PP-4.　リゾート供給水産物モニタリング／エコラベル認証パイロットプロジェクト

1) Report on Survey on Reef Fish Landings to Tourist Resorts

2) Guidelines on Best Fishing and Fish Handling Practices

3) Overview of reef fish sampling in K. Dhiffushi – Nov-Dec 2016

REPORT ON SURVEY ON REEF FISH LANDINGS TO TOURIST RESORTS

May 2016

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with the technical assistance of Bernard ADRIEN, MASPLAN

This survey was carried out as part of a Pilot Project under the Project for the Formulation of Master Plan for Sustainable Fisheries (MASPLAN), a technical cooperation project of the Japan International Cooperation Agency (JICA).

All pictures taken by Bernard Adrien.

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1 INTRODUCTION

A Pilot Project on Reef Fisheries was designed in 2015, within the implementation of the MASPLAN Project, with a major objective to set up the basis for proper monitoring of reef fisheries resources on a continuous basis, with the ultimate goal of sustainably managing the Maldivian reef fisheries and conserving the integrity of the reef ecosystems; i.e. set up the basis for the design and implementation of a Reef Fisheries Management Plan.

One of the expected outputs of this Pilot Project is to come up with a better understanding on the reef fish value chain, more specifically in Malé City and North Malé Atoll. To that effect, one activity has been identified as “Implementation and analysis of a rapid survey on fish supply to resorts”.

It is believed that the tourism sector in Maldives is the largest market for locally harvested reef fish. Until the emergence of tourism sector, the reef fishery was essentially a subsistence fishery, and primarily used for local consumption. Although previous studies on reef fishery had estimated the reef landings to resorts, the figures were estimated using data from a limited number of resorts.

This report presents the results of the rapid survey on reef fish landings to resorts of Maldives conducted in November and December 2015, and a review of the figures on reef fish landings, given in previous studies (the scope of the present study has been expanded from merely Malé and North Malé Atoll to the whole country, so as to give a larger outlook and be compared with these previous nation-wide studies). The primary objective of the survey was to estimate the annual reef fish landings to resorts in Maldives and compare with the figures on reef fish reported through national fishery statistics. The survey also gathered information about various aspects of reef fish landings (e.g. market prices, fishing practices of the suppliers, quality of the fish supplied to the resorts etc.), which may be helpful for fisheries management and development purposes.

2 METHOD

The survey was carried out using a questionnaire designed for collecting data on various aspects of reef fish landings to resorts of Maldives. The questionnaire was converted into a fillable online form, to be sent to resort personnel via email (see Annex 1.)

An initial list of all resorts of Maldives with emails and telephone numbers was compiled and updated. The link to the survey form was sent to the publicly available email addresses of all the resorts, with a detailed email with explanation of the purpose and expected output of the survey. This initial email contained a request to forward the questionnaire to be filled, to a relevant department or personnel within the respective resort. The survey questionnaire was filled by either the chef in charge or the purchase manager of the respective resort. Of the 112 operational resort properties in Maldives, 52 sent responses (i.e. a quite relevant 46.4%)[1].

The survey forms received from the resorts were imported directly into an Excel file at MoFA.

The data from the survey was complemented with most recent tourism statistics for accurate estimation of the total reef fish landings to the resort sector of Maldives. The calculations were based on the statistics exclusive to the resorts (e.g. bed capacity, occupancy and tourist nights).

The data on consumption of reef fish by tourist hotels, guest houses and safari vessels, as well as by the general public (national market), were not estimated through the survey, since those operations are thought to have different dynamics and would require specific data collection schemes. Hence, the results of the survey, as initially foreseen, are an exclusive representation of the resorts of Maldives, and not the tourism sector as a whole, or the national market.

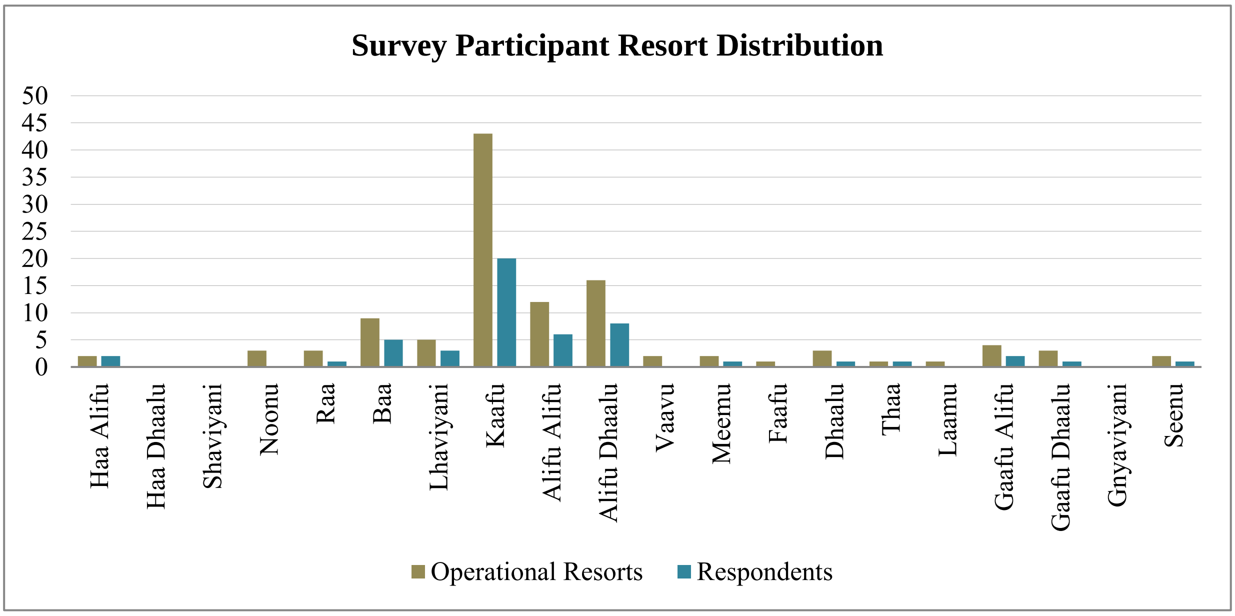


Figure 1: Bar chart depicting participant resort distribution and the number of operational resorts

Registered bed capacity for each of the 52 resorts was retrieved from the Tourism Yearbook 2015 published by Ministry of Tourism. As of November 2015, the registered bed capacity for all tourist resorts was 24,511 beds, which corresponds to 6,524,432 bed nights for the period December 2014 to November 2015.

[1] It should be stressed that in most cases, follow-up phone calls were necessary to get the expected answer to the questionnaire from the resorts. When the total number of answers reached about half the total number of resorts, the sample size was deemed satisfactory, and no further insistence was exerted towards the remaining resorts.

3 RESULTS & ANALYSIS

3.1 Estimates on reef fish production

a) Estimate of Annual Reef Fish Landings to Resorts from the present survey

The survey found that, on average, a resort purchased (landed) 520.5 kg of reef fish per week, as well as 370.3 kg of tuna[2]. Using the total quantity of reef fish landings to resorts and the total number of registered beds for each resort, the consumption of reef fish was calculated at 0.44 kg per registered bed per night.[3] Extrapolation of the consumption rate for reef fish, using the bed capacity of all resorts, gives a quantity of 3,945.8 tons of reef fish landings per year**.**

Using this estimated total quantity of reef fish landings, and the total number of tourist bed nights for the period December 2014 to November 2015, consumption per tourist bed night was calculated at 0.60 kg, which can be used for better comparison with figures from previous studies shown in the section below.

b) Comparison on Annual Reef Fish Landings to Resorts with previous surveys

The first survey carried out on reef fish (Van der Knaap et al. (1991) as cited in Anderson et al. (1992) estimated the total annual catch of reef fish consumed in the resorts to be around 1,000 tons[4], on the basis of 0.63 kg of reef fish per tourist night.

Sattar et al. (2008) estimated the annual reef fish landings to resort at 7,000 tons. A more recent estimation by Sattar et al. (2014) states that the annual reef fish landings to resorts are approximately 5,300 tons, which corresponds to 1.29 and 0.84 kg per bed night respectively; these figures are therefore significantly higher than those of the 1990 survey and the present one. [5]

The annual reef fish landings to resorts are well below the estimated figure of around 7,000 tons, evident from the fisheries statistics reporting (MoFA, 2015).

Table 1 Comparison of reef fish consumption per tourist bed night, estimated annual landings based on previous studies

Source	Qty per Tourist Bed Night	Annual Landings	Survey Year
Van der Knaap et al. (1991)	0.63 kg	1,067 tons	1990
Sattar et al. (2008)	1.29 kg	7,000 tons	2006-2007
Sattar et al. (2014)	0.84 kg	5,300 tons	2012
MoFA (2016)	0.60 kg	3,945.8 tons	2015

[2] Tuna is mainly for the consumption of the resort staff.
[3] Data on registered beds were used for this calculation, since the data for operational capacity or occupancy for sampled resorts was not available from the Ministry of Tourism.
[4] There were 62 resorts in 1991, according to national statistics
[5] The different methods used in estimating the consumption rate has to be acknowledged. Previous studies by Sattar et al. (2008) and Sattar et al. (2014) used data from a limited number of resorts over a given period of time, whereas this survey used a snapshot of an estimated average quantity for large number of resorts.

c) Reef Fish Exports

An annual average of 1,502.9 tons of reef fish was exported from Maldives over the period 2010-2014, as per export statistics data from Maldives Customs Service. This has an average export value of MVR 64.5 million. The amount of reef fish exports are generally in decline since 2012, although 2014 exports have shown a slight increase as seen in Figure 2.

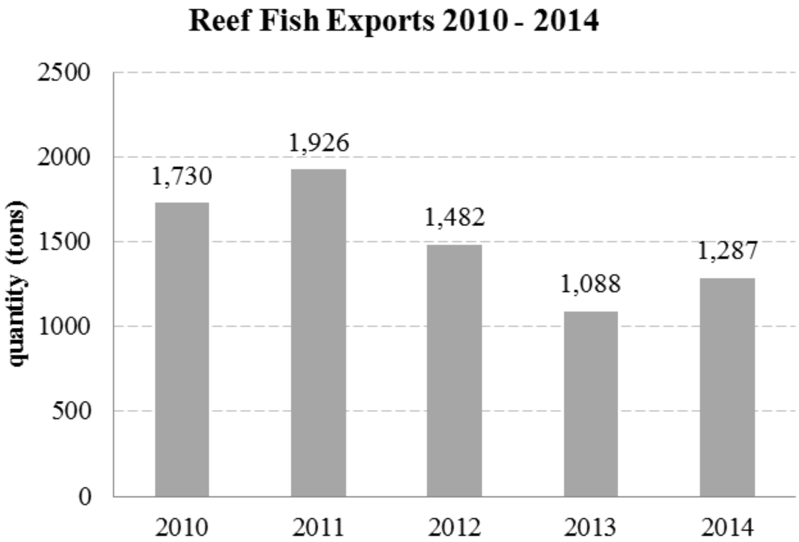


Figure 2: Total quantity of exported reef fish from Maldives (source: Maldives Customs Service)

3.2 Indications on the linkage between reef fish suppliers and resorts

a) Frequency of purchase

In average, each resort buys fish 3 times per week, which, for an average quantity of 520 kilos of reef fish per resort per week, corresponds to 174 kilos of reef fish per delivery.

b) Composition

The questionnaire specifies, for the main 6 groups of reef fish species and 2 of pelagics, the frequency it is delivered to the resort (either very high, high, moderate, low, very low or nil). The intensity of consumption by the resorts is presented in Figure 3. Snappers and trevallies are the more common groups of species used for consumption, followed by rainbow runners and groupers (quite similar), and then jobfish and emperors.

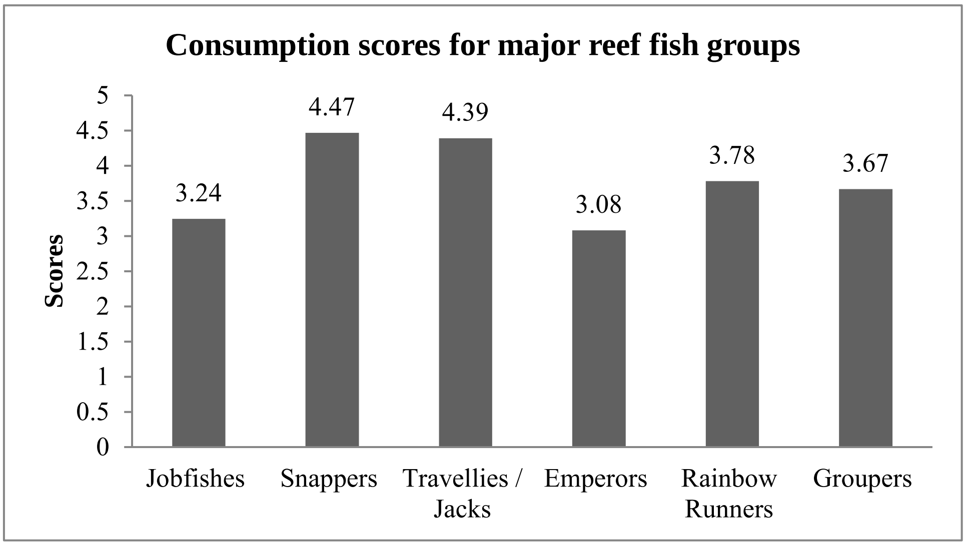
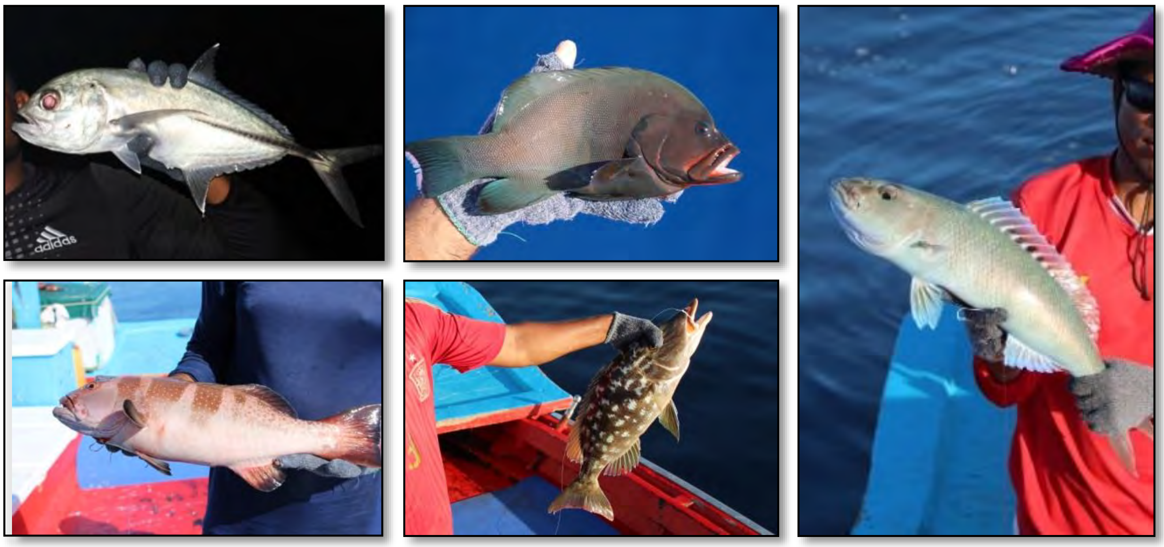


Figure 3: Bar graph showing the intensity of consumption as scores based on the feedback from resorts

As for pelagic species, tuna had a consumption score of 5.00, higher than any reef fish. Billfish had the lowest consumption score with 2.73.



c) Origin of the supply

In about two thirds of the cases, the resorts are supplied exclusively by local fishermen; in a limited number of cases, they are supplied exclusively by middlemen, whereas a mix of local fishermen and middlemen accounts for about one quarter of the cases, as shown in Figure 4.

In the cases of supply from local fishermen, the resorts deal with varying number of fishing boats, up to 10. Most of them (12 resorts) reported that they purchase reef fish from one vessel. Nine resorts have contracts with some or all of the fishing vessels, for buying reef fish on a regular basis.

No resort has its own professional fishing boats to provide its own reef fish supply.

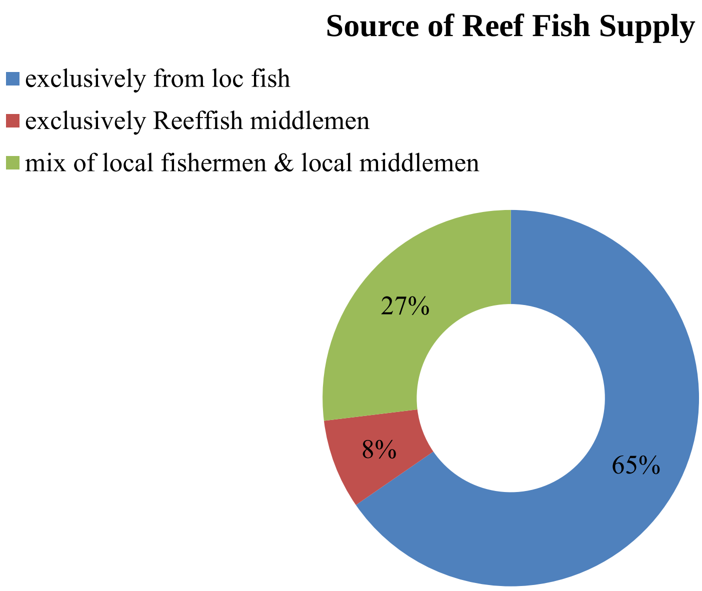


Figure 4: Chart showing the source of reef fish supply for resorts

d) Benefits provided by resorts to fishermen

Besides the price of the fish per se, various incentives can be provided by the resorts to the fishermen, namely food (in about half of the cases – fishermen may have access to the resort staff canteen after they deliver and eventually process the fish upon delivery), fuel (in one third of the cases) and, exceptionally, water and ice[6]; in 10% of the cases, there is no incentive whatsoever.

[6] The number of resorts which provide ice to fishermen is negligible – an indication which needs to be linked to the aspect on fish quality, as presented further in the document (Page 11).

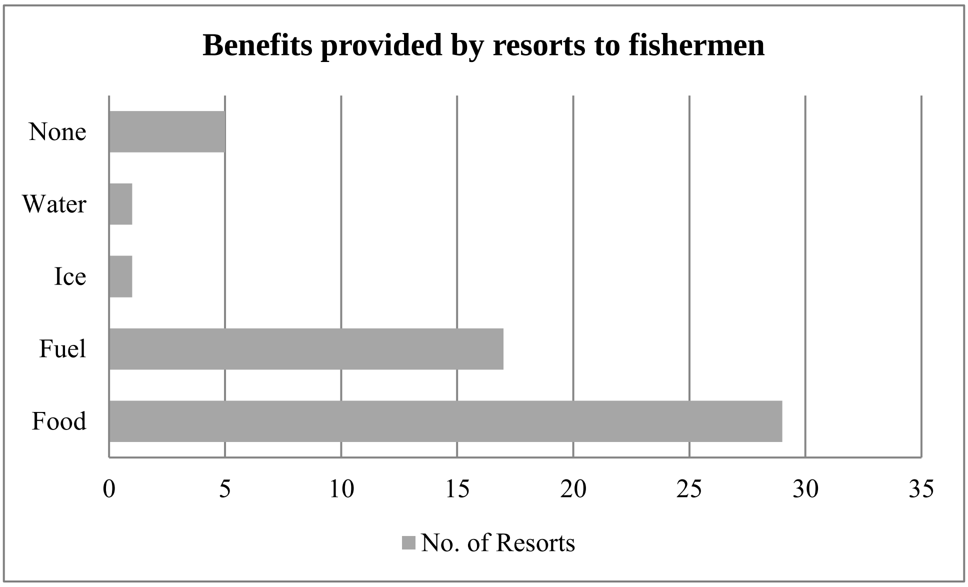


Figure 5: Bar chart showing the benefits for fishermen provided by the resorts

e) Price of Reef Fish

The survey found that reef fish commands an average price of MVR 40.1 per kg in the resort market. There is logically a noticeable difference in price paid to local fishermen and suppliers, as depicted in Figure 6. The resorts buying exclusively from local fishermen, pay an average price of MVR 36.18 per kg for reef fish, whereas the resorts buying from middlemen and suppliers pay an average price of MVR 69.4 per kg.

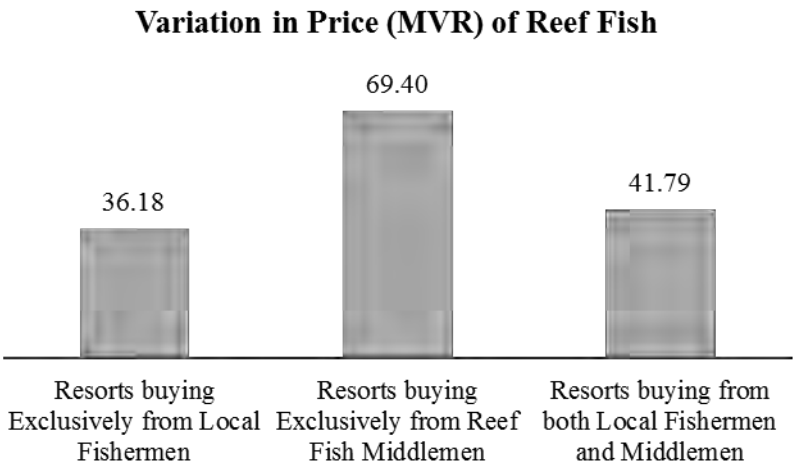


Figure 6: Variation in price of reef fish, based on the type of reef fish sellers

Based on the prices paid by the three different groups of resorts as seen in Figure 6, the value of reef fish landings for a year was calculated at MVR 151.4 million, comparing to the MVR 65 million per year for reef fish export.

f) Good fishing practices

Figure 7 presents the occurrence of rejection of undersized fish by the resorts. It is quite significant that about two thirds of the resorts rarely or never reject any fish – a situation likely due more to the fact that the resorts are not demanding in terms of respect of size limits, than to the fact that fishermen do not fish, and deliver, undersized fish. On the other hand, the remaining third do reject undersized fish, either very often or occasionally – a possible indication that in a significant number of cases, the resorts are aware of good fishing practices and try and make their best for the fishermen to implement them.

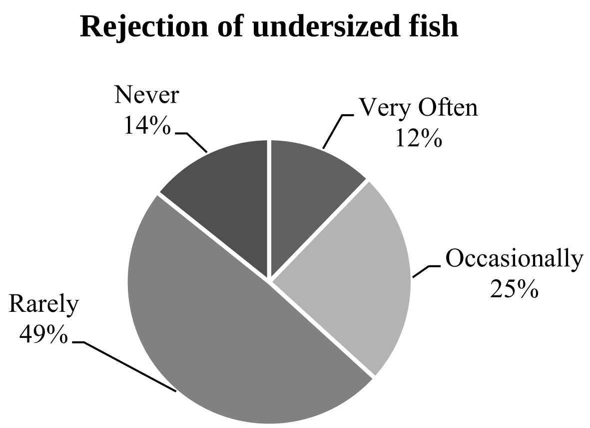


Figure 7: Pie chart showing the responses from resort on rejection of undersized fish at purchase point

g) Mode of fish preservation and quality

Figure 8 presents the various types of presentation of fish (either fresh, i.e. not chilled or frozen, chilled or frozen).

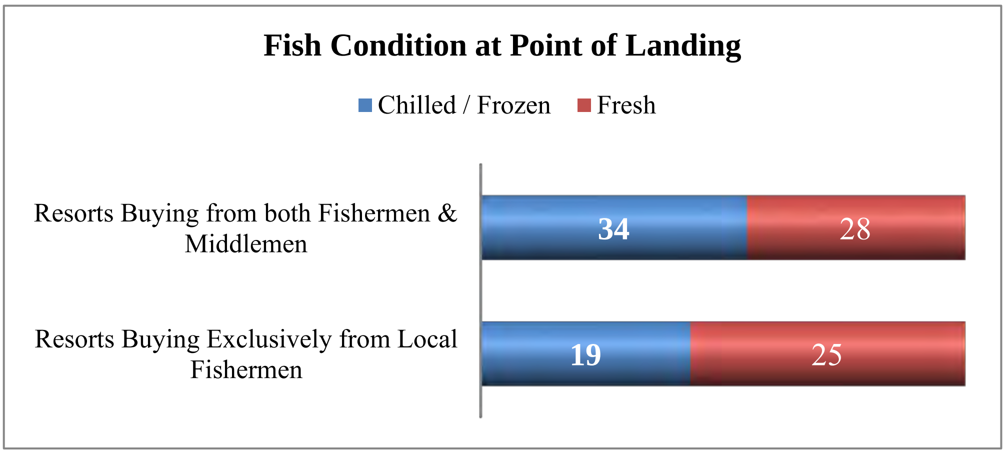


Figure 8: bar graph depicting the condition of fish upon landing to resorts

Overall, it is significant to note that the largest proportion of fish is delivered fresh to the resorts by fishermen, i.e. fish is not kept on ice on board, between the moment it is caught till the time it is stored in the cold room of the resort (this period of time can reach up to 10-12 hours, and with a high temperature, it is clear that the fish quality will not be at its best any more after delivery)[7].

[7] Besides making fish lose its quality, the absence or lack of ice may deter fishermen from fishing: without the possibility to store overnight their catches under ice, they may prefer to limit their fishing time.

Figure 9 presents the distribution of occurrence of fish rejection due to poor quality; significantly, about 20% of the resorts do reject some fish, either very often or occasionally, probably when fish is delivered fresh, without ice. In the majority of cases, resorts never or rarely reject fish – an indication which can be interpreted in two ways: either they are not aware on fish quality and are therefore not demanding in that respect; or they are supplied with chilled fish, kept under good conditions, which corresponds to their proper food safety policy.

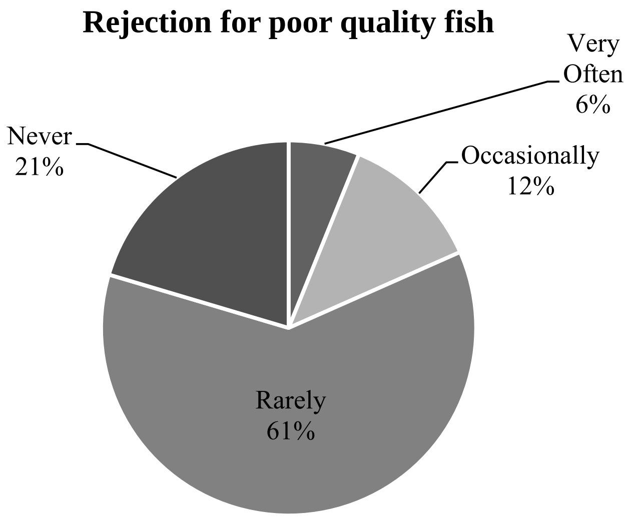


Figure 9: Pie chart showing the responses from resorts regarding the rejection of reef fish based on the quality

4 CONCLUSION AND RECOMMENDATION

4.1 Further understanding on the dynamics of the reef fish value chain in the country

Based on the rapid survey and the export statistics, the reef fish caught for resorts and export market add up to 5,233 tons per year. The amount of reef fish caught for local consumption is unknown, and research needs to be focused on understanding consumption trends across the country. This topic is to be tackled on an initial scale by the Reef Fish Pilot Project, under the same output as the present survey, i.e. "A better understanding on the reef fish value chain in Malé and North Malé Atoll is reached". The respective programmed activity consists in identifying the major fish middlemen in Malé (there are about 3-4 of them) and carrying it out a rapid survey similar to that of the present survey, as a way to gather qualitative and quantitative indications on their actual activities linked to reef fisheries. This will then be expanded nation-wide.

4.2 Update on the MSY for reef fish

In order to assess the sustainability of the reef fishery in Maldives, scientific information on current stock structure and Maximum Sustainable Yield (MSY) is necessary. Based on the rapid survey, fisheries statistics and the results from previous studies, it can be safely assumed that the current reef fish landings are expected to be significantly below the MSY of 30,000 tons, which is the last available estimate, dating back in 1990.

However, the MSY in use today was calculated at a time when the total reef fish landings were estimated around 1,000 tons[8]. As the intensity of reef fishery increased over the years parallel to the growth in tourism sector as well as that of the national population and subsequent consumption, the standing stock of reef fish would also be lower. Hence, an updated MSY is vital for making informed decisions regarding the management of reef fishery in Maldives.

Since the assumption of significant unreported reef fish landings to resorts is deemed unlikely, technical and financial investments need to be allocated to improve species-specific stock assessments. This is very important considering the fact that the current MSY is calculated using aggregate reef fish landings inclusive of all commercially valuable species. However, this MSY figure is irrelevant in decision-making that involves species level management. Such assessments are critical in understanding whether the stocks of most commercially valuable species are in decline and coming up with management measures.

4.3 Promotion of good fishing and fish handling practices

Even though the proportion of catch supplied to the resorts is not exceedingly high, good practice guidelines can be helpful for resorts when purchasing fish. The resorts also have a financial gain in promoting sustainable fishery practices to tourists and fishermen who sell fish to the tourist resorts.

The present survey gave relevant indications on the observance of good fishing practices and good handling practices by fishermen (namely through the rejection of undersized fish by the resorts they deliver to, and the use of ice on board).

Resorts have a very significant role to play in ensuring that the fish resources they deal with are properly used, be it by the local fishers or middlemen they buy fish from and by their customers

[8] The reef fish landings for 1990 was estimated at 1,067 kg by Anderson et al. (1992) based on the consumption rates and tourist bed nights

going out fishing. Some resorts have already set up programmes for the application of best fishing practices. The Reef Fish Pilot Project the present survey is part of will be instrumental to identify these initiatives, if needed widen their scope and, from this basis, support the production of awareness material for fishers and resorts. In addition, training will be delivered to groups of professional reef fishermen, in close interaction with the resorts of their respective zones.

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ANNEX 1: Questionnaire used for the survey

1/4/2015 Reef Fish Landings Survey - Google Drive

Reef Fish Landings Survey

QUESTIONS RESPONSES

Reef Fish Landings Survey

Reef fishes are caught throughout the Maldives to supply local markets, with most of the demand coming from tourist resorts. It is in the interest of buyers, consumers and fishermen to [illegible] reefs in Maldives retain their health, biodiversity and productivity into the future.

Management for sustainability requires basic data about the fisheries, such as the status of the stocks and the numbers and size of fish being taken from the reefs. The Reef Fish Landin[illegible] programme that involves logging essential data on consignments of locally-sourced fish as they are delivered to the resorts. The data collected will be shared with stakeholders and used [illegible] Maldives.

The survey will take approximately five minutes to complete and all your responses will be kept confidential. The data will be reported only in the aggregate form and individuals and orga[illegible]

1. Resort / Hotel

Short answer text

2. Number of Rooms

Short answer text

3. Number of Staff

4. Estimated average quantity of reef fish purchase per week (in Kg)

Short answer text

5. Estimated average quantity of tuna purchase per week (in Kg)

Short answer text

6. How many times a week do you buy reef fish?

Short answer text

7. Consumption level of locally harvested reef fish by the resort

Row 1. Jobfishes

Row 2. Snappers

Row 3. Trevallies / Jacks

Row 4. Emperors

tps://docs.google.com/forms/d/1LgDNGhKGXN8F2ANdeGjt55pF-RV2lcMw1fdlPeyYLxG/edit?usp=forms_home 1/5

11/4/2015 Reef Fish Landings Survey - Google Drive

Row 5. Rainbow Runners

Row 6. Groupers

Row 7. Billfishes

Row 8. Tuna

Column 1. Very High

Column 2. High

Column 3. Moderate

Column 4. Low

Column 5. Very Low

Column 6. None

8. Purchase price of reef fish (per Kg)

Short answer text

9. From whom do you buy reef fish?

Local Fishermen

Reef Fish Middlemen

Directly from Fish Market

Other...

10. Number of fishing boats selling reef fish to the resort

Short answer text

11. Number of suppliers selling reef fish to the resort

Short answer text

12. Do you have supply contracts with reef fishing boats / suppliers?

Yes

No

13. If your answer is yes to the question 12, please specify number of fishing boats in contract

Short answer text

14. If your answer is yes to the question 12, please specify number of fish suppliers in contract

https://docs.google.com/forms/d/1LgDNGhKGXN8F2ANdeGjt55pF-RV2lcMw1fdlPeyYLxG/edit?usp=forms_home

Short answer text

15. Do you have your own professional reef fishing boats? If yes, how many?

Short answer text

16. If you buy reef fish from suppliers, where are they located?

- Within Atoll
- Other Atolls
- Male' City / Hulhumale
- Other Countries

17. If you buy directly from fishermen, what are the benefits you provide for them?

- Food
- Fuel
- Lodging for Overnight stays
- Other...

18. Condition of fish upon unloading / receiving

- Unchilled
- Chilled
- Frozen
- Other...

19. Level of processing by the fishermen / middlemen

- Unprocessed / Wholefish
- Gilled
- Gutted
- Filleted
- Other...

20. How often do you reject fish because of poor quality?

- Very Often
- Occasionally
- Rarely
- Never

21. How often do you reject undersized fish?

- Very often
- Occasionally
- Rarely
- Never

22. Do you reject or give preference for certain species or a group of species? If so, please specify with reasons.

Long answer text

23. If you import reef fish, please specify the consumption level of imported reef fish

Row 1. Jobfishes

Row 2. Snappers

Row 3. Trevallies / Jacks

Row 4. Emperors

Row 5. Rainbow Runners

Row 6. Groupers

Row 7. Billfishes

Row 8. Tunas

Column 1. Very High

Column 2. High

Column 3. Moderate

Column 4. Low

Column 5. Very Low

Column 6. None

24. Estimated imported quantity of reef fish per month (in Kg)

GUIDELINES ON BEST FISHING AND FISH HANDLING PRACTICES

IN THE MALDIVES

Ministry of
Fisheries & Agriculture

MASPLAN

JICA

Ministry of Fisheries and Agriculture
Published in 2017
In cooperation with
Japan International Cooperation Agency (JICA)
and Marine Research Centre (MRC)

Layout & artwork design
Ahmed Naushad

Foreword

This guide book has been prepared by the Ministry of Fisheries and Agriculture of the Maldives (MoFA), as an outcome of the pilot project of MASPLAN implemented by MoFA with technical cooperation of the Japanese International Cooperation Agency (JICA).

It is a practical tool aimed at professional fishermen, resorts and their clientele as well as recreational fishers, describing best fishing and fish handling practices, more specifically for reef fisheries.

Its purpose is to help these various users to respectfully tackle the marine resources of the Maldives and be instrumental for its sustainable management and conservation, and to ensure that the fish caught is of utmost quality.

Enjoy fishing and consuming reef fish in the Maldives!

Contents

ESSENTIAL ELEMENTS OF THE NATIONAL FISHERIES REGULATORY FRAMEWORK

Section 1

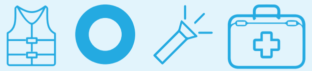
1 Any form of fishing for the purpose of export requires a fishing licence

2 A licenced fishing vessel is required to submit daily catch logs

3 Fishing in the lagoons of tourist resort islands shall only be conducted with prior permission from the resort

BEFORE YOU LEAVE FOR FISHING!

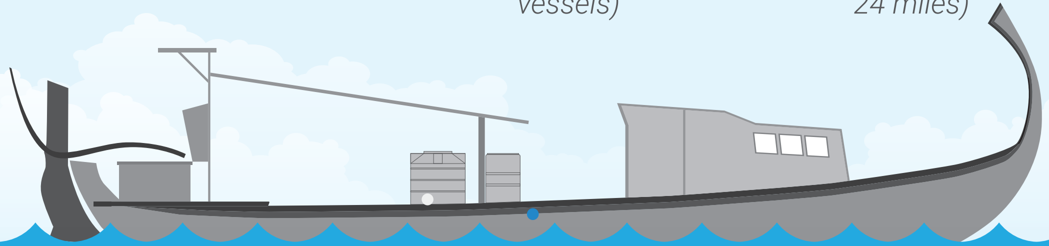
Section 2



The boat must comply with safety requirements (communication and navigation equipment, emergency equipment etc.)

Vessel tracking is mandatory (for all licensed fishing vessels)

Satellite phone is mandatory (for vessels going beyond 24 miles)



Licensed fishing vessels should always carry on board a catch log book for the licensed gear type

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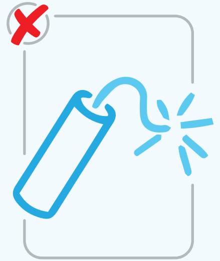
The boat must have a valid registration and a valid license (for vessels catching fish for export)

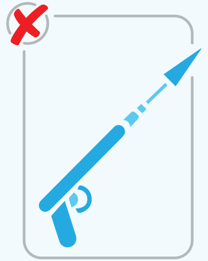
RESTRICTED FISHING ACTIVITIES OR FORMS OF FISHING

Section 3

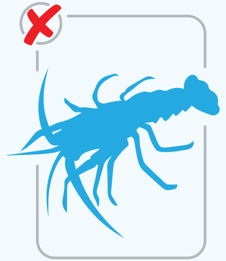


Fishing with explosives/dynamite

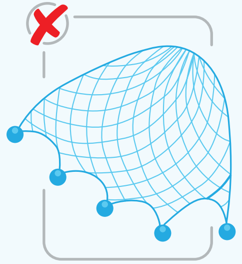
Fishing with toxic substances



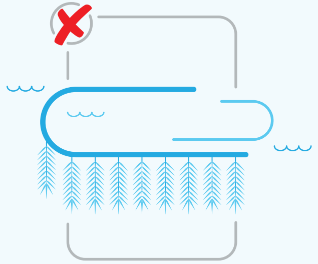
Fishing with speargun



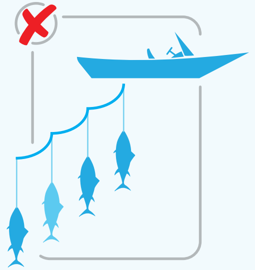
Use of scuba gear to collect lobsters



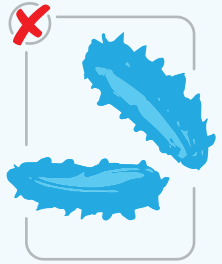
Use of moxy nets for fishing



Use of traditional herd/ seine net (Rodhulun)



Longline fishing inside 100 nautical miles



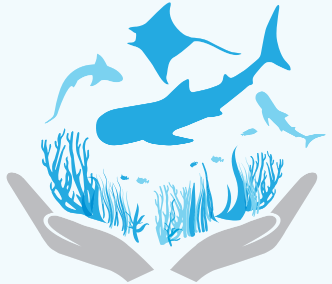
Use of scuba gear to harvest sea cucumber

PROTECTED AREAS

General purposes for protection

A MARINE PROTECTED AREAS (MPAs)

B GROUPER SPAWNING AGGREGATION SITES



C WHALE SHARK & MANTA RAY AGGREGATION SITES

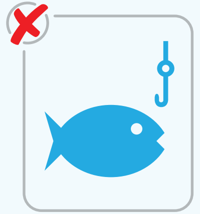
D RESORT HOUSE REEF

A. MARINE PROTECTED AREAS (MPAs)

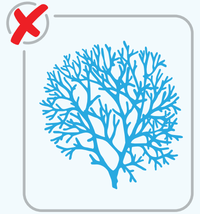
Basic rules to follow in Marine Protected Areas (MPAs)

Restricted activities at different MPAs will differ, hence it is advised to obtain up to date information on restricted activities from relevant authorities before accessing MPAs

Dumping



Any form of fishing



Coral mining

Sand mining

Anchoring

Harvesting turtles & turtle eggs

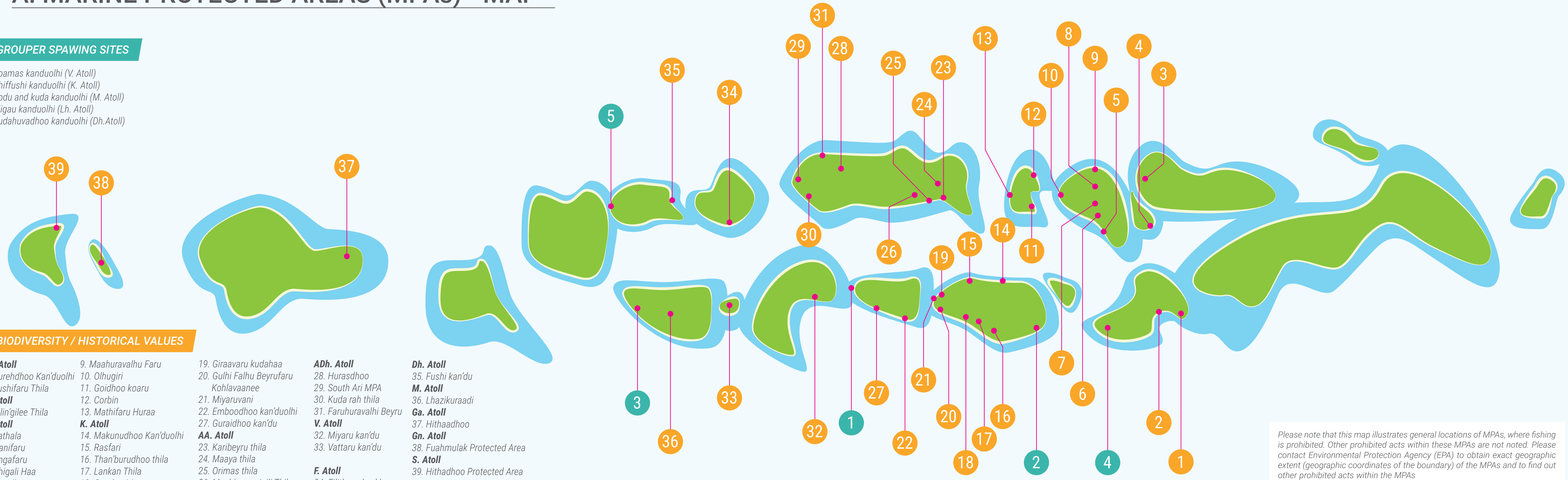
Removal of any natural object or living creatures

Snorkeling

Diving

Navigating through

A. MARINE PROTECTED AREAS (MPAs) - MAP



GROUPER SPAWING SITES

1. Boamas kanduolhi (V. Atoll)
2. Dhiffushi kanduolhi (K. Atoll)
3. Bodu and kuda kanduolhi (M. Atoll)
4. Aligau kanduolhi (Lh. Atoll)
5. Kudahuvadhoo kanduolhi (Dh.Atoll)

BIODIVERSITY / HISTORICAL VALUES

Lh. Atoll
1. Kurehdhoo Kan'duolhi
2. Fushifaru Thila

R. Atoll
3. Vilin'gilee Thila

B. Atoll
4. Bathala
5. Hanifaru
6. Angafaru
7. Dhigali Haa
8. Mendhoo
9. Maahuravalhu Faru
10. Olhugiri
11. Goidhoo koaru
12. Corbin
13. Mathifaru Huraa

K. Atoll
14. Makunudhoo Kan'duolhi
15. Rasfari
16. Than'burudhoo thila
17. Lankan Thila
18. Gaathugiri
19. Giraavaru kudahaa
20. Gulhi Falhu Beyrufaru Kohlavaanee
21. Miyaruvani
22. Emboodhoo kan'duolhi
27. Guraidhoo kan'du

AA. Atoll
23. Karibeyru thila
24. Maaya thila
25. Orimas thila
26. Mushimasmigili Thila

ADh. Atoll
28. Hurasdhoo
29. South Ari MPA
30. Kuda rah thila
31. Faruhuravalhi Beyru

V. Atoll
32. Miyaru kan'du
33. Vattaru kan'du

F. Atoll
34. Filitheyo kan'du

Dh. Atoll
35. Fushi kan'du

M. Atoll
36. Lhazikuraadi

Ga. Atoll
37. Hithaadhoo

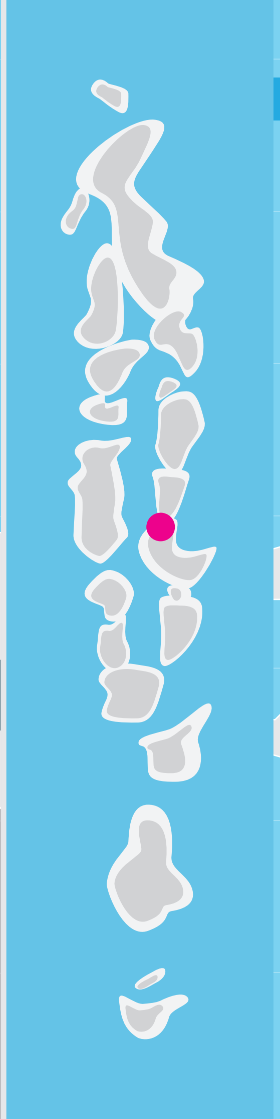
Gn. Atoll
38. Fuahmulak Protected Area

S. Atoll
39. Hithadhoo Protected Area

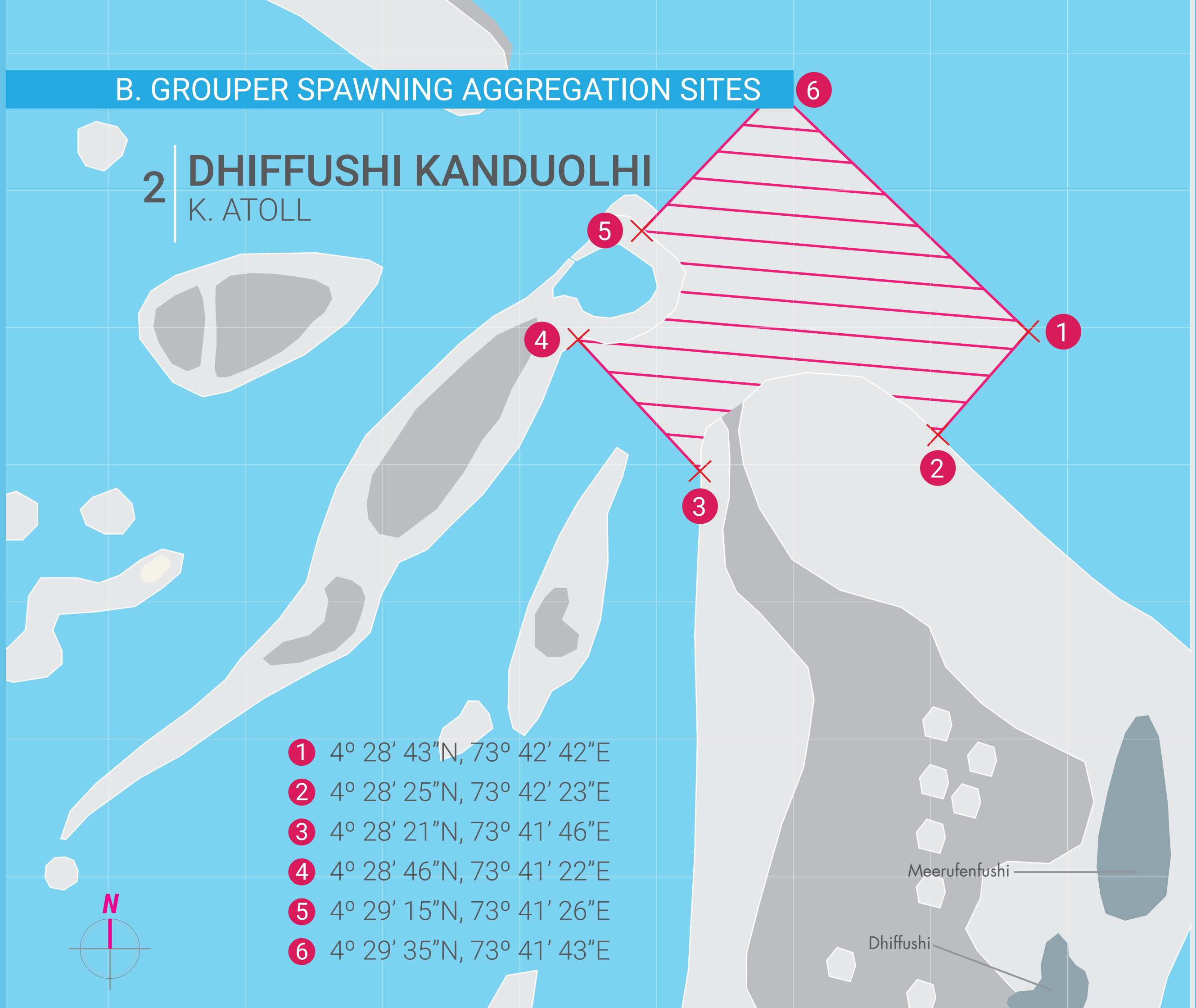
Please note that this map illustrates general locations of MPAs, where fishing is prohibited. Other prohibited acts within these MPAs are not noted. Please contact Environmental Protection Agency (EPA) to obtain exact geographic extent (geographic coordinates of the boundary) of the MPAs and to find out other prohibited acts within the MPAs

1 BOAMAS KANDUOLHI
V. ATOLL

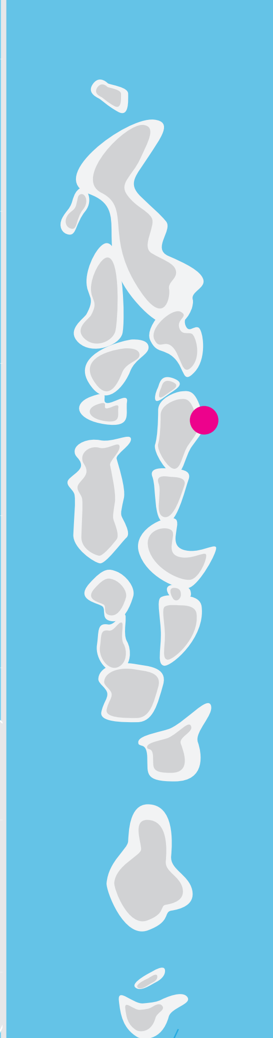
1. 3º 41’ 09”N, 73º 24’ 17”E
2. 3º 40’ 54”N, 73º 24’ 22”E
3. 3º 40’ 41”N, 73º 24’ 04”E
4. 3º 40’ 37”N, 73º 23’ 50”E
5. 3º 40’ 37”N, 73º 23’ 27”E
6. 3º 40’ 53”N, 73º 23’ 21”E
7. 3º 40’ 59”N, 73º 23’ 35”E



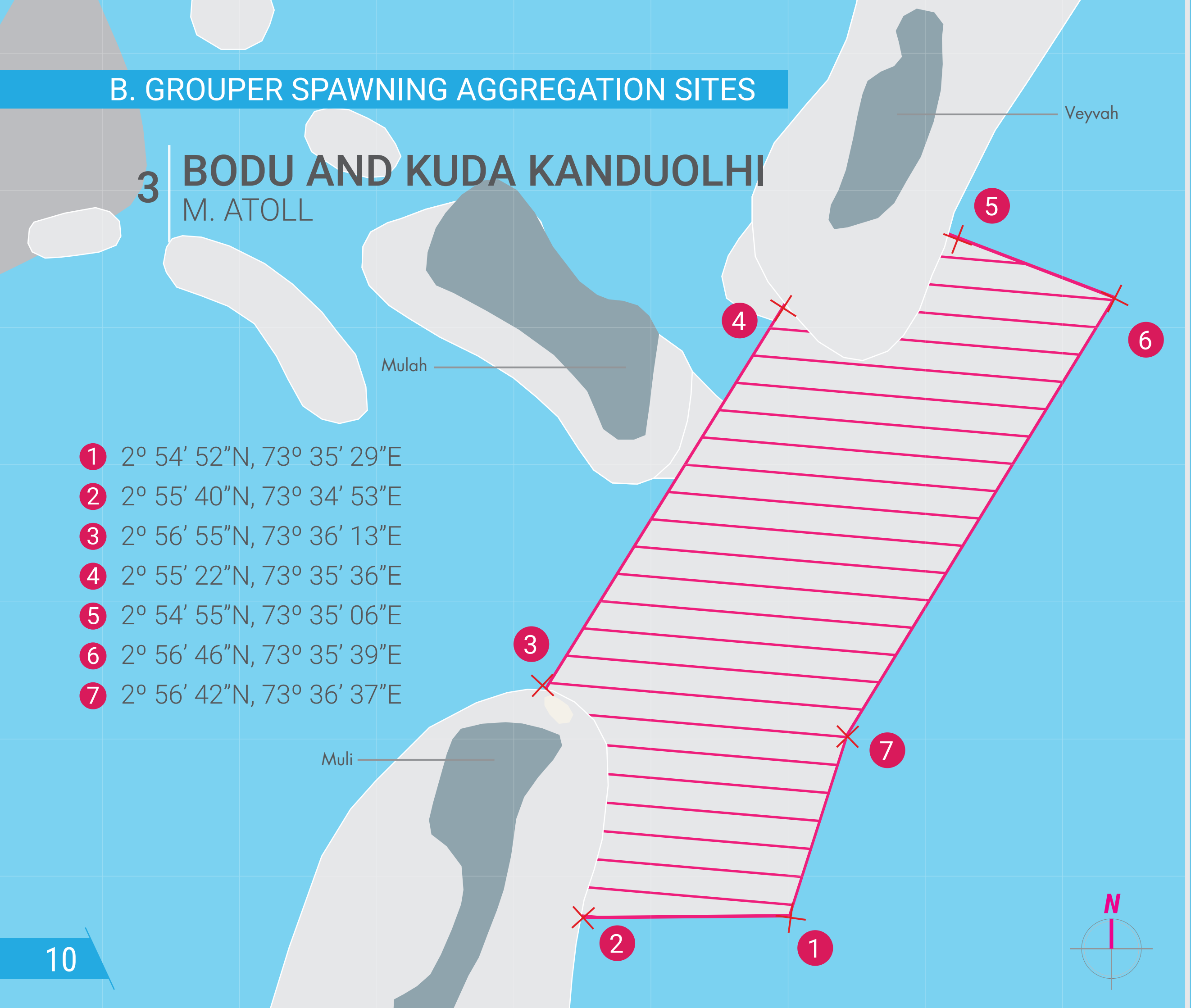
2 DHIFFUSHI KANDUOLHI
K. ATOLL



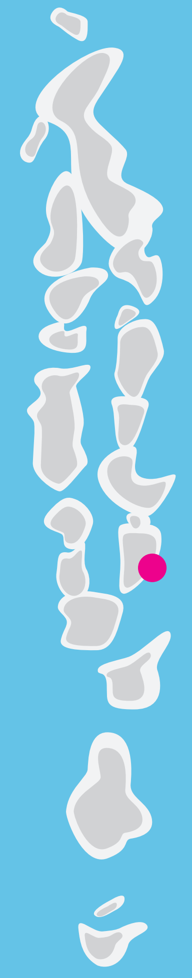
1. 4º 28’ 43”N, 73º 42’ 42”E
2. 4º 28’ 25”N, 73º 42’ 23”E
3. 4º 28’ 21”N, 73º 41’ 46”E
4. 4º 28’ 46”N, 73º 41’ 22”E
5. 4º 29’ 15”N, 73º 41’ 26”E
6. 4º 29’ 35”N, 73º 41’ 43”E



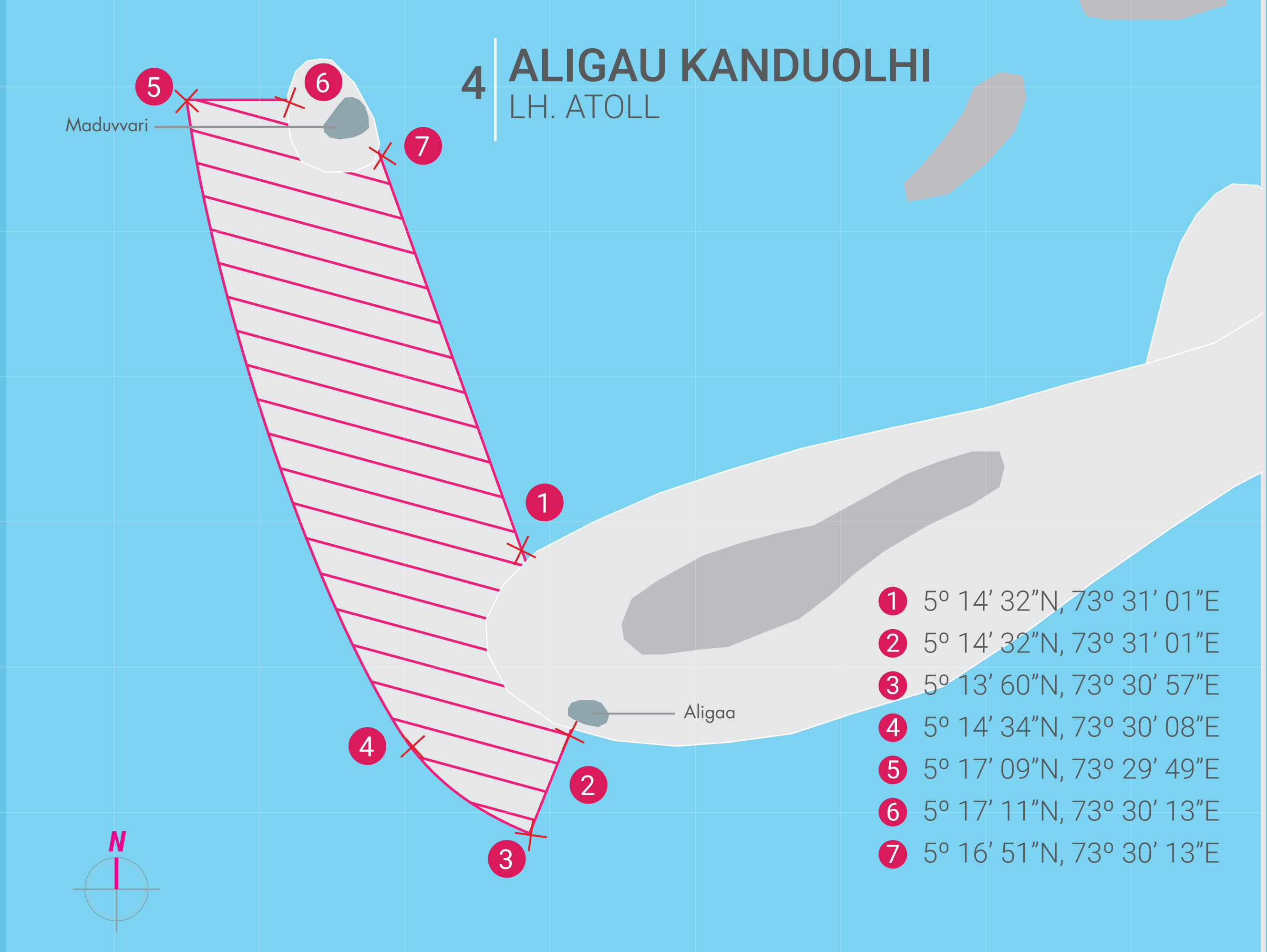
3 BODU AND KUDA KANDUOLHI
M. ATOLL



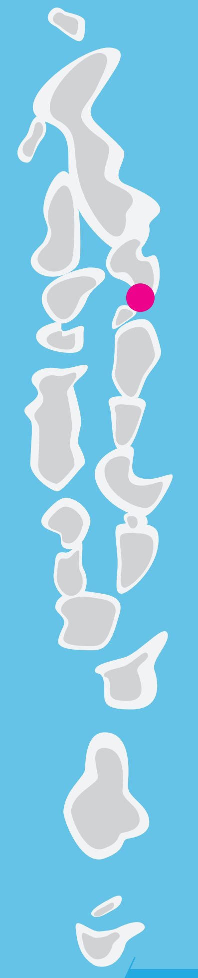
1. 2º 54' 52"N, 73º 35' 29"E
2. 2º 55' 40"N, 73º 34' 53"E
3. 2º 56' 55"N, 73º 36' 13"E
4. 2º 55' 22"N, 73º 35' 36"E
5. 2º 54' 55"N, 73º 35' 06"E
6. 2º 56' 46"N, 73º 35' 39"E
7. 2º 56' 42"N, 73º 36' 37"E



4 ALIGAU KANDUOLHI
LH. ATOLL

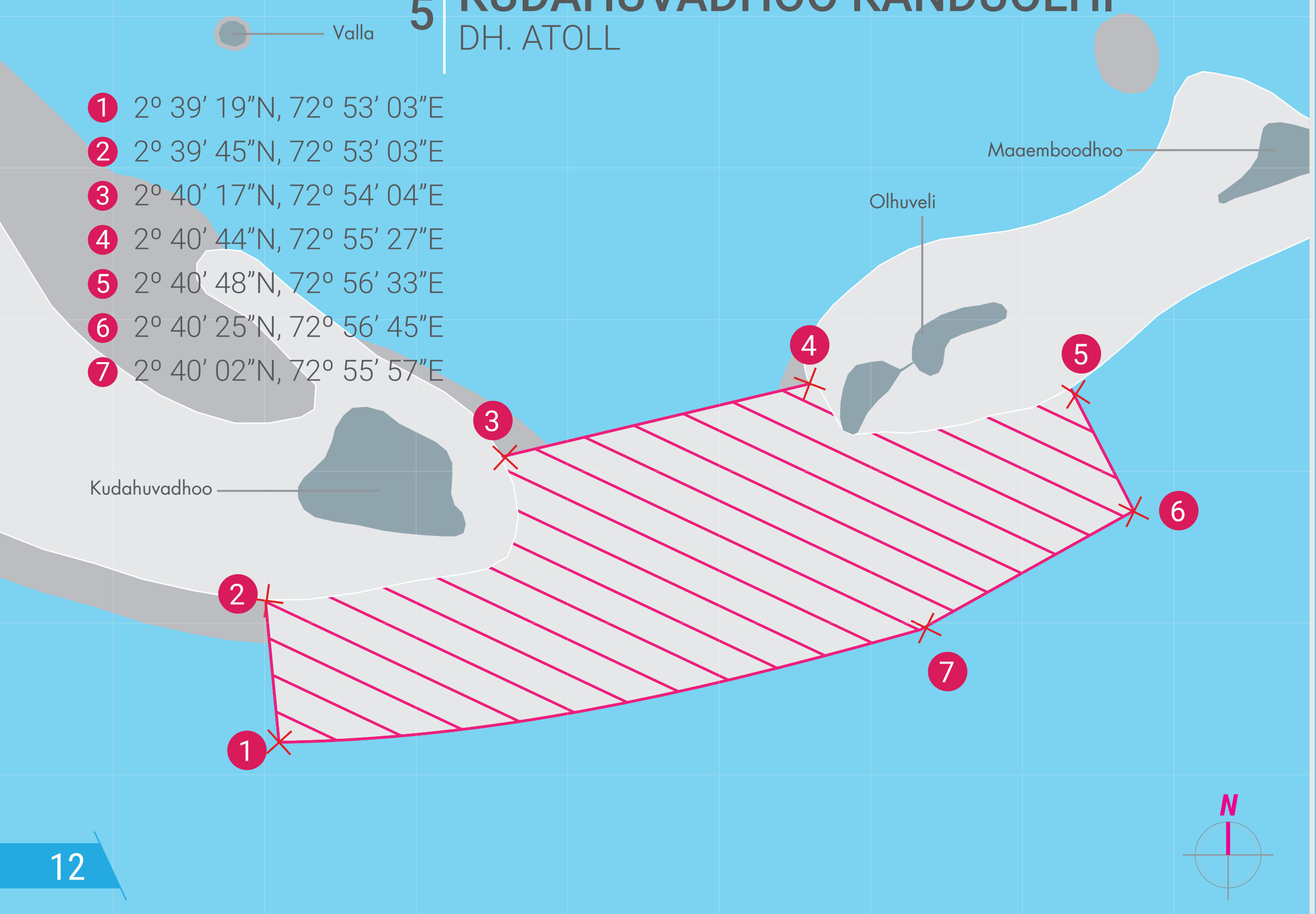


1. 5º 14' 32"N, 73º 31' 01"E
2. 5º 14' 32"N, 73º 31' 01"E
3. 5º 13' 60"N, 73º 30' 57"E
4. 5º 14' 34"N, 73º 30' 08"E
5. 5º 17' 09"N, 73º 29' 49"E
6. 5º 17' 11"N, 73º 30' 13"E
7. 5º 16' 51"N, 73º 30' 13"E

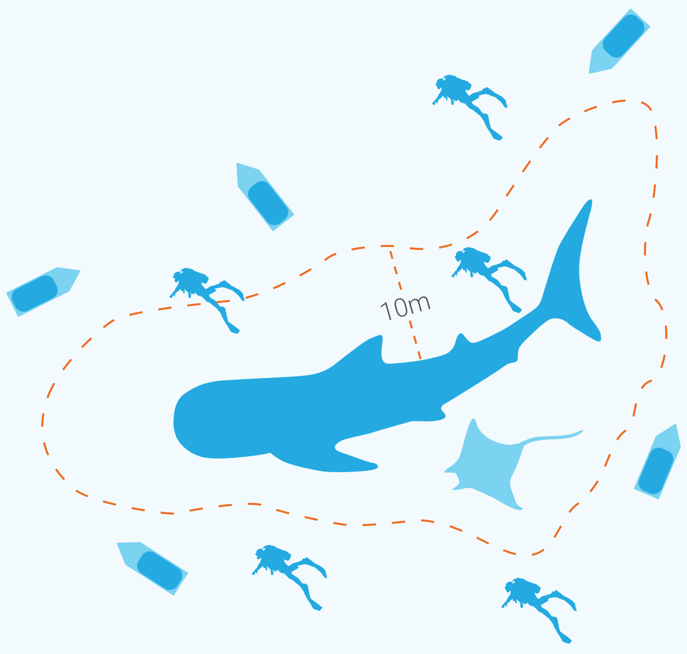


5 KUDAHUVADHOO KANDUOLHI
DH. ATOLL

1. 2° 39' 19"N, 72° 53' 03"E
2. 2° 39' 45"N, 72° 53' 03"E
3. 2° 40' 17"N, 72° 54' 04"E
4. 2° 40' 44"N, 72° 55' 27"E
5. 2° 40' 48"N, 72° 56' 33"E
6. 2° 40' 25"N, 72° 56' 45"E
7. 2° 40' 02"N, 72° 55' 57"E



C. WHALE SHARK AND MANTA RAY WATCHING GUIDELINES



10m
No vessels to come closer than 10 meters from whale sharks, manta rays or other megafauna.

5 VESSELS
Maximum 5 vessels to be engaged in close proximity to megafauna at a given time.

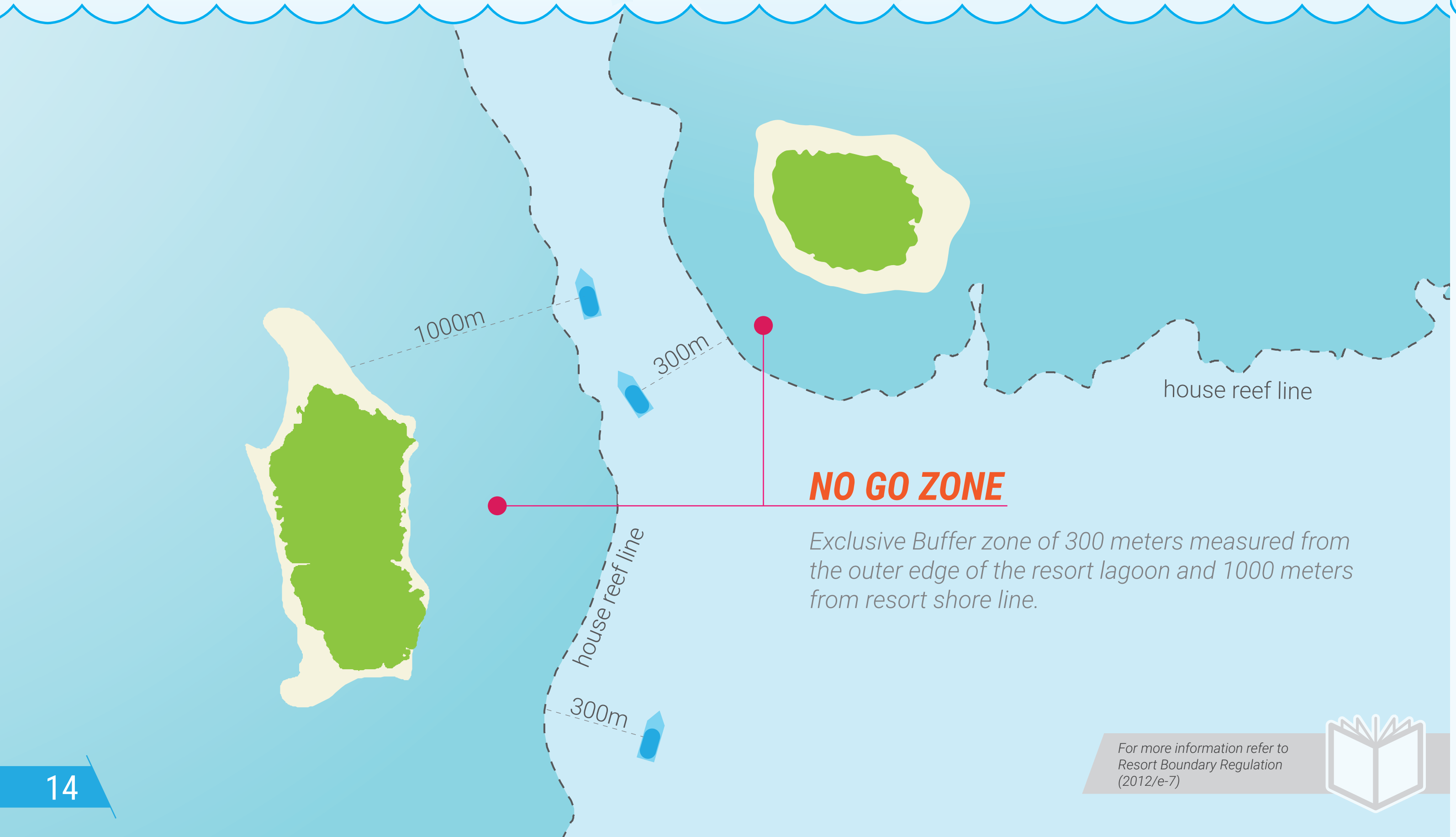
80 SWIMMERS
Maximum 80 swimmers or divers at sea at a given time.

NO DISTURBING
No disturbing or tampering whale sharks, manta rays or any other megafauna.

20m
No vessel over 20m in length, outboard engine vessels and jet skis into the buttress (fore-reef, light blue, shallow) zone.

10nm/h
Speed not exceeding 10 nautical miles per hour.

D. RESTRICTIONS AROUND RESORT AREA



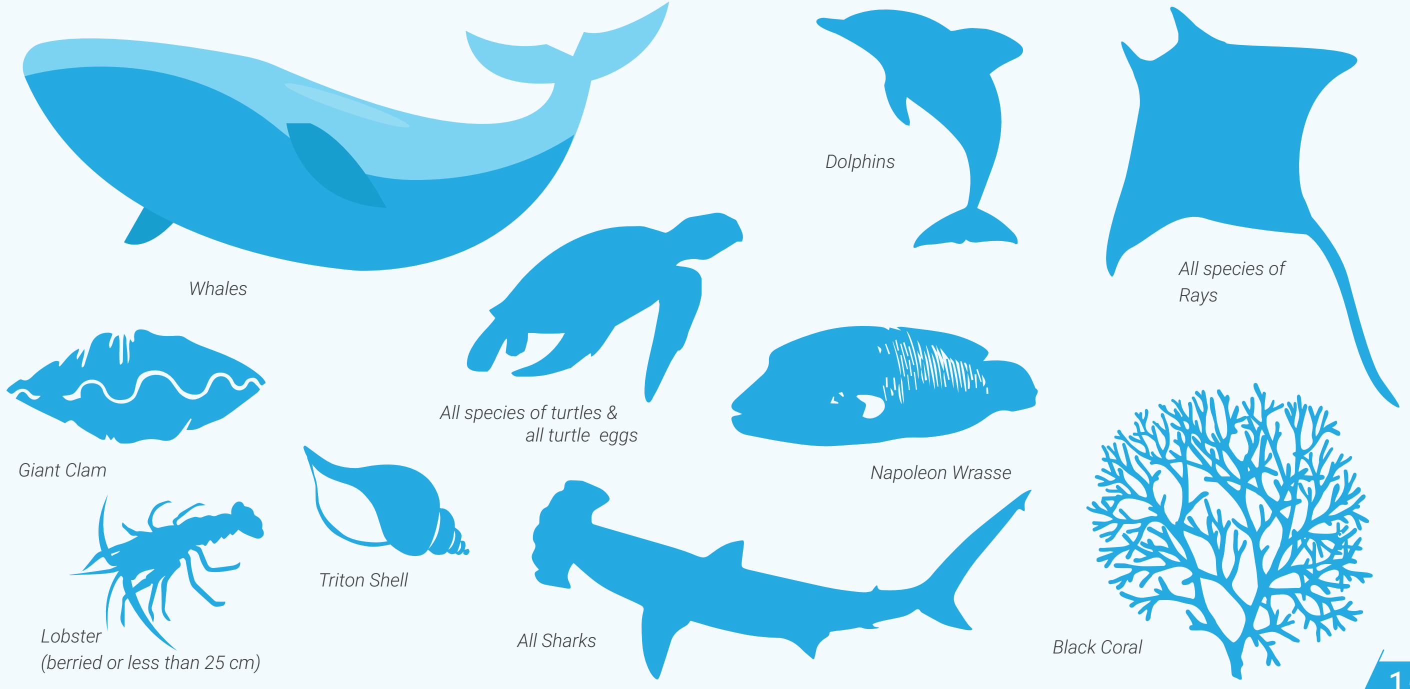
NO GO ZONE

Exclusive Buffer zone of 300 meters measured from the outer edge of the resort lagoon and 1000 meters from resort shore line.

For more information refer to Resort Boundary Regulation (2012/e-7)

PROTECTED / NO TAKE SPECIES

*Protected species are species that have been over exploited and therefore should **NOT** be caught, whatever the **SIZE***



- *Harvesting fish smaller than the size that allows it to* ***breed/reproduce at least once*** *before it is caught, i.e. its* ***maturity*** *size should be avoided*
- *A size limit ensures that the fish spawns at least once before it is caught*

PEACOCK HIND

Minimum Legal Size **20cm**

Cephalopholis argus

For more, refer to:
Grouper Fisheries Handbook
Size limits and Marine Protected Areas declared under the Grouper Fisheries Regulation

YELLOW EDGED LYRETAIL

Minimum Legal Size **22cm**

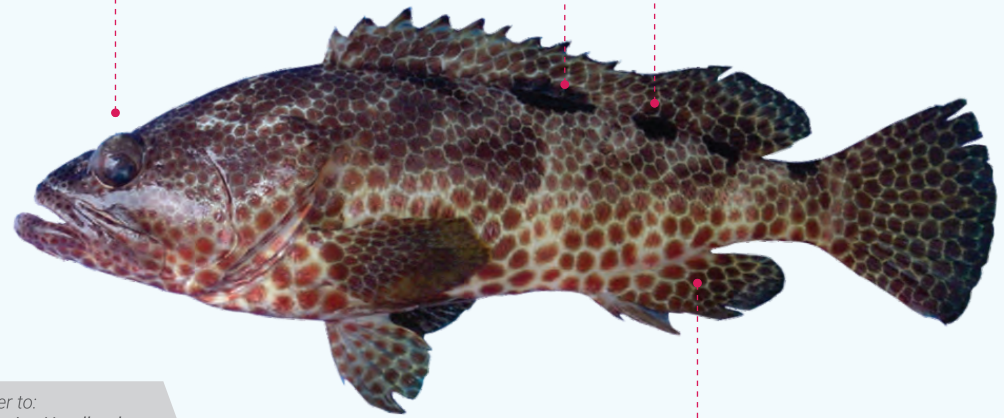
Variola louti

For more, refer to:
Grouper Fisheries Handbook
Size limits and Marine Protected Areas declared under the Grouper Fisheries Regulation

FOUR-SADDLE GROUPER

Minimum Legal Size **20cm**

Epinephelus spilotoceps



For more, refer to:
Grouper Fisheries Handbook
Size limits and Marine Protected Areas declared under the Grouper Fisheries Regulation

CAMOUFLAGE GROUPER

Minimum Legal Size **20cm**

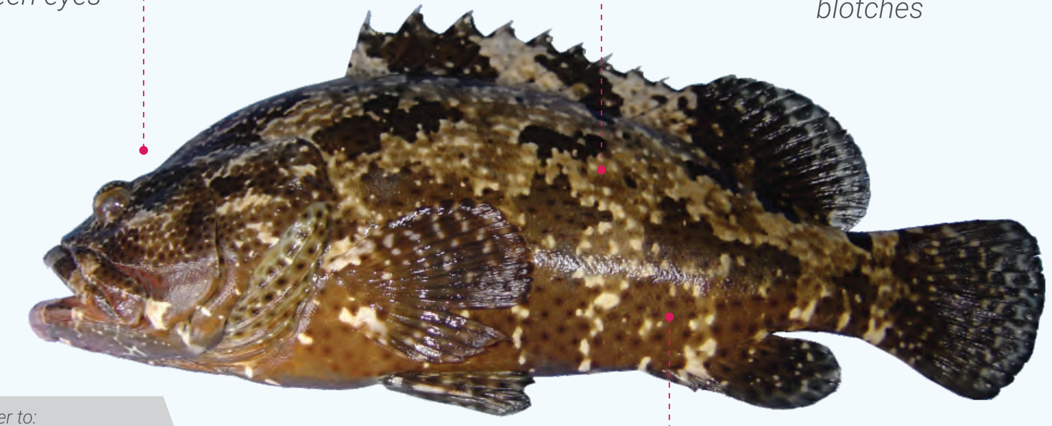
Epinephelus polyphekadion

For more, refer to:
Grouper Fisheries Handbook
Size limits and Marine Protected Areas declared under the Grouper Fisheries Regulation

BROWN-MARBLED GROUPER

Epinephelus fuscoguttatus

Legal Size Range **25-45cm and >63cm**



For more, refer to:
Grouper Fisheries Handbook
Size limits and Marine Protected Areas declared under the Grouper Fisheries Regulation

WHAT ARE THE RECOMMENDED SIZE LIMITS?

SNAPPERS

Two-spot red snapper **39cm**
Lutjanus bohar
Recommended Size

Humpback snapper **25cm**
Lutjanus gibbus
Recommended Size

WHAT ARE THE RECOMMENDED SIZE LIMITS?

EMPERORS

Long nosed emperor **34cm**
Lethrinus olivaceus
Recommended Size

Spotcheek emperor **25cm**
Lethrinus rubrioperculatus
Recommended Size

WHAT ARE THE RECOMMENDED SIZE LIMITS?

JOBFISH

Green jobfish **42cm**
Aprion virescens
Recommended Size

Rusty jobfish **42cm**
Aphareus rutilans
Recommended Size

WHAT ARE THE RECOMMENDED SIZE LIMITS?

TREVALLIES

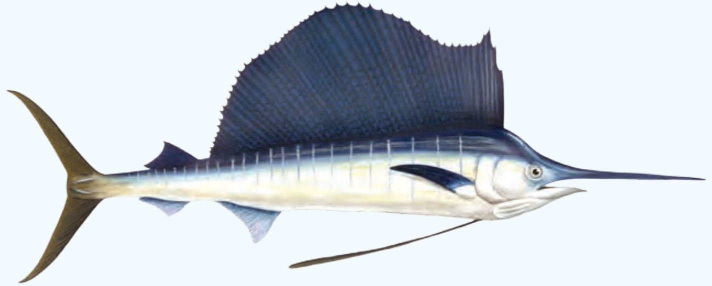
Bluefin trevally **35cm**
Caranx melampygus
Recommended Size

Giant trevally **60cm**
Caranx ignobilis
Recommended Size

WHAT ARE THE RECOMMENDED SIZE LIMITS?

OTHERS

Wahoo **100cm**
Acanthocybium solandri
Recommended Size



Indo-Pacific Sail Fish **150cm**
Istiophorus platypterus
Recommended Size

HOW TO AVOID CATCHING UNDERSIZED FISH?

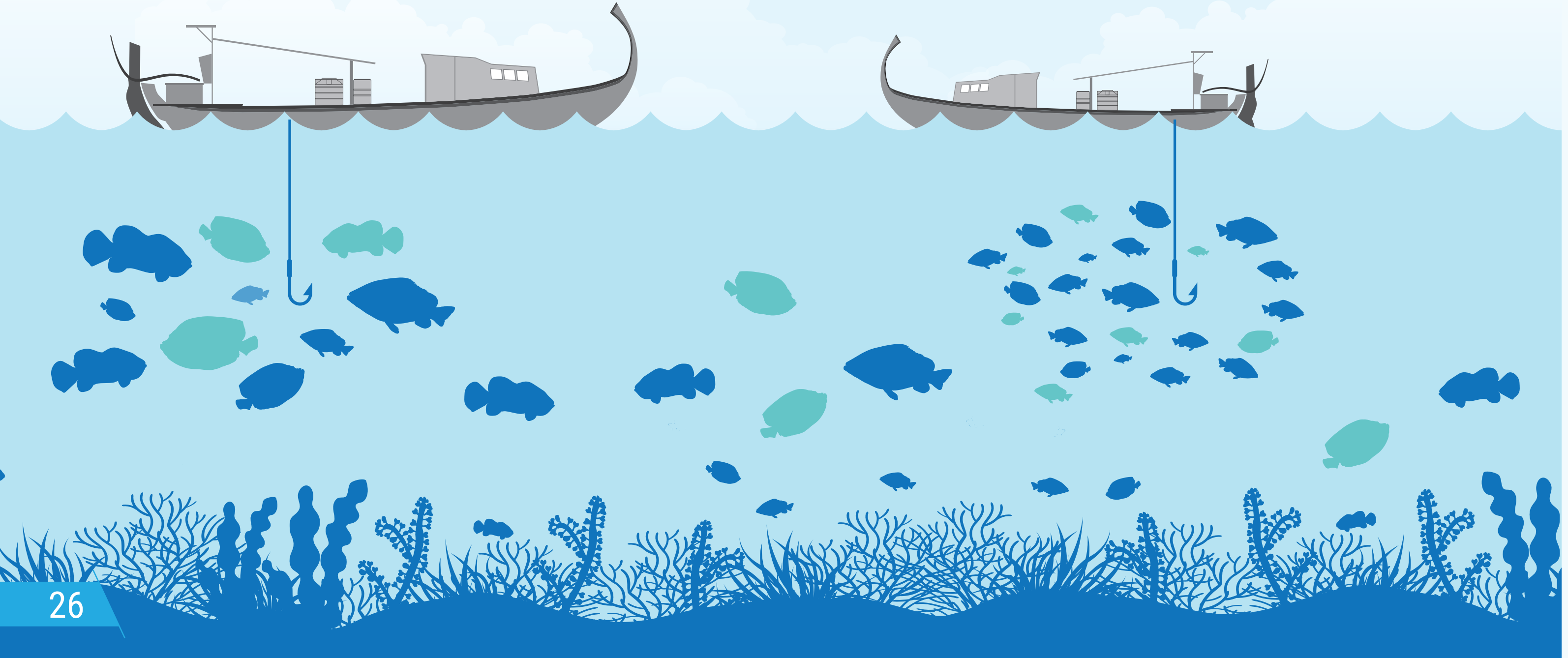
Section 8

USE

Larger hook and bigger bait

AVOID

Avoid fishing in an area where most of the fish caught are small

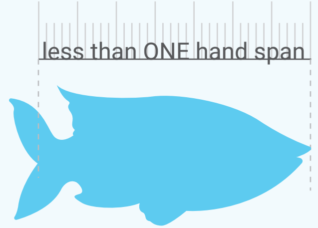


HOW TO ASSESS IF FISH SHOULD BE RELEASED OR NOT?

Section 9

IDENTIFY

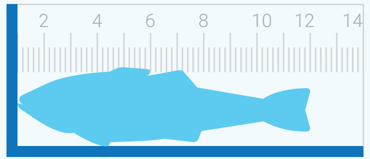
Identify whether the fish is protected or not



HAND SPAN
17-20CM

If fish is less than one hand span ("kaavaiy"), release it

IF SIZE UNCLEAR (UNDERSIZED OR NOT?):



MEASURE

Measure fish, using a measurement board

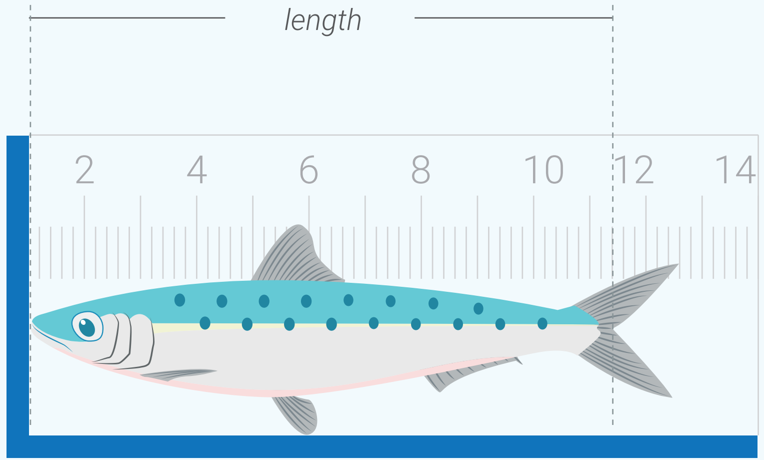
DECIDE

Decide to release, protected or undersized

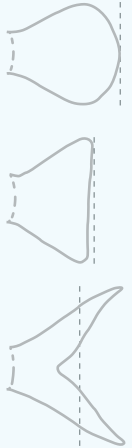
HOW TO HANDLE AND RELEASE HOOKED PROTECTED FISH AND UNDERSIZED FISH?

HOW TO MEASURE FISH?

- *Using a measuring mat / board*
- *Fish shall be measured as shown below*

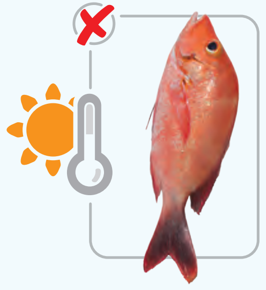


Other tail types



HOW TO HANDLE AND RELEASE HOOKED PROTECTED FISH AND UNDERSIZED FISH?

- *Hold fish around gill covers with one hand and support body with other hand*



DO NOT

drop or place on HOT, DRY deck

DO NOT

squeeze gill covers and gut area

DO NOT

poke / touch eyes, hold by eye sockets

DO NOT

hold by tail

HOW TO HANDLE FISH?

If fish is to be released, the rule is to maximize its survival, avoiding damage to fish (protective mucus and internal organs) through proper handling

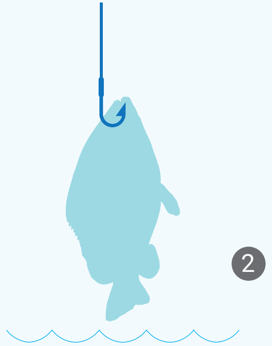
- *Fish should be kept in water if possible*
- *If possible wear gloves to handle fish. If not, hands must be wet*

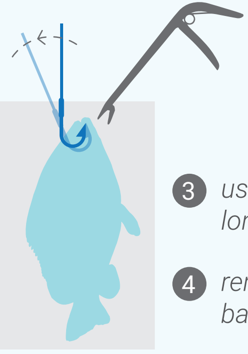
- *Fish should be taken out of water*
  - *Only if necessary (i.e. to measure it and decide whether it needs to be RELEASED or not)*
  - *Shortest possible duration*
- *Whenever possible, fish should be laid on a soft wet surface (sponge or towel), or on a measuring mat / board*

HOW TO DEHOOK FISH?

Ideally, unhook fish while still in water

MOUTH OR LIP-HOOKED

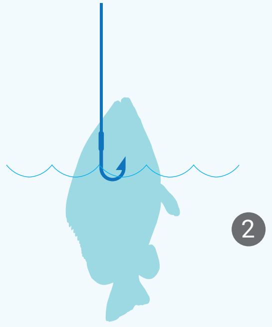


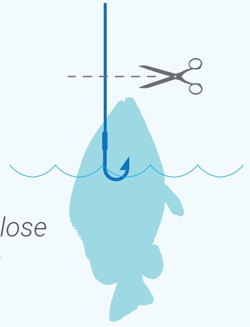


1. *lift small fish by line*
2. *place on a wet, soft surface*
3. *use hook remover or long-nosed pliers*
4. *remove hook backwards carefully*

GUT OR GILL HOOKED

(or hook NOT visible/swallowed)





1. *DO NOT lift by line*
2. *cut line as close to mouth as possible*

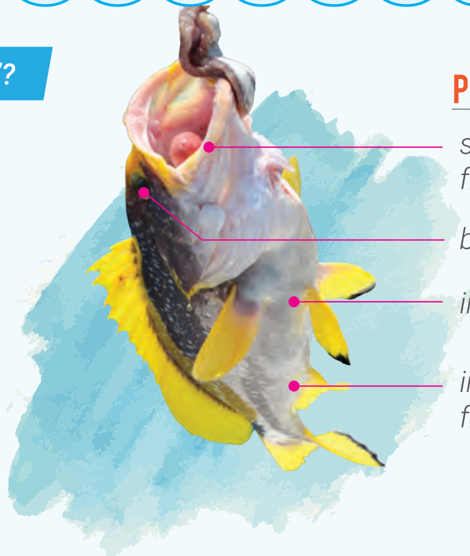
HOW TO RETURN FISH TO THE SEA?

Gently return fish to the sea, head first, ventral side facing down, from the lowest possible height

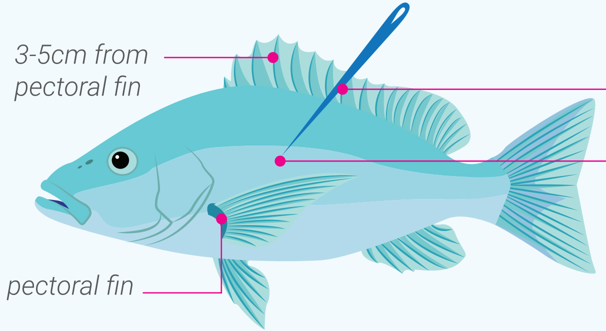
WHAT TO DO IN THE CASE OF "BAROTRAUMA"?

Barotrauma happens when a bottom-dwelling reef fish is reeled up quickly to the surface of the water

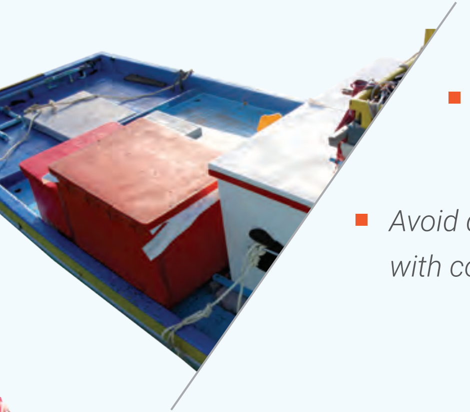
Venting or punching the swim bladder allows the expanded air to escape



HOW TO VENT A FISH?

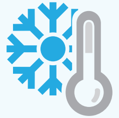


The method may vary slightly with species



- Avoid fish thrashing on the deck
- Avoid direct sun exposure, avoid contact with contaminants

- **DO NOT** step on fish

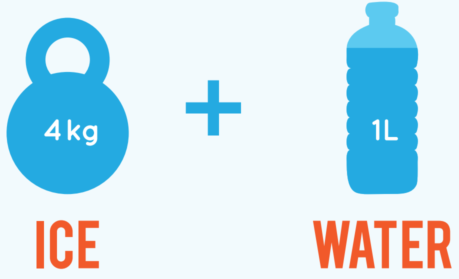


- It is best to use ice, even on a daily fishing trip

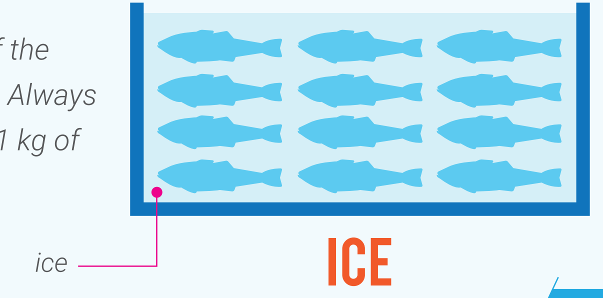
- Put fish in the container or fish hold as soon as possible after catch (during trip from one fishing ground to the other), preferably with ice
- Ensure that fish is stored as rapidly as possible, most preferably with ice

MAKING AN ICE SLURRY

Make an ice slurry, with a proportion of 4 kgs of ice for 1 litre of clean water

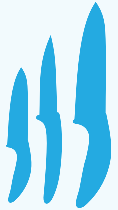


- Alternatively, use ice, putting first a layer of ice at the bottom of the container or hold, then alternate layers of fish and layers of ice. Always maintain fish fully covered with ice and keep a ratio of at least 1 kg of ice for 2 kgs of fish



PREPARATION FOR GUTTING

Wash your hands with soap



Use clean utensils

- Preferably, unload using baskets

HANDLING OF FISH

- Avoid stepping on fish, or leaving it in the sun
- Gut fish as rapidly as possible after it has been unloaded
- Avoid working directly on the floor. Preferably use a clean working table (non-wooden)

GUTTING A FISH

- After cutting the abdomen from the anus, remove quickly and completely the gills, viscera and other internal organs
- Avoid spilling the gut contents on the cut surfaces of the fish, damaging the abdominal cavity

- Remove completely the bloodline
- Wash the fish carefully with clean water
- Wash the working place, utensils and hands carefully

DO NOT LITTER AT SEA!

Estimated life span (decomposition rates) of common ocean debris

Apple Core	2 MONTHS
Cardboard Box	2 MONTHS
Cigarette Butt	1-5 YEARS
Plastic Bag	10-20 YEARS
Styrofoam Cup	50 YEARS
Tin Can	50 YEARS
Aluminium Can	200 YEARS
Plastic Bottle	450 YEARS
Glass Bottle	UNDETERMINED

Estimated individual item timeline depends on product composition and environmental conditions

Sources: U.S. National Park Service; Mote Marine Lab, Sarasota, FL and "Garbage In, Garbage Out," Audubon magazine, Sept/Oct 1998

USEFUL INFORMATION

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Ministry of Environment and Energy
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Maldives Police Service
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Boduthakrufaanu Magu ,
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Fax: +(960) 331 3291
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Fax: +(960) 332 2512
Email: info@tourism.gov.mv

Ministry of Fisheries & Agriculture

MASPLAN

JICA

Overview of reef fish sampling in K. Dhiffushi – Nov-Dec 2016

Mohamed Shimal,
Marine Research Center

Marine Research Centre's staff participated in three trips organized under JICA MASPlan Reef fish pilot project to (i) observe fish supply operation to the Middleman in K. Huraa and carryout species-length sampling, (ii) introduce and guide the marine biologists at Four Season's resort on species-size sampling protocol and (iii) to build a strong working relationship with resorts and middlemen engaged in the pilot project.

1. Summary of sampling at K. Huraa, 8^{th}-10^{th} November – (Mohamed Shimal, Fahmeeda Islam, Shifana Wafeer)

The reef fish species-length sampling was carried out on six occasions when fishes were sold to, Mr. Wahid, the fish middleman at the island. This includes fish bought directly from fishing vessels, from Male' market, from the island and from the reef fishers in K. Himmafushi. All fishes were said to be bought at rate of MRF 35 per kg. The table below summarizes the fish deliveries sampled.

Table 1. Summary of fish deliveries sampled at K.Huraa from 8^{th} to 10^{th} November 2016.

#	Date	Source of fish	Fishing type	No of fishermen (excl. bait chummer)	Weight (kg)	Total number of fishes	No of species
1	8-11-2016	P1164 015H / Dhilaasa	Live bait; handline; single day	10	133	84	15
2	9-11-2016	From the island [1]	-	-	33	7	6
3	9-11-2016	Bought from Malé fish market	-	-	75	46	4
4	9-11-2016	From Himmafushi reef fishers [2]	-	-	51	63	6
5	9-11-2016	P1164 015H / Dhilaasa	Live bait; handline; single day	10	169	126	38
6	9-11-2016	PL tuna vessel / Misraab 3	Live bait; Pole and Line; Multi-day (2 days)	15	174	97	1
				Total	635	423	

[1] It was only possible to identify that fishes (in a basket) came from a local fisher(s) and no other information were available.

[2] These fishes were bought from Himmafushi when one of Mr. Wahid's supply boat visited the island to buy ice. A person from the supply boat informed that the fishes were bought from local fishers who use small dinghies.

2. Summary of sampling at K. Huraa, 30th November -3rd December 2016 – (Mohamed Shimal, Fahmeeda Islam, Bernard Adrien)

The reef fish species-length sampling was done on 3 occasions during this trip when fishes were brought to Mr. Wahid. All the fishes were bought at a rate of MRF 35 per kg except from the vessel owned by Mr. Wahid (#3 in Table 2) from which fishes were bought at a rate of MRF 45 per kg. It was observed that 40 fishes (22kg in total) were rejected from Mr. Wahid's vessel citing they were too small. These were taken by fishermen for home consumption. The table 2 below summarizes the fish deliveries sampled on this trip.

Table 2. Summary of fish deliveries sampled at K. Huraa from 30th November to 3rd December 2016.

#	Date	Source of fish	Fishing type	No of fishermen (excl. bait chummer)	Weight (kg)	Total number of fishes	No of species
1	30-11-2016	P1164 015H / Dhilaasa	Live bait; handline; single day	10	77	57	11
2	30-11-2016	Dhoani / Recreational	Rod and reel; artificial lure	2	13	2	1
3	01-12-2016	Dhoani [1]	Fish chunks; Weighted-handline; Multi-day (4 days)	3	554	446	29
				Total	631	505	

[1] This vessel is owned by Mr. Wahid and usually go out for multi-day fishing outside of Kaafu Atoll. On this occasion, the vessel returned after 4 days of fishing in Noonu Atoll.

3. Detailed overview of purchase information

- Composition

The information presented here is a combined summary of sampling data obtained on aforementioned trips to K. Huraa.

The fish middleman at K. Huraa sourced reef fish from 7 different sellers during the four days of sampling. These purchases amount to a total of 1244 kg of reef fish, comprising 7 families of reef fish and at least 42 different species. Out of 888 fishes purchased, 93.9% of fishes belonged to three families; Lethrinidae (Emperors and breams), Carangidae (Trevallies and Jacks) and Lutjanidae (Snappers). Other reef fish families within the purchased fishes were Serranidae (Groupers), Sphyraenidae (Barracuda), Holocentridae (Squirrel fishes) and Haemulidae (Grunts). Three species from three major families found in the purchased fishes accounted for more than half of the species composition. These species are; *Lethrinus microdon* (Smalltooth emperor), *Elagatis bipinnulata* (Rainbow runner) and *Aprion virescens* (Green jobfish). The table 3 below provides more details on the family, species composition of purchased fishes.

Table 3. Family and species composition of reef fishes purchased.

Family *Species*	Total count per Family Count per species	% composition by family by species
Lethrinidae	**345**	**38.9**
Lethrinus microdon	250	28.2
Lethrinus olivaceus	43	4.8
Gymnocranius griseus	15	1.7
Lethrinus conchyliatus	10	1.1
Lethrinus sp.	10	1.1
Lethrinus xanthochilius	10	1.1
Lethrinus rubrioperculatus	3	0.3
Lethrinus letjan	2	0.2
Lethrinus erythracanthus	1	0.1
Wattsia mossambica	1	0.1
Carangidae	**325**	**36.6**
Elagatis bipinnulata	153	17.2
Gnathanodon speciosus	54	6.1
Caranx sexfasciatus	44	5.0
Caranx melampygus	40	4.5
Carangoides orthogrammus	8	0.9
Caranx ignobilis	8	0.9
Seriola rivoliana	6	0.7
Carangoides sp.	5	0.7
Carangoides coeruleopinnatus	6	0.6
Carangoides ferdau	1	0.1
Lutjanidae	**164**	**18.5**
Aprion virescens	113	12.7
Lutjanus gibbus	22	2.5
Lutjanus bohar	13	1.5
Aphareus rutilans	6	0.7
Pritipomoides filamentosus	5	0.6
Pinjalo lewisi	4	0.5
Macolor macularis	1	0.1
Serranidae	**40**	**4.6**
Epinephelus areolatus	9	1.0
Cephalopholis sonnerati	6	0.7
Aethaloperca rogaa	5	0.6
Cephalopholis miniata	5	0.6
Epinephelus miliaris	4	0.5
Epinephelus longispinis	3	0.3
Epinephelus flavocaeruleus	2	0.2
Epinephelus fuscoguttatus	2	0.2
Plectropomus laevis	2	0.2
Plectropomus pessuliferus	1	0.1
Variola louti	1	0.1
Epinephelus chlorostigma	1	0.1

Sphyraenidae	**11**	**1.2**
Sphyraena spp.	11	1.2
Haemulidae	**1**	**0.1**
Plectorhinchus chaetodonoides	1	0.1
Holocentridae	**1**	**0.1**
Sargocentron spiniferum	1	0.1

- Size

The figures 1, 3 and 5 shows average sizes of species purchased for the three most common families of reef fish during the 4 days of sampling. Generally, length of fishes belonging to these families varied from about 30cm to 60cm. However, small sizes recorded for some species do not indicate either over-exploitation or a change in population structure due to consistent fishing pressure. Rather, the small size for some species may be due to natural size-growth ranges for these species. Any concrete inferences relating to population will not possible with a small sample size and with only two datasets obtained over a short period of time. Hence, continuation of sampling is required to enrich this dataset, to use with other MRC's reef fishery sampling datasets, and to derive usable statistics to understand the fishery and its impacts on reef fish populations.

In addition to the average sizes of all the species purchased, size distribution is also provided for the three most common species purchased during the 4 days of sampling. The sample size of each of these species exceeded over 100 individuals; hence the size distributions may indicate how the fishery could impact the population of these species if exploitation of these size classes continues. However, similar to what's mentioned above, continuation of sampling and its use in combination with other MRC's sampling datasets will yield a more certain conclusions on impacts of reef fishery on reef fish population.

Lethrinidae

- The figure below shows the average sizes of 10 Lethrinidae species purchased during the 4 days of sampling at K. Huraa.

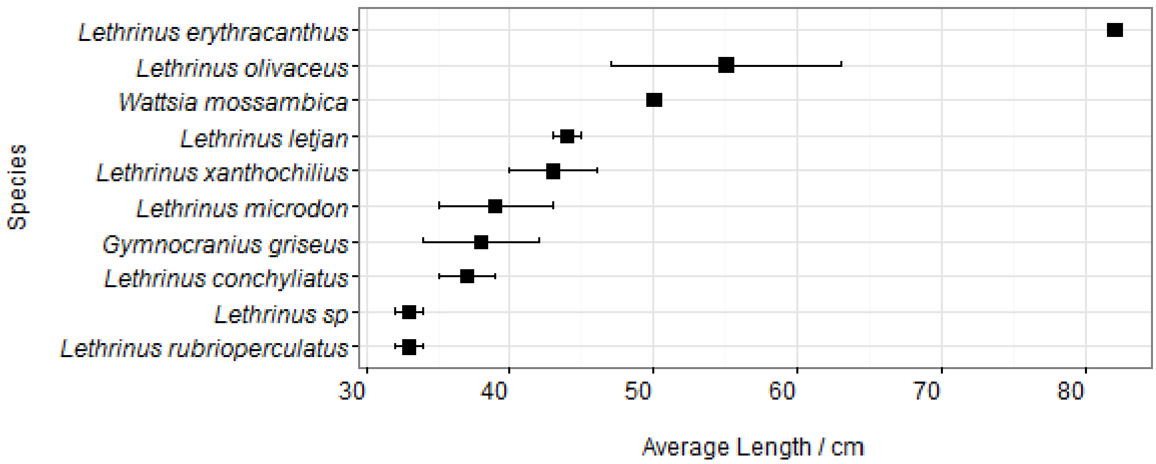

Figure 1. Average size (± standard deviation) of Lethrinidae species purchased. (For number of samples 'n' per species refer to Table 3).

- The size distribution graph for *L. microdon* (Figure 2) indicates that all the fishes purchased were over the maturation length.

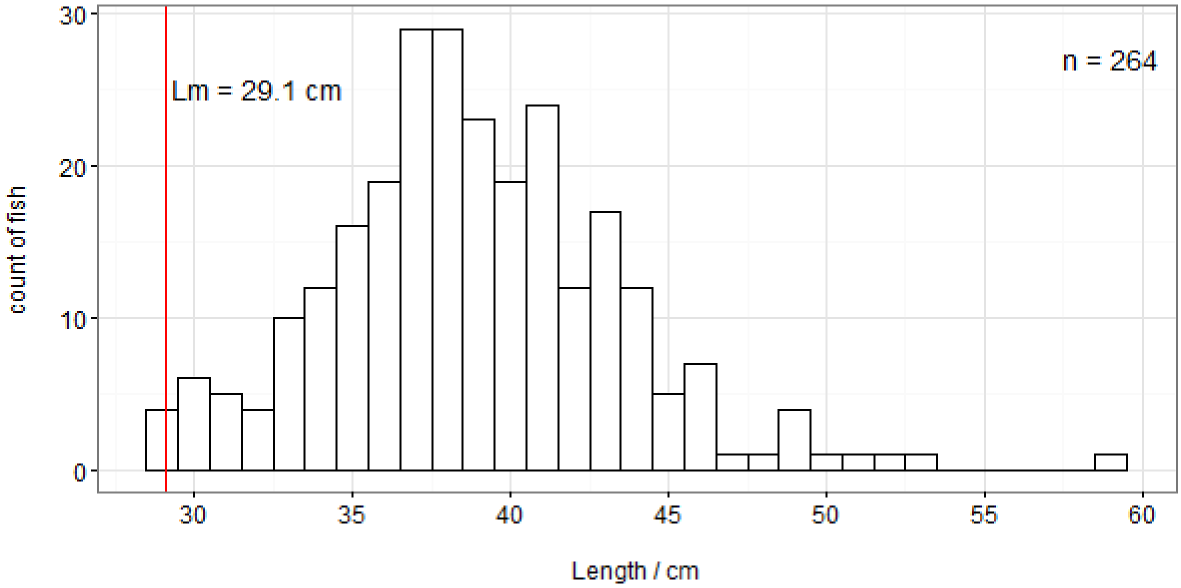

Figure 2. Size distribution of *L. microdon* (Smalltooth emperor). Lm = Length at Maturity (females) [i]

Carangidae

- The figure below shows the average sizes of 10 Carangidae species purchased during the 4 days of sampling at K. Huraa.

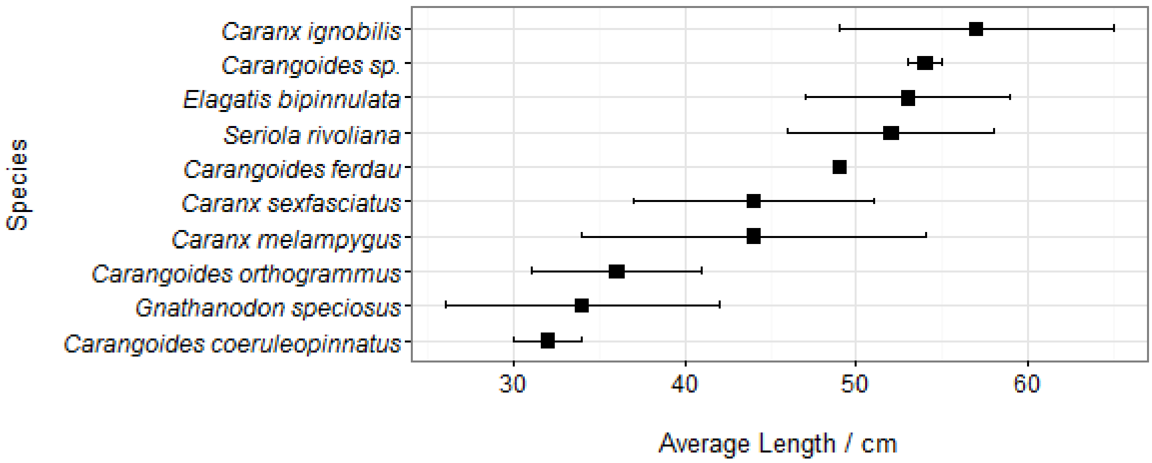

Figure 3. Average size (± standard deviation) of Carangidae species purchased. (For number of samples 'n' per species refer to Table 3)

- The size distribution graph for *E. bipinnulata* (Figure 4) indicates that most of the fishes purchased were well below the maturation length.

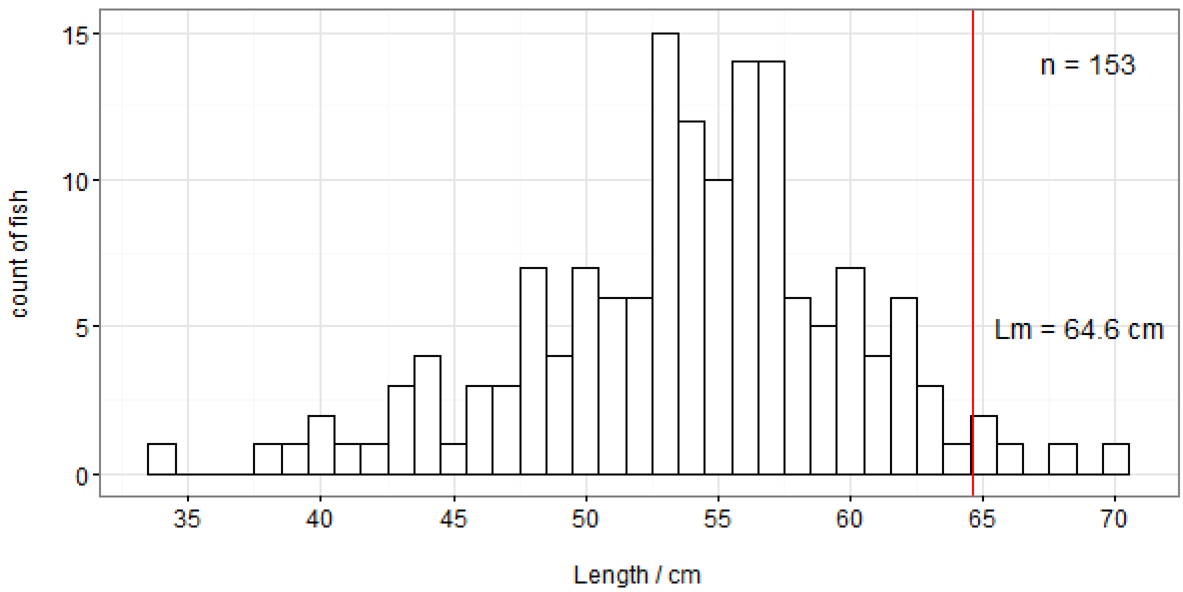

Figure 4. Size distribution of *E. bipinnulata* (Rainbow runner). Lm = mean length at maturity (females) [ii]

Lutjanidae

- The figure below shows the average sizes of 7 Lutjanidae species purchased during the 4 days of sampling at K. Huraa.

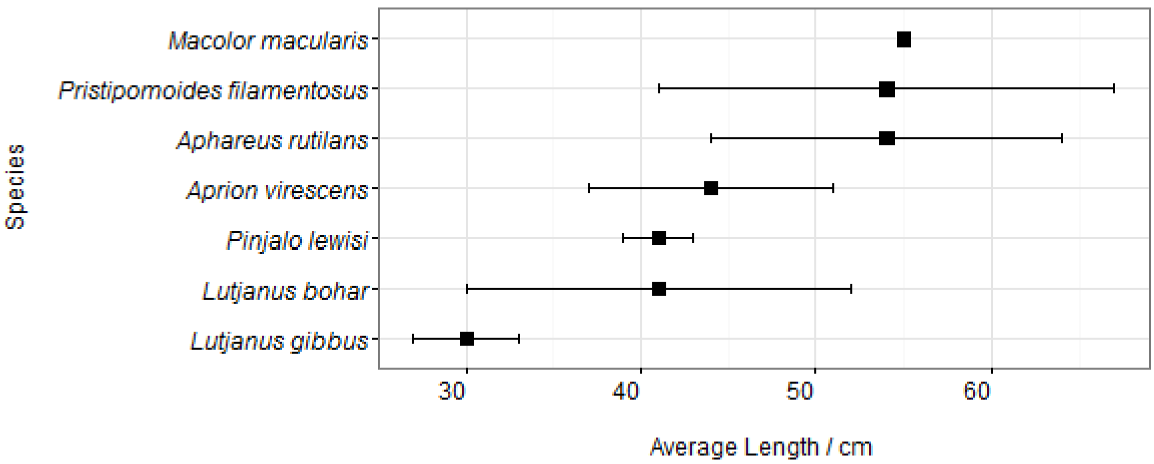

Figure 5. Average size (± standard deviation) of Lutjanidae species purchased. (For number of samples 'n' per species refer to Table 3)

- The size distribution graph for *A. virescens* (Figure 6) indicates that almost half of the fishes purchased were below the maturation length.

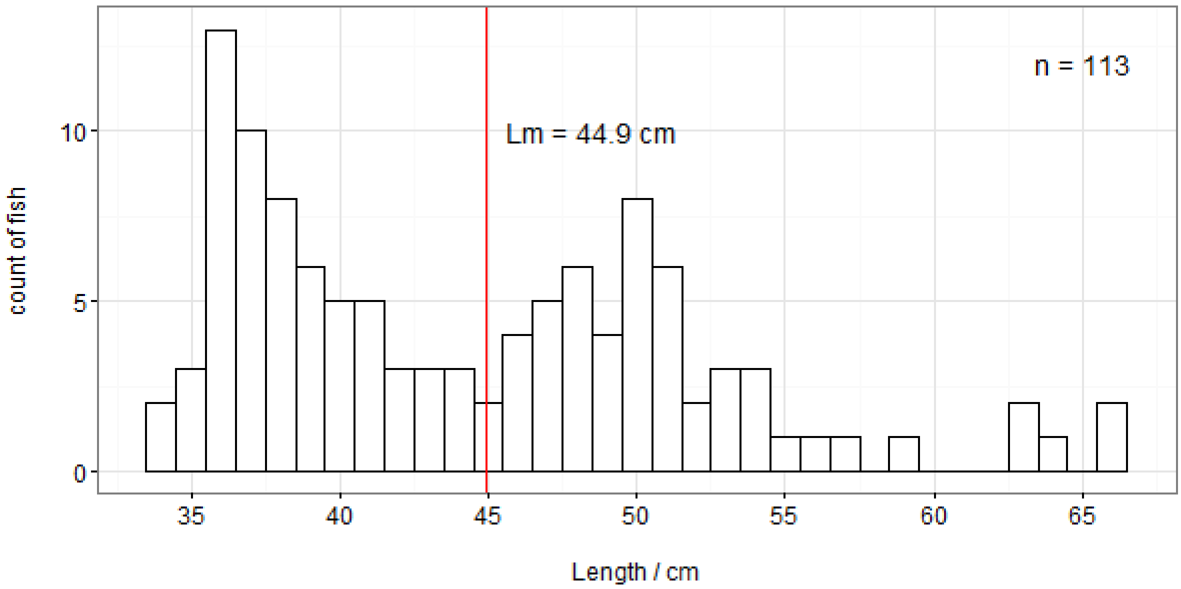

Figure 6. Size distribution of *A. virescens* (Green jobfish). Lm = Length at maturity (females) [iii]

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[i] Fishbase, accessed 10th January 2017, <www.fishbase.org/summary/1845>
[ii] Fishbase, accessed 10th January 2017, <www.fishbase.org/summary/412>
[iii] Fishbase, accessed 10th January 2017, <www.fishbase.org/summary/84>

PP-5.　モルディブ国における選定魚種の養殖にかかるフィージビリティ調査

1) Applicable Method of Groupers and Sandfish Culture in Maldives

2) Pilot Study on Grow-out Culture of Sandfish (*Holothuria scabra*) in Bottom-set Sea Cages in Lagoon

3) Grouper grow-out operations in the Maldives

4) Small-scale Sandfish grow-out operations in the Maldives

Applicable method of Groupers and Sandfish culture in Maldives

April 2016

Master Plan for Sustainable Fisheries (MASPLAN)

Japan International Cooperation Agency (JICA)

Table of contents

Chapter 1. Grouper culture

1. Introduction

1-1. Groupers production

In the FAO statistics, there are 45 species of groupers production data in the fisheries and aquaculture commodities. The 11 species in aquaculture are recorded. Groupers belong to family Serranidae, Subfamily Epinephelinae and over 100 species of groupers are known worldwide. The habitation of the groupers is widely in subtropical and tropical area.

The groupers are one of the important trading and high valued fish species in Asia countries for the Chinese dishes. According to the FAO statistics, the groupers production in Asia covered over 94% of the total production in the world. The production of the groupers in Asia is shown in Figure 1. The consumers in China, Hong Kong, Singapore and Malaysia prefer the wild groupers (Silh 2004). Among 85 species of the wild groupers (Serranidae), 43.5% of them are considered as threatened species, and of which two are endangered, and the remaining 35 are vulnerable (Annalie 2000). Therefore, the trend of the aquaculture production is increasing continually. It also indicates that the captured production will not increase any more. The groupers are carnivorous species in the habitation of reef and coastal area. It is difficult to recover the declining natural resource due to the overfishing. Therefore, it seems that it is necessary to increase the aquaculture production to meet the demand.

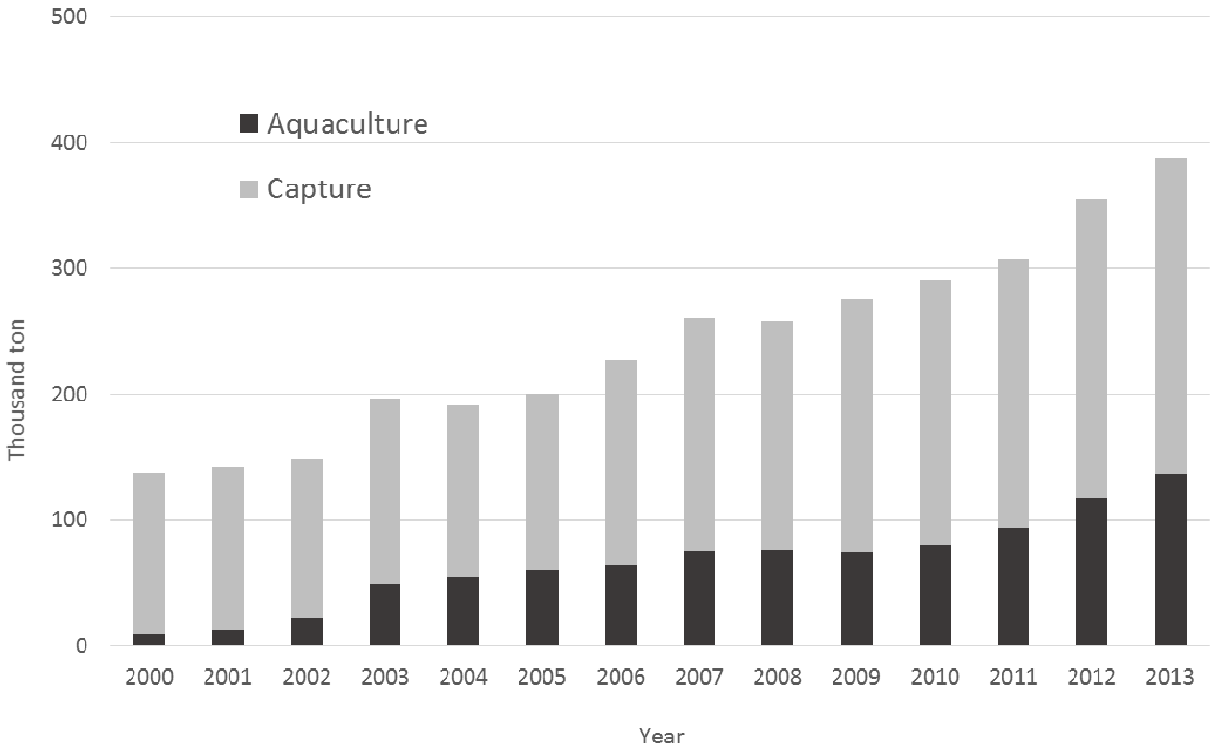


Figure 1 . Total production of groupers including aquaculture production in Asia

Source: FAO (http://www.fao.org/fishery/en)

Figure 2 shows the main production countries of the groupers are China, Taiwan, Indonesia, Malaysia and Thailand. Vietnam and Maldives. Those countries are located near China, main consumer country.

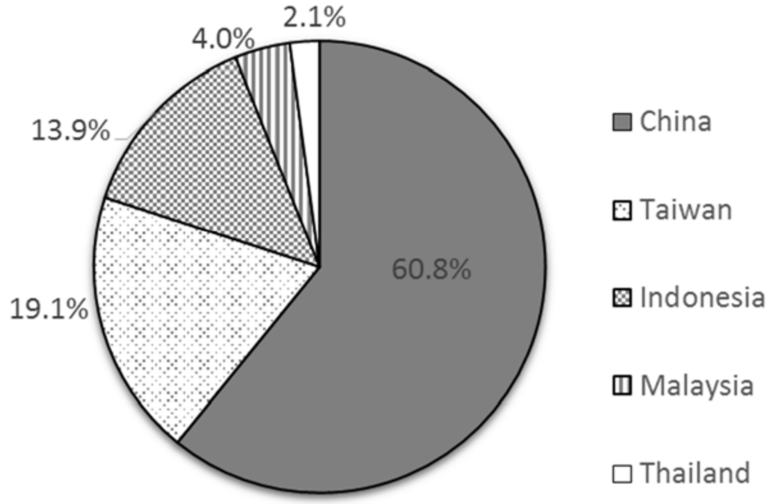


Figure 2. Groupers production by countries
Source: FAO (http://www.fao.org/fishery/en)

1-2. Groupers in Maldives

The below table shows the 23 groupers habitat in Maldives. Giant grouper and Brown-marbled grouper in the list will be target species for aquaculture. Mariculture Training and Demonstration Facilities (MTDF) in Manifafushi Island as governmental aquaculture station has been already producing the juveniles of Brown-marbled grouper through natural spawning. According to IUCN, Black-saddled coral grouper and Giant grouper are being designated as vulnerable species.

Table 1. List of groupers inhabit in Maldives, candidate culture species and the evaluation of the resources

(Source: MRC, FAO and IUCN)

Scientific name	English name	Aquaculture species	Evaluation of the resource
Cephalopholis argus	Peacock hind		LR/lc
Cephalopholis miniata	Coral hind		LR/lc
Cephalopholis sexmaculata	Sixblotch hind		NE
Cephalopholis sonnerati	Tomato hind		LR/lc
Cephalopholis aurantia	Golden hind		DD
Plectropomus areolatus	Squaretail coral grouper		Vulnerable
Plectropomus pessuliferus	Roving coral grouper		LR/nt
Plectropomus laevis	Black-saddled coral grouper		VN
Aethaloperca rogaa	Red mouth grouper		NE
Anyperodon leucogrammicus	Slender grouper		LR/lc
Variola louti	Yellow edged lyretail		LR/lc
Variola albimarginata	White edged lyretail		LR/lc
Epinephelus fuscoguttatus	Brown-marbled grouper	+	LR/nt
Epinephelus flavocaeruleus	Blue and yellow grouper		LR/lc
Epinephelus lanceolatus	Giant grouper	+	VN
Epinephelus polyphekadion	Camouflage grouper		LR/nt
Epinephelus spilotoceps	Four-saddle grouper		LR/lc
Epinephelus macrospilos	Snubnose grouper		LR/lc
Epinephelus areolatus	Areolate grouper		LR/lc
Epinephelus chlorostigma	Brown-spotted grouper		LR/lc
Epinephelus caeruleopunctatus	White-spootted grouper		LR/lc
Epinephelus ongus	White streaked grouper		LR/lc
Epinephelus miliaris	Netfin grouper		LR/lc

VN: Vulnerable, LR/nt: Low Risk (Near Threated), LR/lc: Low risk (Latest Concern)
DD: Data Deficient, NE: Not Evaluated

The groupers fisheries in Maldives provide an important source of income for the population. It is estimated that about 14,000 individuals are involved in full-time fishing activities (FAO 2009). The export volume of the groupers from Maldives is shown in Figure 3. The export-based grouper fisheries started in 1994. At first, fishing was concentrated in the central atolls, but later it has spread to all over the country (FAO 2009). The groupers in Maldives are mostly traded in fresh, chilled and fillet or live fish. The buying price of a fish varies with size and species (Shahaama et al. 2011). The commercial size of the groupers is 500 g to 600 g/fish. According to the interview to a large scale export company, the price of live groupers is 100 - 120 MVR/kg depend on the body size at landing site (Comment by Doi 2015). Although, the export volume of live groupers was larger than that of the fresh and chilled groupers until 2004, at the moment most of the export is processed to fresh, chilled and fillet. A total weight of the export reached 900 ton in 2012 and decreased in 2013. The main destinations of the export are Hong Kong, Taiwan and Thailand. Live groupers are being exported around 10 ton every year. Almost 100% of the live groupers is exported to Hong Kong (Shahaama et al. 2011).

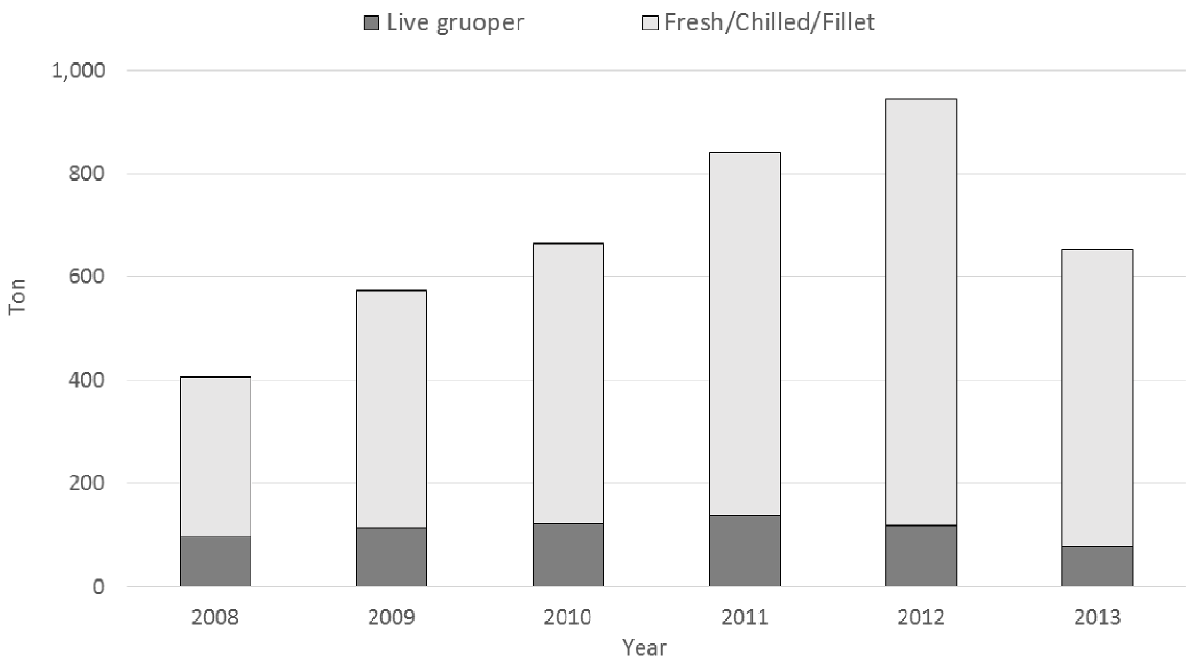


Figure 3. Export of the groupers from Maldives
(Source: Maldives statistic 2008-2013)

On the other hand, a company of the grouper exports raises the commercial size fish from the captured small groupers (300g) by using canning factory's offal as the feed for 2 months (Survey report by MASPLAN 2015).

Although Maximum Sustainable Yield (MSY) of the groupers in Maldives is estimated to 2,118 ton (Darwin reef fish project 2011), it is pointed out that the estimate of total groupers catch shows a sharp declining trend (Shahaam 2005). It is deeply worried that the natural resource of groupers is declining due to overfishing in Maldives. Mean length of the groupers in 2003 is significantly smaller than the 2010. The 70% of the individuals belonging to the common groupers are caught prior to reaching their theoretical maturity lengths (Shamaama 2011). It seems that the cause of the affect is over fishing of the groupers. Therefore, the production by capture fishery should be managed in the future in order to recover the natural resource of the groupers in Maldives.

In domestic consumption, according to the latest survey, approximately 4,000 ton of reef fish including groupers is estimated to be landed in the resorts of whole country (MASPLAN 2016). According to the survey of MASPLAN, the average price of the reef fish (not alive) including groupers at the resort is 40.1 MVR/kg (Muawin et al 2016).

In Maldives, the wild groupers that caught in reef fisheries can be used as the broodstock for the seed production. There are fish meal and residues produced in processing factory for Skipjack and Yellowfin tuna. Those factors indicate that there is a high potential to develop the groupers culture in Maldives. Although, the fingerlings of *Epinephelus fuscoguttatus* were produced in MTDF, the grouper culture isn't extended yet in Maldives. There is no hatchery and grow-out of commercial base in private sector so far. Additionally, there is no reviews to confirm the feasibility of the grouper culture in terms of economic and technical discussion.

The purposes of the review are to summarize the methods for the groupers grow-out, to make discussion for the feasibility.

2. Methods of groupers culture for Maldives

The table size of the groupers in China is 400 - 800 g/fish which can be served in a plate. The juveniles of 10 cm in total length can be stocked in net cages for grow-out. Usually, the juveniles grow to reach the table size after 7 – 8 months in the floating net cages. The juveniles caught in the wild and produced in hatchery are used. 70 percent of the groupers production relies on the wild -caught seeds (Sena S. De Sliva et al. 2007). The wild juveniles are stable quality. However, the supply isn't stable depending on the natural resource and the condition. In the hatchery juveniles, it can be supplied stably by mass production. However, the deformity juveniles in the early stage caused by nutrition and physical shock often appeared.

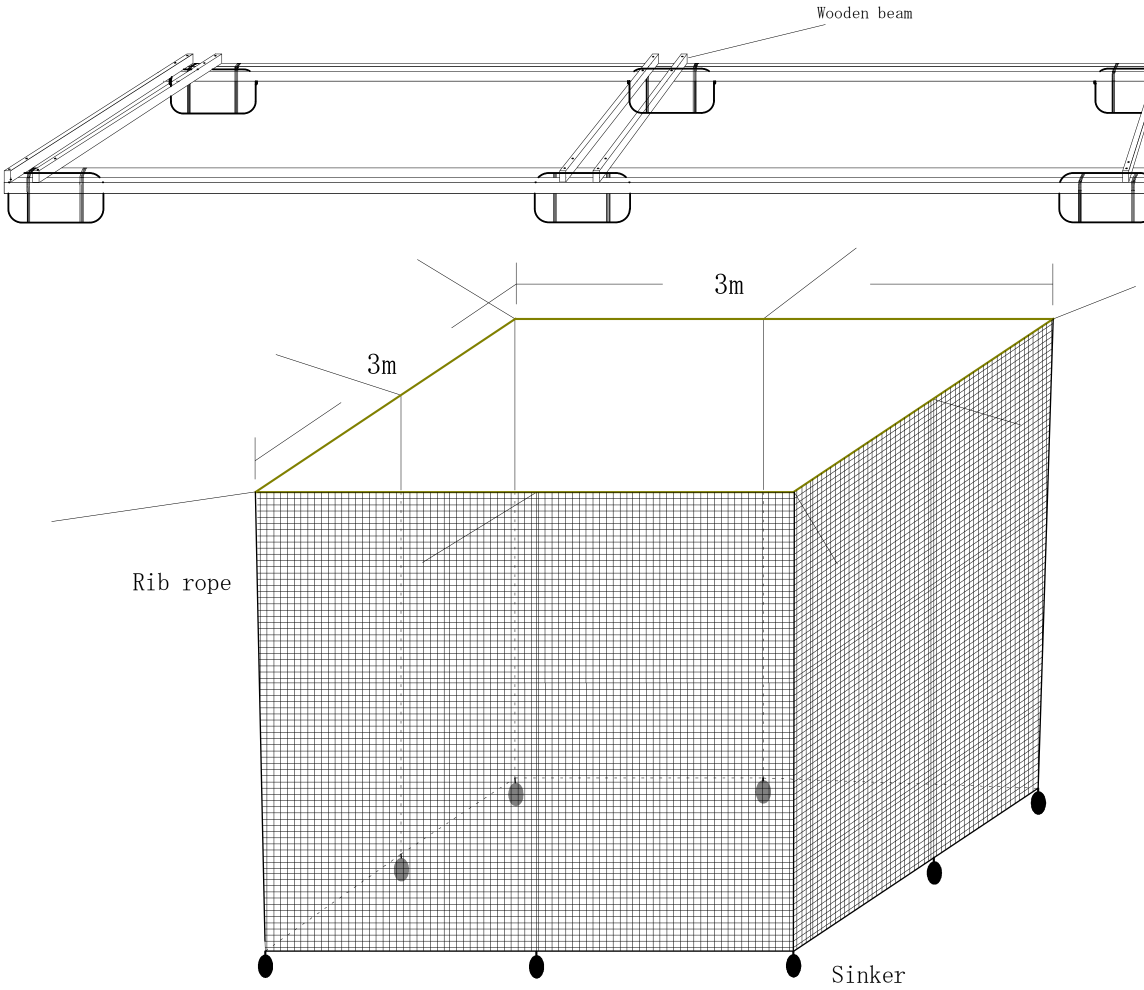
The groupers culture are carried out by a variety of methods such as; floating net cage culture, pond culture and on-land culture including running water system and closed recirculating system. The floating net cage culture is most popular method for the groupers. The productivity of the cage culture is higher than other methods. The initial cost is lower than the others. However, this method is affected by natural condition such as high wave, strong wind, and water pollution. Therefore, the location is limited by the environmental and geological condition. The closed recirculating system in on-land culture is up-to date method and expanded in European countries. This system can use sea water isolated from natural environment and produces the safety fish without disease and water pollution. Since the organic matters discharged from the culture facilities is trapped in the filtering system, it is environment friendly method. The closed recirculating system will be suitable for the Maldives, if the groupers culture is feasible and advanced. However, the initial investment and running cost is highest of all the methods.

The land area in Maldives is limited to use pond culture. In consideration of the development of the groupers culture at present, closed recirculating system is too early to introduce in Maldives. Therefore, the floating cage culture was focused on in the review.

3. Floating net cage culture

3-1. Design of the floating net cage

The design of the floating net cage (3 x 3 x 3 m) used on the experiment for bait culture in MASPLAN is shown in Figure 4. The cage is made up with frame, net, anchor, float and rope. Shapes of fish cages are always square or rectangular, and there are several sizes such as; 1.5 x 1.5 x 2.5 m, 2 x 2 x 2.5 m, 3 x 3 x 2.5 m, 4 x 4 x 2.5 m, 5 x 5 x 2.5 m and 10 x 10 x 3 m in Thailand (R. Yashiro et al. 1999). Based on the production plan and environmental situation, appropriate size of the cage should be selected. The latest net cage can sink down under the sea water in order to avoid the high wave and surge due to storms. The fully automatic monitoring system of water quality, feeding and condition is introduced.



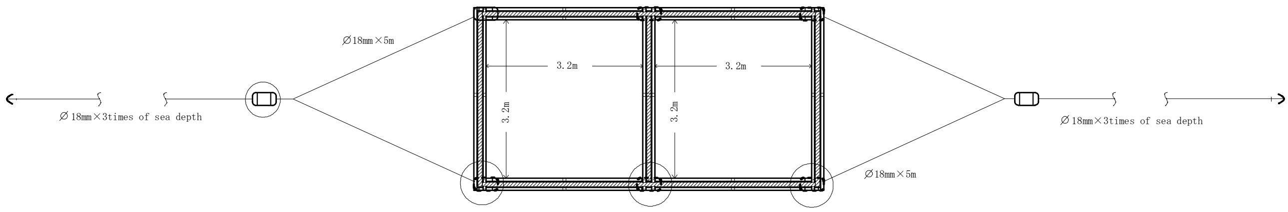


Figure 4. Example design of the floating net cage

3-2. Site selection

The net cages should be set up in calm water such as sheltered lagoons, coves, inlets and bay, behind an island or a river mouth. This will avoid damages caused by strong waves and current. The locations should be protected from strong winds, waves and current. An ideal area would be protected bay, sheltered cove or inland sea with sufficient water exchange to maintain good water quality. Most of grouper's grow-out is conducted in cages located in marine estuaries or sheltered coastal area (Sena S et al. 2007). Water depth should be not less than 3 meters during lowest tide (Baliao, Dan D et al. 2000).

The recommended water quality for cage culture in Thailand is shown in Table 2.

Table 2. Water quality for cage culture (S. Tookwinas 1989)

Parameters	Ranges
pH	7.5 - 8.3
Dissolved oxygen	4.0 - 8.0 mg/l
Salinity	20 - 32 ppt.
Water temperature	25 - 32 °C
Ammonia – Nitrogen	Less than 0.02 mg/l
Hydrogen sulfide	None
Current	Normal

The site of floating net-cage must be relatively free from any source of pollution. The source of the pollution are industrial, agricultural, and domestic waste water, and the site should be protected from environmental hazards such as typhoon, flood, erosions, etc. (Baliao, Dan D et al. 2000).

3-3. Cage frame

A floating cage module usually has from 4 to 12 compartments supported by framework. In constructing a floating net cage module, the following points should be considered (Baliao, Dan et al. 2000). The frames are made of galvanized iron pipe, wooden, bamboo or large PVC pipe. The structure should be durable enough to withstand stress caused by wave action and increased weight during the culture period (Baliao, Dan et al. 2000).

3-4. Sinkers and anchors

Concreate blocks, plastic containers filled with sand and galvanized pipes are used as sinkers suspended by ropes, placed to the bottom of four corners of the net cage for rigging (Baliao, Dan D et al. 2000).

Neither estuaries nor sheltered coast exists in Maldives. Since the floating net-cages are affected by the wave and the current by seasonal monsoon, the anchors which are fixed at the bottom of the sea should be introduced.

3-5. Float materials

Plastic drums or empty plastic containers (200 liter capacity). Four pieces of floats are combined, and placed at the edge of the frame (see picture) To prevent the floaters from drifting especially when the module is subjected to strong wave action, the floaters should be securely tied to the cage frame using a rope (Baliao, Dan D et al. 2000).

3-6. Cage netting

Suitable size of nursery net is 0.5 to 1.0 cm mesh size with knotless. The production net is 2.0 to 5.0 cm mesh size. Nets are fabricated like inverted mosquito net. Each net cage is supported with polyethylene rope (0.5 cm in diameter) inserted along the sewed portion of the net and held together using a clove hitch with overhand knot. Each cages should have layered nets to avoid loss of stock due to tearing and other mechanical damages (Baliao, Dan D et al. 2000).

Relation between the mesh size and cultured fish are shown in Table 2. The nets is replaced for cleaning every two to four weeks, therefore, two nets are necessary for one cage.

Table 3. Suitable mesh size of nylon net for various lengths of cultured fish (Tookwinas & Charernrid 1988)

Mesh size (cm)	Size of fish (cm)
0.5	1 - 4
1.0	5 - 19
2.0	20 - 30
4.0	> 30

3-7. Anchor

The length of the anchor rope from the float to an anchor should be 2-3 times of the water depth at the spring tide. In general, concrete blocks are used as an anchor. Generally, the weight of the anchor should be 2 times the weight of the entire floating cage module (Baliao, Dan D et al. 2000). In the location where there is the tidal current, steel processed like sea anchor is used to fix the net cage.

3-8. Stocking rate

Stocking density is 30 - 125 fish/m^3. It is depending on the location of the net-cage. Four stocking densities (15, 30, 60 and 120 fish/m^3) and two sizes of fish (26 ± 0.2 gm and 15.2 ± 0.1 gm) were studied. Results indicated that 60 fish/m^3 is grew equally fast and showed comparable food conversion ratio and survival rate and survival rate as those at lower stocking densities of 15 and 30 fish/m^3 (Teng et al. 1978). Total length 5 cm (2 g) and 10cm (17 g) of grouper are appropriate size for the stocking, because the survival rate of those groupers becomes higher without the predation and nutritional problem.

3-9. Hiding space

Hanging car tires as obstruction things in the net-cages provides hiding space for the fish. It was found that providing hiding space in the net-cages rises optimum stocking density from 60 fish/ m^3 (without artificial hides) to 156 fish/m^3. The net production is increased from 8.5 kg/m^3 to 19.5 kg/m^3 after 3 months (Teng 1979). The hanging tires makes the groupers gather in the center of the cage. It also prevent shark from attacking and the net is maintained without breaking by the shark.

4. Feeding

Groupers are carnivorous and consequently prefer feeds high in fish protein. Most grouper farms in Asia still rely on what is commonly termed 'trash fish'. However, trash fish goes rotten easily and the supply of the trash fish is not stable due to seasonal variation. Trash is cut into small pieces for feeding. Consequently, as much as 30 to 50% of the trash fish fed can be lost during the feeding process (Sih-Yang 2005). The trash fish used for the grouper culture in Thailand are Yellowstripe trivially (*Selaroides leptolepis*), Thread fin bream *(Nemipterus hexodon*), Fingescale sardinella (*Sarainella fimbriata*) and Round scad (*Decapterus russelli*) etc. (R. Yashiro 1999).

Table 4. Feeding rate of trash fish to groupers (Sih-Yang 2005)

Fish size (g)	Feeding per day (% average body weight)	Frequency of feeding per day
5 – 10	15 – 20	3 – 4
10 – 50	10 – 15	2 – 3
50 – 150	8 – 10	1 – 2
150 – 300	6 – 8	1

300 – 600	4 – 6	1

Farmers in some Asian countries practice fish farming-based on moist feeds for marine finfish. Moist feeds generally prepared with a prescribed formula, originally developed from fisheries or aquaculture research and development authorities in the country, and modified by the farmers according to requirements, farming situation and availability of materials. The moist pellet feed for groupers can be made on farm (Sih-Yang 2005). In the Maldives, the culture farmer can obtain the residue of skipjack and yellowfin tuna from canning plant. Fish oil is added to the residue and necessary vitamins for moist pellet are available. However, transportation cost and purchase of large quantity are the limiting factors.

Table 5. Example of material for moist pellet (Sih-Yang 2005)

Material	Kg
Trash fish*1	60
Soybean meal*2	15
Rice bran*3	15
Vitamin premix	1
Vitamin C	0.02
Trace mineral premix*4	0.5
Fish/squid oil	2
Water	0 - 10
Total	~100

*1 It can be replaced with 20 kg of good quality fish meal (65% crude protein) and extra water is added to form a dough.

*2 Cocked / defatted

*3 Dry weight

*4 Preferred but not essential

The above formula feed provides the following nutritional composition for the moist feed.

Table 6. Nutritional composition of the moist pellet (Sih-Yang 2005)

Nutritional Composition	(%)
Dry matter	< 40
Crude protein	18.9
Digestible protein	16.2
Gross energy	8.8
Digestible energy	6.1
Lipid	4.8

Ash	4.4

Water pollution is less because formulated feed is more stable in water and waste of the feed is less. In turn, this provides a better environment for the fish leading to a reduction of disease problems (Sih-Yang 2005).

By-product of skipjack in processing factory is expected to use as a supplemental material of the formula feed. In Maldives, there are fish meal and by-product produced in skipjack process factories. Those products can be utilized for aquaculture feed.

Table 7. Feeding rate of dry pellet to groupers (Sih-Yang 2005)

Fish size (g)	Feeding per day (% average body weight)	Frequency of feeding per day
1 – 5	4.0 – 10.0	3 – 5
5 – 20	2.0 – 4.0	2 – 3
20 – 100	1.5 – 2.0	2
100 – 200	1.2 – 1.5	1 - 2
200 – 300	1.0 – 1.2	1
>300	0.8 – 1.0	1

Table 8. Comparison of trash fish and prepared dry pellet as a feeding value on grow-out culture of seabass (Niwes Ruangpanit & Renus Yashiro 1994)

6-month culture period	Trash fish	Dry pellet
Final size (g)	240	271
Survival rate (%)	80.0	86.7
Production yield (kg/m^2)	15.4	18.8
FCR	7.8	4.3
Fattiness	13.0	13.7

The above table indicates that the dry pellet is better than trash fish in all parameters.

The commercial dry pellets used for grouper farming are generally slow sinking pellets that give fish more chance to get food. Commonly pellet is spread widely over the cage, so that all fish can access to the feed easily and evenly. However, groupers quickly become accustomed to feeding times and they will often aggregate close to where the feed is first added. This reduces the need to spread the feed over all of the cage area. The rule always is to add the feed slowly and ensure that all fish in the cage have good access to the feed (Sih-Yang 2005).

5. Monitoring

The monitoring should be periodically carried out during the grow-out stage. pH, dissolved oxygen, salinity and water temperature as well as swimming behavior are monitored twice a week. Fish sampling is carried out every 15 days to determine feed requirement and growth rate of the grouper stocks. About 10-15 fish are sampled by scoop net, and their body weight and length are measured. Inspection of the nets is done to check its breakage, and the net is dried to remove debris and fouling organisms attached on the net (Dan D. Baliao et al. 2000). The nets should be replaced when the monitoring is carried out.

6. Disease and prevention

6-1. Parasitic disease

Parasitic disease such as *Benedenia epinepheli* and *Neobenedenia girellae* can be removed by freshwater or low salinity water treatment for few minutes. The treatment is conducted periodically in monthly or at the occasion of the monitoring. When the parasites infested on the grouper's body, the groupers rub their body against the net, so that red spot and scuff marks appear on their body. The method of prevention is to observe carefully the swimming behavior and body surface of the groupers (Kaneshiro et al. 1996).

6-2. VNN

Viral Nervous Necrosis (VNN) is serious virus disease of groupers in juvenile stage. When VNN breaks out in the early stage of larval rearing, a total mortality happens in most of the case. In case of Humpback grouper seed production in Indonesia, control method is shown in below (Ketut Sugama et al. 2001).

1) To prevent contamination of VNN virus into rearing water
   - Disinfection of facilities and equipment
   - Selection of viral free broodstock
   - Immersion of eggs in iodine solution
   - Viral examination for larvae at day 2
2) To decrease the density of VNN virus in rearing water
   - Increase of water exchange
   - Early removal of dead and weak larvae
3) To reduce stress to larvae
   - Avoidance of high larval density
4) Others

- Administration of an anti-biotic

7. Cost evaluation for the culture
   The estimation of the initial and running cost for 4 cages (3.0 x 3.0 x 3.0 m/cage) is shown in Table 9.

Table 9. Estimation of initial cost for the floating net cage culture

No.	Material	Quantity	Unit price (MVR)	Sub total (MVR)	Depreciation (year)	Remarks
1	Wooden frame	40	875	350,000	3	Size 13 x 6 x 2
2	Thread rod (12 mm)	20	200	4,000	3	6 x 6 feet/set
3	Nut (12 mm)	8	165	1,320	5	Kg
4	Washer (12 mm)	2.5	175	437.5	5	Kg
5	Nylon nets (1.5 cm mesh size)	8	-	-	3	
6	Nylon nets (3.0 cm mesh size)	8	-	-	3	
7	Floatation containers (200L)	15	1,220	18,300	4	
8	Anchors	4	8,100	32,400	10	Steel processed like sea anchor
9	Anchor rope (18 mm)	2	12,000	24,000	3	300 m/roll
10	Anchor rope (6 mm)	1	1,200	1,200	3	300 m/roll
11	Nails	4	85	340	5	Galvanized 3, kg
12	Labor for cage construction	450	60*	27,000	-	5 labors x 12 days
13	Other materials	1	3,000	3,000	3	Scoop net, weight, bucket etc.
Total				461,998		

Table 10. Estimation of running cost for the floating net cage culture

No.	Material	Quantity	Unit price	Sub total	Remarks
1	Fingerlings	6,480	15.0	97,200	60 fish/m^3 x 27 m^3/cage x 4 cages ($1.0/fish)
2	Formula Feed Grain size (1.5, 1.9, 30, 4.5, 6.0 mm)				

3	Caretaker (labor cost)	7 months	7,500	52,500	Based on Doi's report
4	Repair and maintenance	1	23,000	23,000	5% of initial cost

8. Consideration

The first step of the extension of grouper culture, the price of cultured grouper must be cheaper than the wild groupers (100 – 120 MVR/kg). To sell grouper to resort hotels is necessary for sustainable domestic consumption. According to the survey of MASPLAN, the average price of the reef fish (not alive) including groupers at the resort is 40.1 MVR/kg (Muawin et al 2016). Therefore, cultured groupers for domestic consumption should be produced with the cost of less than 40.1 MVR/kg. "It is said that the number of Chinese tourists to Maldives is increasing" or "It is expected that the number of Chinese tourists to Maldives will increase". According to the surveys to two resorts by MASPLAN, one resort, that guest is mainly from China, showed the possibility to buy the cultured groupers, if the quality and the price are similar to those of wild groupers. Another one, that guest is mainly from British, didn't show possibility to buy the cultured groupers due to distrust of the quality and the price.

In terms of the environmental aspect, the over feeding of the floating net cage culture affects the natural environment. Existing study indicates the 80% of nitrogen utilized in the cage culture is released into the sea as uneaten food, fish faeces and dead fish, and it eutrophicates the sea. Tourist industry using clean nature is the basis in Maldives. The Maldives government should conduct coastal environment monitoring including the aquaculture. The aquaculture industry would be managed strictly to avoid the negative impact. Therefore, it is necessary to feed proper quantity and dry pellet or EP should be introduced.

In the running cost, development of the feed for the culture is important to make the profit. In initial investment, the cost of floating net cage is cheapest of all methods. However, all materials should be imported from foreign countries. The cost of formula feed is the most important point of the grouper culture. It is necessary to consider cooperative purchase for saving the cost.

The supply of fingerlings is limited to extend the grouper culture. The MTDF as government facility should produce number of fingerlings and variety of species for fish farmer. The government should continue to give the guidance of the grow-out techniques through the workshop or training.

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Chapter 2. Sandfish culture in Maldives

1. Introduction

Over 1500 species of sea cucumber exist in the world, and approximately 30 species are edible one. More than 70 countries are involved in sea cucumber business (harvesting and trading). The scale of the business ranged from artisanal to industrial level in all regions of the world. In some fisheries, more than 20 species can be exploited by fisheries and should be distinguished from each other by fishery, officers and scientist (Purcell et al. 2012).

The main consuming country of sea cucumbers is China. Chinese people consume the sea cucumber as food like the traditional medicine. The sea cucumbers are gathered to China from all of the world. Sandfish (*Holothuria scabra*) is one of the most valued species in sea cucumbers. The retail price of dried sandfish is ranging 100 - 300 USD/kg at distributional markets in Singapore and Hong Kong (Purcell, Steve 2014).

According to the statistical data of FAO in 2014, only Malaysia, Vietnam and Saudi Arabia had been reported in the sandfish fishery or aquaculture. However, according to the other technical papers, at least Australia, Philippine, Fiji, Madagascar, Sri Lanka, India and South Africa had been reported as producer countries. Actually, the trade of sandfish has spread to all over the world with a focus on Asia.

Sea cucumber fisheries in Asian countries have been depleted due to overexploitation as well as lack of proper management and conservation (Rahman, M. Aminur 2015). The trend of the aquaculture production of sandfish is shown in Figure 1. The production is increasing from 2008.

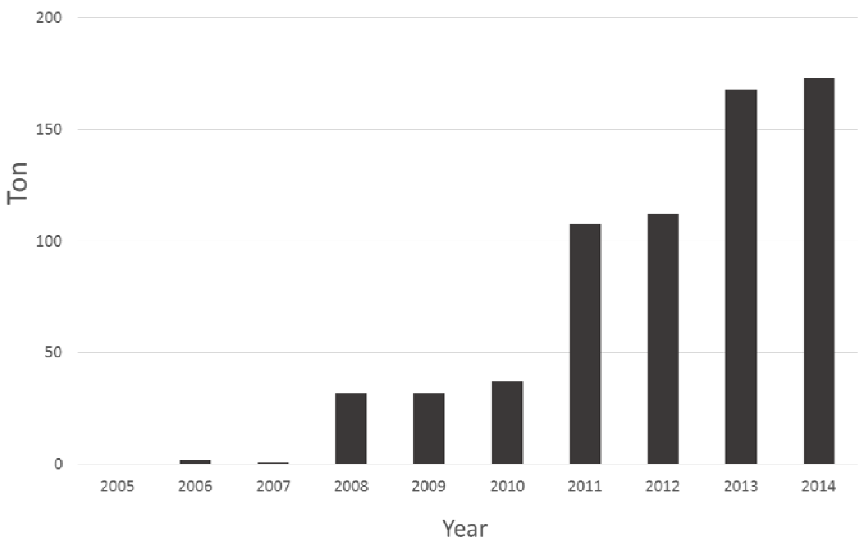

Figure 5. Aquaculture production of Sandfish in the world

(Source: FAO statistic)

The protocol of the seed production for sandfish was already established in many countries. The manuals were published by SEAFDEC. The technical training also is implemented annually in Philippine organized by SEAFDEC. The pawning is induced by exposing in the air, by giving heat shock, and by Spirulina bath (Ruth U. Gaamboa et al. 2012) as well as hormone injection. Thirty five days after hatching, the juveniles are moved to nursery system (David J. Mills et al. 2012). In Maldives, Mariculture Training and Demonstration Facility as the governmental aquaculture station and a private sector had already succeeded in producing the juveniles. IFAD project is carrying out the small scale grow-out in pilot farm using pen culture to generate income in Laam Atoll.

In the review, based on the existing technical reports and articles, the basic information of the grow-out on the sandfish culture was summarized to adopt in Maldives.

2. Biology

In general, sandfish is admitted as exotic species in Maldives. However, based on Figure 2, the inhabit distribution of the sandfish shown by IUCN covers surrounding countries from west Pacific Ocean to west Indo-pacific including Maldives. Based on a number of quantitative and qualitative studies, populations are estimated to have declined by more than 90% in at least 50% of its area of the distribution, and are considered overexploited in at least 30% of its area of the distribution, although exact declines are difficult to estimate (IUCN 2016).

Figure 6. Habitat range of sandfish

(http://maps.iucnredlist.org/map.html?id=180257)

The sandfish can be found in shallow waters, but occasionally to depths of up to 20m. Commonly found on inner flat reefs beds of fringing and lagoon reefs, and coastal sandflats and seagrass beds with muddy sandy substrates, near mangroves. Both adults and juveniles bury in sand and sandy-mud at some localities. Attains size at maturity is about 25 cm in India and northern Australia (Purcell et al. 2012).

Like other sea cucumbers, sandfish can regenerate some of their organs. After spending long periods out of water, or being affected by the use of chemicals, being handled during collection and transport, or when stressed by predators, sandfish may eviscerate their internal organs. Regeneration of internal organs occurs within 2 months (Agudo, Natacha 2006).

The sandfish feed on detritus, i.e. organic matter in the mud or sand. They appear to feed continuously using the peltate tentacles surrounding the mouth to place sediment into the mouth (Agudo, Natacha 2006). Table 1 shows that the sandfish swallows the most large amount sand (81.8kg/ind./year) in the sea cucumbers.

Table 11. The amount of sand swallowed by species per year

Scientific name	English name	Amount of food ingested (kg/ind./year)
Holothuria atra	Lollyfish	24.5−70.0
Holothuria edulis	Pinkfish	21.5
Holothuria scabra	Sandfish	81.8
Holothuria moebii		42.0
Holothuria floridana		30.0
Bohadschia bivittata		45.4
Bohadschia vitiensis	Brown Sandfish	26.7
Bohadschia variegatus		18.1
Stichopus chloronotus	Greenfish	21.5
Stichopus tremulus		0.6

Feed containing the diatom makes the sandfish grow better (Minami et al 2013). The culture for juveniles of 238 days after hatching needs the sand in the bottom for 4 weeks at least (Minami et al 2013).

Among the tropical species, sandfish is the only species that is currently mass produced in hatcheries (Toral-Granda 2008). Sandfish can be sexually mature at a size as small as 200 g. There is no apparent relationship between fecundity (egg production) and body size (Agudo, Natacha 2006).

3. Current situation of sandfish in Maldives

In Maldives, more people are involved in sea cucumbers harvesting in Raa, Thaa and Gaaf alif Atoll (Maldives fisheries survey 2015). The sea cucumbers are harvested by small scale fisheries.

In the Maldives, the production has been presented a huge increase in 1997 (318 ton in dry weight), followed by a steep drop for two years and then a more recent increase. These fluctuations seem characteristic of unregulated sea cucumber fisheries, and likely to soon experience overexploitation (FAO 2001).

The sandfish culture is being conducted in the Maldives since 1996 (Azari et al. 2013). Barakahor Bhar is a leading firms in Shaviyani Atoll at the northern part of Maldives. The firms is conducting seed production and grow-out the sandfish using pond and pen culture in Nalandhoo Island that has distinguishing landform. Blue Bridge is conducting the grow-out culture using the pen culture method in Laamu Atoll. As of 2016, 6 applications for the sandfish culture were submitted to the government.

4. Culture method

The sandfish can grow by formula feed and the feces of fish (Watanabe 2013). Animal-based feeds (shrimp and mussel) are potentially more reliable sources of digestible protein than the plant-based feeds (diatom and seaweed) for sandfish juveniles. The table 12 shows the composition of sandfish feed used for the experiment in MASPLAN. In general the sandfish can be cultured in pond without feeding, and pen and cage culture with feeding (Zenith et al 2014).

Table 12. Materials and the ratio of sandfish feed by MASPLAN

Ingredient	Composition (%)
Fishmeal	40
Sea grass powder	4.8
Rice bran	1.6
Soybean meal	2.8
Rice flour	10
Fine sand, carbonate	40
Vitamin premix	0.4
Mineral premix	0.4
Total	100

A range of alternative livelihood option are possible, as illustrated by case studies from around the world including sea ranching in Fiji and Philippine, sea pen farming in Madagascar and pond culture in Vietnam. The choice and implementation of a particular development model are influenced by a wide range of social and economic factors that are characteristic of each geographic region (Robinson 2012).

Co-culture is expected based on the some experiments. The species selected for the co-culture with sandfish are milkfish (*Chanos chanos*), sea bass (*Lates calcarifer*), rabbitfish (*Siganus guttatus*), orange-spotted grouper (*Epinephelus coioides*), pompano (*Trachinotus blochii*), and mangrove red snapper (*Lutjanus argentimaculatus*) (Mills 2012). Although, the co-culture of juveniles sandfish with the blue shrimp (*Litopenaeus stylirostris*) in the tank reported the high survival rate of the sandfish (Steven 2006), the survival and growth rate of sandfish in co-culture with blue shrimp for 3 weeks in earthen pond were significantly lower than the sandfish rearing alone (Bell 2007).

Table 13 shows the comparison of the growth and grow-out by the culture methods based on the existing reports. In Maldives, the period of sandfish grow-out varies between 12 and 18 months (Azari et al/ 2012). Most of sandfish culture are normally carried out by pond culture. After attaining a biomass of 692 g/ m^2 following 6 months of grow-out in the natural environment, sandfish stopped the growing (Lavitra et al. 2010). In case of New Caledonia, the biomass at the harvest is range of 143 – 434 g/m^2 in pond culture (Natacha 2012).

Table 13. Comparison of culture method and the production

Culture type	Feeding	Stocking rate	Body weight (g) Start	Body weight (g) Finish	Days	Country	Report
Pen culture	Y			300 – 400	180	Maldives	
Pen culture	N	3 fish/m^2	15	198	270	Madagascar	Thierry Lavitra et al. 2010
Pond culture	N	200–240g/m^2	50	350	90–150	Vietnam	Pitt, R. et al. 2003
Pond culture	N	1.6 fish /m^2	9.0	325	365	New Caledonia	Natacha 2012
Pond culture	N	0.8 fish /m^2	11.7	395	395	New Caledonia	
Pond culture	–		2–5	350 – 400	365	Vietnam	David J. Mills et al. 2012
Pond culture	Y	10 fish /m^2	0.2	18	56	Madagascar	Thierry Lavitra et al. 2010
Sea ranching	N		5–7	180	300	Philippine	Juinio-Meñez et al. 2012

4-1. Pond culture

The earthen ponds are currently most effective for nursery rearing of juvenile sandfish to a size for stocking (Steven 2012). Survival rates in the pond and pen culture are higher than that of in natural sea. The comparison of sediment quality among sandy, muddy and mixed sandy and muddy, the sediment type did not affect the survival and the growth for grow-out (Lavitra et al.

2010).

The maximum growth rate is 2 - 3 g/ ind./ day in the pond culture (Pitt, R. et al. 2003). Maximum growth rate in New Caledonia is 1.3g/day (Natacha 2012). The juveniles stocking densities of 10, 20, 30 and 40 individuals/ m^2 for 10 weeks, 10 individuals/ m^2 (0.24 – 15 g/ individual) is highest growth rate (Lavitra et al. 2010).

If the water level of the pond suddenly drops, sandfish buried near the edge of the pond can be trapped in dried area (Natacha 2012).

4-2. Pen culture

The juveniles stocking densities of 3, 6, 9 and 12 individuals/ m^2 (> 15g/ ind.) for 9 months, 3 individuals/ m^2 is highest growth rate in pen culture (Lavitra et al. 2010). Depend on the size of mesh, the sandfish can escape from the fence. Based on the experiment in MASPLAN, small juveniles (0.25 - 3.00 g/ ind.) can pass through the small mesh (0.3 x 0.3 cm) within 1 hour. The medium juveniles (25 g - 8 g/ind.) can pass through the medium mesh (1.1 x 1.1 cm) for 1 hour. Pen culture is easily broken by a thief. To prevent the pen from breaking by the thief, it is necessary to enhance the monitoring by watcher or to build up a surveillance system by co-management.

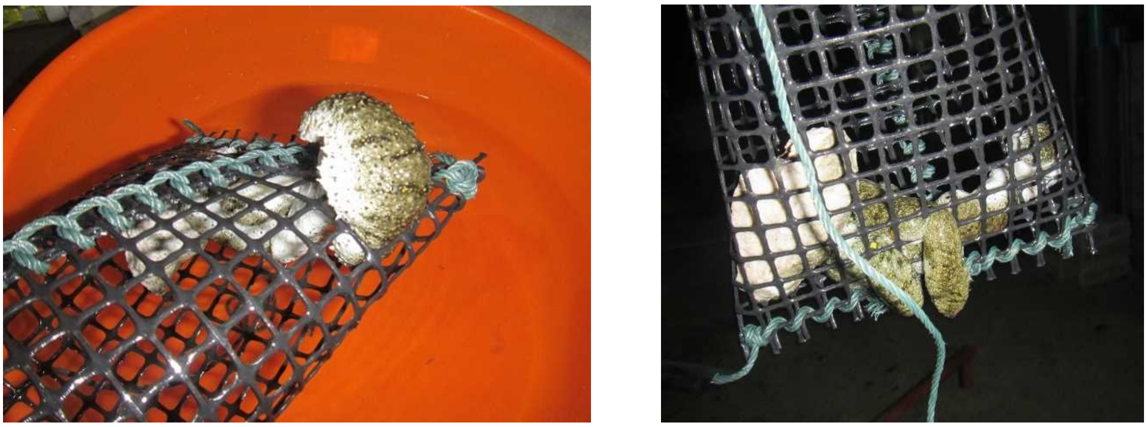

Figure 7. Sandfish can go through the small net mesh examination by MASPLAN

As mention 4-1., the sediment quality among the sand and muddy didn't affect the growth of the sandfish. However, the tidal wave in the pen and cage markedly obstructs inhibits the growth of the sandfish. The calm condition is needed for the pen culture. The potential islands that have suitable characteristic landform for the grow-out are selected in Annex 1.

4-3. Cage culture

The study of the grow-out by the cage is scarce. There is no data of the growth rate by the culture method. In the nursing stage, the bottom-set cages using hapa net is examined to compare with the hapa net cage in pond and the coastal area. The growth rate of bottom-set is more effective than the other hapa cages (Juinio-Meñez et al. 2012). The experiment using floating cage with feeding for the grow-out recorded mean body weight to 23g and 31g/ind. (initial 3.8 g/ ind.) for 95 days (Minami et al 2013). It is expected that sandfish cage culture will be developed with finfish polyculture by utilizing the fish feces (Watanabe 2013).

In the MASPLAN, the experiment of bottom-set cage for grow-out is being carried out in Mariculture Training and Development Facility in 2016. The objective of the experiment is to obtain data of the growth rate and biomass in the cage for 6 months. The results of the experiment will be described in the technical report.

Figure 8. Experiment of the cage culture in Maldives

4-4. Sea ranching

The sea ranching is the extensive methods for the grow-out. It is low survival rate (2 - 39%) and low productivity (59 - 220 kg/ha) (Juinio-Meñez et al. 2012). The standard size to start the sea ranching is range of 7 - 20 mm/body length in Japanese common sea cucumbers. Although, the habitat of sandfish covers Maldives, Maldives government admits the sandfish as foreign species. Therefore sea ranching will not be applied in Maldives.

5. Water quality

It is necessary to prevent salinity from declining to below about 20 ppt due to heavy rain, excessive filamentous weed growth, anaerobic condition and putrid pond (Pitt, R. et al. 2003). The growth rate slowed during the cold season when mean water temperature was in the range of 20.7 – 22.7°C. When the mean water temperature was 27.3°C, the growth rate reached a peak of 1.04 g/day (Natacha 2012). The high mortality in pond culture was recorded due to excessive weed proliferation during high water temperature and salinity (Natacha 2012). Table 14 shows the proper value range of the water quality based on training of the SEAFDEC.

Table 14. Proper value of the water quality (Albacete 2014)

Parameter	Proper value
Do	5 - 6 ppm
Temperature	26 - 30
pH	6.5 - 9.0
Ammonia-N	0.07 - 0.43 ppm
Salinity	27 – 35 ppt

6. Disease and predation

Disease of tropical sea cucumbers culture is infrequent (Steven 2012). Isopods (*Cymodoce* sp.) infested sea cucumbers in outdoor ponds during the hot season, provoking a high mortality rate in cultivated sandfish (Thierry 2009).

The crabs (*Thalamita crenata*) were abnormally abundant in the pens during some periods of the year. They are the most redoubtable serious predators for sea cucumber in the region and may provoke the mortality of the juvenile stocking within a month (Thierry 2009). The skin lesions were always on the dorsal surface of the sandfish, and appeared to have been caused by predators such as large crabs and bird (Natacha 2012). If the pens are suffering high rates of predation from by crabs, the farmers should organize regular monitoring for crabs at night, because the crabs are often more active during nighttime. The crabs can be caught by the net, spear, gloves and traps (Pascal 2010).

7. Cost for the culture

7-1. Pen culture

The example of the ROI (Return on Investment) analysis of pen culture in Philippine was shown in the table. The estimation was calculated with the following conditions

- Location is in Santiago island, Bolinao, Pandasinan, Philippine
- Scale of the culture is two pens (200 m^2 x 2)
- 200 juveniles (50 g/ individual) with a survival rate of 80%
- Harvest size is 320 g after 6 – 8 months
- Dried weight is 4.5% of wet weight

Table 15 Economic analysis of pen culture (Juinio-Meñez et al. 2012)

Unit: USD

	1st cycle	2nd cycle	
Estimate cost			
Juveniles (400 pcs)	24	24	
Pen materials & labour	186	30	
Processing materials & labour	22	22	
Transport to Manila	40	40	
Total cost	272	116	388
Total revenue	244	244	488
(4.6kg trepang @ US$53/kg)			
Net revenue	(-28)	128	100
ROI			**25%**
IRR			**40%**

In this case, result of IRR (internal rate of return) for 2 years is 40%. It indicated to satisfy for investment of the sandfish culture. Another case of pen culture in Madagascar, the result showed 88% of IRR (Pascal et al. 2016).

7-2. Pond culture

Ponds were leased, more workers were needed but labor costs were relatively low, and pond water was exchanged by tidal movement. Prices for whole fresh sandfish varied by size for 150-250 g (US$2.50), for 250-400 g (US$4.00) with the market accepting relatively small-sized sandfish. A 10-month growing period was practiced by farmers to avoid the risk of low pond salinities in the wet season (Purcell 2012).

7-3. Sea ranching

In case of Vietnam, 540,000 sandfish juveniles were distributed in the sea by the restocking project. The project was carried out in the Van Ninh, Ninh Hoa, Nha Trang, and Cam Ranh municipalities of Khanh Hoa Province from June to August 2002. The results data were obtained through Participatory Rural Appraisal (PRA) from the related persons. The total project cost is 64,000 USD. According to the results, IRR of 17.3% in the project was estimated (Strehlow 2004).

8. Consideration

The grow-out culture of sandfish can be done easily in the pen and pond, if the aquaculture site has the suitable condition for the sandfish. However, the abundant supply of the seed, the proper processing, and low cost of shipment are important to develop the extension of sandfish culture. It is necessary to foster the firms to have ability of producing sandfish seed and postharvest and trading before the aquaculture promotion. Fortunately, there are some firms which produce sandfish seed, postharvest and trading in Maldives. If the government tackles to expand the sandfish culture in islands, it should be confirmed the economic feasibility of the sandfish culture.

The land for the pond culture is limited in Maldives. The escape of the sandfish from the pond into natural area should be avoided, because the sandfish is being recognized as exotic species in Maldives. The pen and cage culture are expected culture methods for the isolated island to generate income. In Annex 1, the candidate sites for the pen culture in Maldives are selected. Those are picked up from google map. The points of the selection are existence of the sand beach available for the habitation of sandfish and/or having curved landform like a cove to block the wave. In the Maroshi Island (No. 23) and Nalandhou Island (No. 25), the private firms have already launched the sandfish culture. The pond culture limited the water depth to set up the fence. The fence is visible object in the sea and it is easily found by others. It needs to consider the prevention of the thief. The cage culture can be applied without limitation of water depth. The data and information related to the cage culture should be accumulated through the experiments in order to utilize them for the extension.

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Annex 1. Potential islands for sandfish culture

1. Dhaalu Issari

2. Dhaalu Thilabolhufushi

3. Dhaalu Thinhuraa

4. Gaafu Alifu Maafehelaa

5. Haa Alifu Baarah

6. Laamu Bileiytheyrahaa

7. Laamu Faress

8. Laamu Kalhaidhoo

9. Laamu Maabaidhoo

10. Laamu Thunburi

11. Lhaviyani Hudhufushi

12. Lhaviyani Selhlhifushi

13. Meemu Kurali

14. Noonu Bodulhaimendhoo

15. Gaafu Dhaalu Kalherehaa

16. Gaafu Dhaalu Keremitta

17. Gaafu Dhaalu Maathoda

18. Gaafu Dhaalu Maavaarulaa

19. Gaafu Dhaalu Nadallaa

20. Gaafu Dhaalu Fiyoari to Rathafandhoo

21. Gaafu Dhaalu Nadallaa to Rathanfandhoo

22. Shaviyani Eriyadhoo

23. Shaviyani Maroshi

24. Shaviyani Mathikomandoo

25. Shaviyani Nalandhoo

Pilot Study on Grow-out Culture of Sandfish (*Holothuria scabra*) in Bottom-set Sea Cages in Lagoon

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Table of Contents

1. Executive summary

Although mariculture is relatively new to the Maldives, sandfish culture has been practiced in the country for a little over a decade. Currently sandfish grow-out in pens is being carried out by island communities on a limited scale.

Two studies were carried out in the lagoon of Maniyafushi Island, Kaafu Atoll, to determine the growth and survival of hatchery-produced juvenile sandfish cultured in bottom-set cages in lagoon in order to assess the potential use of such cages in small scale sandfish grow-out operations. The initial study, which was discontinued when an extreme weather event damaged the cages, was designed to determine the effects of two stocking densities and two feeding frequencies on the growth and survival of sandfish cultured in bottom-set cages in lagoon. Juvenile sandfish with a mean body weight of 2.12 g were first nursed in land-based tanks for 2 months at a stocking density of 100 individuals m^{-2} until they attained a mean weight of 11.43 g. The juveniles were then randomly assigned to 4 treatments and their replicates. The second study was conducted to assess the growth and survival of sandfish in bottom-set cages in the lagoon without varying stocking density and feeding frequency. In both studies feed was introduced in each experimental cage at the rate of 3% of the total sea cucumber biomass in the cage.

Results of the second study showed that the survival was high; mean survival was 97.14%. At the end of the 124 day culture period the animals reached a mean body weight of 147.05 g and yielded an average biomass of 1424.64 gm^{-2}. The specific growth rate for the culture period was 1.58% day^{-1}.

Based on the growth and survival of sandfish in bottom-set cages used in the second study and the performances of sandfish in other culture systems, it can be concluded that bottom-set cage is a suitable culture system for small scale grow-out of sandfish with feed inputs, particularly for early stages of grow-out. This type of cage can also be used for nursing smaller juveniles in the sea before putting them in sea pens for further growing. Further studies are needed to determine the most suitable cage size and materials, stocking density, culture period and scale of grow-out operation. Pen, bottom-set cage and off bottom cage can be used in different environmental conditions of the lagoons. These culture systems have the potential for widening sea cucumber grow-out in the country.

2. Background

Island communities of Maldives rely heavily on natural marine resources both as their economic basis as well as their subsistence. The fisheries sector has played a significant role in employment as well as foreign exchange earnings in the Maldives for many years. The development of a tourism sector and improvements in transportation have led to the diversification of the Maldivian fisheries sector from the traditional pole-and-line skipjack tuna fishery to hand-lining for yellowfins and harvesting of high-valued reef animals targeting tourist resorts as well as export markets. Sea cucumber and grouper fisheries are the most significant reef fisheries today. They provide additional or alternative income to the fishers.

Sea cucumber fishery in the Maldives began in 1985, with a single shipment of 30 kg of prickly redfish (*Thelenota ananas*) to Singapore. Since then, the fishery quickly expanded, targeting high-valued species like the white teatfish (*Holothuria fuscogilva*) and *T. ananas*. Within a few years since the start of sea cucumber exports, over 16 sea cucumber species, including those that fetched lower market prices, were being harvested. The abundance of high-valued sea cucumbers in shallower waters is now depleted to the extent that bulk of these species is now caught at depths ranging from 5-30 m.

A review of sea cucumber fishery in the Maldives by Joseph (1992) revealed that the stocks of high-valued species were extensively harvested and highlighted the urgent need for managing the fishery. It is believed that in addition to conventional fishery management measures, marine aquaculture (mariculture) is a potential solution for reducing fishing pressure on the threatened sea cucumber stocks, while at the same time meeting market demands. The development of sea cucumber mariculture would also provide an alternative livelihood for communities.

Culture techniques for some species of sea cucumbers have been developed and are being used commercially in Asia-Pacific. Australia, Philippines, Vietnam and Madagascar have been practicing commercial aquaculture of sandfish (*Holothuria scabra*) at different scales (Bowman, 2012; Duy, 2012; Eeckhaut et al, 2008; Olavides et al, 2011; Juinio-Menez et al, 2012) and some Pacific Island countries are trialing small-scale production for community-managed sea ranching (Hair et al. 2011).

Maldives is believed to have an ideal setting for mariculture development based on the widespread nature of the islands, and the availability of sheltered lagoon areas. Although mariculture is relatively new to the Maldives, sandfish culture has been practiced by a single private group in the Maldives for a little over a decade. Currently Mariculture Enterprise Development Project (MEDeP), being implemented by the Ministry of Fisheries and Agriculture (MoFA) and International Fund for Agricultural Development (IFAD), is assisting island communities to grow sandfish in shallow, sandy sea pens (low tide minimum depth 0.5 ft.). MoFA is also trying to develop other sea cucumber grow-out systems such as submerged bottom-set cage (submerged cage sitting on the seabed) or off-bottom cage (submerged cage sitting on legs) to expand sea cucumber grow-out for island communities. Two studies were carried out by Marine Research Centre (MRC) of MoFA and the MASPLAN project (a Japanese Government funded project to formulate a framework for the sustainable development of the Maldivian fisheries sector) to assess the potential use of bottom-set cage in small scale sea cucumber grow-out by island communities.

3. Study objective

The objective of the studies was to determine the growth and survival of hatchery-produced juvenile sandfish cultured in bottom-set cages in lagoon in order to assess the potential use of such cages in small scale sandfish grow-out operations. Submerged bottom-set or off bottom cages can be used in different environmental conditions of the lagoons. These cages together with the traditional pen can be used to widen sea cucumber grow-out in the country.

4. Materials and methods

The initial study was designed to determine the effects of stocking density and feeding frequency on growth and survival of sandfish in bottom-set cages in lagoon. Unfortunately the experimental cages were damaged by an extreme weather event in southwest monsoon. As a result, instead of the initial study a second study was conducted to assess the growth and survival of sandfish in bottom-set cages in the lagoon without varying stocking density and feeding frequency.

4.1. Study sites

The two studies were carried out in the lagoon of Maniyafushi Island, Kaafu Atoll, Maldives, where Mariculture Training and Demonstration Facility (MTDF) of MRC was located (Fig. 1). The lagoon was relatively protected from strong current and waves. It had good water quality and visibility. Tidal fluctuation in the lagoon was approximately 1m, with a mean depth of 0.5m and 1.5m at low and high tides, respectively. The sites of the initial and the second studies are shown in Fig. 1.

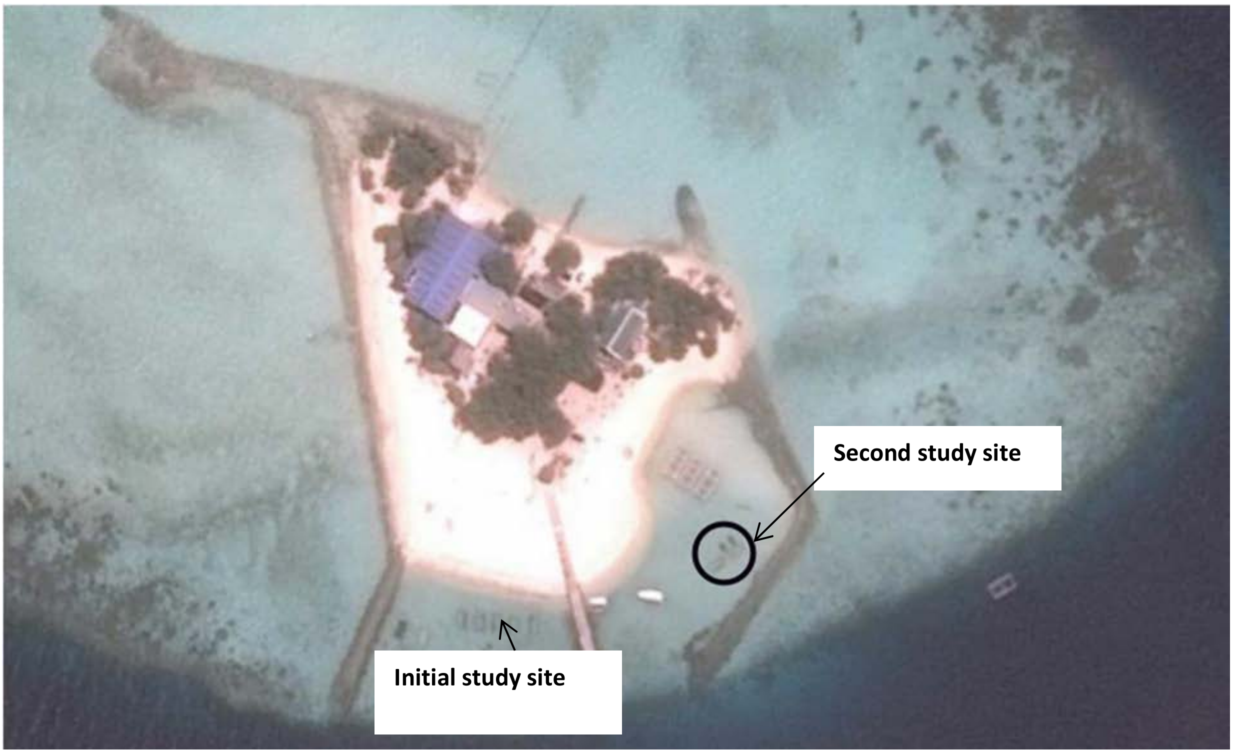

Fig. 1. Study sites in the lagoon of Maniyafushi Island, Kaafu Atoll

4.2. On-land juvenile nursing

To conduct the initial study 1,000 juvenile sandfish with a mean body weight of 2.12 g were obtained from a private hatchery. As the juveniles were too small for stocking in sea cages, they were first reared in land-based tanks at a stocking density of 100 individuals m^{-2} for 2 months. During this period the juveniles attained a mean weight of 11.43 g, a size adequate for stocking in sea cages. The tanks had 4-5 mm layer of fine sand at the bottom and continuous water flow at the rate of 6 L min^{-1}. They were siphoned daily to remove accumulated wastes; tank water quality was monitored daily.

4.3. Sea cage culture

The initial study was conducted between August 2016 and February 2017. 12 Bottom-set cages, each measuring 2.75 m x 1.28 m x 0.6 m (depth) and having a bottom area of 3.52 m^2, were constructed for the study. The cage frame was made from welded 12 mm concrete reinforcing metal rods. A plastic net of mesh size 7mm covered the whole inner surfaces of the cage sides and bottom. A piece of PVC canvas was spread on the entire net at the bottom of the cage. The canvas, which held sand inside the cage and limited feed getting out of the cage, was raised to a height of 20 cm at the sides of the cage. The top of the cage was covered with a nylon net having mesh size of 12 mm. The bottom of the cage had 4 inch thick layer of fine sand. Seawater got in and out of the cage through the top part of the sides (the part without canvas) and through the entire top of the cage. Three sides of top net could be unfastened to get access to the inside of the cage when introducing feed and making observations.

There were 4 treatments resulting from the combination of stocking densities - 10 individuals m^{-2} and 15 individuals m^{-2}; and feeding frequencies - feeding every other day and feeding every third day. Each treatment had 3 replicates. Sea cucumber juveniles were assigned randomly to the treatments. A total of 528 juveniles with an average initial weight of 11.43 g were stocked in the experimental cages. Feed was introduced in each cage at the rate of 3% of the total sea cucumber biomass in the cage.

Unfortunately the study had to be terminated after 44 days of its commencement due to damage caused to the cages by an extreme weather event in southwest monsoon. Nearly all stocked animals were lost during the adverse weather conditions. The recovered animals weighed 29.4 g on average. As there were not enough sea cucumber juveniles it was not possible to repeat the same study. Under the circumstances instead of repeating the initial study a second simpler study was carried out.

The second study was carried out from August to December 2016 for 124 days. Two rectangular bottom-set cages, each measuring 2.7 m x 1.3 m x 0.5 m (height) and having a bottom area of 3.5 m^2 were constructed in the same way as for the initial study. The cage walls and bottoms were covered with two layers of nets to make these cages stronger than the cages used in the initial study. Nylon nets with a mesh size of 12mm and 7mm were used as the outer and inner layers respectively.

As in the cages used in the initial study, a piece of PVC canvas was spread on the entire net at the bottom of the cage. The canvas was raised to a height of 20cm at the sides of the cage. Fine sand was placed in the cage bottom to a thickness of 4 inches. Top of the cage was covered with nylon net having 12 mm mesh. As in the previous cage, seawater got in and out of the cage through the top part of the sides (the part without canvas) and through the entire top of the cage. Three sides of top net could be unfastened to get access to the inside of the cage when introducing feed and making observations. The cages were labeled as A1 and A2 for identification. They were deployed in a calmer site in the lagoon compared to the previous cage site of the first study (Fig. 1).

From a stock of sea cucumber juveniles, 35 individuals were randomly selected for each of the two cages and placed in them to obtain a stocking density of 10 m^{-2} (Fig 2). Each juvenile was individually weighed. The average weight of the stocked juveniles was 20.6 g.

Fig. 2. Juvenile sea cumbers being stocked in bottom-set cages deployed in the lagoon

Feed for the land-based nursing and sea cage culture was prepared at MTDF using locally produced fish meal; and imported soybean meal, rice bran, rice, vitamin premix and mineral premix. Microalgae paste was made from microalgae cultured at MTDF and sea grass powder was made from dead sea grass collected from the beach. The composition of the feed is given in Table 1 and Table 2.

Table 1. Composition of feed used for land-based juvenile nursing

Ingredient	Quantity (g)	%

Fishmeal	40	40
Sea grass powder	20	20
Rice bran	15	15
Soybean meal	10	10
Microalgae paste	14	14
Vitamin premix	0.5	0.5
Mineral premix	0.5	0.5
Total	**100**	**100**

Table 2. Composition of feed used for sea cage culture

Ingredient	Quantity (g)	%
Fishmeal	40	40
Sea grass powder	11	11
Rice bran	3	3
Soybean meal	5	5
Rice flour	14	14
Fine sand	26	26
Vitamin premix	0.5	0.5
Mineral premix	0.5	0.5
Total	**100**	**100**

Feed was put in the cages every other day at the rate of 3% of total biomass in the cage. The cage walls and top net were cleaned of biofouling every two weeks. All the animals in the cage were weighed every month, and the feed amount was adjusted every month based on the biomass in the cage. Weather conditions, water quality, and sea cucumber health were also monitored and recorded.

5. Results and discussions

Growth and survival data for sea cucumbers cultured in the second study are presented in Table 3, Fig. 3 and Fig. 4. The survival was high; mean survival for the two cages was 97.14%. At the end of the culture period the animals reached a mean body weight of 147.05 g and yielded an average biomass of 1424.64 gm^{-2} (Table 3, Fig. 5 and Fig. 6). The specific growth rate (%weight gain day^{-1}) for the culture period was 1.58% day^{-1}.

Table 3. Growth and survival of sandfish in bottom-set sea cages

Indicator	**Cage A1**	**Cage A2**	**Mean**
Survival (%)	100	94.29	97.14
Mean initial body weight (g)	20.17	21.02	20.6
Mean final body weight (g)	147.86	146.24	147.05
Specific growth rate (% day^{-1})	1.61	1.56	1.58
Biomass yield (g m^{-2})	1474.36	1374.93	1424.64

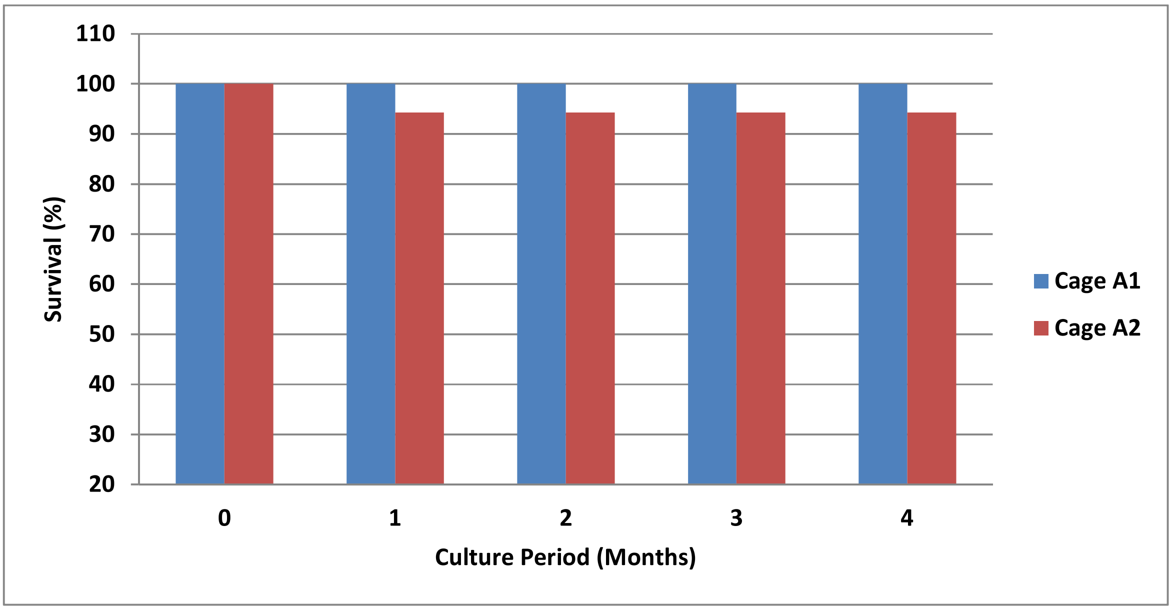

Fig. 3. Monthly survival of sandfish in bottom-set sea cage culture over 124 days

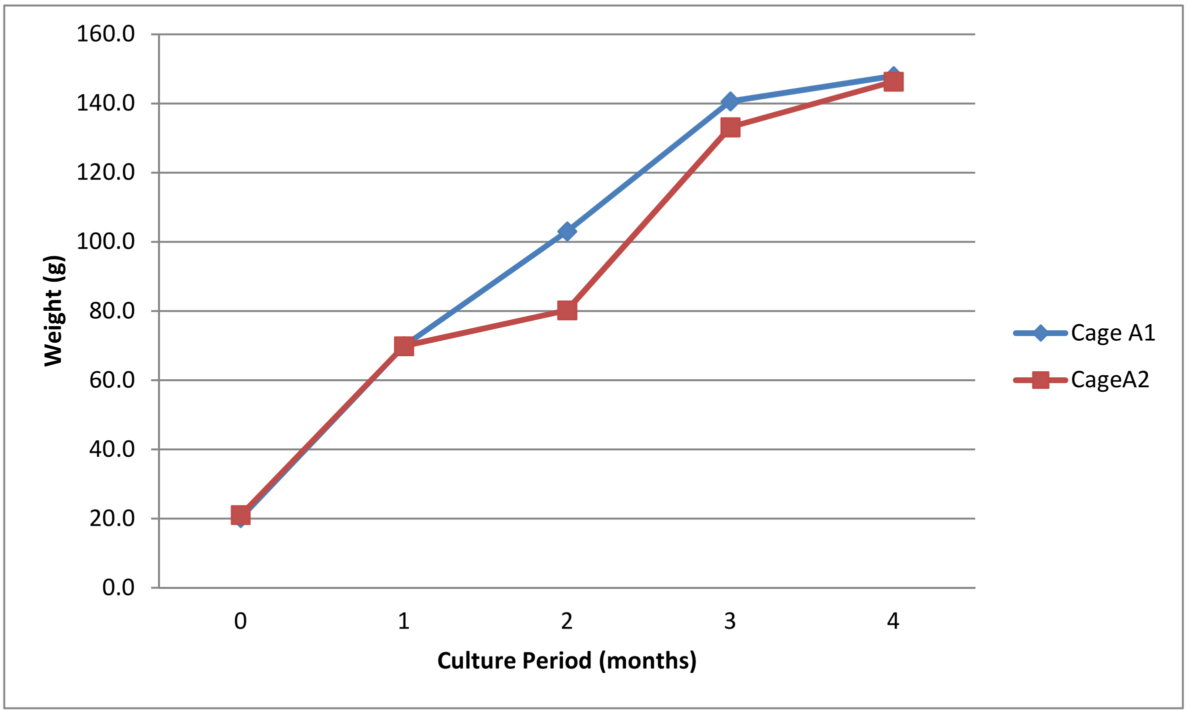

Fig. 4. Mean monthly growth of sandfish in bottom-set sea cage culture in shallow lagoon.

Fig. 5. Harvested sandfish after 124 days of culture in bottom-set sea cages in shallow lagoon

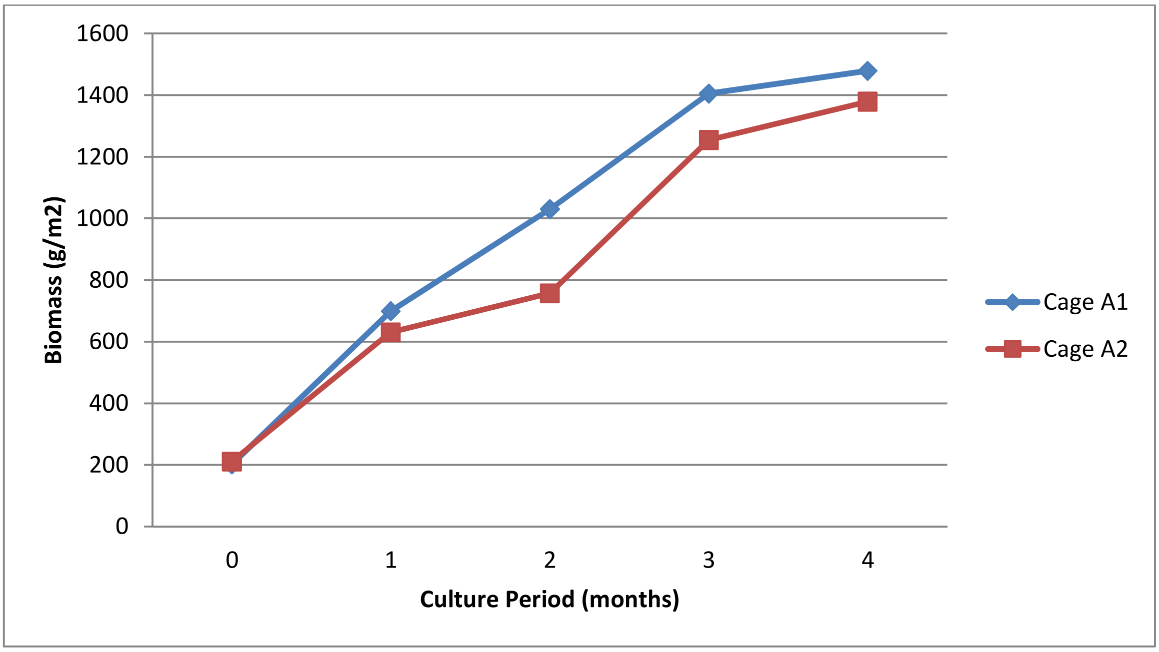

Fig. 6. Biomass yield per unit area for sandfish cultured in bottom-set cages in shallow lagoon

Studies on sandfish growth and survival have been done in various culture systems including ponds and sea pens (Table 4). However, most of these studies were on culturing sandfish from larvae to juveniles. Only limited number of studies has been done on grow-out culture of sandfish (Duy, 2012; Robinson & Pascal, 2011; Bell, J.D *et al*, 2007; Agudo, 2012; Purcell & Simetoga, 2008 and Junio-Menez *et al*, 2016). These grow-out studies were based on extensive methods of culture with no feed inputs. No reports of sandfish culture in bottom-set cages are found in literature. The studies listed in Table 4 differ from the present study in initial weight of the stocked juveniles and length of the study; these studies used smaller juveniles and cultured them for a longer period of time. Due to these differences, comparisons between the listed studies and present study may not be meaningful. However, growth and survival of sandfish in bottom-set cages used in the present study show that this type of cage is a suitable culture system for small scale grow-out of sandfish with feed inputs.

Pen and submerged bottom-set cage and off-bottom cages require different levels of habitat modification. Pen when constructed in seagrass areas requires the removal of seagrass to make a conducive sandy bottom for the sea cucumbers. Bottom-set cage makes the seabed area immediately under the cage inaccessible to living organisms. The off-bottom cage does not have the inaccessibility disadvantage. Living organism and water current can pass between the seabed and bottom of the cage. Unlike pen and bottom-set cage, off-bottom cage can be deployed with minimum impacts in areas of coral rubble and patchy seagrass. Various viable sea cucumber grow-out systems allow island communities to conduct sea cucumber grow-out in different bottom conditions of lagoons and minimize habitat modification impacts of the grow-out operation.

Table 4. Sandfish culture studies carried out in different culture systems.

Culture system	No. of days	Initial weight (g)	Final weight (g)	Stocking density (ind m^{-2})	SGR (%BW day^{-1})/Absolute growth* (g day^{-1})	Biomass yield (g m^{-2})	Survival (%)	Source
Bottom-set cage	124	20.6		10	1.58/1.0	1424.6	97.15	Present study
Pond	420	2	350	1	1.22/0.83	434	80	Duy, 2012

Pond	305	10	310	1	1.12/0.97	147	85	Duy, 2012
Pond	365	11.7	400	0.8	0.96/-	N/A	70	Bell,J.D *et al*, 2007
Pond	360-390	0.9-11.7	325-395	1.6	0.9-1.6/0.9-1.0	N/A	69-73	Agudo, 2012
Sea-pen	250	15	350	1	1.25/1.4	220	80	Robinson & Pascal (2011)
Sea pen	365	8-20	180	3	0.6 – 0.85/1 – 1.8	250	7-20	Purcell & Simetoga, 2008;
Sea pen	162	21.9	106.20	0.6	0.97/1.09	430	86.95	Junio-Menez *et al*, 2016

* Absolute growth for the past studies were calculated based on the data in the study reports.

6. Conclusions and recommendations

Based on the growth and survival of sandfish in bottom-set cages used in the second study and the performances of sandfish in other culture systems, it can be concluded that bottom-set cage is a suitable culture system for small scale grow-out of sandfish with feed inputs, particularly for early stages of grow-out. This type of cage can also be used for nursing smaller juveniles in the sea before putting them in sea pens for further growing. Further studies are needed to determine the most suitable cage size and materials, stocking density, culture period and scale of grow-out operation.

9. Acknowledgements

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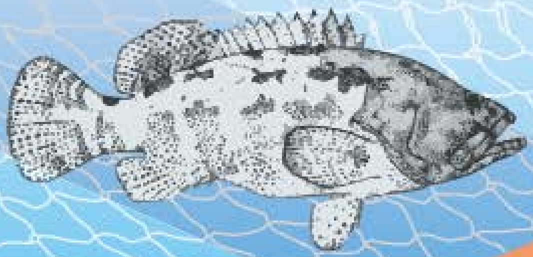
Grouper Grow-out Operations in the Maldives

For Brown-Marbled Grouper (*Epinephelus fuscoguttatus*)



A Feasibility Study

Marine Research Centre, Maldives
Project for the Formulation of Fisheries Sector Master Plan (MASPLAN)

2017

Financial feasibility of grouper grow-out operations in the Maldives

1 Introduction

The establishment of a tourism industry in the Maldives and the development of sea transport, air transport and export markets led to the diversification of the fisheries sector beyond the traditional pole-and-line tuna fishing. Reef fisheries became prominent after the development of the tourism industry that created a local demand. Developments in the transport sector also resulted in the development of export-oriented fisheries for high-valued reef resources (Sattar and Adam, 2005).

The export-oriented fishery for groupers in the Maldives began in 1993. The fishery expanded throughout the Maldives and reached a peak of about 1000 tons within a few years (Sattar and Adam, 2005). Larger animals were usually exported as fresh chilled products, while the smaller individuals were sold for the live reef fish trade, which usually fetches a higher market value. On average over the past 10 years, some 100,000 live groupers (about 50 tons assuming an average weight of 500g each), and 500 tons of fresh or chilled groupers were exported annually (Figure 1). The average annual revenue from the export of live and fresh or chilled groupers was 9 million and 36 million MVR, respectively (Figure 2). Over 90% of the total grouper exports are sold in Hong Kong and Taiwanese markets (Maldives Customs Service, 2017). A gradual downward trend is evident in the contribution of live groupers to the total earnings from grouper exports since the beginning of the fishery in 1993, although the export value of live groupers shows a steady increase (MRC and MCS, 2011).

The fish catch had reduced since the beginning of the fishery and the average sizes of groupers, especially the larger high-valued species, started showing a drastic decline – an indication that the grouper stocks were being over-fished. Management measures are now being implemented for the grouper fishery including the protection of 5 grouper aggregation sites and establishment of size limits for the commercially harvested species of groupers. Mariculture development for species of high-commercial value is also believed to be a potential solution for reducing fishing pressure on these species, while at the same time meeting the market demand. Mariculture development also has potential for creating alternative livelihoods as well as income and employment opportunities for local communities.

The brown-marbled grouper (*Epinephelus fuscoguttatus*) is among the high valued grouper species in the Maldives. Culture techniques for brown-marbled grouper have been developed and are in commercial practice in countries within the Asia-Pacific region. The application of mariculture over wild fish catch in the Maldives is based on four key assumptions (Pomeroy et al., 2004):

- Availability of technology to produce animals in a "closed cycle" and on a regular basis, where the cycle is complete from egg to adult
- Economic feasibility of the operation, in that sufficient quantities are produced at a competitive price with the wild captured animals as well as animals produced elsewhere, targeting the same export markets
- Accessibility to capital, technology and incentives to move into a mariculture business
- Technologies with a low impact to the coral reef environments are available.

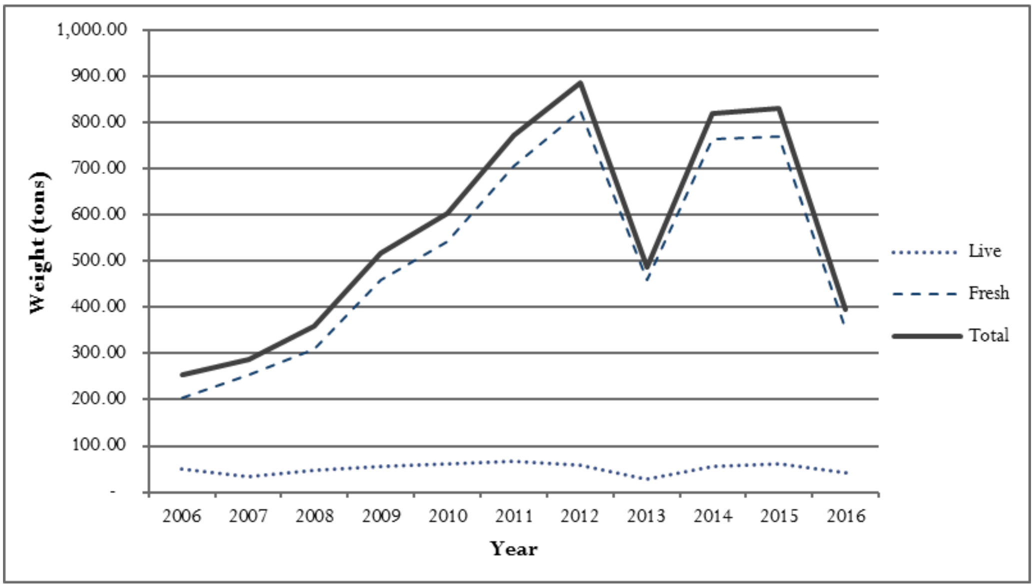


Figure 1. Weight (tons) of groupers exported annually between 2006 - 2016. The figure shows the total weight and the weights of live (assuming on average 500g animals were exported live) and fresh or chilled groupers (source: Maldives Customs Service, 2017a)

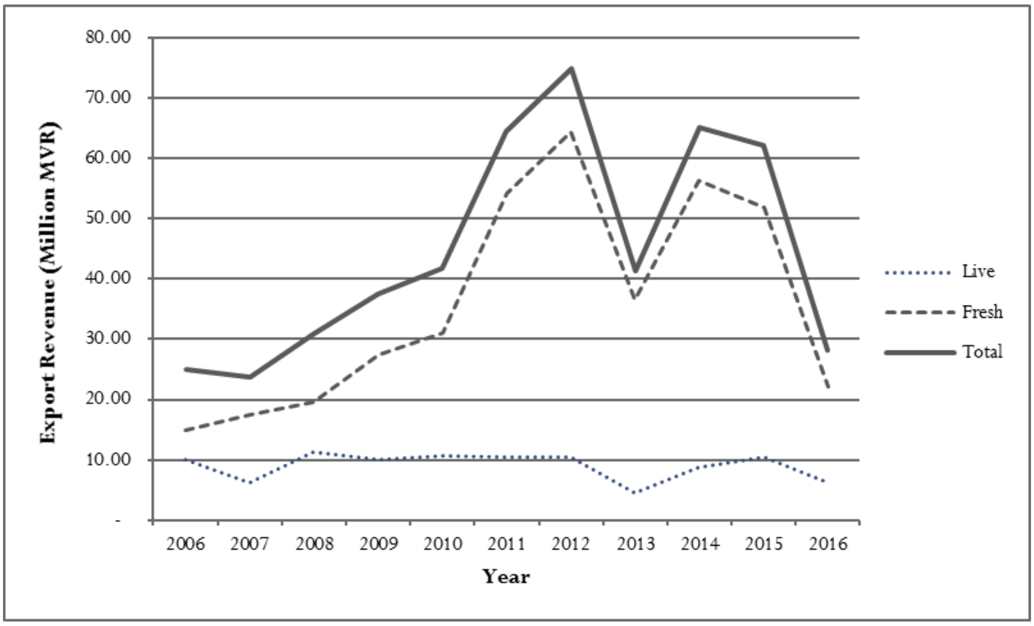


Figure 2. Annual export revenue (million MVR) from grouper sales between 2006 - 2016. The figure shows the total annual earnings and the earnings from live and fresh animals (source: Maldives Customs Service, 2017).

A comprehensive assessment of biology, technology, economics and socio-economic feasibility is required prior to the broad development of mariculture of groupers as a solution for over-fishing in the Maldives. To address this, the Marine Research Centre (MRC) of the Ministry of Fisheries and Agriculture, Maldives, has been working on refining existing mariculture technology to optimize it to the Maldivian setting.

This paper is produced to fulfil a component of MASPLAN, a joint project undertaken by the Ministry of Fisheries and Agriculture, Maldives and Japan International Corporation Agency (JICA) to formulate a framework for the sustainable development of the Maldivian fisheries sector over a 10-year period. The project included several activities related to mariculture development, one of which involves the production of a financial feasibility of grouper grow-out in the Maldives.

2 Objectives

This paper provides an assessment of:

1. The minimum feasible model for a grouper grow-out operation of the brown marbled grouper (*E. fuscoguttatus*) targeting the live reef fish trade.

2. The optimum grouper grow-out model which provides returns that can attract individuals or local companies to invest in this business.

3. Illustrate the key determinants of a successful grow out model starting from operational parameters to business aspects.

2.1 Methods

A combination of primary and secondary data was used for this analysis. Primary data for this study was obtained from technical studies carried out by MRC. As mariculture is relatively new and commercial mariculture operations of groupers are at present non-existent in the Maldives, secondary economic information was sought through interviews of existing grouper exporters and relevant market information available in public domain. The technical assumptions made in this feasibility are derived from mariculture development initiatives undertaken by MRC.

2.2 Grow-out process

Grouper grow-out is carried out in land-based tanks, inland ponds or sea cages (Ismi *et al.*, 2012). The limitations in the availability of adequate land area make the land-based options (tanks and ponds) not feasible for the Maldivian setting. Hence, this study will focus on analyzing the feasibility of grouper grow-out in floating sea cages. The site selected for setting up a floating sea cage system should be calm and sheltered, with a good water flow through the cages (Pérez *et al.*, 2003).

The floating cage modules usually have 4 – 12 compartments supported by a wooden frame measuring 3mx3mx3m on each compartment. Modules with 4 compartments will be used in this study. The frames are kept afloat using plastic drums. The cage module is fastened in place using anchors. Cages are fitted with knotless nylon nets, initially with 4.5 mm mesh, increasing to 12 mm and finally 25 mm mesh (Baliao *et al.*, 2000). The cages are regularly cleaned to control biofouling and to maintain good water flow and reduce the incidence of parasite infestations.

Hatchery bred fingerlings measuring a length of approximately 10 cm and weighing about 15 g are stocked until they reach a size of 450-600 grams (see Table 2). The animals are graded and stocked at an adjusted density based on their growth. Grading is carried out multiple times over the culture period of 8 months. The stocking density adjustments can be made by initially stocking one compartment of a 4-cage module, subsequently increasing the number of stocked cages as the animals grow.

Commercially available dry pellets, farm-made moist pellets and 'trash' fish are used as grow-out feeds (Ismi *et al.*, 2012). Trash fish is widely used as a grow-out feed in Southeast Asia, however, their use is not recommended in order to minimize the incidence of parasite transmission from feed and achieve a better feed conversion ratio. In addition, as Maldives lacks a trash fish industry, it would not be viable to rely on trash fish, as large quantities will be required as grow-out feed. As dry pelleted feeds are the preferred feeding option, this study will assume that dry pellets will be used for grow-out operations. The sizes of the pellets as well as feeding rates are adjusted as the animals grow. The recommended pellet sizes and feeding regime for using dry pellets in grouper culture are shown in Table 1.

Table 1. Recommended pellet sizes for different sizes of groupers and feeding regime for feeding dry pellets to groupers (Ismi et al., 2012)

Fish size (g)	Pellet size (mm)	Daily feeding rate (%BW day^{-1})
5 – 20	2	2 – 4
20 – 100	3	1.5 - 2
100 – 200	4.5	1.2 – 1.5
200 – 300	6	1 – 1.2
>300	6	0.8 – 1

Groupers may take approximately 6 – 8 months to reach market size of 600 – 800 g in grow-out cages, with survival rates of above 80% (Ismi et al., 2012). The figures may vary between regions and the culture practice used.

Current practice for the grouper fishery in the Maldives is that fishermen hold live groupers in cages or sell them directly to exporters; the exporters keep the live fish in cages until they can be exported. It is expected that this arrangement will be used by grouper farmers and exporters for grouper grow-out production as well, at least at the beginning.

Table 2. Culture method to be used:

Culture period	8 months
Cage size	27 m^3
Survival	80%
Max. nos per cage (assuming final stocking at 40 / m^{-3})	1080
Feeding requirements	See table
Market size	600 g

3 Feasibility

This feasibility analysis is for the grow-out production of the brown-marbled grouper (*E. fuscoguttatus*) in floating sea cages in the Maldives. The findings of the analysis indicate that, based on the assumptions outlined below, the sea-cage grow-out production is financially feasible at the scale presented in this paper.

3.1 Baseline assumptions:

- That there is excess demand in the grouper export market; the current declining export figures is a result of being unable to harvest market-size animals for live trade in adequate numbers.
- The initial startup capital including operating costs is structured as: 50% loan, 50% own finance.
- Assumptions for Bank Loan:
    - Interest rate on bank loans is assumed to be 11.75%; at the common current rate for commercial loans available in Maldives.
    - Any additional fees or bank charges for loans are not included.
    - The operator fulfills all obligations to obtain the loan including providing the equity contribution and is assumed to have an asset to offer as collateral as required by the Bank
- General Sales Tax (GST) does not apply to fish products in Maldives.
- Business Profit Tax rate is 15% for Net Profit over MVR 500,000 in Maldives.
- US Dollar to Maldivian Rufiyaa Exchange Rate is the official rate of 15.42 Maldivian Rufiyaa per US Dollar.
- The discount rate for Net Present Value is taken as 11.75%, the same as the cost of capital (bank loan interest rate).
- The production system can be managed/operated by two paid staff for up to 16 cage units.
- All required imported items including feed are duty-exempt.
- General overhead/Miscellaneous expenses are estimated at 3% of total cost (excluding depreciation and loan payments) per year.
- Repair and maintenance costs are assumed at 5 % of total capital costs per year.
- Sea area is rented at MVR 0.05 / square feet / year (the current lagoon rental rate for uninhabited islands set by the Maldives Government)
- Insurance costs are assumed at MVR 250 per cage (MVR 1000 for a 4 Cage unit) per year.
- Capital assets are depreciated in a straight-line method; the salvage value is zero for all capital assets.
- Harvest volumes, revenues and operational expenses are assumed to be constant for each production cycle. For the purposes of this analysis any working capital required to maintain production at maximum capacity is injected into the operation by the business owner at zero financing cost.
- Environmental Impact Assessment is estimated to cost MVR 60,000 (In practice this may increase or decrease depending on the location of the grow-out facility).
- The Grow-out operation is assumed to be located in an inhabited island.
- No losses in production are assumed for adverse weather events or theft.
- Inflation assumptions:
    - Inflation for feeding costs is assumed to grow 1 percent per year from year 2 onwards.
    - No inflation is applied to License fees, accounting fees and other fees paid to the Government.
    - No Inflation is applied to general overhead/miscellaneous expenses.

- No inflation is applied to fingerling purchase prices which are assumed be controlled by the Government.
- No Inflation is assumed for the purchase of aquaculture nets.
- An inflation rate of 2 % per annum is applied to all other costs.

3.2 Technical assumptions for grow out

- This analysis assumes that the grow-out operation is not linked with a hatchery or nursery operation (i.e. the grow-out farms will be stand-alone operations).
- Fingerlings for stocking are assumed to be purchased from a local production facility, to be established in the future.
- Size of initial stock is 15g, assumed to cost at MVR 15 /piece.
- Stocking densities are adjusted within the cage system and the sizes of the cage nets are changed three times during the production cycle, as required. It is assumed that the mechanism for doing these tasks is within the cage design and costings given in the feasibility.
- Fingerlings will be raised from 15 g to a marketable size of 450-600 g in 8 months.
- Each cage unit is 3m x 3m x 3m (27 m^3).
- Assuming stocking density at harvest does not exceed 40 individuals/m^3, maximum number of animals at harvest is 1080 individuals / cage.
- The survival rate is 80% and this is assumed to remain even throughout the grow-out cycle.
- Total numbers of fingerling stocked is 5400 animals for a 4-cage system.
- Dry pelleted feeds are used and all feed inputs are imported.
- Selling price of a market sized grouper starts at MVR 170/kg.
- The risk of losses due to disease incidence and escapes is not factored in.

3.3 Evaluating the investment opportunity

For the purposes of this feasibility, we try to distinguish the levels of profitability and attractiveness for different models from a Maldivian context. An investment decision for an individual or company can depend on many factors. Some companies may already have some of the supporting infrastructure for a grow-out operation such as staff and sea area. This would make it easier for them to decide to start a grow-out even at a smaller scale.

This feasibility study would focus on a new investor examining the business opportunity without any existing infrastructure. It would take into account that a grouper grow-out investment has substantial risks and opportunity costs, such as:

a. All feed and materials need to be imported and that exchange rates can have a high impact on all costs.
b. The risks are currently difficult to quantify or visualize (such as disease, loss of stock due to escape or adverse weather, grouper grow outs not already existing in Maldives), leading to investors feeling reluctant to choose the business.
c. Grouper grow-out operations would compete with countries such as Philippines which already has an established industry with substantially lower cost of production (Pomeroy *et al.*, 2004).
d. An assessment of the growth of the grouper market or stability of pricing requires further study (market data and expertise is required).
e. Opportunity cost: Investment in tourism related businesses are already believed to provide high margins. For example, the investment size for a grouper grow out can be compared to a small-scale guest house operation for tourism, which is currently popular in the Maldives.

Based on these factors, it is necessary to provide an attractive business model with large returns for investors to justify the risks. Table 3 outlines the criteria required to identify an attractive business.

Table 3. Evaluation criteria

Evaluation Criteria	Low Value (unattractive)	Good Value	High value (attractive)
Average net margin	5-10%	11-29%	30% and above
Payback Period (Investment Recovery)	5+ Years	3-5 Years	Less than 3 years
Substantial net Positive Cash Flows: over MVR 500,000	5+ Years	3-5 Years	Less than 3 years
Ability to expand production without external financing	5+ Years	3-5 Years	Less than 3 years
Net Present Value in 5 Years	Negative	Positive	Positive
IRR in 5 Years	>12%	>20%	>30%

4 Findings: key determinants of a successful grow out model.

The parameters found to have the highest impact on the feasibility of the business are:

- Final Harvest weight
- Harvest Stocking density
- Sale Price
- Price of Fingerlings

The single largest cost in a grouper grow-out is cost of feed and it certainly qualifies to make or break the model. There are no alternatives to importing as Maldives does not currently produce suitable feeds. The reason why cost of feed is not considered as a determining factor here is because it is beyond any control of an investor whereas the other factors stated above can be possibly changed to some degree.

4.1 Harvest weight and incremental feeding costs

The production cycle length was assumed to 8 months, which supports growth of up to 600 grams (Figure 3). The growth curve used in the model shows that the possible harvest weights (450-600g) are all close to the end of the cycle (7-8 months).

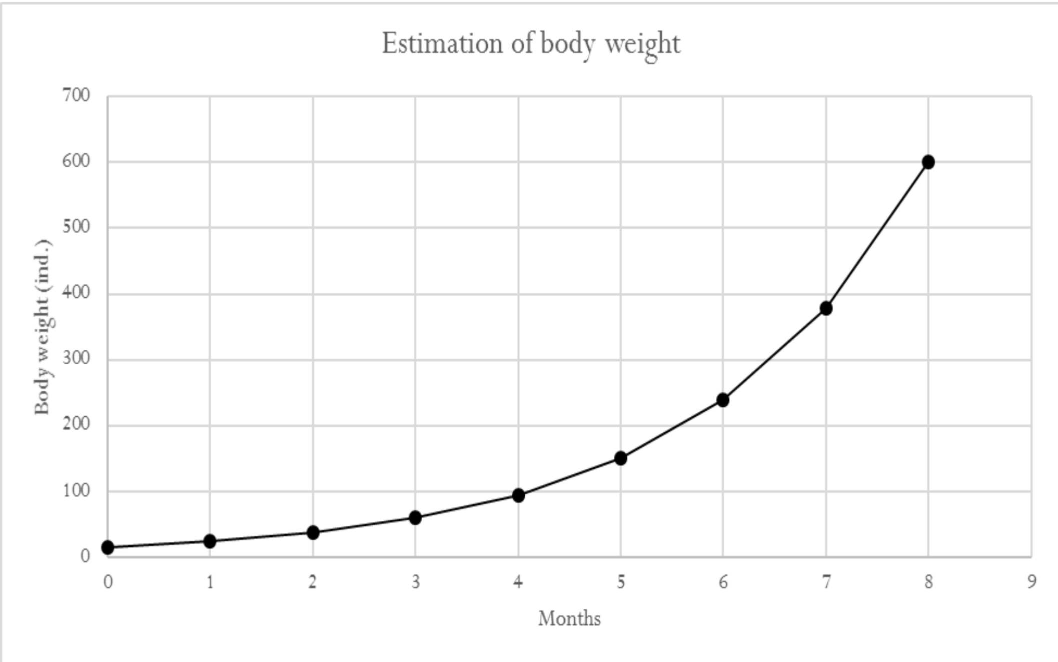


Figure 3: Growth curve for harvest weight of 600 grams (SGR at 1.537)

An analysis was done for feeding costs for 3 target market weights: 450 grams, 500 grams and 600 grams (Table 4)

Table 4. Comparison of feeding cost variations between different possible harvest weights

Weight at Harvest (grams)	Feeding Cost per kg (MVR)	Incremental cost per kg from 450 grams (MVR)
450	62.63	
500	60.71	-1.92
600	53.00	-9.63

As weight increases, incremental feeding costs per gram decline. This translates to a large financial return depending on final harvest weight, as seen in Table 5.

Table 5. Comparison of feeding cost and revenue generated for three different harvest sizes (Calculations were done for the production of 810 market sized groupers from 1 cage at stocking density of 30 individuals/m^3).

Weight	450 grams	500 grams	600 grams
Feeding cost	22,829.31	24,587.19	25,759.11
Incremental Feeding Cost from 450 grams		1,757.88	**2,929.80**
Sale Value	61,965.00	68,850.00	82,620.00
Difference		6,885.00	**20,655.00**

The feed cost to increase harvest weight from 450 grams to 600 grams is MVR 2929.8. This results in an increase in the sale value by MVR 20,655. Other than selling price and stocking density, the weight of the fish has the largest impact on the feasibility of the grow-out.

The ideal target market weight is 600 Grams and this is chosen for the model.

4.2 Harvest Stocking Density

The harvest stocking density values for Grouper are between 30-60 fish/m^3. Analysis was done for values 30, 35 and 40 which are assumed to be feasible (Table 6).

Table 6. Comparison of sales values for a single cage at different stocking densities (A single cage unit is 3m x 3m x 3m, with a volume of 27 m^3)

Stocking Density (fish/m^3)	30	35	40
Amount of fish per cage at 27 m^3	810	945	1080
Sale value at MVR 170 per kg (600 grams per fish)	82,620.00	96,390.00	110,160.00
% Difference from stocking density of 30.		17%	33%

As Table 6 illustrates, changing stocking density from the lowest value of 30 to 35 increases the yield by 17%. A stocking density of 40 increases the yield by 33%.

Stocking density is the production capacity for the sea cages. Increasing stocking density would mean increasing production capacity while keeping fixed costs the same. This has a high impact on the model.

A stocking density value of 40 fish/m$^{3\ is}$ chosen for this feasibility.

4.3 Sale Price

As grouper culture is not currently present in the Maldives, a sale price for the feasibility was based on anecdotal data from an active exporter and prices from Hong Kong.

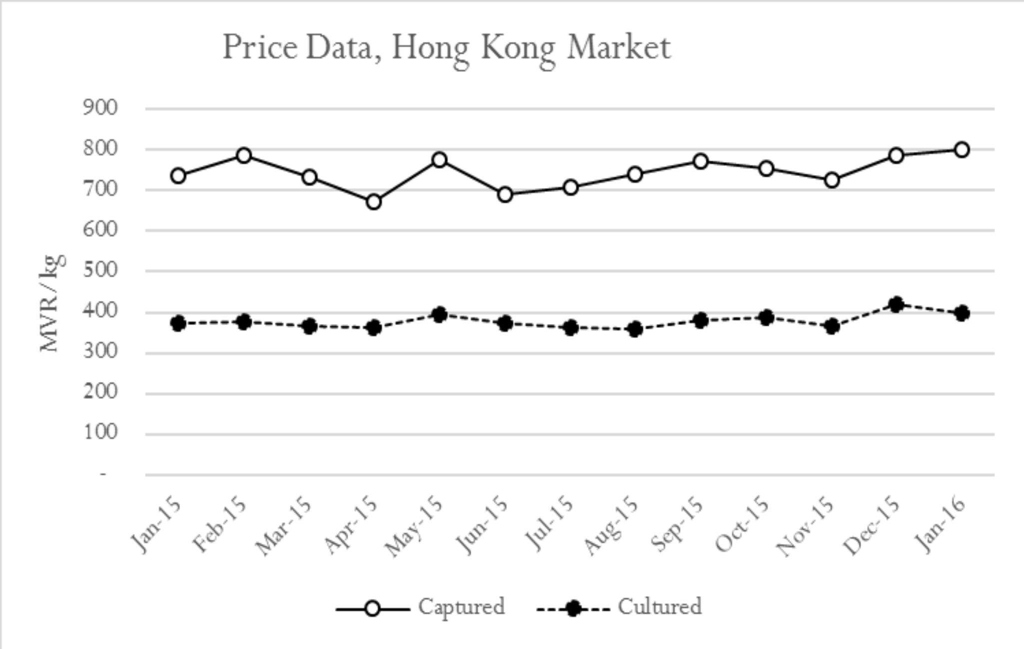


Figure 4: Captured vs Cultured grouper price data. Source: www.hk-fish.net (Agriculture, Fisheries and Conservation Department, The Government of Hong Kong Special Administrative Region)

On average, cultured grouper is priced to be 50% less than wild caught fish. The average sale price for cultured grouper for a period over 13 months ending January 2016 is MVR 378.77 per kg. It is also observed to loosely follow the pricing for wild caught grouper.

Table 7. International market price analysis for cultured grouper (The analysis was carried out using historical market price information available from Hong Kong, Source: www.hk-fish.net)

Prices assumed for Model (MVR)	**170**	**185**	**200**
% Difference from Hong Kong average market price	45%	49%	53%
Hong Kong average price (MVR)	378.77	378.77	378.77
Difference:	208.77	193.77	178.77

The prices assumed for the model leave a very healthy margin for an exporter if these prices are still valid. It is assumed that as per usual in similar industries, the exporter commands an equal or greater margin from the sale.

Additional market data is required to confirm the viability of these sale price figures.

4.4 Price of Fingerlings

Analysis was done for fingerling prices at MVR 15, 18 and 20. Fingerling prices are a large component (approximately 30%) of the direct costs of the grow-out model and can be up to 30-38% of all direct costs (Figure 5).

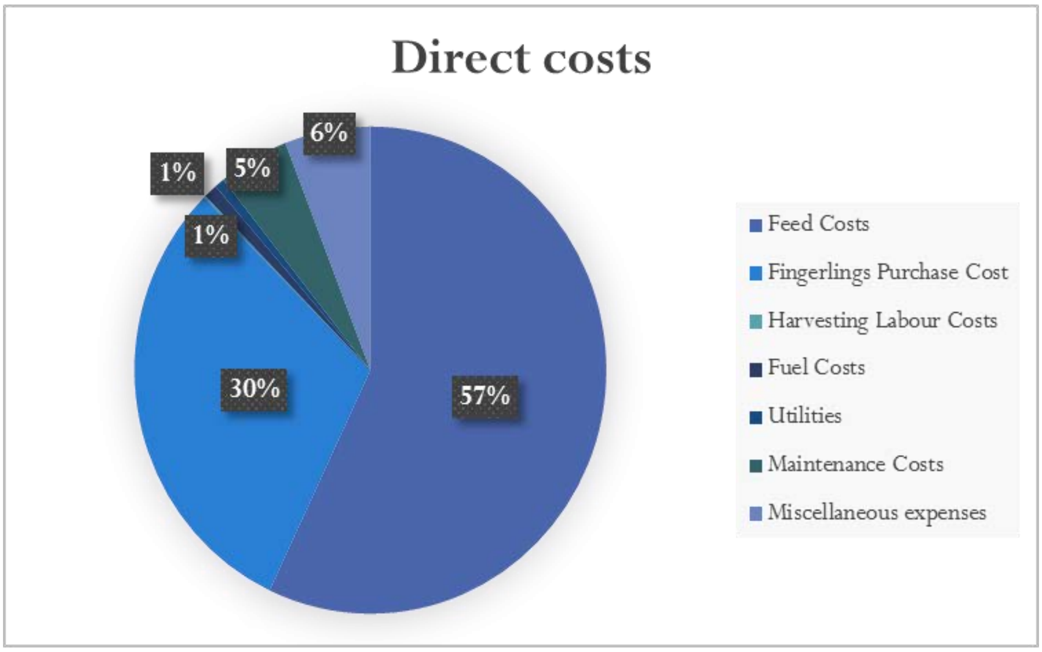


Figure 5: Break down of direct costs for a typical year showing the proportion of fingerling costs.

As fingerlings are not currently available in the Maldives, these figures are assumed values provided by Marine Research Centre.

5 Cost analysis

5.1 Initial Investment

Table 8: Investment breakdown

Startup Expenses	**Costs**		
Number of Cages	**4 Cages**	**8 Cages**	**16 Cages**
Environmental Impact Assessment	60,000.00	60,000.00	60,000.00
Company Registration	4500.00	4500.00	4500.00
Sub Total	**64,500.00**	**64,500.00**	**64,500.00**
Capital Expenses			
Sea Cage Construction	166,905.00	333,810.00	667,620.00
Sea Cages - Deployment	16,691.00	33,381.00	66,762.00
Floating Guardhouse/feed storage-attached to sea cages	41,726.00	41,726.00	41,726.00
Other equipment	8,000.00	16,000.00	32,000.00
Tender Boat with outboard engine	100,000.00	100,000.00	100,000.00
Power Generator	6,000.00	6,000.00	6,000.00
Sub Total	339,322.00	530,917.00	914,108.00
Total Startup and Capital Investment	**403,822.00**	**595,417.00**	**978,608.00**
Total Initial Working Capital	327,629.00	549,024.00	991,812.00
Total Investment	731,451.00	1,144,441.00	1,970,420.00

Based on the analysis, the capital requirement for setting up a grow-out operation may be beyond the financial capacity for some entrepreneurs or small businesses. A total initial capital investment of MVR 1,145,441 is estimated for 8 cages and MVR 2,039,691 is required for 16 Cages (Table 8). The smallest scale of 4 cages requires an initial investment of MVR 732,451, which is still beyond the means for most small-scale investors.

5.2 Initial Working capital

Initial working capital is the amount of cash that is needed at the start to support the entire operation till the first harvest is reached. The assumption is that the grow-out shall receive payment in the 9th month (the month following the harvest).

Initial Working Capital is about 50% of the total investment (Table 9). If the business makes any losses, working capital will need to be replenished so that production can continue at maximum capacity. This may mean the owner needing to add personal funds to the business or borrow from other sources. As in any kind of farming type business, availability of working capital or access to working capital loans determines the level of production that can be maintained.

Table 9: Working capital breakdown

Working Capital Requirements at Start	4 Cages	8 Cages	16 Cages
Fingerling Purchase	81,000.00	162,000.00	324,000.00
Feed Costs	126,537.00	253,073.00	506,146.00
Staff Costs	90,000.00	90,000.00	90,000.00
Maintenance	12,725.00	19,909.00	34,279.00
Harvesting Cost	250.00	500.00	1,000.00
Fuel Expenses	3,750.00	3,750.00	3,750.00
Phone / Utilities	2,700.00	2,700.00	2,700.00
Miscellaneous expenses	10,668.00	17,091.00	29,937.00
Total	**327,629.00**	**549,024.00**	**991,812.00**

5.3 Fixed Costs

These costs are considered minimum values needed to operate the grow-out. Except sea area rental and aquaculture annual license fees, all other costs are the same 4 through to 16 cages (Table 10). If a scenario with more than 16 cages is to be implanted, an additional staff and larger warehousing may be required.

Table 10: Fixed costs breakdown

Staffing Costs	Quantity	Rate	Total
Manager	1 nos.	6,000.00	72,000.00
Laborer	1 nos.	4,000.00	48,000.00
Total	**2**		**120,000.00**
Rent			
Warehouse	1 nos.	3000.00	36,000.00
Total			**36,000.00**
Licenses and Fees			
Insurance	16 unit	250.00	4,000.00
Company Annual License Fees	1 nos	2000.00	2,000.00
Accounting fees	1 nos.		1,500.00
Total			**7,500.00**
Aquaculture nets Replacement	*1 unit*	*5,726.25*	
Sea Area rental	*1 m^2*	*1.1 MVR*	
Aquaculture license annual fees	1 m^2	0.2 MVR	
	4 Cages	**8 Cages**	**16 Cages**
Nets are replaced every 3 years	22,905.00	45,810.00	91,620.00
Sea Area rental charges	39	77.00	155.00
Aquaculture license annual fees	7	14.00	29.00

5.4 Variable costs and assumptions

Table 11: Variable costs

Item	Quantity	Rate (MVR)	Total (MVR)
Fuel Costs (Liters of Fuel per year)	500	10	5,000
Utilities (Phone, water, electricity)	12	300	3,600
Temporary labour costs	MVR 62.5 per hour		
Maintenance Costs	5% of all fixed costs		
General Overhead costs	3% of all expenses except loan payments and depreciation costs		

5.5 Feed Costs

Table 12: Feed costs

Formula Feed (dia. mm)	Price Per bag (USD) (20 kg)	Freight & handling per Bag(distributed) (MVR)	Total Cost (MVR)
1.9	66	167	1,184
3	39	167	768
3	39	167	768
4.5	38	167	753
4.5	38	167	753
6	38	167	753
6	38	167	753
6	38	167	753

Freight and handling costs are based on a figure of MVR 26,667 for 164 kg of feed.

5.6 Production Schedule

For the purpose of the feasibility, a "linear" production schedule is chosen. This means that all cages will produce a harvest at the same time and so the grow-out operation will only receive revenue every nine months. The alternative and better model is a staggered production schedule where the grow-out is phased out in cages, enabling multiple harvests every year. This would distribute costs more evenly and improve monthly cashflow for the business.

A linear production schedule is chosen here to demonstrate the viability of the business in a more straightforward way. The production capacity and costs per cycle remains the same with either method. Given that the length of a cycle is 8 months, there may be 2 harvests in a single year in a linear schedule while the preceding year only produces a single harvest. Fingerlings and feed (major cost components) will need to be purchased for harvests that will occur in the next year (Table 13).

Table 13: Sample linear production schedule

year	months	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8	Cycle 9	Cycle 10	Cycle 11	Cycle 12	Cycle 13	Cycle 14	Year Summary	
	1	2,361															
	2	1,528															
	3	2,292															
	4	2,994	(feed costs)														
	5	3,743															
YEAR 1	6	5,240															
	7	5,240														Fingerlings Purchase	2
	8	8,235		(one month gap before next cycle begins)													
	9															Feeding Costs	37,815
	10		2,361														
	11		1,528													Harvests for Year	1
	12		2,292														
	13		2,994														
	14		3,743														
	15		5,240														
	16		5,240														
	17		8,235														
YEAR 2	18																
	19			2,361												Fingerlings Purchase	1
	20			1,528													
	21			2,292												Feeding Costs	43,612
	22			2,994													
	23			3,743												Harvests for Year	1
	24			5,240													
	25			5,240													
	26			8,235													
	27																
	28				2,361												
	29				1,528												
YEAR 3	30				2,292												
	31				2,994											Fingerlings Purchase	1
	32				3,743												
	33				5,240											Feeding Costs	45,109
	34				5,240												
	35				8,235											Harvests for Year	2
	36																

5.7 Scenario 1: 4 Cages Profit and Loss Statement

Table 14: 4 Cages scenario summary

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Harvests during the period per cage	1	1	2	1	1	2	1	1	2	1
Production Volume in kg	2,592	2,592	5,184	2,592	2,592	5,184	2,592	2,592	5,184	2,592
Fingerling Purchase during period, per cage	2	1	1	2	1	1	2	1	1	2
Revenue Types										
Live Fish for export	518,400	518,400	1,036,800	518,400	518,400	1,036,800	518,400	518,400	1,036,800	518,400
Total Revenues	518,400	518,400	1,036,800	518,400	518,400	1,036,800	518,400	518,400	1,036,800	518,400
Direct costs										
Feed Costs	151,260	176,193	184,046	155,798	181,426	189,459	160,336	186,660	194,872	164,874
Fingerlings Purchase Cost	81,000	81,000	81,000	162,000	81,000	81,000	162,000	81,000	81,000	162,000
Harvesting Labour Costs	250	255	260	265	271	276	282	287	293	299
Fuel Costs	5,000	5,100	5,202	5,306	5,412	5,520	5,631	5,743	5,858	5,975
Utilities	3,600	3,672	3,745	3,820	3,897	3,975	4,054	4,135	4,218	4,302
Maintenance Costs	16,966	16,966	16,966	16,966	16,966	16,966	16,966	16,966	16,966	16,966
Miscellaneous expenses	12,559	13,406	13,740	15,422	13,860	14,200	15,856	14,315	14,662	16,291
Sub Total	270,635	296,591	304,960	359,578	302,832	311,397	365,125	309,107	317,869	370,708
Gross profit	*247,765*	*221,809*	*731,840*	*158,822*	*215,568*	*725,403*	*153,275*	*209,293*	*718,931*	*147,692*
Gross Margin %	*48%*	*43%*	*71%*	*31%*	*42%*	*70%*	*30%*	*40%*	*69%*	*28%*
Indirect Costs										
Aquaculture Nets replacement	-	-	-	22,905	-	-	-	22,905	-	-
Staff Costs	120,000	122,400	124,800	127,200	129,600	132,000	134,400	136,800	139,200	141,600
Licenses and Fees	4,507	4,507	4,507	4,507	4,507	4,507	4,507	4,507	4,507	4,507
Rental Costs	36,039	36,760	37,480	38,201	38,922	39,643	40,363	41,084	41,805	42,526
Loan Repayment- Interest only	39,962	32,878	24,916	15,966	5,906	-	-	-	-	-
Total Depreciation Expenses	20,502	20,502	20,502	20,502	20,502	20,502	20,502	20,502	20,502	20,502
Sub Total	221,010	217,047	212,205	229,281	199,437	196,651	199,772	225,798	206,014	209,135
Total Expenses	491,645	513,638	517,165	588,859	502,269	508,048	564,897	534,905	523,883	579,843
Net Profit Before Tax	26,755	4,762	519,635	(70,459)	16,131	528,752	(46,497)	(16,505)	512,917	(61,443)
Net margin %	*5%*	*1%*	*50%*	*-14%*	*3%*	*51%*	*-9%*	*-3%*	*49%*	*-12%*
Business Profit Tax	-	-	77,945	-	-	79,313	-	-	76,938	-
Profit After Tax	**26,755**	**4,762**	**441,690**	**(70,459)**	**16,131**	**449,439**	**(46,497)**	**(16,505)**	**435,979**	**(61,443)**

Investment Analysis	Year 10	Year 5	Year 3	Recovery Period- Years
NPV	(197,357)	(497,699)	(394,495)	8.4
IRR	5%	-	-19%	Cost of production MVR/kg
Cumulative Cashflow: Including Investment	247,730	(518,681)	(333,087)	105.78
Average Monthly Revenue/loss- over 10 Years	11,784	Average net profit margin		12%

5.8 Scenario 2: 8 Cages Profit and Loss Statement

Table 15: 8 Cage scenario summary

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Harvests during the period per cage	1	1	2	1	1	2	1	1	2	1
Production Volume in kg	5,184	5,184	10,368	5,184	5,184	10,368	5,184	5,184	10,368	5,184
Fingerling Purchase during period, per cage	2	1	1	2	1	1	2	1	1	2
Revenue Types										
Live Fish for export	1,036,800	1,036,800	2,073,600	1,036,800	1,036,800	2,073,600	1,036,800	1,036,800	2,073,600	1,036,800
Total Revenues	1,036,800	1,036,800	2,073,600	1,036,800	1,036,800	2,073,600	1,036,800	1,036,800	2,073,600	1,036,800
Direct costs										
Feed Costs	302,521	352,386	368,092	311,596	362,853	378,918	320,672	373,319	389,745	329,748
Fingerlings Purchase Cost	162,000	162,000	162,000	324,000	162,000	162,000	324,000	162,000	162,000	324,000
Harvesting Labour Costs	500	510	520	531	541	552	563	574	586	598
Fuel Costs	5,000	5,100	5,202	5,306	5,412	5,520	5,631	5,743	5,858	5,975
Utilities	3,600	3,672	3,745	3,820	3,897	3,975	4,054	4,135	4,218	4,302
Maintenance Costs	26,546	26,546	26,546	26,546	26,546	26,546	26,546	26,546	26,546	26,546
Miscellaneous expenses	19,853	21,448	22,018	25,283	22,060	22,641	25,854	22,673	23,266	26,426
Sub Total	520,019	571,661	588,124	697,082	583,308	600,153	707,320	594,991	612,218	717,595
Gross profit	*516,781*	*465,139*	*1,485,476*	*339,718*	*453,492*	*1,473,447*	*329,480*	*441,809*	*1,461,382*	*319,205*
Gross Margin %	*50%*	*45%*	*72%*	*33%*	*44%*	*71%*	*32%*	*43%*	*70%*	*31%*
Indirect Costs										
Aquaculture Nets replacement	-	-	-	45,810	-	-	-	45,810	-	-
Staff Costs	120,000	122,400	124,800	127,200	129,600	132,000	134,400	136,800	139,200	141,600
Licenses and Fees	5,514	5,514	5,514	5,514	5,514	5,514	5,514	5,514	5,514	5,514
Rental Costs	36,077	36,799	37,521	38,242	38,964	39,685	40,407	41,128	41,850	42,571
Loan Repayment- Interest only	62,525	51,442	38,984	24,981	9,240	-	-	-	-	-
Total Depreciation Expenses	34,337	34,337	34,337	34,337	34,337	34,337	34,337	34,337	34,337	34,337
Sub Total	258,454	250,492	241,156	276,084	217,655	211,536	214,658	263,589	220,901	224,022
Total Expenses	778,473	822,154	829,280	973,166	800,964	811,689	921,977	858,581	833,119	941,617
Net Profit Before Tax	258,327	214,646	1,244,320	63,634	235,836	1,261,911	114,823	178,219	1,240,481	95,183
Net margin %	*25%*	*21%*	*60%*	*6%*	*23%*	*61%*	*11%*	*17%*	*60%*	*9%*
Business Profit Tax	-	-	186,648	-	-	189,287	-	-	186,072	-
Profit After Tax	**258,327**	**214,646**	**1,057,672**	**63,634**	**235,836**	**1,072,624**	**114,823**	**178,219**	**1,054,409**	**95,183**

Investment Analysis	Year 10	Year 5	Year 3	Recovery Period- Years
NPV	968,416	(6,591)	(55,478)	2.72
IRR	30%	11%	9%	Cost of production MVR/kg
Cumulative Cashflow: Including Investment	2,909,554	374,491	275,883	102.09
Average Monthly Revenue/loss - over 10 Years	40,895	Average net profit margin:		29%

6 Scenario 2: 8 Cages: Cashflow

Table 16: 8 Cage scenario cashflow

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash at hand- Beginning Balance		549,024	841,687	990,233	1,969,348	1,940,421	2,067,956	3,023,038	3,172,197	3,384,753	4,473,499
Cash at hand- Ending Balance		841,687	990,233	1,969,348	1,940,421	2,067,956	3,023,038	3,172,197	3,384,753	4,473,499	4,603,018
Cash injection - Own Finance			0	0	0	0	0	0	0	0	0
Cash Income- Inflow		1,036,800	1,036,800	2,073,600	1,036,800	1,036,800	2,073,600	1,036,800	1,036,800	2,073,600	1,036,800
Total Inflows		**1,036,800**	**1,036,800**	**2,073,600**	**1,036,800**	**1,036,800**	**2,073,600**	**1,036,800**	**1,036,800**	**2,073,600**	**1,036,800**
Feed Costs		(302,521)	(352,386)	(368,092)	(311,596)	(362,853)	(378,918)	(320,672)	(373,319)	(389,745)	(329,748)
Fingerlings Purchase Cost		(162,000)	(162,000)	(162,000)	(324,000)	(162,000)	(162,000)	(324,000)	(162,000)	(162,000)	(324,000)
Harvesting Labour Costs		(500)	(510)	(520)	(531)	(541)	(552)	(563)	(574)	(586)	(598)
Fuel Costs		(5,000)	(5,100)	(5,202)	(5,306)	(5,412)	(5,520)	(5,631)	(5,743)	(5,858)	(5,975)
Utilities		(3,600)	(3,672)	(3,745)	(3,820)	(3,897)	(3,975)	(4,054)	(4,135)	(4,218)	(4,302)
Maintenance Costs		(26,546)	(26,546)	(26,546)	(26,546)	(26,546)	(26,546)	(26,546)	(26,546)	(26,546)	(26,546)
Miscellaneous expenses		(19,853)	(21,448)	(22,018)	(25,283)	(22,060)	(22,641)	(25,854)	(22,673)	(23,266)	(26,426)
Aquaculture Nets replacement		0	0	0	(45,810)	0	0	0	(45,810)	0	0
Staff Costs		(120,000)	(122,400)	(124,800)	(127,200)	(129,600)	(132,000)	(134,400)	(136,800)	(139,200)	(141,600)
Licenses and Fees		(5,514)	(5,514)	(5,514)	(5,514)	(5,514)	(5,514)	(5,514)	(5,514)	(5,514)	(5,514)
Rental Costs		(36,077)	(36,799)	(37,521)	(38,242)	(38,964)	(39,685)	(40,407)	(41,128)	(41,850)	(42,571)
Loan Repayment- Interest only		(62,525)	(51,442)	(38,984)	(24,981)	(9,240)	0	0	0	0	0
Loan Repayment- Capital		0	(100,437)	(112,895)	(126,898)	(142,638)	(151,879)	0	0	0	0
Cash Withdrawal:											
Business Profit Tax		0	0	(186,648)	0	0	(189,287)	0	0	(186,072)	0
Total outflows		**(744,137)**	**(888,253)**	**(1,094,486)**	**(1,065,727)**	**(909,265)**	**(1,118,518)**	**(887,641)**	**(824,244)**	**(984,854)**	**(907,280)**
	Investment										
Net Cashflow	**(1,144,440.90)**	**292,663**	**148,547**	**979,114**	**(28,927)**	**127,535**	**955,082**	**149,159**	**212,556**	**1,088,746**	**129,520**
Cumulative Cashflows		**(851,778)**	**(703,231)**	**275,883**	**246,956**	**374,491**	**1,329,573**	**1,478,733**	**1,691,289**	**2,780,034**	**2,909,554**

6.1 Scenario 3: 16 Cages: Profit and Loss Statement

Table 17: 16 Cage scenario summary

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Harvests during the period per cage	1	1	2	1	1	2	1	1	2	1
Production Volume in kg	10,368	10,368	20,736	10,368	10,368	20,736	10,368	10,368	20,736	10,368
Fingerling Purchase during period, per cage	2	1	1	2	1	1	2	1	1	2
Revenue Types										
Live Fish for export	2,073,600	2,073,600	4,147,200	2,073,600	2,073,600	4,147,200	2,073,600	2,073,600	4,147,200	2,073,600
Total Revenues	2,073,600	2,073,600	4,147,200	2,073,600	2,073,600	4,147,200	2,073,600	2,073,600	4,147,200	2,073,600
Direct costs										
Feed Costs	605,042	704,771	736,184	623,193	725,705	757,837	641,344	746,639	779,489	659,495
Fingerlings Purchase Cost	324,000	324,000	324,000	648,000	324,000	324,000	648,000	324,000	324,000	648,000
Harvesting Labour Costs	1,000	1,020	1,040	1,061	1,082	1,104	1,126	1,149	1,172	1,195
Fuel Costs	5,000	5,100	5,202	5,306	5,412	5,520	5,631	5,743	5,858	5,975
Utilities	3,600	3,672	3,745	3,820	3,897	3,975	4,054	4,135	4,218	4,302
Maintenance Costs	45,705	45,705	45,705	45,705	45,705	45,705	45,705	45,705	45,705	45,705
Miscellaneous expenses	34,441	37,532	38,574	45,004	38,459	39,523	45,848	39,388	40,473	46,694
Sub Total	1,018,788	1,121,801	1,154,452	1,372,090	1,144,261	1,177,665	1,391,709	1,166,759	1,200,916	1,411,368
Gross profit	*1,054,812*	*951,799*	*2,992,748*	*701,510*	*929,339*	*2,969,535*	*681,891*	*906,841*	*2,946,284*	*662,232*
Gross Margin %	*51%*	*46%*	*72%*	*34%*	*45%*	*72%*	*33%*	*44%*	*71%*	*32%*
Indirect Costs										
Aquaculture Nets replacement	-	-	-	91,620	-	-	-	91,620	-	-
Staff Costs	120,000	122,400	124,800	127,200	129,600	132,000	134,400	136,800	139,200	141,600
Licenses and Fees	7,529	7,529	7,529	7,529	7,529	7,529	7,529	7,529	7,529	7,529
Rental Costs	36,155	36,878	37,601	38,324	39,047	39,770	40,494	41,217	41,940	42,663
Loan Repayment- Interest only	107,652	88,570	67,120	43,010	15,910	-	-	-	-	-
Total Depreciation Expenses	62,007	62,007	62,007	62,007	62,007	62,007	62,007	62,007	62,007	62,007
Sub Total	333,342	317,383	299,057	369,690	254,092	241,306	244,429	339,172	250,675	253,798
Total Expenses	1,352,130	1,439,184	1,453,508	1,741,780	1,398,354	1,418,970	1,636,138	1,505,931	1,451,591	1,665,166
Net Profit Before Tax	721,470	634,416	2,693,692	331,820	675,246	2,728,230	437,462	567,669	2,695,609	408,434
Net margin %	*35%*	*31%*	*65%*	*16%*	*33%*	*66%*	*21%*	*27%*	*65%*	*20%*
Business Profit Tax	108,220	95,162	404,054	-	101,287	409,234	-	85,150	404,341	-
Profit After Tax	**613,249**	**539,254**	**2,289,638**	**331,820**	**573,959**	**2,318,995**	**437,462**	**482,518**	**2,291,268**	**408,434**

Investment Analysis	Year 10	Year 5	Year 3	Recovery Period- Years
NPV	3,061,776	768,768	467,707	2.4
IRR	43%	29%	24%	Cost of production MVR/kg
Cumulative Cashflow: Including Investment	7,843,381	1,856,165	1,290,441	100.24
Average Monthly Revenue/loss	99,117	Average net profit margin:		38%

6.2 Scenario 3: 16 Cages: Cashflow

Table 18: 16 Cage scenario cashflow

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash at hand- Beginning Balance		991,812	1,667,068	2,095,403	4,252,674	4,428,016	4,818,397	6,937,905	7,437,373	7,981,898	10,335,173
Cash at hand- Ending Balance		1,667,068	2,095,403	4,252,674	4,428,016	4,818,397	6,937,905	7,437,373	7,981,898	10,335,173	10,805,613
Cash injection - Own Finance			0	0	0	0	0	0	0	0	0
Cash Income- Inflow		2,073,600	2,073,600	4,147,200	2,073,600	2,073,600	4,147,200	2,073,600	2,073,600	4,147,200	2,073,600
Total Inflows		**2,073,600**	**2,073,600**	**4,147,200**	**2,073,600**	**2,073,600**	**4,147,200**	**2,073,600**	**2,073,600**	**4,147,200**	**2,073,600**
Feed Costs		(605,042)	(704,771)	(736,184)	(623,193)	(725,705)	(757,837)	(641,344)	(746,639)	(779,489)	(659,495)
Fingerlings Purchase Cost		(324,000)	(324,000)	(324,000)	(648,000)	(324,000)	(324,000)	(648,000)	(324,000)	(324,000)	(648,000)
Harvesting Labour Costs		(1,000)	(1,020)	(1,040)	(1,061)	(1,082)	(1,104)	(1,126)	(1,149)	(1,172)	(1,195)
Fuel Costs		(5,000)	(5,100)	(5,202)	(5,306)	(5,412)	(5,520)	(5,631)	(5,743)	(5,858)	(5,975)
Utilities		(3,600)	(3,672)	(3,745)	(3,820)	(3,897)	(3,975)	(4,054)	(4,135)	(4,218)	(4,302)
Maintenance Costs		(45,705)	(45,705)	(45,705)	(45,705)	(45,705)	(45,705)	(45,705)	(45,705)	(45,705)	(45,705)
Miscellaneous expenses		(34,441)	(37,532)	(38,574)	(45,004)	(38,459)	(39,523)	(45,848)	(39,388)	(40,473)	(46,694)
Aquaculture Nets replacement		0	0	0	(91,620)	0	0	0	(91,620)	0	0
Staff Costs		(120,000)	(122,400)	(124,800)	(127,200)	(129,600)	(132,000)	(134,400)	(136,800)	(139,200)	(141,600)
Licenses and Fees		(7,529)	(7,529)	(7,529)	(7,529)	(7,529)	(7,529)	(7,529)	(7,529)	(7,529)	(7,529)
Rental Costs		(36,155)	(36,878)	(37,601)	(38,324)	(39,047)	(39,770)	(40,494)	(41,217)	(41,940)	(42,663)
Loan Repayment- Interest only		(107,652)	(88,570)	(67,120)	(43,010)	(15,910)	0	0	0	0	0
Loan Repayment- Capital		0	(172,925)	(194,374)	(218,484)	(245,585)	(261,494)	0	0	0	0
Cash Withdrawal:											
Business Profit Tax		(108,220)	(95,162)	(404,054)	0	(101,287)	(409,234)	0	(85,150)	(404,341)	0
Total outflows		**(1,398,344)**	**(1,645,265)**	**(1,989,930)**	**(1,898,257)**	**(1,683,219)**	**(2,027,693)**	**(1,574,132)**	**(1,529,075)**	**(1,793,926)**	**(1,603,159)**
	Investment										
Net Cashflow	**(1,970,420.35)**	**675,256**	**428,335**	**2,157,270**	**175,343**	**390,381**	**2,119,507**	**499,468**	**544,525**	**2,353,274**	**470,441**
Cumulative Cashflows		**(1,295,165)**	**(866,829)**	**1,290,441**	**1,465,784**	**1,856,165**	**3,975,672**	**4,475,141**	**5,019,666**	**7,372,940**	**7,843,381**

7 Discussion

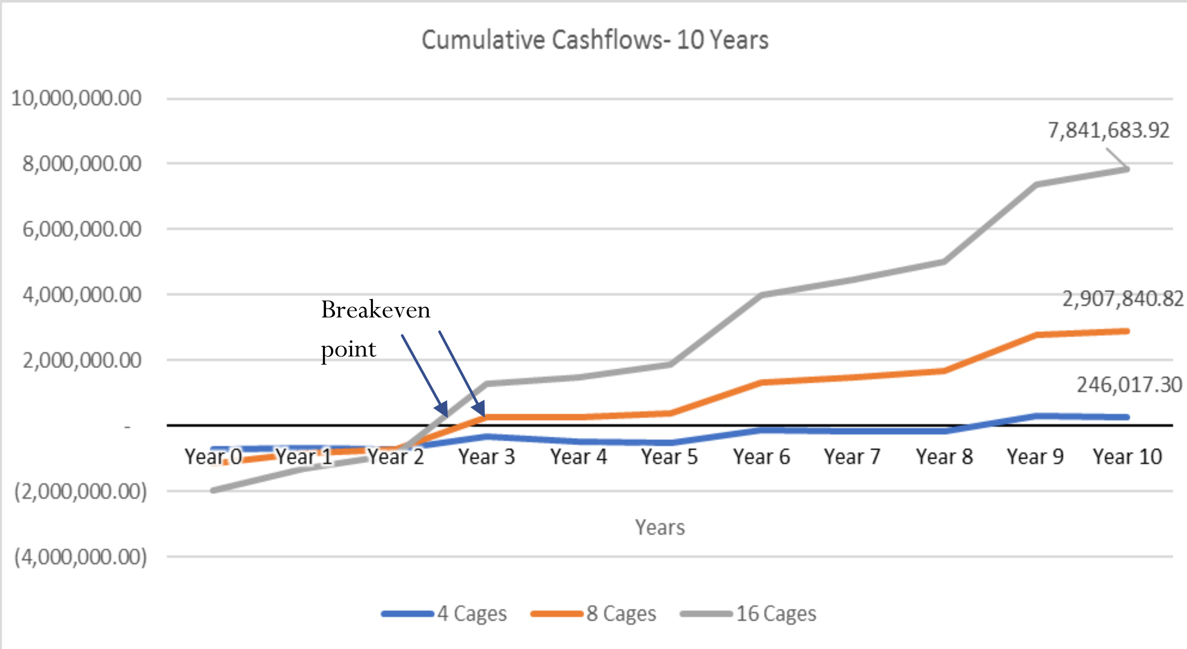


Figure 6: Cumulative Cashflows for all Scenarios

7.1 4 Cage Scenario

The model shows that a 4-cage system is unfeasible (see Table 14). Although the average net profit margin over 10 years is 12% (generating a profit of MVR 11,784 per month), the Net Present Value remains negative throughout the entire 10-year forecast. Simply stated, this means that after accounting for the time value of money, the total value of the investment at the end of 10 years is less than the amount of cash put in to start it. The scenario does eventually break even in 8.4 years, yet at no point does it generate enough profit to expand production capacity by another 4 cages.

A price sensitivity analysis shows that the 4 Cage Scenario starts to become viable if the sale price is increased to MVR 245 (23% increase) from MVR 200 used in the model (Table 19). The Scenario becomes attractive if the price is increased to MVR 260 (30% increase).

Table 19: Price sensitivity analysis for year 5 - 4 cages

4 Cages	Investment at Year 5				
Sale Price per Kg	200	215	230	**245**	**260**
Cumulative Cashflow	(518,681)	(297,065)	(75,449)	**146,167**	**367,783**
Net profit margin	12%	18%	24%	**28%**	**32%**
Average Monthly Profit	11,784	15,996	20,208	**24,420**	**28,632**
Recovery Period- Years	8.4	5.7	5.1	**2.8**	**2.6**
NPV	(497,699)	(354,050)	(210,401)	(66,751)	76,898
IRR	(n/a)	-20%	-4%	7%	17%

Based on the assumptions used in this model, a 4-cage system is unfeasible and can be deemed to hold little interest for an investor unless the sale price can be increased to MVR 260 per kg. If the grow-out operation was able to export the product by itself (cutting out the middle man) it may be possible that a similar price can be achieved. This is because the international market price is higher. Also, feedback from exporters point to a healthy margin from groupers. However, such a strategy will require further investment and analysis as profit margins of an exporter is unknown.

7.2 8 Cage Scenario

The 8-cage scenario (see Table 15) shows that it is viable, yet does not meet the requirements for high value investment criteria (see Table 3. Evaluation criteria). The Scenario breaks even within 3 years, which is quite good for an investment. At year 5, the cumulative cashflow (Table 16) is MVR 374,491. By Year 6, the cumulative cashflow increases to MVR 1,329,573; this is because there are 2 harvests occurring that year based on liner production cycle (a staggered production cycle can even out this difference, refer to Table 13: Sample linear production schedule). This return enables the business to expand production to 16 cages without external financing provided that the investor does not withdraw money over the preceding 5 years. Production capacity can be increased by 4 cages (to a total of 12 cages) in 5 years. The net present value is negative by a very small amount at Year 5 (MVR -6,591) and becomes positive from the next year onwards. The average monthly revenue is MVR 40,895 with an average net profit margin of 29%. Cost of production per kg of fish (using feed and direct costs) is MVR 102/kg which remains similar through all scenarios as can be expected.

The Internal Rate of Return (IRR) at year 5 is 11%, slightly less than the interest rate (11.75%). As an indicator, an investor would desire that the IRR figure be significantly higher than the interest rate.

Over 10 years, after investing MVR 1.14 million at the start, the investor generates MVR 2.9 million in cumulative cashflow (profit) after repaying all loans and recovering the initial investment. The scenario can be considered of average to good value and yet not highly attractive enough by itself for investors considering a similar investment in a tourism related business may bring in potentially higher returns. It still qualifies as a good starting scenario with a view to expand to 16 cages.

Table 20: Sensitivity analysis- year 5- 8 cage scenario

8 Cages	Investment at Year 5				
Sale Price per Kg	200	215	**230**	245	260
NPV	(6,591)	280,707	**568,006**	855,305	975,590
IRR	11%	23%	**33%**	42%	45%
Cumulative Cashflow	374,491	**817,723**	**1,260,955**	1,704,187	1,901,130
Net profit margin	29%	34%	**38%**	42%	46%
Average Monthly Profit	40,895	49,319	**57,743**	66,167	74,591
Recovery Period- Years	2.7	2.5	**2.3**	2.2	2.2
Double production Capacity (Year)	6	6	5	4	3

The sensitivity analysis (Table 20) shows that the 8-cage scenario becomes a highly attractive investment if the sale price can be increased to MVR 230. It will still take 5 years to double production capacity. The cumulative cashflow even at MVR 215 /kg is quite substantial.

7.3 16 Cages Scenario

The analysis shows that 16 cages (Table 17) is the best scenario for a grouper grow-out operation. It requires an investment of MVR 1.9 million (72% more than for an 8-cage system) but the total profit earned over 10 years after investment recovery is 170% higher (MVR 7.8 Million for 16 cages, MVR 2.9 Million for 8 cages). The investment is recovered within 2.4 years with a cumulative cashflow of MVR 1.85 million in 5 years. NPV is positive throughout. It also allows expansion at a faster pace than an 8-cage model (refer Table 29: Production expansion options from the model.)

Table 21: Evaluation of 16 and 8 cage scenarios against high value investment criteria.

Evaluation Criteria	High value (attractive)	16 Cages	8 Cages
Average net margin	>30%	38%	29%
Payback Period (Investment Recovery)	< 3 years	2.4 Years	2.72 Years
Substantial net Positive Cash Flows: over MVR 500,000	< 3 years	MVR 1.29 million in 3 years	MVR 275,883 in 3 years
Ability to expand production without external financing	< 3 years	Additional 8 cages in 3 years	Additional 4 cages in 5 years
Net Present Value in 5 Years	Positive	Positive	Negative
IRR in 5 Years	>30%	29%	11%

We can see that the scenario fulfills the high value investment criteria set at outset with only the IRR at 5 years a single percentage point below at 29%, which is negligible (Table 21).

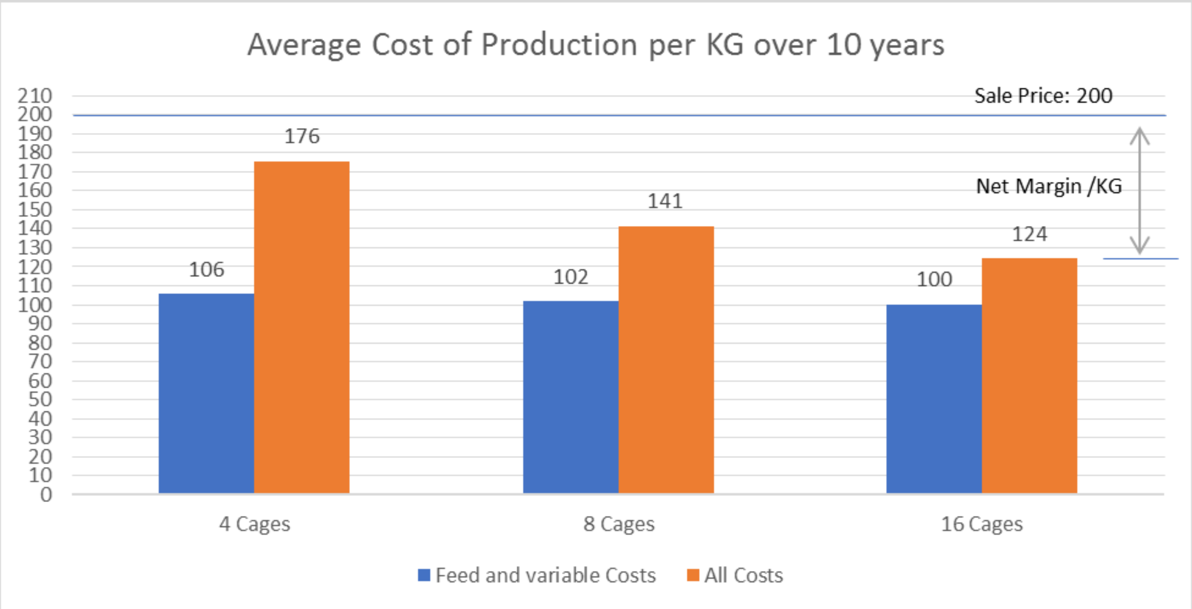


Figure 7: Average Cost of Production for all Scenarios

In Figure 7: Average Cost of Production for all Scenarios, we can see the cost of production per kg (considering all costs) is MVR 17 (14%) less for 16 cages than for 8 cages. The cost of production using feed and other variable costs doesn't change significantly across scenarios. What this comparison shows is that the incremental cost of production decreases as the production capacity increases; it can scale very well. Most of the major fixed cost factors such as salaries, rent etc. are the same for all scenarios.

7.4 Sensitivity Analysis

7.4.1 Price Sensitivity

The price sensitivity analysis (Table 22) shows a 16-cage scenario can accept a price decrease from MVR 200 /kg to 185/kg and remain profitable. A price of MVR 170 keeps the scenario feasible but would no longer be considered a high value investment.

Table 22: Price Sensitivity Analysis - 16 Cages

16 Cages	**Investment at Year 5**				
Sale Price per Kg	170	185	200	215	230
NPV	(173,570)	293,019	768,768	1,295,991	1,767,882
IRR	7%	19%	29%	39%	47%
Cumulative Cashflow	387,907	1,111,519	1,856,165	2,672,645	3,392,696
Net profit margin	27%	33%	38%	42%	46%
Average Monthly Profit	65,421	82,269	99,117	115,965	132,813
Recovery Period- Years	2.8	2.6	2.4	2.2	2.1
Years for doubling production	8	6	**6**	5	3

7.4.2 Impact of MVR -USD exchange rates change

The exchange rate is fixed at MVR 15.42 per US Dollar by the Government, but this may go up depending on availability of foreign currency. Availability of foreign currency (US Dollars) for trade is an issue faced by all businesses in Maldives from time to time. The impact of exchange rate fluctuations is significant, given that all feed (the biggest cost) needs to be imported. The analysis (Table 23) shows that an increase of the exchange rate to MVR 17.0 per USD decreases the cumulative cashflow by 13% and average net profit margin by 3%. Although these are large differences, the returns from the business qualify it to remain high value and attractive based on Table 3. Evaluation criteria. The investment recovery remains below 3 years.

Table 23: Sensitivity Analysis: Impact of exchange rate on model indicators at Year 5– 16 Cages

16 Cages	Investment at Year 5				
Exchange Rate	**15.42**	**15.8**	**16.2**	**17.0**	**17.3**
Cumulative Cashflow	**1,856,165**	**1,795,968**	**1,732,602**	**1,605,871**	**1,558,347**
% difference from 15.42		-3%	-7%	-13%	-16%
Net profit margin	**38%**	**37%**	**37%**	**35%**	**35%**
% difference from 15.42		-1%	-1%	-3%	-3%
Average Monthly Profit	**99,117**	**97,951**	**96,723**	**94,268**	**93,348**
% difference from 15.42		-1%	-2%	-5%	-6%
Recovery Period- Years	**2.4**	**2.4**	**2.4**	**2.5**	**2.5**
NPV	**768,768**	**729,959**	**689,108**	**607,406**	**576,768**
% difference from 15.42		-5%	-10%	-21%	-25%

7.4.3 Impact of Exchange rate on Feeding Costs

Table 24: Sensitivity Analysis: Impact of Exchange rate on feed costs and production - 16 Cages

16 Cages	Feeding Costs (Average over 10 years)				
Exchange Rate	**15.42**	**15.8**	**16.2**	**17.0**	**17.3**
Feed and Variable costs per kg	100.2	101.4	102.6	104.9	105.8
% difference from 15.42		1%	2%	5%	6%
All Costs per kg	124.4	125.6	126.7	129.1	130.0
% difference from 15.42		1%	2%	4%	4%
Average Breakeven Sales Price /MVR	124.4	125.6	126.7	129.1	130.0
% difference from 15.42		1%	2%	4%	4%
Feed cost per cycle -1 Cage	31,634	32,249	32,897	34,192	34,678
% difference from 15.42		2%	4%	8%	10%

7.4.4 Sensitivity to Technical and Major assumptions

The 16 Cage scenario was tested using the key technical assumptions (Harvest Weight and Stocking Density) and major assumptions (Fingerling Price and Sale price /kg). The values tested were:

- Sale Price: 170, 185, 200
- Stocking Density: 40,35,30
- Harvest Weights: 600,500,450
- Fingerling Prices: 15, 18,20

Table 25: Sensitivity Analysis of Technical assumptions impact on feasibility

	Scenarios	Cages	Market Size weight	Stocking Density	Fingerling Prices	Sale price	Net Cashflow-5 Years	NPV 5 Years	Average Monthly Profit	Payback Period	Average Net Profit Margin
Feasible, High Value Scenarios	Scenario 1	16	600	40	15	200	1,856,165	768,768	99,117	2.40	38%
	Scenario 2	16	600	40	18	200	1,391,599	457,501	91,796	2.51	34%
	Scenario 3	16	600	35	15	200	1,132,812	312,749	81,039	2.56	34%
	Scenario 4	16	600	40	15	185	1,111,519	293,019	82,269	2.56	33%
	Scenario 5	16	600	40	20	200	1,081,888	249,989	86,915	2.58	32%
	Scenario 6	16	600	35	18	200	860,849	128,693	74,629	2.63	31%
	Scenario 7	16	600	40	18	185	778,695	68,629	74,948	2.65	29%
	Scenario 8	16	600	35	20	200	571,521	(65,330)	70,356	2.72	28%
	Scenario 9	16	600	35	15	185	519,186	(83,047)	66,297	2.76	29%
Low value to unfeasible	Scenario 10	16	600	40	20	185	448,244	(152,970)	70,067	2.74	26%
	Scenario 11	16	600	30	15	200	446,899	(123,400)	63,126	2.80	30%
	Scenario 12	16	600	40	15	170	387,907	(173,570)	65,421	2.79	27%
	Scenario 13	16	500	40	15	200	190,915	(301,259)	61,677	2.86	25%
	Scenario 14	16	600	35	18	185	85,193	(374,080)	59,887	2.30	25%
	Scenario 15	16	600	30	18	200	74,959	(372,822)	57,632	2.47	27%
	Scenario 16	16	600	40	18	170	(107,769)	(505,969)	58,100	6.03	22%
	Scenario 17	16	600	30	20	200	(173,002)	(539,103)	53,970	5.13	24%
	Scenario 18	16	600	35	20	185	(204,135)	(568,102)	55,614	5.14	22%
	Scenario 19	16	600	30	15	185	(217,949)	(554,348)	50,490	5.17	25%
	Scenario 20	16	600	35	15	170	(256,470)	(585,820)	51,555	5.19	23%
	Scenario 21	16	500	40	18	200	(304,761)	(633,657)	54,356	5.21	21%
	Scenario 22	16	500	35	15	200	(428,838)	(697,547)	48,279	5.34	21%
	Scenario 23	16	600	40	20	170	(438,220)	(727,568)	53,219	5.30	19%
	Scenario 24	16	500	40	15	185	(547,805)	(780,090)	47,637	5.42	19%
	Scenario 25	16	600	30	18	185	(589,889)	(803,770)	44,996	5.49	21%
	Scenario 26	16	500	40	20	200	(635,212)	(855,256)	49,475	5.45	18%
	Scenario 27	16	600	35	18	170	(690,463)	(876,853)	45,145	5.54	18%
	Scenario 28	16	600	30	20	185	(837,850)	(970,051)	41,334	5.72	18%
	Scenario 29	16	500	35	18	200	(862,831)	(988,580)	41,869	5.71	17%
	Scenario 30	16	600	30	15	170	(882,797)	(985,296)	37,854	5.84	18%

Based on the analysis, we can find that the minimum requirements for a high value successful model are:

Table 26: Minimum price and technical factor(s) combinations.

Factors:	Market Weight	Stocking Density	Price	Fingerling Prices
Factor Impact	1 (higher)	2	3	4 (lower)
Combination option	600	40	185	18
Combination option	600	35	185	15

7.5 Investor Profile

A grouper grow-out is not immediately accessible for “small” investors or new entrepreneurs due to the startup costs. Access to capital for a startup is difficult and interest rates are quite high. However, we should consider the fact that an owner of a yellow fin tuna fishing vessel would have made an investment of similar or larger size and it would also be a bigger operation than 16 sea cages. Such fishing vessels are not always financed by banks. Many use other means of financing such as savings, borrowing from friends and family etc. Given the profitability and scaling possibilities, it is quite likely that a grouper grow-out operation would receive interest from both established businesses and individual entrepreneurs with means.

The business is quite ideal for an already existing grouper export operation, especially since some already use sea cages. An integrated grow-out and export operation should yield the highest margins.

A case for a community owned business model could be made for grouper culture. This is due to the fact that sea area in local islands falls under the jurisdiction of island councils. However, community led business projects are not quite common in the Maldives.

Although this model considers that the grow-out operation would be carried out in an inhabited island, an investor wishing to expand production capacity may consider a long-term lease of an uninhabited island or lagoon. This brings about a whole new set of costs which needs to be assessed.

The model considers that 50% of the investment is financed by a loan with a term of 5 years+ 1 year grace period. A simple analysis was done to find the minimum amount of cash on hand needed to start considering common bank requirements. This does not consider bank charges as they vary from bank to bank.

Table 27: Minimum cash amounts need for loans to startup

	8 Cages	16 Cages
Total Investment	1,144,441	1,970,420
50% Loan Financed	8 Cages	16 Cages
Loan Amount	572,220	985,210
Equity (20% of loan amount)	114,444	197,042
Mortgage Asset Value (200% of loan)	1,144,440	1,970,420
Self-financed	572,220	985,210
Cash amount needed	**686,665**	**1,182,252**
100% Loan Financed	8 Cages	16 Cages
Loan Amount	1,144,441	1,970,420
Equity (20% of loan amount)	228,888	394,084.07
Mortgage Asset Value (200% of loan)	2,288,882	3,940,841
Self-financed	0	0
Cash amount needed	**228,888**	**394,084**

7.6 Impact of Loan Interest rates on viable scenarios

It must be noted that commercial interest rates for loans are relatively high in Maldives at 11.75%. Considering the impact of loan interest rates, considering that the loan period is 5 years with a 1 year grace period the results can be seen in Table 28: Sensitivity analysis for interest rates- 8 Cages. For each interest rate, the discount rate for NPV is also adjusted to that amount

Lowering interest rates have a markedly positive impact on the model. At an interest rate of 6%, the cumulative cashflow (the accumulated profit) increases by 33%, close to MVR 500,000. This shows that an 8-cage model which has been determined to be of average value become more attractive at a lower interest rate. The IRR still lags behind that needed for a high value model. It is reasonable to assume that a lot of smaller investors (who wouldn't have otherwise considered it), would be interested in starting with 8 cages if the interest rate is lower. This same analysis for a 16-cage model would increase the attractiveness of an already high value model.

Table 28: Sensitivity analysis for interest rates- 8 Cages. For each interest rate, the discount rate for NPV is also adjusted to that amount

8 Cages	Investment at Year 5					
Loan Interest rate	11.75%	9%	8%	7%	6%	5%
NPV	(6,591)	98,887	141,317	186,135	233,491	283,548
IRR	11%	13%	13%	14%	14%	15%
Cumulative Cashflow	374,491	425,225	443,313	461,207	478,904	496,404
% Increase from 11.75%		14%	18%	23%	28%	33%
Average Monthly Profit	40,895	41,284	41,422	41,558	41,692	41,824
Net profit margin	29.3%	29.7%	29.8%	29.9%	30.1%	30.2%
Recovery Period- Years	2.72	2.69	2.68	2.67	2.66	2.65

7.7 Growth Options

The model shows the year in which production capacity can be expanded or doubled without using any external financing (provided that no capital is withdrawn from the business and value of investment needed doesn't change substantially over the period).

Table 29: Production expansion options from the model.

Expansion	8 Cages Scenario	16 Cages Scenario
Additional 4 Cages	Year 5	Year 3
Additional 8 Cages	Year 6	Year 5
Additional 16 Cages	Year 9	Year 6

As we can see, a 16-cage model is able to scale up very quickly. At a scale 32 cages, the costs could look very different. The operation size would be large enough to warrant running a full office setup with full time accountants, management staff etc. Although 16 Cages is the ideal operation size for a grouper grow-out it should be highlighted again that it is not a large operation. It should be expected that larger investors would be interested in 32 to 64 cages and higher, perhaps with even their own integrated hatchery operation.

Table 30: Revenue possibilities beyond 16 cages

Scale	Average annual revenue over 10 years	% Difference from 8 cages
8 Cages	1,347,840	
16 Cages	2,695,680	100%
32 Cages	5,391,360	300%
64 Cages	10,782,720	700%

7.8 Conclusion

The objectives of this paper were to determine the minimum feasible model (found to be an 8 cage Scenario), the optimum model (found to be a 16-cage scenario) and to identify the key determinants of a successful model (see Findings: Determinants of a successful grow out model). Additionally, possible investors and the impact of financing costs were evaluated.

The Grouper grow-out model shows excellent potential for applicability in Maldives provided that the assumptions used hold true. With the establishment of a hatchery operation providing a steady supply of fingerlings, a grow-out industry can start with both smaller investors starting operations in inhabited islands (as assumed in the model) and larger investors pursuing the businesses at scale. Cultured groupers have the potential to be a major export product considering that the demand is expected to grow.

Looking ahead, for grouper grow-outs to be established it is important that the industry is supported to reach a critical mass quickly. Lowering the cost of feed and awareness of tried and tested practices cannot happen without a significant number of participants in the industry.

7.9 Observations on the model results

- A possible weakness of the model parameters is that it is geared to running as an efficient, lean operation whereas in practice there may be a higher management cost. It assumes that 2 employees will manage the entire operation without the direct involvement of the business owner (this is assumed because remuneration of directors or dividend pay outs is not included). The model also implies that the intent of the investor is to grow the business to a larger scale as soon as possible to gain higher revenues later on.
- The stocking density values (40 fish/m^3 used in the model) are significantly higher than the minimum of 30 fish/m^3. If this value is not practical, a solution would be to increase the size of the cage. The additional cost needed to increase the size of the cage to accommodate a higher number of fish should be worth the investment.
- The model assumes a reliable availability of fingerlings for grouper operations. A central hatchery (whether government- or privately-owned), with an adequate production capacity to meet fingerling requirements is necessary for the grow-out operations to be viable. A thorough analysis of feasibility of hatchery production is required to verify the fingerling purchase cost assumptions.

7.10 Recommendations

- Loan facility with lower interest rate or grants to facilitate startup of the businesses will spur the establishment of the grow-out industry. This is important for the industry to reach a critical mass where costs of production will start becoming lower.

- The government could identify and screen locations in selected areas where grow-out operations could be implemented as a pilot project. This could attract investors in that target area to start the businesses. Being able to see successful grow out operations in practice locally is the best way to attract new investors to start in other areas.
- Development of locally produced alternatives to imported feed: The government could lead in developing feed formulations derived from fish by-products from the local fishing industry. This could reduce the cost of feed generating higher margins. Even if locally produced feed is made available at similar prices, it will protect the industry from foreign exchange risks.
- A thorough understanding of the fish export prices and exporter margins is necessary.
- It is advised that those creating plans for the industry have sufficient exposure to the market needs, perceptions, trends and value addition options that can allow them to advise investors.
- Development of certification procedures for encouraging product quality and good culture practices will be required. Additionally, there needs to mechanisms to distinguish between wild caught and cultured groupers; it is possible that exporters may mislabel to grain higher prices which may affect the perception of Maldivian grouper exports.
- It may be possible to promote Maldivian Grouper Grow-outs as of higher quality, produced in cleaner environments using certified methods and feed. This may enable the product to compete better internationally and be sold in more “sophisticated” markets such as the USA or Europe. We can safely assume that cost of production in Maldives will always be higher than in places such as the Philippines and Indonesia. Creating an identity for Maldivian cultured groupers, especially utilizing the image of Maldives as a pristine environment could allow the industry to compete with lower priced competition. Such an identity needs to be supported by a framework of supervision to assure quality.
- To assist grow-outs to gain a larger share of the profit from exporters, the Government or relevant authority could enable the publication of up-to date pricings of cultured grouper prices in Markets such as Hong Kong. This will increase the bargaining power of grow-outs when dealing with exporters.
- By enabling access to the grow-out business model and scenarios to the general public, they can modify the model to produce scenarios suitable for themselves. This can allow investors to readily create business plans which they can submit to the Bank, test assumptions and to evaluate the investment. The use of a website or distribution of the model as modifiable spreadsheet is suggested. Alternatively, create a grouper grow-out startup kit could be released; both as a reference tool and as a decision-making tool for potential entrepreneurs. This could also be packaged with incentives such as loan or grants.

8 Acknowledgements

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Epinephelus fuscoguttatus cover image credit: FAO

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Small-scale Sandfish Grow-out Operations in the Maldives

For Sandfish (*Holothuria scabra*)

A Feasibility Study

Marine Research Centre, Maldives

Project for the Formulation of Fisheries Sector Master Plan (MASPLAN)

2017

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Financial Feasibility of small-scale sandfish grow-out operations in the Maldives

1. Introduction

The establishment of a tourism industry in the Maldives and the resulting widening of domestic market for fish, and the development of export markets led to the diversification of the fisheries sector beyond the traditional pole-and-line tuna fishing. Reef fisheries became prominent after the development of the tourism industry that created a local demand. Developments in the transport sector also resulted in the development of export-oriented fisheries for high-valued reef resources (Sattar and Adam, 2005).

The export-oriented fishery for sandfish in the Maldives began in 1985, with the fishery limited to the high-value species, the prickly redfish *(Thelenota ananas)* and the white teatfish (*H. fuscogilva*). The fishery that began in the northern atolls of Maldives quickly expanded to the entire country within two years (FAO, 2011). The fishery also changed from one that exclusively targeted high-valued species to one that exploited medium- and low-valued animals. The fishing methods also changed from the traditional hand-picking from intertidal zones to relying mainly on snorkeling and SCUBA diving to enable harvests from deeper waters, indicating some degree of stock depletion.

Past 10 years of export statistics reveal that the fishery was highly variable both in terms of the export quantities and the revenues generated (Figure 1). While the quantities exported over the past 10 years were comparable to the trends in historic data, the revenue generated has fallen drastically compared to the historic data. The variability in annual revenues may be an indication of shipments containing larger quantities of lower-valued animals. The total sea cucumber exports also do not differentiate between cultured sea cucumbers vs. wild-caught. This may be another contributor to the variability in revenues, as the only sea cucumber cultured in the Maldives, the sandfish (*H. scabra*) is considered a high-valued one.

A non-native species of sea cucumber, the sandfish (*H. scabra*) was introduced into the Maldives about two decades ago, by a private venture aspiring to pioneer commercial aquaculture in the Maldives. The introduced animals were used as broodstock to enable commercial production. Until recently this facility had operated as a vertically integrated, standalone business which produced market sized animals from larvae produced within their own facility. More recent developments include the involvement of local communities in grow-out production.

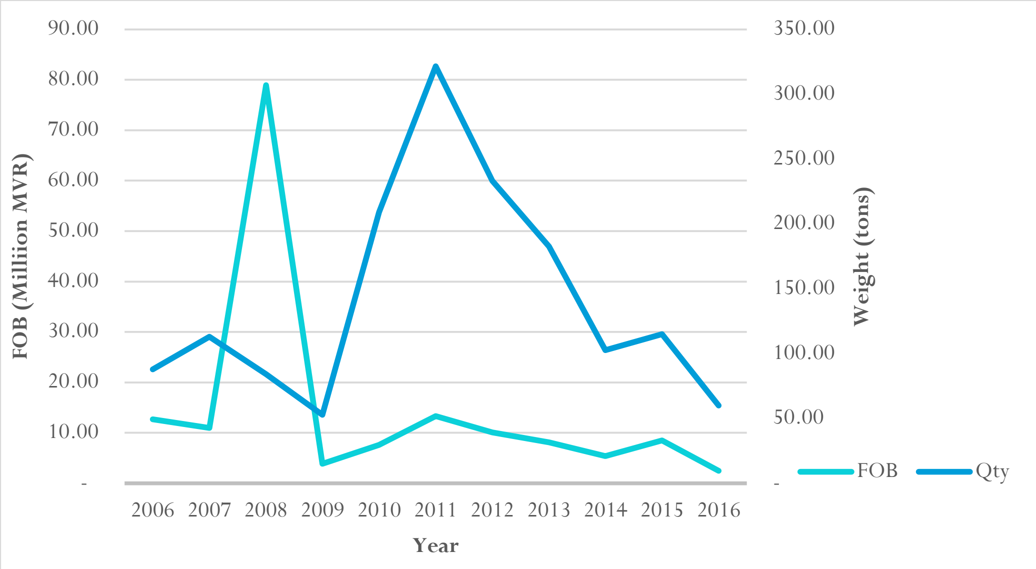

Figure 1: Sea Cucumber exports 2006-2016 (source: Maldives Customs Service, 2014)

2. Sandfish culture technique

Hatchery bred sandfish seed measuring approximately 15-30 g in weight are stocked in grow-out areas. These grow out areas can range from inland ponds to shallow, sheltered lagoons. The most commonly practiced grow-out techniques involve stocking in designated areas at relatively low densities, usually with no feed inputs throughout the grow-out period. Some techniques, especially those that utilize lagoon areas, require some feed supplementation.

Grow-out operations in shallow lagoon areas would be the most suitable for the Maldivian setting. Sandfish grow-out operations are currently being carried out in relatively sheltered lagoons with a minimum depth of 0.3 m at the lowest tide. The current practice is to supplement the cages/pens with feed once every 3 days. The feeds used is a mix of dried seaweed, rice bran and fish meal, which can easily be produced on farm. Feasibilities were assessed for two techniques that could be employed for sandfish grow-out operations in shallow lagoons:

1. The pen system: This type of system is one where 24 m x 24 m enclosures are constructed using GI pipes along its perimeter, fixed to the bottom of the shallow lagoon on to which plastic mesh nets are fastened. Sand-filled geobag linings are used to minimize the incidence of escapes as well as to provide structural support for the netting (Figure 2).
2. Bottom-set cage and pen combination: The survival rate of sandfish grow-out in lagoons are generally low. One method of improving survival is to culture the seed in a more protected environment at initial transfer. Rearing the sandfish in bottom-set cages during the initial month(s) have shown promising results towards improving survival. These are submerged cages, with an area of 15 m^2, with a removable top cover. The bottom surface of the cage is lined with canvas and covered with sand (Figure 3). The initial seed are stocked in these bottom-set cages, at a high stocking density and grown for 1 month prior to being transferred to the pen system described above.

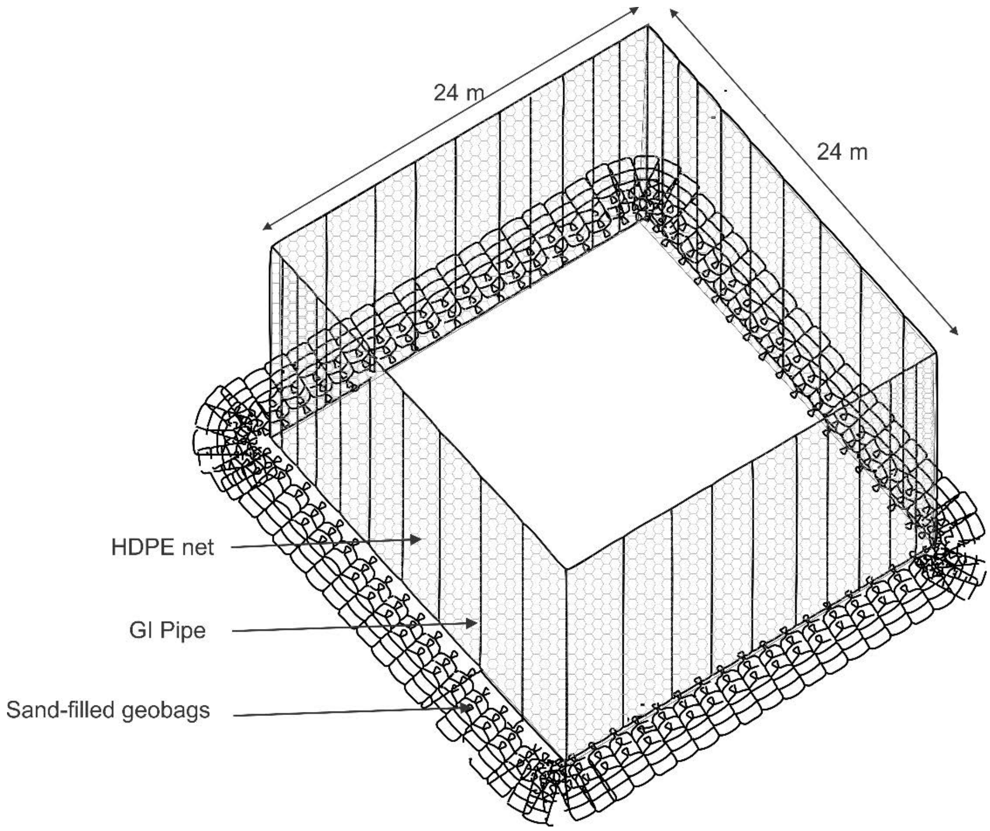

Figure 2: Pen design

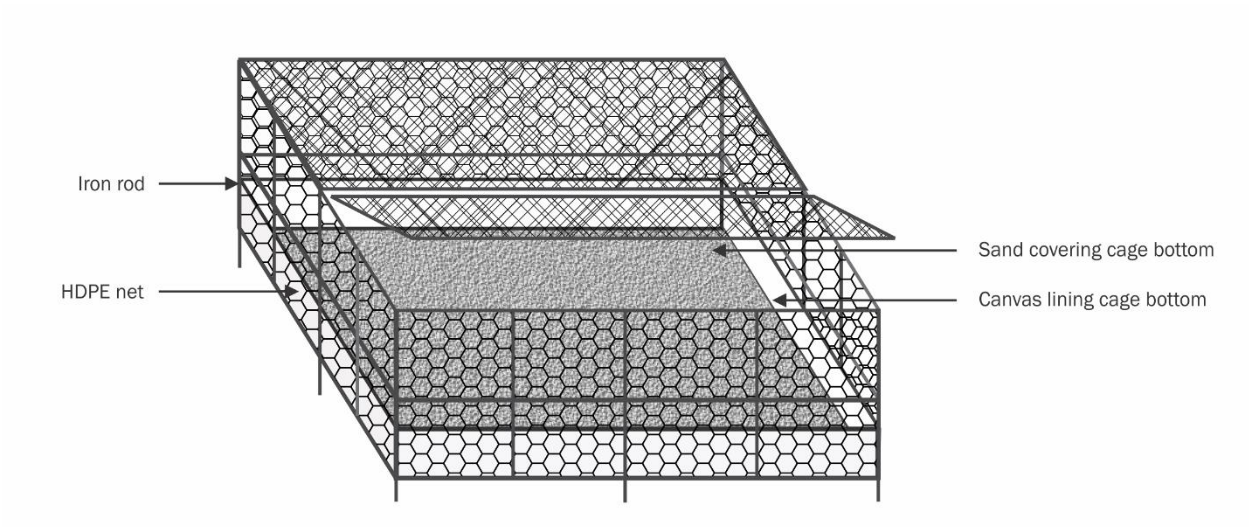

Figure 3: Bottom-set cage design

3. Method

A combination of primary and secondary data was used for this feasibility study. Primary data for this study was obtained from technical studies carried out by MRC and the pilot sandfish culture project in Laamu Atoll. The technical assumptions made in this feasibility are derived from mariculture development initiatives undertaken by MRC. A pilot project was carried out under the current MASPLAN project to test growth and survival of seed stocked in a bottom-set cage design. The figures assumed for the bottom-set cage were derived from the results of this study.

4. Objectives of the study

The objectives of this feasibility are to produce:

1. a detailed feasibility of two types of grow-out methods in Maldives
   a. Bottom-set cage method using a combination of a 24m x 24m pen and 15 m^2 bottom-set cages
   b. Pen method using only a 24 m x 24 m pen system
2. an evaluation of the business opportunity and its challenges

5. Assumptions of the study

5.1 General Assumptions for both culture methods

- A loan of value MVR 50,000 with a 5-year term and 11.75% interest is utilized to startup the businesses. The entrepreneur will need to provide the necessary collateral for the loan. Any additional fees or bank charges for loans are not included.
- 1 full time employee is hired for the business at a monthly rate of MVR 5000, which includes food and accommodation.
- Period of grow-out per production cycle is 8 months (until a weight of 500g per individual is reached).
- Stocking rate is 6 seed/m^2 in pen (a total of 3456 seeds).
- Feeding costs are assumed to be MVR 700 per month for 3456 individuals based on data from MRC.
- Repair and Maintenance costs are assumed to be 5% of initial costs per year.
- Transportation costs are assumed to be MVR 400 per boat trip to pen location.
- Cost of seeds is MVR 8.
- Sandfish produced is sold to a local exporter for MVR 74 per piece of 500 grams each.
- Capital assets are depreciated in a straight-line method; the salvage value is zero for all capital assets.
- Due to the small-scale nature of the business, a full-fledged Environmental Impact Assessment (EIA) will not be required and no costs for such is included.
- The business will be registered as a "Sole Proprietorship" (sole trader) type with the government.
- It is assumed that all imported feed ingredients will be import duty exempted.
- It is assumed that there are no utilities (electricity, water) used for production.
- Hourly rate for temporary labor is assumed to be MVR 62.5.
- General Sales Tax (GST) does not apply to fish products in Maldives.
- Business Profit Tax rate is 15% for Net Profit over MVR 500,000 in Maldives.
- The discount rate for Net Present Value is taken as 11.75%, the same as the cost of capital (bank loan interest rate).
- It is assumed that Insurance charges will be MVR 500 per year for both methods.
- Depreciation Details:
  - Net replacement: 2 years

- Geo Bags: 10 years
- Ropes and other items: 5 years
- Bottom-set cage complete replacement: 3 Years

5.2 Assumptions for Bottom-set cage culture method:

- Seeds will be kept in bottom-set cages for 1 month until they achieve weight of 50g per individual. Following this, Pen culture will commence for 7 months until a weight of 500g per individual is achieved.
- Survival rate is assumed to be 80%.
- Capacity of a bottom set cage is 15 m^2 and pen is 576 m^2 (24m x 24m)
- It is assumed that 8 bottom set cages will be required for 1 pen of sized mentioned above. A set of 8 bottom-set cages can be used to support up to 8 pens.

5.2.1 Costs

- Construction of pen is assumed to be MVR 26,000
- Construction of bottom-set cage is assumed to be MVR 9102 per unit, and 8 bottom-set cage units will be needed at a total cost of MVR 72,816.

5.3 Assumptions for Pen culture method:

- Survival rate is assumed to be 70%.
- Capacity of the pen setup is 576 m^2 (24m x 24m)

5.3.1 Costs

- Construction of pen is assumed to be MVR 26,000.

6. Evaluating the investment opportunity

It is an objective of the study to evaluate whether an individual in an inhabited island (where there are suitable areas for sandfish culture) can manage a grow-out sustainably and at a reasonable profit. This feasibility will also try to determine how well sandfish culture lends itself to scaling up as well as finding the minimum scale at which a reasonable profit can be made.

The expected limitations for an individual entrepreneur starting a sandfish culture business are access to finance and suitable culture area. The average income of a household in the Atolls is MVR 11,200 (Department of National Planning, 2011). To see if sandfish culture can provide an additional income source for residents of atolls, which can result in a significant increase to monthly income, is one of the goals of this study.

It is assumed that in general, atoll residents may have access to certain advantages if the sandfish culture is done on the island itself.

- Advantages of business owner or operator residing on the island, utilizing their own land for storage and accommodation purposes etc. Even if needed, cost of accommodation and warehousing is generally cheaper in Atolls, compared to Male' area.
- Better Security- as the production site is close by and can be monitored frequently.

6.1 Evaluation criteria

The intended target for the business is individuals in inhabited islands with suitable sea area for small scale sandfish grow-outs. However, expansion possibilities are also explored which may be of interest to larger corporate investors.

The evaluation criteria (Table 1) is designed to broadly identify what financial indicators of the investment needed to be reached for it to be seen as an attractive opportunity for entrepreneurs. These include indicators for long term business viability such as investment recovery period, Internal Rate of Return (IRR) and Net Present Value (NPV). The other indicators are expected monthly income from the investment and the net profit margin. These indicators should allow the first-time entrepreneur as well as an experienced businessperson to make a decision to explore the investment opportunity further.

Table 1: Evaluation Criteria

Evaluation Criteria	"Low Value" Investment (unattractive)	"Good Value" Investment (reasonably attractive)	"High Value" investment (attractive)
Average net profit margin per year	5-10%	11-29%	30% and above
Payback Period (Investment Recovery period)	5+ Years	3-5 Years	Less than 3 years
Average monthly income	Above MVR 4,500	Above MVR 7,000	Above MVR 10,000
Net Present Value in 5 Years	Negative	Positive	Positive
IRR in 5 Years	>12%	>20%	>30%

7. Cost Analysis

All figures are given in Maldivian Rufiyaa (MVR).

7.1 Startup and working capital requirements

Table 2: Investment breakdown

Cost Items	Bottom-set cage method	Pen method
Registration as a Sole Trader	500	500
Total Registration fees:	**500**	**500**
Capital Expenses		
Pen Construction (1 unit)	26,000	26,000
Bottom Set Cage Construction (8 units)	72,816	
Total Capital Expenses	**98,816**	**26,000**
Total Startup and Capital Investment *(Capital expenses + registration fees)*	**99,316**	**26,500**
Total Initial Working Capital *(See Table 3)*	**77,042**	**74,615**
Total Investment	**176,358**	**101,115**

Table 3: Details of initial working capital

Working Capital Requirements at Start	Bottom-set cage method	Pen Method
Seeds Purchase Cost	27,648	27,648
Harvesting Labor Costs	500	500
Feed Costs	5,600	5,600
Staff Costs	40,000	40,000
Maintenance Charges	3,293.87	866.67
Total initial working capital	**77,042**	**74,615**

7.2 Fixed Costs for Bottom-set Cage Method

Table 4: Fixed cost details for bottom-set cage method

Fixed Costs (per year)	Quantity	Rate	Total
Sea Area rental - Pen	576	0.538	310
Sea Area rental - Bottom Set Cage	15	0.538	8
Aquaculture license fees	591	0.2	118
Trade licensing fees	1	500	500
Total Licensing and rental fees:			**936**
Insurance *(per year)*	1 unit	500	500
Staff Costs *(inflation of 3% per annum added from year 2 onwards)*	1 staff	5000	5,000

7.3 Fixed Costs for Pen Method

Table 5: Fixed cost details for Pen Method

Fixed Costs	Quantity	Rate	Total
Sea Area rental - Pen	576	0.538	310
Aquaculture license fees	576	0.2	115
Trade licensing fees	1	500	500
Total Rental and licensing fees:			**925**
Insurance *(per year)*	1 unit	500	500
Staff Costs *(inflation of 3% per annum added from year 2 onwards)*	1 staff	5000	5,000

7.4 Variable Costs

Table 6: Variable cost details for all culture methods

Variable Costs	Details	Bottom-set cage Method	Pen Method
General Repair and Maintenance	*5% of initial costs per year*	4,940.80	1,300
Transportation	*Cost of transportation on public ferry transport per year*	400	400
Harvesting Costs	*1 days' work; 8 man hours per pen @ MVR 62.5 per hour*	500	500
General Overheads	*Percentage of Total revenue per year*	3%	3%
Feed Costs	*Feeding cost per month for both methods, with inflation of 3% from year 2 onwards.*	700	700

7.5 Discussion on Costs

The pen method costs MVR 101,115 to startup, which is substantially less than the MVR 176,358 required by the bottom-set cage method. The increased costs are due to the bottom-set cage construction costs (MVR 72,816). The study assumes that a loan of value MVR 50,0000 with a 5-year term and at an 11.75% interest rate will be used to startup the businesses.

Owing to the small-scale nature of the business, a sole proprietorship (sole trader) type license is chosen, the costs will be higher if the businesses is registered as a company.

The type of expenditures necessary to start with either method appear to be straightforward, without requiring much technical input. The pen and bottom-set cage construction costs given includes all material costs and labour. It is expected that the entrepreneur, along with hired staff shall be involved in deployment of the pen and/or bottom-set cage setup. The study assumes that the entrepreneur will be actively involved in operations and will also contribute where additional manpower is required.

The study assumes that a large portion of the feed is produced on farm with locally available ingredients. This reduces importing and transportation costs for the business significantly.

8. Findings

Table 7: Profit and Loss summary: Bottom-set cage method

Bottom Set Cage and Pen- Sandfish Grow-Out Feasibility										
Profit and Loss Summary										
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Harvests during the period	1	1	2	1	1	2	1	1	2	1
Production Volume in Pieces	2,765	2,765	5,530	2,765	2,765	5,530	2,765	2,765	5,530	2,765
Fingerling Purchase during period	2	1	1	2	1	1	2	1	1	2
Revenue Types										
Price	204,595	204,595	409,190	204,595	204,595	409,190	204,595	204,595	409,190	204,595
Total Revenues	**204,595**	**204,595**	**409,190**	**204,595**	**204,595**	**409,190**	**204,595**	**204,595**	**409,190**	**204,595**
Direct costs										
Feed Costs	7,700	7,931	8,169	8,414	8,666	8,926	9,194	9,470	9,754	10,047
Fingerlings Purchase Cost	55,296	27,648	27,648	55,296	27,648	27,648	55,296	27,648	27,648	55,296
Harvesting Labour Costs	500	500	1,000	500	500	1,000	500	500	1,000	500
Maintenance and Transport	5,341	5,341	5,341	5,341	5,341	5,341	5,341	5,341	5,341	5,341
Sub Total	68,837	41,420	42,158	69,551	42,155	42,915	70,331	42,959	43,743	71,184
Gross profit	*135,758*	*163,175*	*367,033*	*135,044*	*162,440*	*366,275*	*134,264*	*161,636*	*365,447*	*133,412*
Indirect Costs										
Staff Costs	60,000	61,800	63,654	65,564	67,531	69,556	71,643	73,792	76,006	78,286
Pen - Net Replacement	-	-	1,560	-	-	1,560	-	-	1,560	-
Pen - Geo Bags	-	-	-	-	-	-	-	-	-	-
Pen - Ropes and Other Items	-	-	-	-	-	7,824	-	-	-	-
Bottom Set Cage Replacement	-	-	-	9,102	-	-	-	9,102	-	-
Licenses Fees	936	936	936	936	936	936	936	936	936	936
Insurance	500	500	500	500	500	500	500	500	500	500
General Overheads	6,138	6,138	12,276	6,138	6,138	12,276	6,138	6,138	12,276	6,138
Rent (warehouse and accomodation)	-	-	-	-	-	-	-	-	-	-
Loan Repayment - interest only	5,463	4,495	3,406	2,183	807	-	-	-	-	-
Depreciation Expenses	6,209	6,209	6,209	6,209	6,209	6,209	6,209	6,209	6,209	6,209
Sub Total	79,247	80,078	88,542	90,632	82,121	98,862	85,427	96,678	97,487	92,070
Total Costs	*148,084*	*121,498*	*130,699*	*160,183*	*124,277*	*141,777*	*155,758*	*139,637*	*141,230*	*163,253*
Net Profit before Tax	**56,512**	**83,097**	**278,491**	**44,413**	**80,319**	**267,413**	**48,838**	**64,959**	**267,960**	**41,342**
Business Profit Tax (15%)	-	-	-	-	-	-	-	-	-	-
Profit After Tax	**56,512**	**83,097**	**278,491**	**44,413**	**80,319**	**267,413**	**48,838**	**64,959**	**267,960**	**41,342**
Monthly Profit	4709.298516	*6,925*	*23,208*	*3,701*	*6,693*	*22,284*	*4,070*	*5,413*	*22,330*	*3,445*

Table 8: Cashflow summary: Bottom-set cage method

Bottom Set Cage and Pen- Sandfish Grow-Out Feasibility											
10 Year Cashflows											
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Cash at hand- Beginning Balance		77,042	125,746	200,067	468,693	502,018	569,873	837,286	886,124	951,082	1,219,042
Cash at hand- Ending Balance		125,746	200,067	468,693	502,018	569,873	837,286	886,124	951,082	1,219,042	1,260,384
Cash injection - Own Finance			-	-	-	-	-	-	-	-	-
Cash Income- Inflow		204,595	204,595	409,190	204,595	204,595	409,190	204,595	204,595	409,190	204,595
Total Inflows		**204,595**	**204,595**	**409,190**	**204,595**	**204,595**	**409,190**	**204,595**	**204,595**	**409,190**	**204,595**
Feed Costs		(7,700)	(7,931)	(8,169)	(8,414)	(8,666)	(8,926)	(9,194)	(9,470)	(9,754)	(10,047)
Fingerlings Purchase Cost		(55,296)	(27,648)	(27,648)	(55,296)	(27,648)	(27,648)	(55,296)	(27,648)	(27,648)	(55,296)
Harvesting Labour Costs		(500)	(500)	(1,000)	(500)	(500)	(1,000)	(500)	(500)	(1,000)	(500)
Maintenance and Transport		(5,341)	(5,341)	(5,341)	(5,341)	(5,341)	(5,341)	(5,341)	(5,341)	(5,341)	(5,341)
Staff Costs		(60,000)	(61,800)	(63,654)	(65,564)	(67,531)	(69,556)	(71,643)	(73,792)	(76,006)	(78,286)
Pen - Net Replacement		-	-	(1,560)	-	-	(1,560)	-	-	(1,560)	-
Pen - Geo Bags		-	-	-	-	-	-	-	-	-	-
Pen - Ropes and Other Items		-	-	-	-	-	(7,824)	-	-	-	-
Bottom Set Cage Replacement		-	-	-	(9,102)	-	-	-	(9,102)	-	-
Licenses Fees		(936)	(936)	(936)	(936)	(936)	(936)	(936)	(936)	(936)	(936)
Insurance		(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)
General Overheads		(6,138)	(6,138)	(12,276)	(6,138)	(6,138)	(12,276)	(6,138)	(6,138)	(12,276)	(6,138)
Rent (warehouse and accomodation)		-	-	-	-	-	-	-	-	-	-
Loan Repayment- Interest only		(5,463)	(4,495)	(3,406)	(2,183)	(807)	-	-	-	-	-
Loan Repayment- Capital		(7,808)	(8,776)	(9,865)	(11,088)	(12,464)	-	-	-	-	-
Cash Withdrawal:		-	-	-	-	-	-	-	-	-	-
Depreciation Expenses		(6,209)	(6,209)	(6,209)	(6,209)	(6,209)	(6,209)	(6,209)	(6,209)	(6,209)	(6,209)
Business Profit Tax		-	-	-	-	-	-	-	-	-	-
Total outflows		**(155,891)**	**(130,274)**	**(140,564)**	**(171,271)**	**(136,740)**	**(141,777)**	**(155,758)**	**(139,637)**	**(141,230)**	**(163,253)**
	Investment										
Net Cashflow	**(176,357.87)**	48,704	74,321	268,626	33,324	67,855	267,413	48,838	64,959	267,960	41,342
Cumalative Cashflows		**(127,654)**	**(53,333)**	**215,294**	**248,618**	**316,473**	**583,886**	**632,724**	**697,683**	**965,643**	**1,006,984**

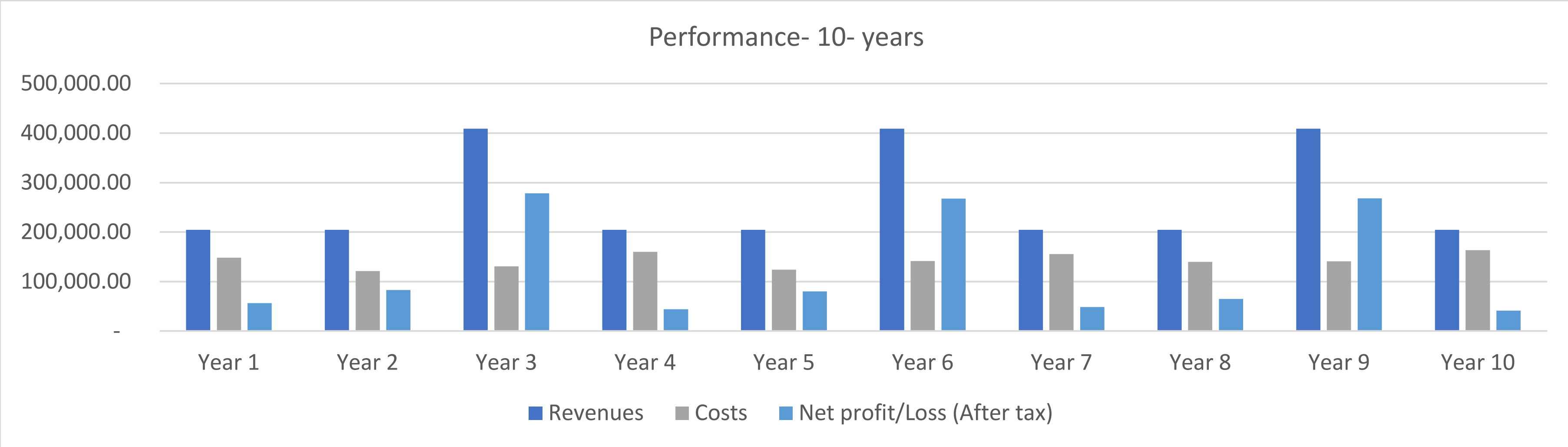

Figure 4: Financial Performance: Bottom-set cage method

Table 9: Investment Analysis: Bottom-set cage method

Bottom-set Cage Method: Investment Analysis over 10 years			
	10 years	**5 Years**	**3 Years**
NPV	427,913	160,654	106,692
IRR	55%	45%	38%
Investment Recovery Time	2.2 Years		
Average Annual Revenue	265,974		
Average Net Profit-Annual	123,334		
Average monthly Profit	10,278		
Average Net Margin	40.4%		
Total Investment	176,358		
Loan Amount	50,000	(at 11.75% interest rate, no grace period)	
Own Finance	126,358		
Average Cost of Production- Direct Costs	57.0		
Average Cost of Production- All Costs	61.1		

Table 10: Profit and Loss summary: Pen method

Pen Only Culture- Sandfish Grow-Out Feasibility

Profit and Loss Summary

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Harvests during the period	1	1	2	1	1	2	1	1	2	1
Production Volume in Pieces	2,419	2,419	4,838	2,419	2,419	4,838	2,419	2,419	4,838	2,419
Fingerling Purchase during period	2	1	1	2	1	1	2	1	1	2
Revenue Types										
Price	179,021	179,021	358,042	179,021	179,021	358,042	179,021	179,021	358,042	179,021
Total Revenues	**179,021**	**179,021**	**358,042**	**179,021**	**179,021**	**358,042**	**179,021**	**179,021**	**358,042**	**179,021**
Direct costs										
Feed Costs	7,700	7,931	8,169	8,414	8,666	8,926	9,194	9,470	9,754	10,047
Fingerlings Purchase Cost	55,296	27,648	27,648	55,296	27,648	27,648	55,296	27,648	27,648	55,296
Harvesting Labour Costs	500	500	1,000	500	500	1,000	500	500	1,000	500
Maintenance and Transport	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
Sub Total	**65,196**	**37,779**	**38,517**	**65,910**	**38,514**	**39,274**	**66,690**	**39,318**	**40,102**	**67,543**
Gross profit	*113,825*	*141,242*	*319,525*	*113,111*	*140,506*	*318,767*	*112,331*	*139,703*	*317,939*	*111,478*
Indirect Costs										
Staff Costs	60,000	61,800	63,654	65,564	67,531	69,556	71,643	73,792	76,006	78,286
Pen - Net Replacement	-	-	1,560	-	-	1,560	-	-	1,560	-
Pen - Geo Bags	-	-	-	-	-	-	-	-	-	-
Pen - Ropes and Other Items	-	-	-	-	-	7,824	-	-	-	-
Licenses Fees	925	925	925	925	925	925	925	925	925	925
Insurance	500	500	500	500	500	500	500	500	500	500
General Overheads	5,371	5,371	10,741	5,371	5,371	10,741	5,371	5,371	10,741	5,371
Rent (warehouse and accomodation)	-	-	-	-	-	-	-	-	-	-
Loan Repayment - interest only	5,463	4,495	3,406	2,183	807	-	-	-	-	-
Depreciation Expenses	3,175	3,175	3,175	3,175	3,175	3,175	3,175	3,175	3,175	3,175
Sub Total	**75,435**	**76,266**	**83,962**	**77,718**	**78,309**	**94,282**	**81,614**	**83,764**	**92,908**	**88,258**
Total Costs	*140,631*	*114,045*	*122,479*	*143,628*	*116,823*	*133,557*	*148,304*	*123,082*	*133,010*	*155,800*
Net Profit before Tax	**38,390**	**64,976**	**235,563**	**35,393**	**62,197**	**224,485**	**30,716**	**55,939**	**225,032**	**23,221**
Business Profit Tax (15%)	-	-	-	-	-	-	-	-	-	-
Profit After Tax	**38,390**	**64,976**	**235,563**	**35,393**	**62,197**	**224,485**	**30,716**	**55,939**	**225,032**	**23,221**
Monthly	*3,199*	*5,415*	*19,630*	*2,949*	*5,183*	*18,707*	*2,560*	*4,662*	*18,753*	*1,935*

Table 11: Cashflow summary: Pen method

Pen Only Culture- Sandfish Grow-Out Feasibility

10 Year Cashflows

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash at hand- Beginning Balance		74,615	105,197	161,397	387,095	411,400	461,134	685,619	716,335	772,274	997,306
Cash at hand- Ending Balance		105,197	161,397	387,095	411,400	461,134	685,619	716,335	772,274	997,306	1,020,526
Cash injection - Own Finance			-	-	-	-	-	-	-	-	-
Cash Income- Inflow		179,021	179,021	358,042	179,021	179,021	358,042	179,021	179,021	358,042	179,021
Total Inflows		**179,021**	**179,021**	**358,042**	**179,021**	**179,021**	**358,042**	**179,021**	**179,021**	**358,042**	**179,021**
Feed Costs		(7,700)	(7,931)	(8,169)	(8,414)	(8,666)	(8,926)	(9,194)	(9,470)	(9,754)	(10,047)
Fingerlings Purchase Cost		(55,296)	(27,648)	(27,648)	(55,296)	(27,648)	(27,648)	(55,296)	(27,648)	(27,648)	(55,296)
Harvesting Labour Costs		(500)	(500)	(1,000)	(500)	(500)	(1,000)	(500)	(500)	(1,000)	(500)
Maintenance and Transport		(1,700)	(1,700)	(1,700)	(1,700)	(1,700)	(1,700)	(1,700)	(1,700)	(1,700)	(1,700)
Staff Costs		(60,000)	(61,800)	(63,654)	(65,564)	(67,531)	(69,556)	(71,643)	(73,792)	(76,006)	(78,286)
Pen - Net Replacement		-	-	(1,560)	-	-	(1,560)	-	-	(1,560)	-
Pen - Geo Bags		-	-	-	-	-	-	-	-	-	-
Pen - Ropes and Other Items		-	-	-	-	-	(7,824)	-	-	-	-
Licenses Fees		(925)	(925)	(925)	(925)	(925)	(925)	(925)	(925)	(925)	(925)
Insurance		(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)
General Overheads		(5,371)	(5,371)	(10,741)	(5,371)	(5,371)	(10,741)	(5,371)	(5,371)	(10,741)	(5,371)
Rent (warehouse and accomodation)		-	-	-	-	-	-	-	-	-	-
Loan Repayment- Interest only		(5,463)	(4,495)	(3,406)	(2,183)	(807)	-	-	-	-	-
Loan Repayment- Capital		(7,808)	(8,776)	(9,865)	(11,088)	(12,464)	-	-	-	-	-
Cash Withdrawal:											
Depreciation Expenses		(3,175)	(3,175)	(3,175)	(3,175)	(3,175)	(3,175)	(3,175)	(3,175)	(3,175)	(3,175)
Business Profit Tax		-	-	-	-	-	-	-	-	-	-
Total outflows		**(148,438)**	**(122,821)**	**(132,344)**	**(154,716)**	**(129,287)**	**(133,557)**	**(148,304)**	**(123,082)**	**(133,010)**	**(155,800)**
	Investment										
Net Cashflow	**(101,115)**	**30,583**	**56,200**	**225,698**	**24,305**	**49,734**	**224,485**	**30,716**	**55,939**	**225,032**	**23,221**
Cumalative Cashflows		(70,532)	(14,332)	211,366	235,671	285,404	509,890	540,606	596,545	821,577	844,797

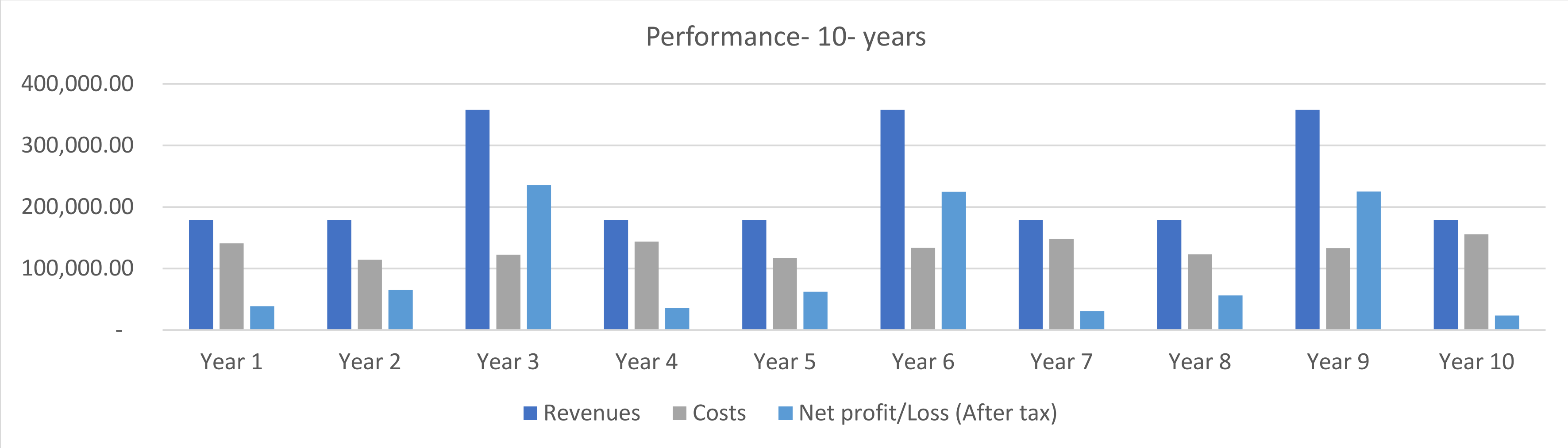

Figure 5: Financial Performance: Pen method

Table 12: Investment Analysis: Pen method

Pen Method: Investment Analysis over 10 years			
	10 years	**5 Years**	**3 Years**
NPV	375,775	158,484	119,001
IRR	71%	62%	57%
Investment Recovery Time	2.1 Years		
Average Annual Revenue	232,727		
Average Net Profit-Annual	99,591		
Average monthly Profit	8,299		
Average Net Margin	36.5%		
Total Investment	101,115		
Loan Amount	50,000		(at 11.75% interest rate, no grace period)
Own Finance	51,115		
Average Cost of Production per animal- Direct Costs	55.8		
Average Cost of Production per animal- All Costs	65.2		

9. Discussion on findings

The results of the feasibility and financial projection show that both methods perform very well compared to the evaluation criteria (see Table 1). The main contributing factors for differences between both methods is the increased survival rate in bottom-set cage method (80% vs 70% for pen method) and costs for bottom set cages construction.

Table 13: Comparison of results for both culture methods

	Bottom Set Cage Method	Pen Method	Comparison/compared to Evaluation Criteria
Total positive Cumulative cash flows after investment recovery (over 10 years)	1,006,984	844,797.15	19% higher for bottom-set cage method
Years with losses	0	0	No loss-making years in either culture method; fits a high value Investment criteria
NPV – 5 Years	160,654.70	158,483.58	Positive NPV fits both Good/High Value Investment criteria
IRR – 5 Years	45%	62%	High Value Investment, more than 30%
Investment Recovery Time	2.2 Years	2.1 Years	High Value Investment, less than 3 years
Average Annual Revenue	265,974	232,727	Pen method has a 13% lower average annual revenue
Average Net Profit-Annual	123,334	99,591	Pen method has a 19% lower average annual net profit
Average monthly Profit	10,278	8,299	Results from bottom-set cage method fits the High Value Investment criteria while the pen method shows good value
Average Net Margin	40.4%	36.5%	High Value Investment
Total Investment	176,357.87	101,114.67	Pen Method requires a 43% lower investment
Loan Amount	50,000.00	50,000.00	-
Own Finance	126,357.87	51,114.67	-
Average Cost of Production- Direct Costs	57.0	55.8	Bottom-set cage has a MVR 1.2 higher direct cost of production.
Average Cost of Production- All Costs	61.1	65.2	When all costs are included, production cost of bottom-set cage is MVR 4.1 lower due to higher numbers produced.

As seen in Table 13, the bottom-set cage method has a slightly higher Net Present Value at 5 (the pen method has a higher NPV at 3 years as the initial investment is lower (Table 12)). The bottom-set cage method delivers higher value overtime as it has a better average net profit margin due to the higher survival rate. Both culture methods make a profit during the first year and continue to do so over the 10-year period.

Overall both culture methods are attractive and should find support among entrepreneurs, especially from islands. A likely factor determining what method can be chosen maybe the available sea area. If shallow areas with a sandy bottom are not available, the bottom-set cage method would need to be used.

The returns provided by bottom-set cage method over 10 years is 19% higher (MVR 162,187) than the pen method. This translates to additional earnings of 16,218.7 per year. Although this is significant for an individual investor, the additional MVR 72,000 investment can be the deciding factor.

Further technical input on the determining the better method will be useful to make investment decisions.

9.1 Sensitivity Analysis

9.1.1 Sale Price Sensitivity

Table 14: Price Sensitivity analysis for bottom-set cage method

Sale Price (MVR)	Monthly Profit (MVR)	Net Margin (%)	NPV at Year 5 (MVR)	IRR at Year 5 (%)	Payback (years)
45	1,852	4%	(141,656)	n/a	8.1
50	3,305	13%	(89,534)	-16%	5.5
55	4,758	21%	(37,411)	2%	2.3
66	7,954	34%	77,259	29%	2.4
70	9,116	37%	118,957	37%	2.3
74	10,278	40%	160,655	45%	2.2
78	11,440	43%	202,353	52%	2.1
82	12,602	46%	244,051	59%	2.0
86	13,764	48%	285,749	66%	1.9
90	14,926	50%	327,447	73%	1.7
94	16,089	52%	369,145	80%	1.6
98	17,251	54%	410,843	86%	1.5
102	18,413	56%	452,541	93%	1.4

The analysis (Table 14) shows that the business remains feasible and provides good value even at a selling price of MVR 66. A reduced price of 55 still gives good support to the viability of the business, however there will be losses made in some years at this price. There are no years with negative cash flow at a selling price of MVR 66 using the bottom-set cage method.

Table 15: Price Sensitivity analysis for Pen Method

Sale Price (MVR)	Monthly Profit (MVR)	Net Margin	NPV at Year 5	IRR at Year 5	Payback (years)
45	927	-2%	(106,039)	n/a	8.9
50	2,198	7%	(60,431)	-24%	5.5
55	3,469	16%	(14,824)	5%	2.8
66	6,266	29%	85,512	41%	2.3
70	7,282	33%	121,998	52%	2.2
74	8,299	36%	158,484	62%	2.1
78	9,316	40%	194,969	72%	1.9
82	10,333	42%	231,455	82%	1.7
86	11,350	45%	267,941	91%	1.5
90	12,367	47%	304,427	101%	1.4
94	13,384	49%	340,913	110%	1.2
98	14,400	51%	377,398	119%	1.1
102	15,417	53%	413,884	128%	1.0

As with the bottom-set cage method, the lowest acceptable sale price for the pen method (Table 15) is MVR 66.

9.1.2 Seed Cost Sensitivity-

Table 16: Sensitivity to cost of seed- Bottom-set Cage method

Seed Cost (MVR)	Monthly Profit (MVR)	Net Margin (%)	NPV-5 Years (MVR)	IRR-5 Years (%)	Payback Period (Years)	Direct Production Cost per animal	Total Production Cost per animal
6	11,084	45%	198,776	53%	2.1	60.1	54.9
8	10,278	40%	160,655	45%	2.2	57.0	61.1
10	9,471	36%	122,533	36%	2.3	53.8	67.4
12	8,665	32%	84,412	29%	2.4	50.7	73.6
14	7,859	28%	46,290	21%	2.5	47.6	79.9
16	7,052	24%	8,169	13%	2.7	44.5	86.1
18	6,246	19%	(29,952)	6%	2.8	41.3	92.4
20	5,439	15%	(68,074)	-2%	5.6	38.2	98.6
22	4,633	11%	(106,195)	-11%	5.3	35.1	104.9

The analysis (Table 16) shows that it can support the price of seed doubling to MVR 16 from the MVR 8 assumed for the study. Even at this price a reasonable profit is made, however the attractiveness of the investment is diminished. While keeping the NPV and IRR indicators at a desirable level, the maximum price of seed that doesn't significantly harm the business is at MVR 12.

Table 17: Sensitivity to cost of seed- pen method

Seed Cost (MVR)	Monthly Profit (MVR)	Net Margin (%)	NPV-5 Years (MVR)	IRR-5 Years (%)	Payback Period (Years)	Direct Production Cost per animal	Total Production Cost per animal
6	9,106	41%	196,605	77%	1.8	59.4	58.0
8	8,299	36%	158,484	62%	2.1	55.8	65.2
10	7,493	32%	120,362	49%	2.2	52.2	72.3
12	6,686	27%	82,241	36%	2.3	48.7	79.5
14	5,880	22%	44,119	25%	2.5	45.1	86.6
16	5,074	17%	5,998	14%	2.6	41.5	93.7
18	4,267	12%	(32,123)	2%	2.1	38.0	100.9
20	3,461	8%	(70,245)	-11%	3	34.4	108.0
22	2,654	3%	(108,366)	-31%	5.6	30.8	115.2

The impact of the 10% lower survival rate of the pen method is apparent here (**Error! Reference source not found.**), as it can only support a cost increase of MVR 2-3 from the MVR 8 assumed for the study. At MVR 12, the revenue drop is very significant compared to bottom set cage method.

9.1.3 Survival Rate Sensitivity

Table 18: Sensitivity to survival rate: bottom-set cage method

Survival Rate	Monthly Profit (MVR)	Net Margin (%)	NPV at 5 Years	IRR at 5 Years	Payback Period (years)	No. of Animals produced
85%	11,622	44%	208,868	53%	2.1	2938
80%	10,278	40%	160,655	45%	2.2	2765
75%	8,934	37%	112,441	36%	2.3	2592
70%	7,590	32%	64,228	26%	2.5	2419
65%	6,247	27%	16,015	16%	2.7	2246
60%	4,903	22%	(32,199)	3%	2.9	2074

The sensitivity analysis (Table 18) shows that the business using the bottom-set cage method can support a drop in the survival rate to 65% and retain acceptable returns. Ideally the survival rate should not drop below 70% in order for the investment to be considered of good value.

Table 19: Sensitivity to survival rate: Pen Method

Survival Rate	Monthly Profit (MVR)	Net Margin (%)	NPV at 5 Years (MVR)	IRR at 5 Years (%)	Payback Period (years)	No. of Animals produced
75%	9,643	41%	206,697	75%	1.8	2592
70%	8,299	36%	158,484	62%	2.1	2419.2
65%	6,956	32%	110,270	48%	2.2	2246.4
60%	5,612	26%	62,057	34%	2.4	2073.6
55%	4,268	20%	13,843	17%	2.6	1900.8
50%	2,924	12%	(34,370)	-4%	6.0	1728

In the pen method (Table 19), a survival rate of 65% can be supported as it just barely drops monthly revenue below MVR 7,000.

The analysis shows that both models can provide acceptable returns if survival rate drops to 65%. This means that the business can tolerate 5% drop in survival rate from the optimum 70% for both methods. The business itself loses attractiveness if 65% is the normal survival rate.

9.2 Scaling up

In scaling up, it is assumed that a single staff can take care of two 24m x 24m pens, along with 8 bottom set cages for the bottom-set cage method. Staff amounts were increased accordingly to reflect the number of pens being used, which had a significant impact on the business. In the bottom-set cage method (Table 21), when a third pen is added, the payback period increases over using 2 pens only due to the addition of a staff.

At higher scales, the NPV and IRR values (values given at year-5 to compare investment performance at the midpoint of the 10-year time frame) are very high, indicating strong performance. The recovery periods of less than 1 year as scale increases, in both culture methods show the potential of business.

Table 20: Analysis of Bottom-set method at increasing scale

Bottom-set cage Method					
Pens	Monthly Profit (MVR)	Net Margin	NPV-5 Years (MVR)	IRR-5 Years	Payback Period (years)
1	10,278	40%	160,655	45%	2.20
2	24,731	53%	663,755	111%	1.12
3	34,525	49%	950,339	116%	1.10
4	49,582	53%	1,463,848	151%	Less than 1 year
8	90,135	47%	2,654,648	158%	Less than 1 year

Table 21: Analysis of Pen method at increasing scale

Pen Method					
Pens	Monthly Profit (MVR)	Net Margin	NPV-5 Years (MVR)	IRR-5 Years	Payback Period (years)
1	8,299	36%	158,484	62%	2.06
2	20,662	50%	583,951	139%	Less than 1 year
3	28,205	45%	788,773	126%	1.07
4	41,010	50%	1,220,519	161%	Less than 1 year
8	75,192	44%	2,149,820	150%	Less than 1 year

Both culture methods show that sandfish culture can be done profitably at higher scales. The figures here are expanded on the basic assumptions provided and should be approached with some caution. The analysis needs to be adjusted with added management, warehousing, staff accommodation, additional costs to leasing of a large sea area etc. to verify the exact value of the business at scale.

10. Conclusion

The sandfish grow-outs, using both culture methods evaluated, show that they provide very favorable returns and should provide excellent value to the individual investor. Additionally, it provides security in that it can tolerate significant fluctuations to price of seed, sale price and survival rate. The price of entry to the business can be deemed low compared to the returns generated. It is likely that the initial investment requirements could be achieved by a significant number of entrepreneurs without applying for financing. Overall, given the assumptions used, sandfish culture can be a viable and highly profitable venture.

Sandfish culture has significantly lower external risks as it does not depend heavily on imported feed or material. This removes factors such as currency risks and transportation. It keeps the entire operation more compact and faces fewer risks such as diseases. It should be noted that sandfish culture has a very low cost base and few operational activities, which makes it compare favorably to other business activities in Maldives.

Sandfish culture can be of interest to corporates and larger investors as well. Provided that the supply of seed is constant, some larger investors may take on the business, given that they may already have leased islands or suitable areas available.

In order for the results of this study to be refined, a broad analysis of sale of sandfish is required. Currently this study assumes that sandfish is sold to a local exporter for MVR 74 per piece of 500 grams. For investors seeking to fully understand the value of the opportunity and its growth options, finding ways to increase the selling price by exporting themselves will be of importance. The market pricing in importing countries and understanding the market needs have to be understood.

This study also does not assume any cost for trainings in sandfish culture, which may be needed for grow-out operations. It is expected that sandfish culture is reasonably uncomplicated process which can be easily learned. This will also be an attracting factor and needs to be highlighted to the public.

11. Recommendations

- Create awareness on sandfish culture and successful culture projects in Maldives.
- Identify areas ideal for sandfish grow-out to enable faster entry into the business by entrepreneurs.
- Loan facility with lower interest rate or grants to facilitate startup of the businesses will spur the establishment of the grow-out industry.
- A thorough understanding of the sandfish export prices and exporter margins are necessary.
- Development of certification procedures for encouraging product quality and good culture practices will be required.
- It may be possible to promote sandfish cultured in Maldives as a higher quality product produced in cleaner environments using certified methods and feed. This may enable the product to compete better internationally and obtain better prices over other countries.
- By enabling access to the grow-out business methods and business scenarios to the general public, they can modify the "model" to produce scenarios suitable for themselves. This can allow investors to readily create business plans which they can submit to the banks, test assumptions and evaluate the investment. The use of a website or distribution of the model as modifiable spreadsheet is suggested. Alternatively, a sandfish grow-out startup kit can be created and released, both as a reference tool and as a decision-making tool for potential entrepreneurs. This could also be packaged with incentives such as a startup loan or grants.

12. References

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Holothuria scabra cover photo credit: Brian Jones, Blue Ventures

PP-6.　伝統水産加工品の品質向上パイロットプロジェクト

1) Manual for Heat Sterilization

2) Manual for Analysis on Quality of Valhoamas

3) Report of Hygiene status of Valhoamas

Manual for heat sterilization

Post-harvest/value addition SSWG
MASPLAN

1. Equipment/tools

- Sets of equipment/tools for heating water

Pot, fuel for heating (Direct heating: gas, petroleum, firewood), clean water, thermometer

2. Heating methods

Vacuum packaged Valhoamas is heated in hot water of 90 degree Celsius for 45 minutes.

(1) Heating temperature

-Insufficient heating temperature causes increase of bacteria sometimes.

-Boiling status with 100 degree Celsius generates vapor and it lowers effect of sterilization. Because of this, the temperature must be controlled between 85 and 95 degree Celsius to keep 90 degree Celsius on average.

(2) Vacuum packaging material

-Heat-proof film which tolerable against 100 degree Celsius must be used for making vacuum packaged heated Valhoamas.

(3) Controlling method of heating water

-Clean water such as tap water etc. must be used.

-Pot for heating water must be cleaned before it is used, especially inside of the pot must be cleaned well to remove oil soiling etc., before the use.

-If the pot and equipment to use is dirty, dirt attaches on surface of the packaging material.

-Firewood (Fig.1), gas (Fig.2), and gasoline (Fig.3) are utilized for heating.

-Water in the pot must be heated by measuring the water temperature using thermometer (Fig.4 and 5).

3. Important points

- How to put the product into hot water

In order to realize equal heat conductivity as much as possible, vacuum-packaged Valhoamas must be put into pot to avoid pile up of the products one another.

When large pot is utilized for heating, some shelves are used not to pile up the products on the shelf in the pot.

- Timing of putting the product into hot water

It is O.K. to put the product into hot water when the temperature becomes 90 degree Celsius. Or it is also recommendable to put the product into hot water with around 70 degree Celsius and heat it for 45 minutes with 90 degree Celsius.

It is advisable to stop heating and make a lid to keep 90 degree Celsius for 45 minutes when the temperature exceeds 90 degree Celsius, if the pot has good heat retention, and also advisable to measure temperature of hot water sometimes while heating is stopped and heat when the temperature goes down below 85 degree Celsius.

4. Film material for vacuum packaging

- Use of heat-resistant film

It is recommendable to use film which is tolerant to heating of 100 degree Celsius.

- Use of low-permeability film

Low permeability film is effective to extend best before date and preserve taste and flavor of the product.

Fig.1 Heating by firewood

Fig.2 Heating by gas range

Fig.3 Heating by petroleum

Fig.4 Measuring water temperature using infrared thermometer

Fig.5 Measuring water temperature using thermometer

Manual for analysis on quality of Valhoamas

Post-harvest/value addition SSWG

MASPLAN

Table of Contents

1. Method for measuring water content

How to analyze water content of Valhoamas (The method is almost same as the method to analyze other processed fish products.)

(1) Equipment and consumables to use:

・Electronic balance・Grinder ・Moisture measuring instrument・Cutting board ・Kitchen knife・Medicine spoon

(2) Experimental method

(2)-1. Preparation of samples

・Cut into 3 to 5mm of pieces in thickness by kitchen knife (Fig.1). Chop the pieces more to the size of about 5mm square pieces.

・Put about 10-20g of the chopped sample into the cup of grinder and powder it by the grinder for about 30 seconds (Fig.2).

Fig.1 Cut the sample into pieces by kitchen knife

Fig.2 Chopping of the sample using grinder

Fig.3 Powdered sample

The prepared sample can be utilized for the analysis of other parameters such as water activity (Aw), pH, salt content, and histamine content etc. However, it is important to prepare the sample for bacterial analysis in order not to contaminate bacteria from the equipment and environment.

(2)-2. Measurement of water content

・Measure water content of the powdered sample using moisture measurement instrument (Fig.4).

・Put about 1g of the powdered sample on the aluminum measuring dish of the water activity measuring instrument. The value may be inaccurate, if quantity of the sample measured is too little and it takes longer time to get the value, if the quantity is too much. Spread the powdered sample on the measuring dish thinly and homogenously as much as possible.

・How to use water activity measuring instrument is as follows:

a. Press the power switch (Fig. 5).

b. Open lid of sample room.

c. Set the empty measuring dish and adjust the 0 point (Press the button shown in Figure 6).

d. Remove the measuring dish from the measuring instrument and put powdered sample on it.

e. Set the measuring dish with sample in the measuring instrument.

f. Make lid and press button for start (Fig.5).

g. Buzzer sound shows finish of the measurement. Confirm water content indicated in digital when the sound arises.

Fig.4 Moisture measurement instrument

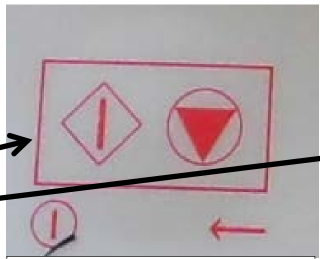


Fig.5 Power switch

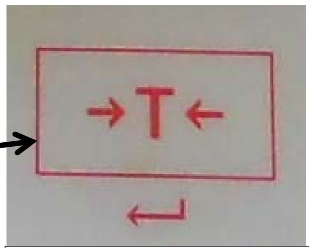


Fig.6 Switch for removing tare

2. Method for measuring water activity (Aw)

(1) Preparation of samples

The same method for preparation of samples is adopted as when water content is measured (See page 2). Powder about 10-20g of the sample homogenously and use about 2g from the sample powdered.

(2) Measurement of Aw

・Use water activity measuring instrument (Fig.7) for measuring Aw.

・Put about 2g of powdered sample into measuring cup (receptacle in right in Fig. 7). Put the amount of sample to be measured in the cup about eighth degree of the cup in order not to be spilled over from the cup.

・Open sensor cap on the back of instrument and set the measuring cup with the sample in it. (Fig.8).

・Press the button in the left on the surface of the instrument and then start measurement.

・Buzzer sound shows finish of the measurement. Confirm Aw indicated in digital when the sound arises.

Fig.7 Water activity measuring instrument

Fig.8 Set measuring cup with sample to the instrument

3. Method for measuring salt content

(1) Preparation of samples

The same method for preparation of samples is adopted as when water content is measured (See page 2). However, more quantity, 30-40g of the sample needs to be powdered.

(2) Measurement of salt content

・Use electronic salinometer to measure salt content of water solution. Soak sample into 9 times' quantity of water since fish meat of Valhoamas is solid and measure salt content using electronic salinometer after salt content elutes into water solution.

・Put about 10g of powdered sample into beaker of 100 ml in capacity and weigh it (Fig.9).

・Add 9 times' of water in quantity of the powdered sample into the beaker with the sample (Fig.10).

・Stir well inside of the beaker after about 10 minutes of keeping the sample solution quiet.

・Put electronic salt meter into sample solution and read the value when the figure indicated on the digital display board becomes stable (Fig.11).

・Multiply 10 of the value on the digital display board and regard the 10 times' value as the salt content.

Fig.9 Accurate weighing of 10g of sample

Fig.10 Adding 9 times' water of the sample in quantity

Fig.11 Measuring salt content using electronic salt meter

4. Method for measuring pH

(1) Preparation of samples

The same method for preparation of samples is adopted as when water content is measured (See page 2). However, more quantity, 30-40g of the sample needs to be powdered.

(2) Measurement of pH

・Use pH meter to measure pH of water solution. Powder the sample and soak it into 9 times' quantity of water since fish meat of Valhoamas is solid and measure pH.

・Put about 10g of powdered sample into beaker of 100 ml in capacity and weigh it (Fig.9).

・Add 9 times' of water in quantity of the powdered sample into the beaker with the sample (Fig.10).

・Stir well inside of the beaker after about 10 minutes of keeping the sample solution quiet.

・Soak pH meter into solution in the beaker and measure pH by stirring the solution lightly (Fig.12).

・Correct pH meter sometimes by soaking the instrument into standard solution with pH7.02.

Fig.12 Measurement of pH using pH meter

5. Method for measuring histamine content

(1) Preparation of samples

The same method for preparation of samples is adopted as when water content is measured (See page 2). About 1g of sample of the 10-20 g of powdered sample is used.

(2) Extraction of histamine

・Put 1g of the sample into 50ml of centrifuge tube in capacity (Fig.13).

・Put 24ml of water into the centrifuge tube with the sample (Fig.14).

・Put the centrifuge tube with the sample and water into water bath (Fig.15), and keep the condition for 30 minutes.

・After heating, lower the temperature by piping water or water with ice as quickly as possible

・Filter using filter paper No.5 and use the filtered water as liquid for measuring histamine.

(3) Measurement of histamine content

・Use “Check Color Histamine” made by “Kikkoman Co Ltd” and measure.

・Prepare test tubes of 5ml in volume. The number of test tube should be (No. of samples x 2 +2).

・Use 2 test tubes per a sample and also use 2 test tubes for the control.

・Put 0.5ml of sample liquid (histamine-extracted liquid) into each of the test tube except for the controls.

・Put 0.5ml of standard solution which is included in the kit of “Check Color Histamine” into a test tube of control and also put 0.5ml of water into the other test tube of control.

・Put 0.5ml of “Color Checker” into all the test tubes. Then add 0.5ml of enzyme solution to one of the two sample liquid and 0.5ml of buffer solution into the other. Both enzyme solution and buffer solution are included in the kit of “Check Color Histamine”. And also add 0.5ml of enzyme solution to the test tube with standard solution and 0.5ml of buffer solution to the test tube with water, respectively.

・Warm these test tubes in water bath which is controlled to keep 37 degree Celsius for 15 minutes. While warming, put aluminum foil on upper part of the water bath to block light.

・Measure absorbance of sample liquid warmed using absorptiometer (Fig.18). Adjust 0 point by putting water into cell and measuring and use the absorptiometer. Put sample liquid into the cell and press button for measurement. Then the absorbance is indicated.

・Calculate histamine content after absorbance of all the sample liquid measured. Use a formula which is described below:

Histamine content (ppm) = $(a-b)/(c-d) \times 100$

a: absorbance in case of sample liquid and enzyme

b: absorbance in case of sample liquid and buffer solution

c: absorbance in case of control with standard solution

d: absorbance in case of control with water

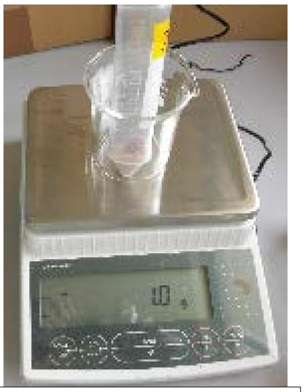


Fig.14 Measurement of 1g of the sample

Fig.15 Adding 24g of water

Fig.16 Heating of sample liquid

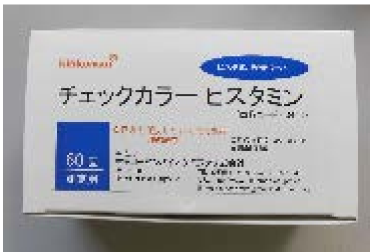


Fig.17 Reagent for measuring histamine content

Fig.18 Enzyme solution, Coloring solution, Standard solution, Buffer solution

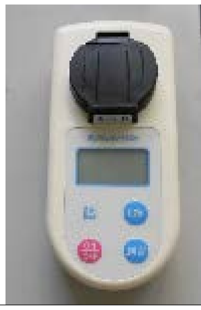


Fig.19 Absorptiometer

6. Method for bacterial analysis

(1) Preparation of samples

・Cut into 3 to 5mm of pieces in thickness by kitchen knife (Fig.20). Chop the pieces more to the size of about 5mm square pieces.

・Put about 10-20g of the chopped sample into the cup of grinder and powder it by the grinder for about 30 seconds (Fig.21).

・Use equipment and tools shown in Figure 20 and 21 after wiping them using 70% of alcohol (Fig. 23) which is made from 70ml of methanol and 30ml of distilled water.

(2) Bacterial analysis

・Put 10g of powdered sample into a bag for dilution (Fig.24) together with 90ml of sterile water (Left of Fig. 25). Then, shake well the bag for about one minute after sealing (use Fig. 26) upper side of the bag. Since the part of filtration of the bag for dilution cannot be sealed, special attention must be paid to avoid water spilling from the bag during shaking the bag.

・Take 1 ml of sample liquid which passes the part of filtration of the bag using sterile pipette. Then, inject the liquid on culture dish.

-Sterile pipette: Use pipetter (Fig. 27) by sterilizing disposable tip part using methanol.

-Culture dish: Disposable culture dish for Total Count of bacteria (TC), *E. coli* (EC), mold & yeast (YM), and Salmonella (SL) was procured. Select the culture dish matches the item(s) to be analyzed and put 1 ml of the sample liquid.

・Store the culture dish with the sample liquid in incubator (Fig. 29) of 35 degree Celsius adjusted for 2 days. Then count number of bacterial colony in the culture dish (Fig. 30 shows bacterial colony grown in the culture dish).

・Since 90 ml of dilution water is added to 10g of sample for dilution of sample liquid, TC obtained from culture of 1 ml of sample liquid is (number of colony in the culture dish) × 10 per 1 gram. Appropriate number of colony on the culture dish is between 30 and 300 for counting. Dilution of sample liquid is necessary, if the number of colony is presumable over 300.

-Method for dilution of sample liquid: Take 1 ml of sample liquid from the bag for dilution and add 9 ml of sterile water (Right, Fig. 25) to it. Shake it well and then take 1 ml of the liquid shaken. Inject the 1 ml of liquid on culture dish. (The number of colony obtained) × 100 = TC. For more dilution, same procedure is taken. Namely, 1 ml of the sample liquid diluted is taken and 9 ml of sterile water is added.

Fig.20 Chopping sample

Fig.21 Powdering sample

Fig.22 Powdered sample

Fig.23 70% alcohol

Fig.24 Bag for dilution (Extraction of bacteria)

Fig.25 Sterile water for dilution (90 ml, 9 ml)

Fig.26 Sealer (in the box)

Fig.27 Pipetter

Fig.28 Culture dish used for bacterial culture

Fig.29 Incubator

Fig.30 Bacterial colony was seen in the culture dish.

7. Method for measuring concentration of solution

・Use refractometer (Fig.31) to measure concentration of solution.

・Use refractometer of which instruction memory of the numbers around 50 to measure Rihaakulu.

・Use refractometer of which instruction memory of 30 or less to measure concentration of salt.

・How to use the refractometer is shown as Figure 32. (Cited from HP of Atago Co Ltd)

Fig.31 Refractometer

・Peep inside the refractometer and read a border line between blue and white parts (Fig.32 & 33). And the figure on the border means refractive index.

Fig.32 Measuring method of concentration of solution

・Drop one or two drops of the sample liquid on the surface of prism.

・Close lid panel gently.

・Peep from eyepiece facing bright direction and read the figure on the border between blue and white parts.

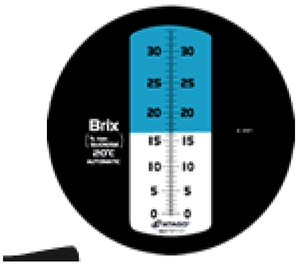


Fig.33 Inside the refractometer

Report on Hygiene status of Valhoamas

Sterilization of Vacuum Packaged Valhoamas

Post harvest and value addition SWG

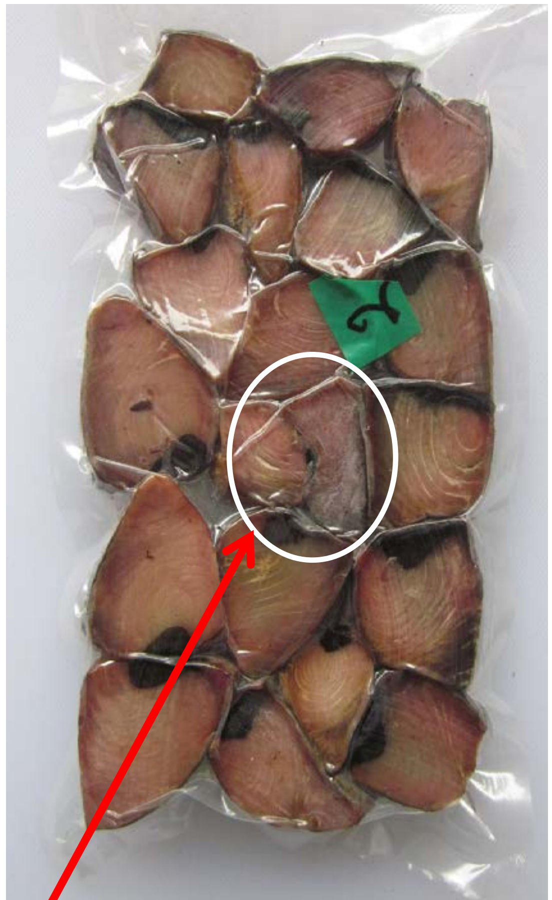
MASPLAN

Valhoamas

Conventional product

Vacuum packaged product

Deteriorated products sold at the market



Mold

Vacuum Packed Product Bulged with Gas

Why dose consumer buy the vacuum packed Valhomas?

Questionnaire for Valhoamas

- **Please cooperate to produce good Valhoamas**
- **Age ____ years Sex : Male☐ ・ Female☐**
- **Purchase number**
- **Place of use home☐ Retail☐ Other (pls specify) ☐**
- 1. Do you prefer packed Valhoamas or unpacked Valhoamas?
- **Packed☐ Unpacked☐**
- 2. What do you think of the price of packed Valhoamas?
- **High☐ Low☐ Reasonable ☐**
- 3. What type of Valhroamas is tastier?
- **Packed☐ Unpacked☐ Same☐**
- 4. What is your reason for buying packed Valhoamas?
- **Good taste☐ More presentable☐ Easy to use☐**
- **Hygienic☐ Good storability☐ Other☐**
- 5. Have you had difficulties in buying packed quality Valhoamas? **Yes☐ No☐**
- Kind of trouble

Questionnaire on Valhoamas

- **Please cooperate to produce good Valhoamas**
- **Age ____ years　　Sex : Male26・ Female6**
- **Purchase number**
- **Place of use　home☐　Retail☐　Other (pls specify) ☐**
- 1. Do you prefer packed Valhoamas or unpacked Valhoamas?
- **Packed29　Unpacked3**
-
- 2. What do you think of the price of packed Valhoamas?
- **High20　Low☐　Reasonable12**
-
- 3. What type of Valhroamas is tastier?
- **Packed19　Unpacked1　Same12**
-
- 4. What is your reason for buying packed Valhoamas?
- **Good taste18　More presentable 7　Easy to use17**
- **Hygienic19　Good storability11　Other2**
- **Among 6 female respondents, 5 voted "Hygienic" and 4 voted "storability". And among 26 male respondents, 13 voted "Easy to use" and 12 voted "Hygienic", respectively.**

Consumers' opinions about vacuum packed Valhoamas

Result of Questionnaire

1. Hygiene
2. Preservation
3. Convenience

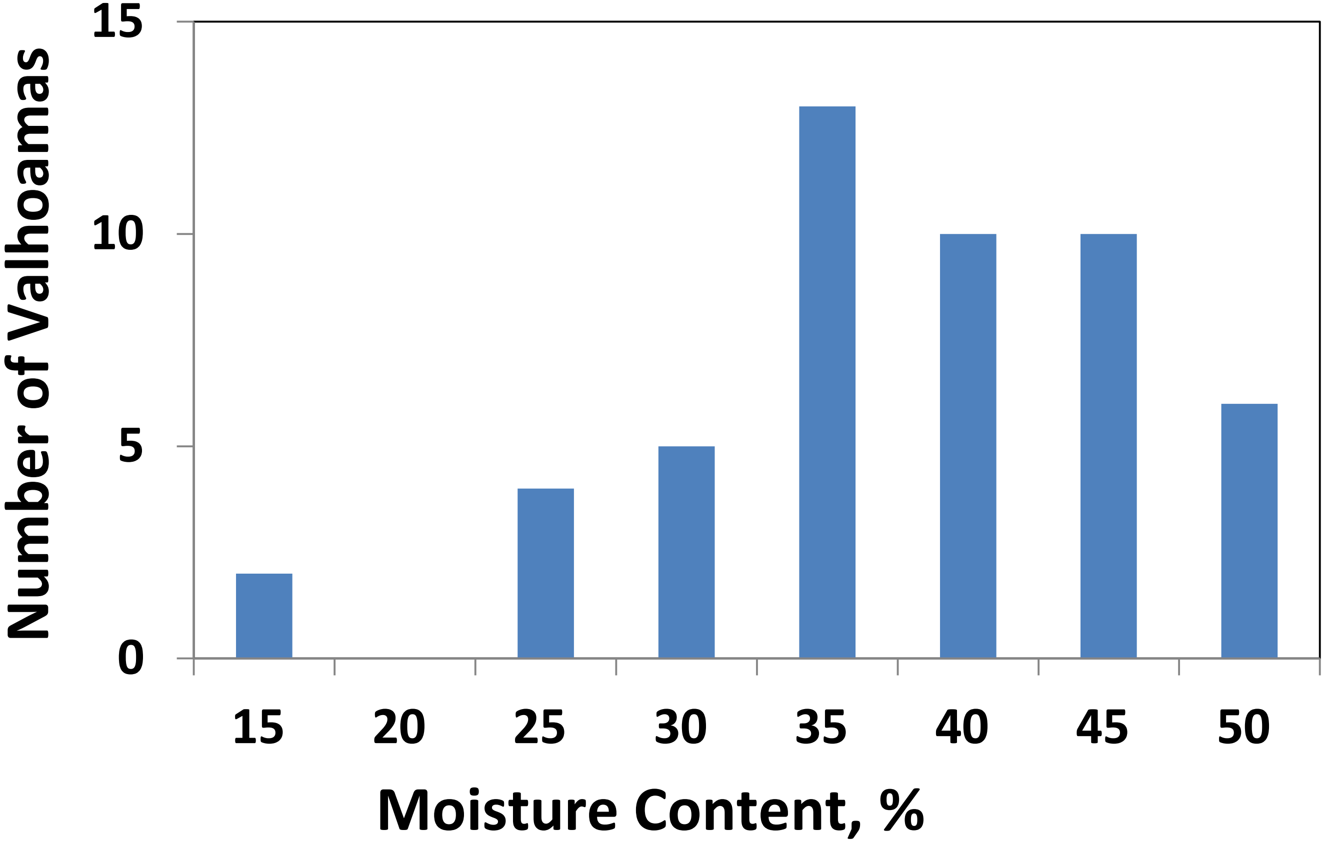
Scientific analysis

60 Valhomas were collected from the market in Male to measure moisture content and water activity(Aw).

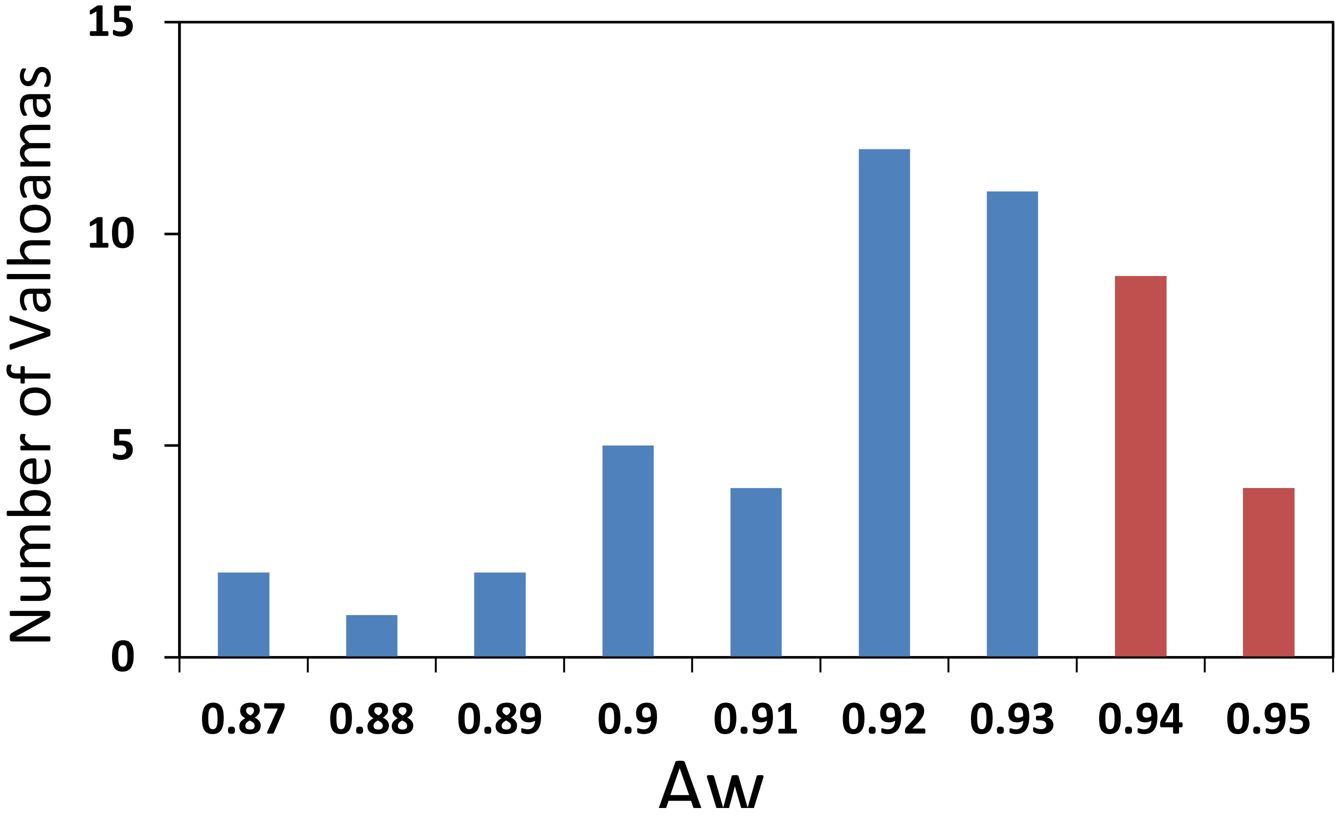
Moisture Content

Water Activity

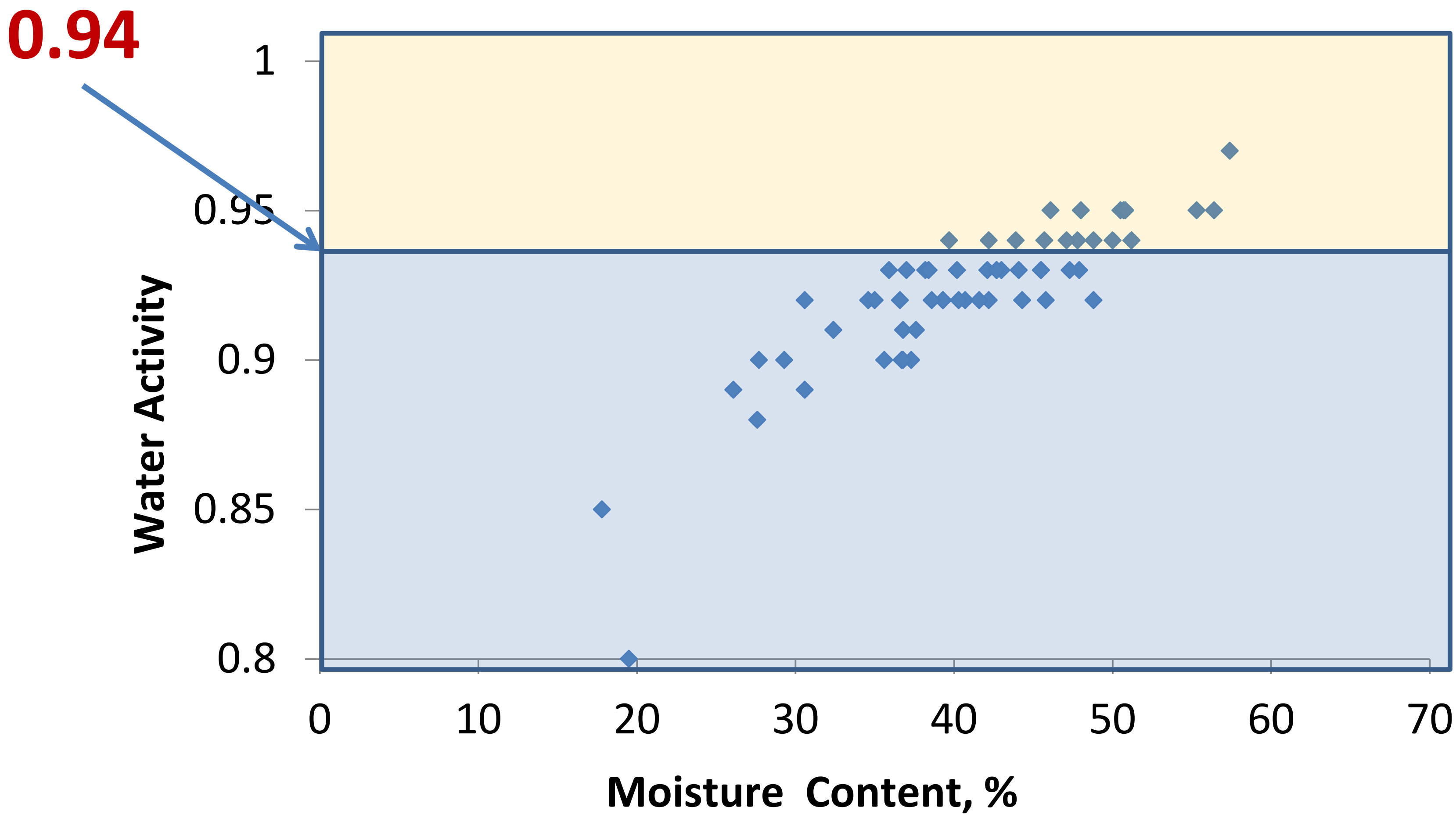
Moisture Content of Valhoamas



Water Activity (Aw) of Valhoamas



Aw and Moisture



Result

Moisture Content 20% ～60%

Water Activity (Aw) 0.85 ～ 0.97

Deterioration due to Aw

Bacteria increase upper Aw 0.94

Mold and Yeast increase upper Aw 0.80

Commercial Valhoamas

30% of the Valhoamas examined were rotten in a few days at room temperature. (Indicator: more than 10^6 of bacterial number)

All Valhoamas have possibility of growth of mold and yeast.

Table 1 Bacterial Number of Valhoamas

Sample Number	Water(%)	Aw	TC	E. Coli
1	50.8	0.95	2.6×10^7	＋(6.0×10)
2	43	0.93	9.2×10^4	—
3	57.4	0.97	8.3×10^7	＋(4.1×10^4)
4	51.2	0.94	2.8×10^6	—
5	42.1	0.93	4.4×10^4	—
6	45.5	0.93	6.5×10^7	—
7	42.2	0.94	1.3×10^5	—
8	42.7	0.93	6.4×10^4	—
9	35.9	0.93	2.8×10^7	＋(6.5×10^2)
10	39.7	0.94	2.4×10^5	—
11	47.1	0.94	1.1×10^7	—
12	52.2	0.96	6.8×10^6	—
13	49.1	0.94	5.2×10^6	—
14	38.2	0.92	5.0×10^6	—
15	34.4	0.89	1.6×10^3	—
16	43.5	0.93	8.4×10^6	—
17	33.7	0.9	7.4×10^3	—
18	41.6	0.93	1.5×10^7	—
19	44.2	0.94	2.2×10^7	＋(3.0×10)
20	40.5	0.92	3.6×10^6	—

Water : Moisture content

Aw : Water activity

TC : Total Count of Bacteria

E. Coli : Escherichia coli

E. Coli is an indicator of pathogenic contamination

Pathogenic Escherichia coli

Cholera

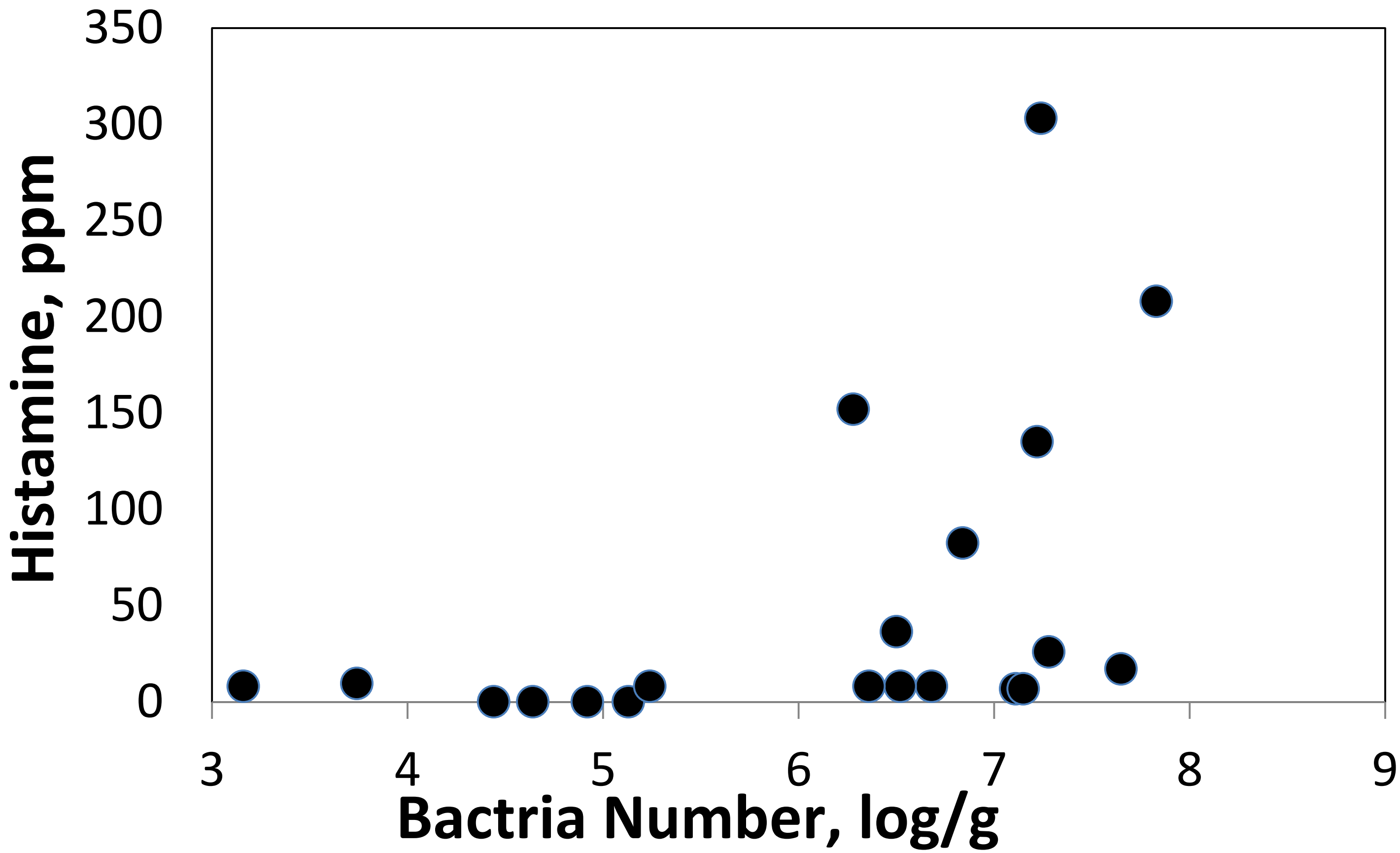
Dysentery

Typhoid

Paratyphoid

and so on

Bacterial Number and Histamine

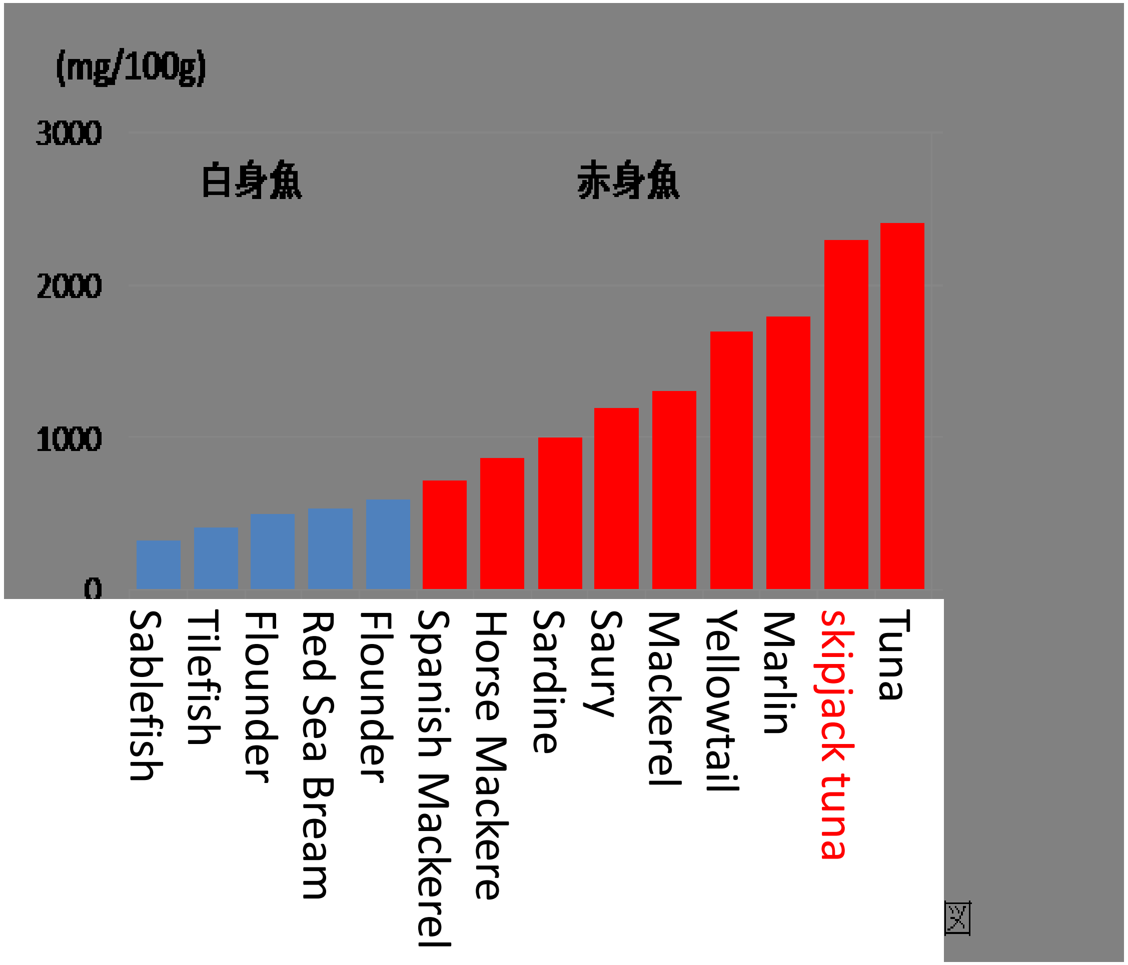


Histamine

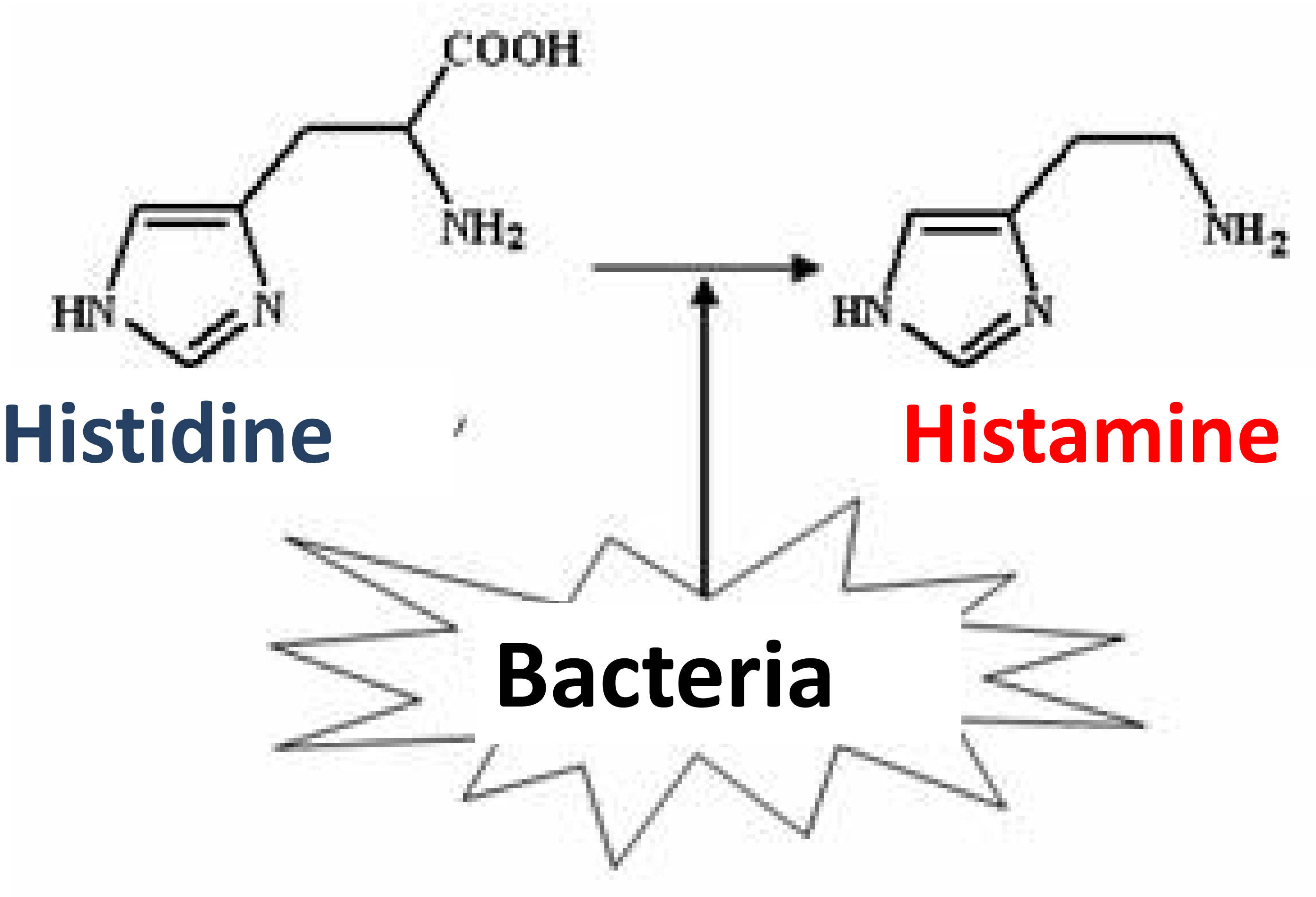
Histamine concentration in Valhoamas tends to be higher, when number of bacteria is 10^6 or more.

From the result, histamine in Valhoamas deems to be concentrated by bacterial growth during storage.

Histidine in Fish



Histamine from Histidine



Result

・Some of commercial Valhoamas were rotten within a few days after they were collected from the markets. ($\times 10^7$, $\times 10^8$)

・*E. coli* was identified from some of Valhoamas analyzed.

・Valhoamas contained large number of bacteria tended to show much histamine content.

Best Before

No.1 No.2

No.1 : Non-heated, stored for 3days, vacuum state broken due to bacteria
N0.2 : Heated, stored for 3days, vacuum state kept

Broken Vacuum Package

Gas is generated by bacterial growth in the vacuum package.

Bacterial Growth

- Increase of bacterial number

  Best before , Date of expiration

- Possibility of pathogen contamination

  ***E. Coli* contamination**

- Increase of histamine

  Histamine is generated by bacteria

Sterilization of Vacuum Packed Valhomas

Retort sterilization

125℃、20min

Bacteria free product

The installation cost is very high

Hot water sterilization

90℃ hot water

Some bacteria survive

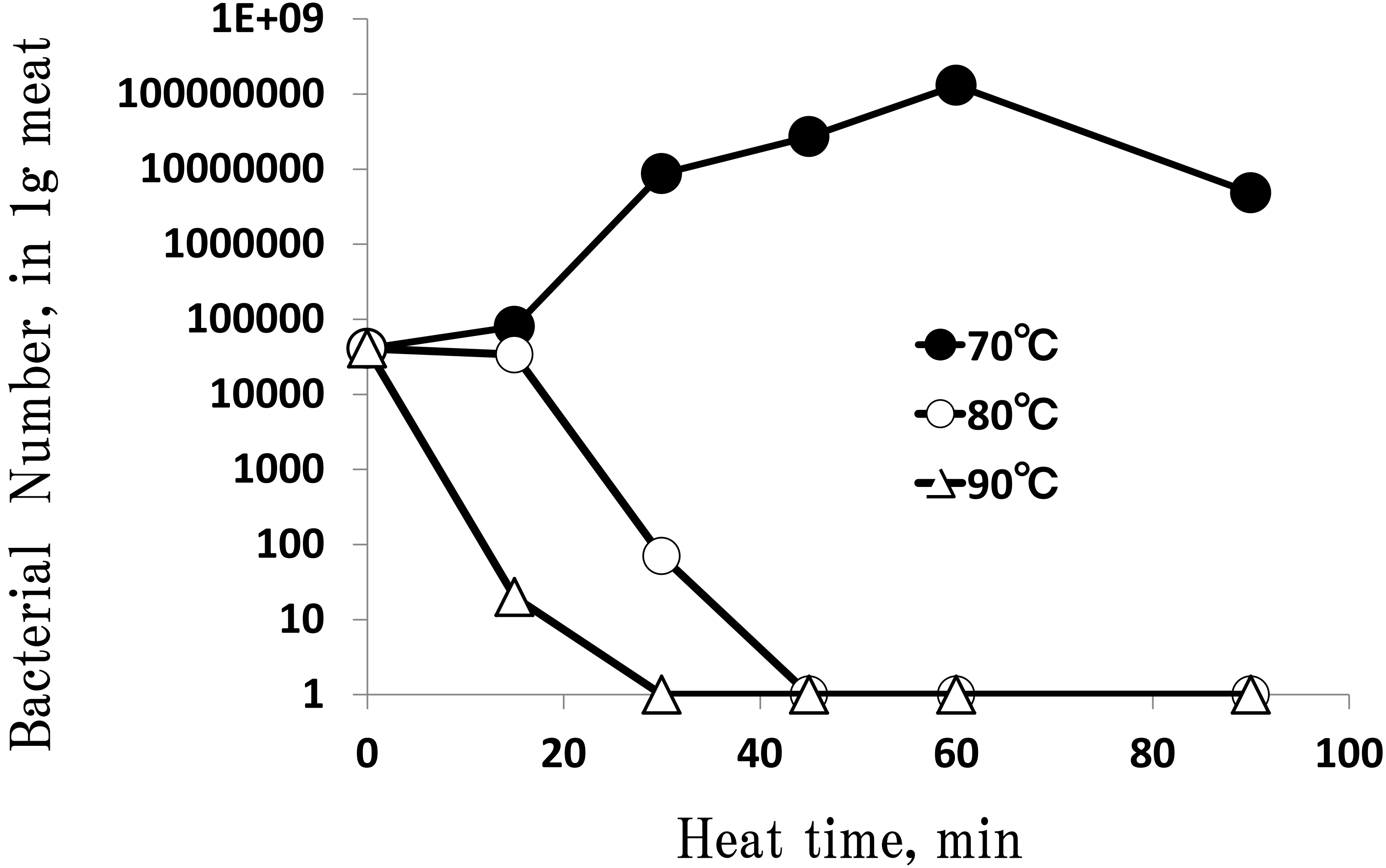
The investment cost is relatively low

Heating by gas range

Heating by burning firewood

Heating in Hikimas processing facility

Effect of heating temperature on the number of bacteria



Temperature for sterilization

70℃ ： Bacteria increase sometimes.

100℃ ： Package inflation by vapor generated from Walhoamas

90℃ ： Appropriate with **85℃ ～ 95℃、over 45min**

Temperature and Time

90℃ (85℃ ～ 95℃)、 45min

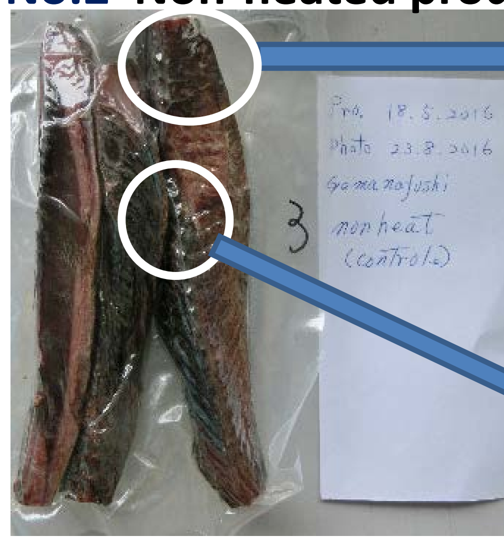
Hot water temperature has to be measured by thermometer

Preservation of Heated Product (Aw0.92)

Storage for 110 days at room temperature

No.1 Heated product

No.2 Non-heated product



No.1 : Bacteria was not detected.

The smell and taste were good.

No.2 : Mold was observed.

The smell was not good.

Mold on the product

Storage Test (Aw0.92)

Heat Sterilized Valhoamas was stored at room temperature

Storage period	Bacterial Number	Taste
3 month	under 10/g	Good
5 month	under 10/g	Good

Mold could be seen in some samples 3 months after the storage test had started.

Storage test (Aw0.96)

	1 day	3 days	5days	7days	9days
Heated product（20 packs)	0	5	8	10	13
Non-heated product (9 packs)	0	9	—	—	—

High Aw(0.96) products, heated and non-heated, were stored at room temperature. The number in the table expresses the number of broken vacuum state (inflation of the package) due to bacterial increase.

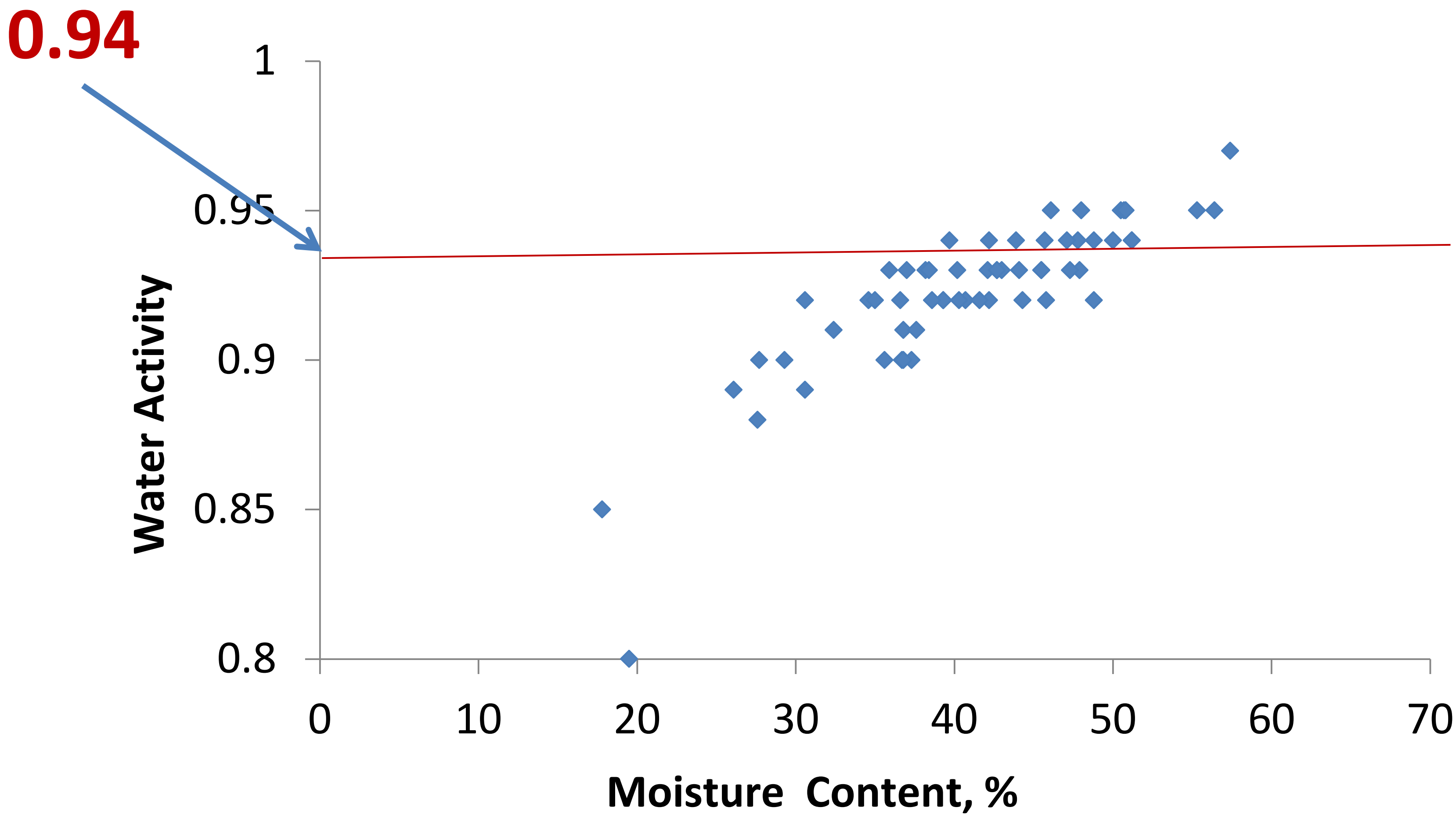
High Aw product could be rotten within 2 or 3 days at room temperature. Heated product also begin to be rotten 2 or 3 days after the storage had started.

Effect of heat sterilization to high moisture content Valhoamas

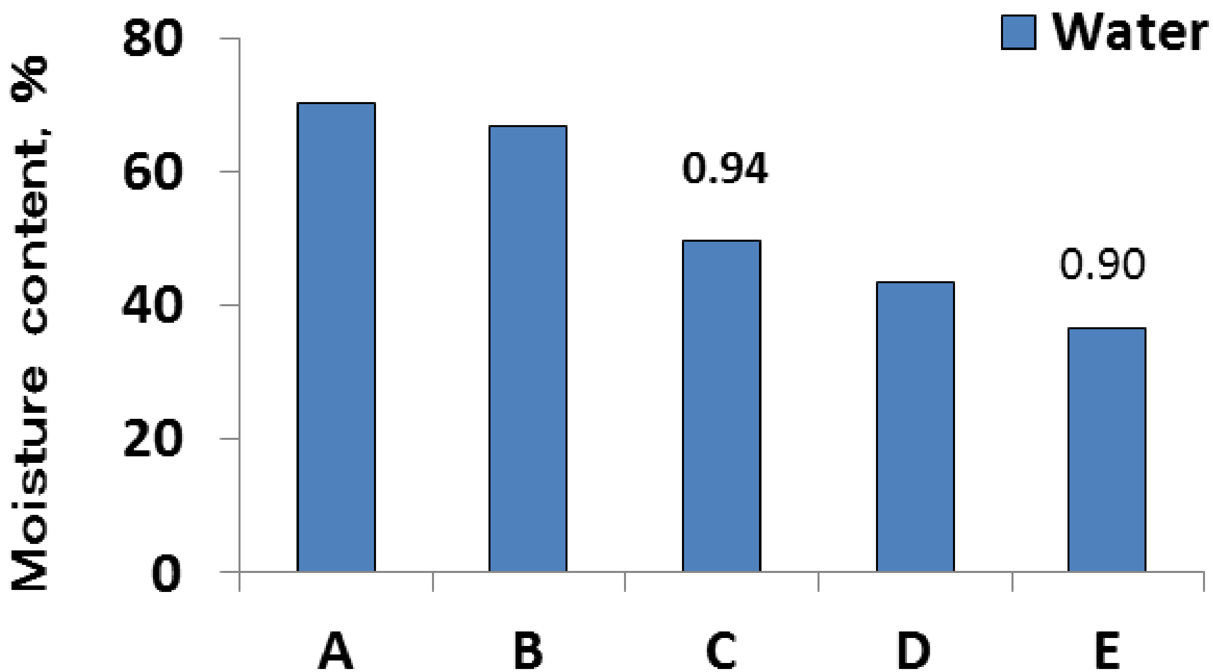
- **Effective for the sterilization of pathogenic bacteria and *E. coli***
- Storability becomes a little better, but the product will be rotten in short term under room temperature.
- Distribution and storage of the product must be done under low temperature.
- The product must be frozen (below -18 ℃) for long term storage.

High Aw product has to be kept at low temperature after the heat sterilization.

Aw and Moisture



Moisture Content in Process



A : After Boiling
B : After Cutting
C : After Smoking
D : After Keeping in room for one night
E : After Smoking

To make condition of under Aw 0.94 Product

- Continuous smoking over four (4) hours
- 2 hours smoking and sun drying
- Lower to 55% or less of the product’s original weight
- It is important for quality control to know moisture content and Aw.

- Special attention must be paid for the following cases:

  Large piece of skipjack tuna

  Yellow-fin tuna

Removal of Oxygen with Packing Material

- Mold needs oxygen to increase.

Gas barrier film

- **NY15/PE60 55cc/m^2/day 10yen (MVR1.5)**
- **NY15/PE60 15cc/m^2/day 14yen (MVR 2.1)**
- **PET12/NY15/PE60 8.5cc/m^2/day 25yen (MVR3.75)**

Oxygen absorber

SPE-30A 3yen (MVR 0.45)

Preservation Test

Effect of **Heat Sterilization** and **Oxygen Remover**

Please evaluate the quality of Valhoamas stored for 80 days under room temperature.

Evaluation items:

Apparance ・ Taste ・ Smell

Extension activities

Maavha Island

Gemanafushi Island

Teaching

Production of Heated Valhoamas

Heating process

Sticker certifies heat sterilization

The sticker put on the product

Test sale of heated Valhoamas

Products in display shelf of the shop

Customers interested in the product

Consumers' opinions were interviewed.

Questionnaire

Opinions of consumers

1. Hygienic and safe
2. Reasonable price
3. Same taste as non- heated one's
4. Eat as it is
5. Can be kept longer
6. Buy it continuously

Remaining subjects

1. More awareness activities are necessary both for producers and consumers to know risks of non-heated product and effectiveness of heat sterilization.
2. Best-before date and date of expiration must be decided based on storage test of the product.
3. Storage test of the samples packaged in gas-barrier film and with oxygen absorber should be continued (So far 3 months after the storage)
4. Storage test of the product with high Aw must be conducted under cool temperature and frozen condition.
5. Method for analysis of product’s quality needs to be disseminated.