs

None of the assessments took account of the regulations applicable in the context of FMPs, LMMAs and MPAs, even though these spatial management mechanisms are expected to become increasingly important in the context of an EAF. However, most sectors are subject to spatial management in one way or another (industrial fishing zones for prawns, LMMAs for crabs, lobsters and/or octopus). It is recommended that the spatial approach to stock assessment and management be extended to AEP training. The need for an explicit spatial approach is also recognised for sea cucumbers in order to demonstrate compliance with CITES and could be the subject of future training courses.

6.3.6 Improving and standardising scientific advice

The project highlighted the scarcity of quantitative catch data, which depends on the existence of research projects or NGOs (CORECRABE, Blue Ventures) and the need to adapt methods to the data available (e.g. for sea cucumbers). A common element that could link the different assessments is the dashboard, which could be developed for any sector to inform scientific advice. It is therefore recommended that dashboards be developed systematically for all sectors.

6.3.7 Data collection (recommendations for fisheries statistics)

Collaboration with the fisheries statistics programme (joint workshop in Mahajanga, 3-8 July 2023) highlighted the challenges of collecting catch data and the Ministry's limited resources to ensure the following such collection. In the rare cases where catch data is collected, it is important that the data is adapted to the industry in question by homogenising it at the level of the fisheries supplying the industry. This requires the use of a consistent data collection manual. We recommend close coordination between the USP (fisheries statistics unit) and the stock assessment unit within the DESP.

In addition, collaboration with NGOs (action underway at Ministry level) needs to be stepped up, particularly for data collection, in coordination with the relevant Malagasy scientific institutions (see §6.3.3 above).

6.3.8 Recommendations for data-deficient resources

Experiments with sea cucumbers have demonstrated the adaptive approaches possible when assessing the state of a resource for which there is a lack of catch data (which will often be the case for fish resources targeted by small-scale fisheries). The case of sea cucumbers has demonstrated the usefulness of making intelligent use of marketing data and specific observations of the state of the resource in the scientific literature. In May 2023, the FAO held the first regional workshop in Nairobi on the 'weight of evidence' approach for data-deficient sectors in fisheries region 151. Although Madagascar was unable to attend, it is recommended that the development of this approach be monitored, and that it be considered for data-deficient commodity chains in Madagascar.

6.3.9 CITES compliance for fish products

Experience with sea cucumbers has highlighted the challenges of compliance with CITES, starting with the taxonomic determination of species, through to estimating the weight or number of individuals.

including determining whether or not fishing pressure is excessive on wild populations of the species affected. Apart from the endangered species of sea cucumbers, the inclusion in Appendix 2 of several shark species whose fins are traded is highly likely in the future. It is recommended that specific training on CITES compliance adapted to fisheries be developed for DESP stock assessment staff in coordination with the national authority responsible for CITES within the Ministry of the Environment.

6.3.10 Conserving ecosystems to support fisheries resources

As far as habitats are concerned, there is an opportunity to implement a mangrove restoration policy if responsible exploitation measures are associated with it. We need to develop standardised indices of the state of health of the ecosystems that are home to the industries being monitored (mangroves, coral reefs, phanerogam meadows, etc.), in consultation with the other stakeholders concerned, so that we can incorporate this index into the management charts.

6.3.11 Specific recommendations for each sector

Specific recommendations for each sector are given in detail in the scientific opinions above.

6.4 MAJOR RESULTS AND IMPACTS (LEGACY)

Following an investment of this size and scale, it is important to summarise the major results and foreseeable impacts (legacies) of the activity.

6.4.1 Results expected from the terms of reference

Overall, the project has achieved all the specific objectives set out in the terms of reference:

Table 23: Expected results

Expected results	**Summary**
Stock assessment or determination of the indicator of the state of health of the fisheries resources of the five priority sectors (depending on the data available)	Stock valuations are carried out for the following resources based on available data: <u>Coastal prawns</u> : • Stock assessment of industrial shrimp updated for the west coast of Madagascar • Indicator of the health of small-scale shrimp stocks on the west coast of Madagascar <u>Mangrove crabs</u> : • Assessment of mangrove crab stocks on the west coast of Madagascar • Crab stock health indicator based on marketing data <u>Coastal lobsters</u> : • Assessment of coastal spiny lobster stocks for the species *P. homarus* in the south-east region of Madagascar • Indicator of the state of health of lobster stocks (all species combined) for Madagascar in general, based on marketing data. <u>Octopus</u> : • Assessment of octopus stocks for the species *O. cyanea* for fisheries in south-west Madagascar. • State of health of octopus stocks for other regions based on analyses of production/marketing data

	Holothurians (data deficient resource) : • Indicator of the health of sea cucumber resources on the west coast of Madagascar. A stock assessment/health status indicator report with a dashboard and scientific management advice is provided for each resource.
Management notices (scientific notices) are prepared for the five sectors	Scientific advice is issued for the assessed stocks listed above. Scientific advice is incorporated into stock assessment reports.
MPEB staff are trained in stock assessment methods for fisheries resources, or in determining indicators of the health of stocks, particularly those with deficient data.	10 MPEB managers are trained and certified by the Group.
MPEB scientific staff are trained in the preparation of science-based fisheries management advice	The same people are trained in scientific advice and data collection.

6.4.2 Results achieved over and above the objectives of the terms of reference

In addition to the results required by the Terms of Reference, the following additional results were completed:

- MPEB staff trained in analysing official marketing statistics for the 5 commodities to identify trends (with report);
- MPEB staff trained in SWOT analysis of small-scale fisheries (through a guided session) ;
- Additional training in strategies and data collection (through an additional training workshop held in Mahajanga on 3-8 July 2023).

6.4.3 Strengthening national institutional capacity in stock assessment, scientific advice and data collection

The central objective of creating a strengthened capacity within the MPEB in stock assessment, scientific advice and data collection has been achieved, with 10 permanent staff in the Ministry.

The participation of national trainers from the IHSM with the support of the IRD constitutes an ancillary reinforcement at the level of a national scientific institution and lays the foundations for future cooperation between the Ministry and partner scientific institutions.

6.4.4 First exhaustive analysis of official marketing statistics for the 5 sectors

Although the MPEB has been collecting data on production and marketing of the various commodities by region of Madagascar for several decades, these data are rarely analysed in full.

For the first time, the project has carried out analyses of the data collected on over a decade to identify national and regional trends.

6.4.5 Basic elements provided to enable Madagascar to comply with CITES for sea cucumbers

In the case of sea cucumbers, the contribution of exporter data collected by ASH has made it possible to carry out partial analyses by species, offering a way for Madagascar to comply with CITES obligations concerning sea cucumbers.

6.4.6 Collaboration between scientific institutions and MPEB established for the future

The project has led to direct collaboration between Ministry officials and the IHSM on stock assessment, scientific advice and data collection. This opens up the possibility of a stock assessment system that enhances and develops national capacities outside the Ministry, similar to the approaches adopted in other countries.

The IRD's involvement, particularly for crabs, serves to further expand opportunities for collaboration, particularly for resources that can be complex to assess.

This pluralisation of stock valuation should be an advantage for the future.

6.4.7 Creation of a stock valuation working group

After an intensive review of stock assessment for the 5 sectors, the participants saw the importance of this stock assessment training and decided to set up a stock assessment working group (WG). This decision has already been communicated and shared with the Minister for Fisheries and the Blue Economy during his visit to our training workshop in Mahajanga last July.

A letter from the participants highlighting this initiative was given to the Minister for Fisheries and the Blue Economy, and is appended to this document.

The MPEB has noted the importance of this Stock Assessment Working Group (SAWG) for the future of the Ministry. Indeed, the forthcoming validation of BANACREM data could be used to update stock assessments by this working group.

7 APPENDICES

7.1 UPDATED CALENDAR OF ACTIVITIES

7.2 LIST OF SPECIES OF SEA CUCUMBERS USED AND THEIR NAMES VERNACULAR

7.3 FFOM ANALYSIS OF THE 5 SECTORS

7.4 DATA SHEETS AVAILABLE BY SECTOR

7.5 DATA COLLECTION MANUAL BY SECTOR

7.6 LETTER OF CONSTITUTION OF THE STOCK VALUATION WORKING GROUP