SEYCHELLES FISHERIES AUTHORITY

Fisheries Research Report: Determination of the length at maturity for Green jobfish (Aprion Virescens) on the Mahe plateau in the Republic of Seychelles

Fisheries Research Department
Seychelles Fisheries Authority
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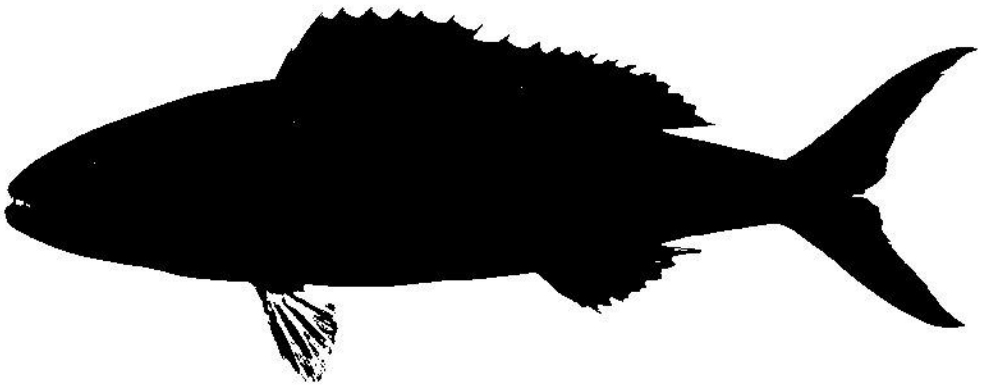
Determination of the length at maturity for Green jobfish (*Aprion Virescens*) on the Mahe plateau in the Republic of Seychelles



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Abstract

Green jobfish (*Aprion virescens*) is a commercially important species targeted by the demersal handline fishery within the Seychelles artisanal fishery. The species is currently being managed under the Mahe plateau trap and line co-management plan with a minimum landing size of 32cm fork length. The minimum landing size was put in place as an interim management measure pending research on the size at maturity for the species. This study aimed to determine the size at maturity (Lm50) for Green jobfish on the Mahe plateau. The main sampling activities took place between May 2015 – September 2017 with additional sampling undertaken in 2021 and 2022 to address the gap in sampling sizes. Biological information such as length, weight and sex were recorded while gonads and otolith were collected for determination of maturity stages and age. Size at maturity were determined microscopically to be 40.2 cm fork length for females, additionally macroscopic determination indicated a size at maturity of 42.7cm fork length for females and 51 cm fork length for males. From the results of this study, it is recommended that the most recent size at maturity is considered and that the relevant regulation is updated in relation to the minimum landing size.

Introduction

Green jobfish (*Aprion virescens*) known locally as "zob gri" is a reef associated fish from the snapper (Lutjanidae) family (Froese & Pauly, 2024). They are geographically distributed in the Indo-Pacific regions from Western Indian Ocean to the Hawaiian Islands, but are largely confined to continental shelves and slopes (Froese & Pauly, 2024). They are slow growing, long-lived species (26 -27 years) that inhabits coral and rocky reefs between 0 -120 m depth (Haight et al., 1993). Green jobfish are considered large top predators that feeds mainly on fishes but their diet can also include shrimps, crabs, cephalopods and planktonic organisms (Meyer et al., 2007). They are commercially important species throughout different regions, especially in Hawaii, where they are an important species within their deep slope bottom fishery (Meyer et al., 2007).

In the Republic of Seychelles, Green jobfish is caught in the demersal handline fishery. The fishery is part of a multi species, multi vessel and multi gear artisanal fishery operating predominantly on the Mahe plateau. The Mahe plateau is a steep-sided plateau with an area of approximately 40,000 km^2 that rises rapidly from around 1000m. The plateau is made up mainly of subsurface granites and coral outcrops forming banks with maximum depth of 50 to 65m. The relatively large area of the shallow banks and plateau provides the main fishing grounds for the multi species artisanal fisheries including the demersal handline fishery (Seychelles Fishing Authority, 2020) . Within the demersal handline fishery, the Green jobfish consisted of approximately 13% of the total catch in 2021 (Seychelles Fishing Authority, 2022). It is a commercially valuable fish within the fishery fetching high market prices locally and internationally as an exported commodity.

The demersal handline fishery on the Mahe plateau is managed under the "Mahe Plateau Trap and Line Fishery Co-management plan 2020" which started implementation in 2022. The plan introduced several management measures, including a minimum size limit for *Lutjanus sebae* (Emperor red snapper) and Green jobfish. A minimum landing size of 32cm fork length for both species were established as an interim management measure pending further research to determine the size of maturity for the two species. Currently there is very little biological information available on the size at maturity for the majority of species targeted within the Seychelles artisanal fishery. The last study assessing the size at maturity of Green jobfish on the Mahe plateau was undertaken in 1992, over 30 years ago (Mees, 1992). Since then, the fishery has undergone significant developments with an increase in the number and size of fishing vessels. Vessels are going further, staying longer at sea and becoming more efficient compared to the fishery of 1992. It has been recognised that exploitation of a stock can lead to changes in the life history parameters of the species as they try to adapt to the shift in the population structure as a result of fishing (Enberg et al., 2012). Therefore, it is necessary to update those parameters regularly to keep up with the changes that the population is undergoing. One of the key parameters which is useful in stock management and for the establishment of a minimum size limit is length at first maturity (Lm_{50}) (Tsikliras & Stergiou, 2014).

Length at maturity (Lm_{50}) is defined as the length at which 50% of a population reach sexual maturity and is a key parameter in fisheries management for establishing minimum landing size limits (Soares et al., 2020). Setting an appropriate minimum landing size in a fishery can protect juveniles in a stock without compromising the social and economic benefits of the fishery. Additionally, Lm_{50} is also an important

parameter used in length-based stock assessments. Since Lm_{50} is species specific and can vary across regions and stocks, it is essential to determine this parameter for each target species within a fishery.

The aim of this study was to determine the size at maturity (Lm50) of Green jobfish on the Mahe plateau to better inform the implementation committee of the "Mahe Plateau Trap and Line Fishery Co-management plan" and to improve the quality of data available for stock assessment.

Materials and methods

Sampling

The sampling programme targeted Green jobfish landed by commercial vessels fishing on the Mahe plateau (Figure 1). To have a better coverage of sample sizes multiple landing sites were targeted around Mahe, the largest and most populous island in the Seychelles.

Based on the available Green jobfish fork length data collected from the annual sampling program undertaken by the Fisheries Research Department of the Seychelles Fisheries Authority (SFA), samples were sorted in 5cm size classes ranging from 25 to 90 cm. For each size class, 25 fish were targeted. The majority of sampling took place between May 2015 to September 2017. However, to address missing size classes and sampling gaps, additional sampling was undertaken between July 2021 and April 2022.

Whole(ungutted) Green jobfish were purchased from fishers at various landing sites around the Mahe island (Figure 1) and were brought to the SFA Fisheries Research wet lab for processing. Total and fork length were measured to the nearest millimetre. Whole and eviscerated weights were recorded to the nearest 0.01kg. Individual fish were dissected, sexed and macroscopic maturity stage for both male and female gonads were identified. Gonads were removed, weighed and preserved in 10% formalin for histological processing.

The macroscopic maturity stages were assessed as follows: Stage I, immature; Stage II, resting; Stage III, developing; Stage IV, ripe; and Stage V, spent. Gonads that were too small and underdeveloped to distinguish between male (M) and female (F) were classified as indeterminate (I).

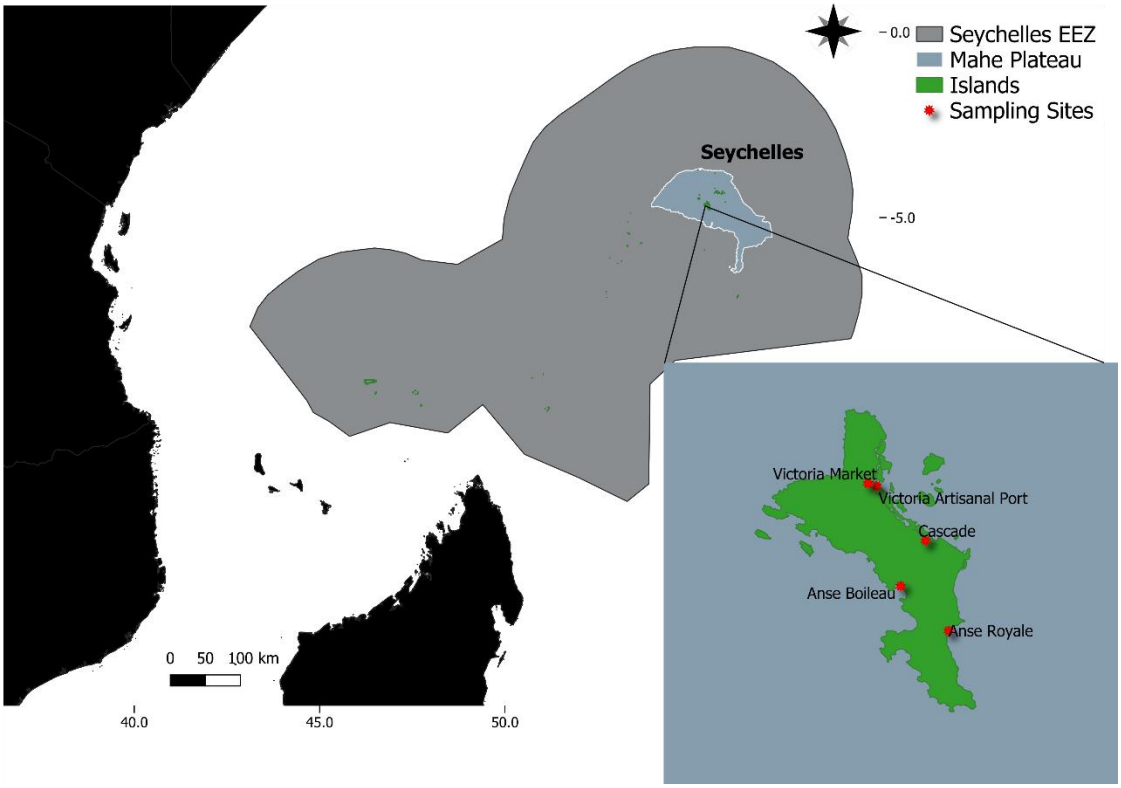

Figure 1: Location of the Seychelles and the Mahe plateau in Western Indian Ocean. Inset showing Mahe island with labelled sites where Green jobfish were purchased (red star)

Otoliths extractions

Otoliths also knowns as “earstones” are hard calcium carbonates structures located directly behind the brain of bony fishes. They are used by fish to assist in balance and hearing (Haight et al., 1993). Most bony fish have three pairs of otoliths (Sagitta, Asteriscus and Lapillus) and their size and shapes vary by species. Otoliths are formed by continuous depositions of calcium carbonates throughout a fish’s life, resulting in the formation of distinct rings or bands. During periods of slow growth, these rings become opaque, whereas during periods of faster growth they become darker (Thomas & Swearer, 2019). The rings can be counted and can be used to determine the age of bony fish (Visconti, 2020).

Sagittal otoliths were removed from the head of Green jobfish by separating the head completely from the body. The top of the head was then removed in the frontal plane above the eyes in order to gain access to the cranial cavity. The sagittal otoliths are located at the back of the cavity in circular canals under the brain. Once located, flat tweezers were used to carefully extract the otoliths which were then cleaned and stored in a dry place.

Histological processing

Processing of gonads were undertaken at the SFA Fisheries Research dry lab following established protocols (Balett et al., 2023). Small sections were taken from the formalin-fixed gonads and dehydrated in a series of graded alcohols, cleared in xylene and embedded in paraffin wax. The embedded gonads were sectioned at 5µm thickness, mounted on a slide and stained using haematoxylin and 1% eosin.

The histological slides were examined under a light microscope at magnification ranging from 10x – 40x to determine sex. Females were kept for further examination to determine the reproductive phase and maturity. Maturity stages were determined based on the observation of the slides in reference to the guide table (Table 1) and were then classified as either mature or immature. Validation of the maturity stages were undertaken by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Tasmania, Australia.

Table 1: Guide table to determine maturity stages of female gonads during microscopic examination (Rose & Balett, 2023)

MATURITY STATUS	PHASE	MAGO AND POF STAGE	ATRESIA OF ADVANCED YOLKED OOCYTES	MATURITY MARKERS
Immature	Immature	Unyolked (PG, CA), no POFs	Absent	Absent
Immature	Developing	Early yolked (EY), no POFs	Absent	Absent
Mature	Non-spawning	Advanced yolked (AY), no POFs	α and β atresia may be present	Possible
Mature	Actively spawning	Migratory nucleus (MN) or hydrated/POFs	α and β atresia may be present	Possible
Mature	Regressing	Unyolked (PG) or (CA) or early yolked (EY), no POFs	All yolked Oocytes are in the α and β stages of atresia	Possible
Mature	Regenerating	Unyolked (PG) or (CA) or early yolked (EY), no POFs	Absent	Present

Otolith processing

The otoliths were processed by the Centre for Environment Fisheries and Aquaculture Science (CEFAS) in the UK. All procedures for preparing and reading the otoliths including; sectioning, grinding and polishing, slide mounting and reading is laid out in the report "Otolith Processing, Analysis and Training" submitted to SFA in April 2020 (Visconti, 2020).

Data Analysis

Data analysis was undertaken using R statistical software version 4.3.3 (R Core Team, 2024). Average Fork length and weight was determined for all fish sampled, male and female. Length distribution for the samples were also determined by male and female.

Length weight relationship

The length-weight relationship parameters (a and b) were estimated using linear regression analysis on log transformed length (fork and total length) and weight data. The relationship is expressed as:

$$\boldsymbol{Log\ W = Log\ a + b\ Log\ L}$$

Whereby **a** is the intercept or a scaling coefficient for the weight at length of the fish species and **b** is a shape parameter for the body form of the fish species (Kuriakose, 2017). Estimate of the intercept (a) was then obtained by getting the exponent of the estimated log a.

Age-length key

The age-length key was constructed using the FSA package in R (Ogle et al., 2023). A sample of 114 fish were used to obtain the age-length key. A multinomial logistic regression model was created from the known age. The model was then applied to the data with the unknown length data to obtain an age estimation for the rest of the data.

Size at maturity

Size at 50% maturity (Lm50) was determined using the sizeMat package in R (Torrejon-Magallanes, 2020). Both microscopic and macroscopic staging were used for females while for males only macroscopic staging was used. Fork length and maturity stages with two categories of either mature or immature were used to estimate size at maturity using a logistic regression model. In the regression model, fork length was considered the explanatory variable, whereas the maturity stage was considered the response variable with two possibilities (binomial) of either mature or immature. The variables were fitted to a logit function as follows:

$$\boldsymbol{P_{mature} = \frac{1}{1+exp^{-(a+b*L)}}}$$

Whereby P_{mature} is the probability of an individual being mature at a determined fork length (L). Gonads that were identified as indeterminate were also included in both the microscopic and macroscopic model to increase the number of immature samples.

Results

Sampling summary

A total of 350 Green jobfish was sampled, which consisted of 154 female, 186 male and 10 indeterminate. The sex ratio of the sample was biased towards males, with 1 male for every 0.80 female. The FL ranged between 27 – 92.5cm with a mean of 51.1 cm. The mean FL for females were 48.8 cm, while for males, the mean FL was 53.9cm (Figure 2). The total weight (TW) ranged between 0.29 – 10.22 kg with a mean TW of 2.36 kg. For females, the mean TW was 1.97 kg while for males the mean TW was 2.77 kg. The age was estimated to be between 1 – 6 years old for both sexes. Unfortunately, due to lack of samples an age-length key for Green jobfish could not be determined.

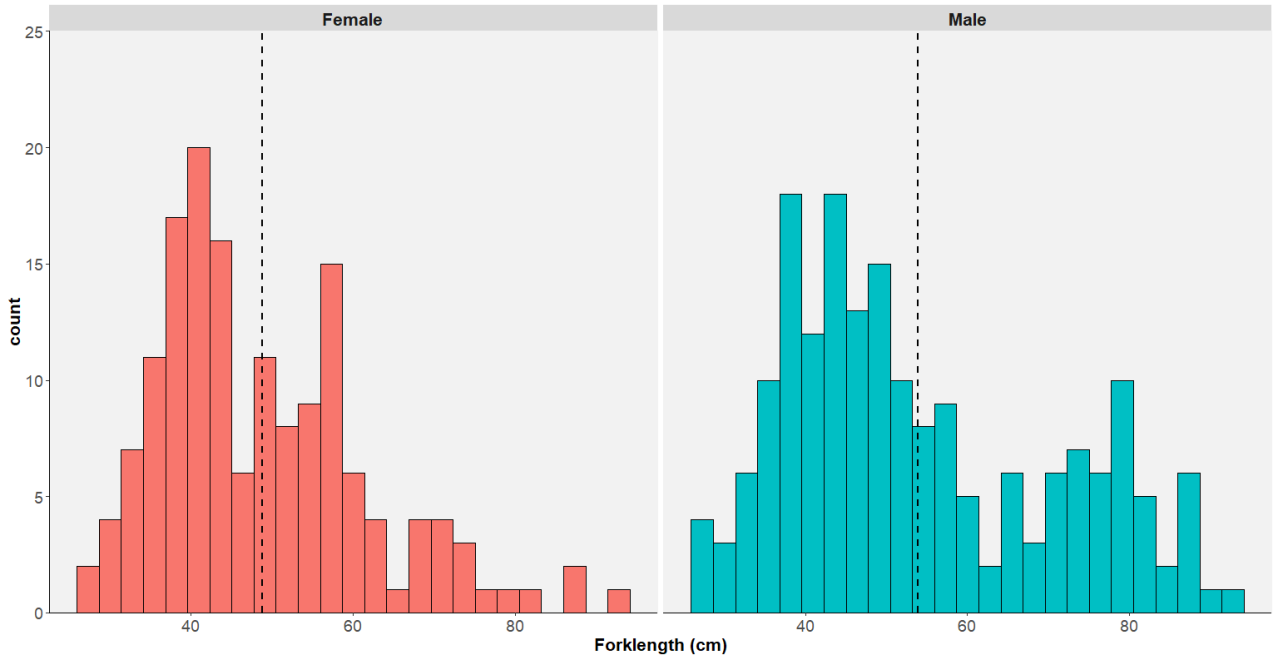

Figure 2: Fork length frequency distribution by sex (F, n = 154; M, n = 186) of Green jobfish sampled. Dashed line is indicating mean fork length for each sex

Size – weight conversion

The estimated growth coefficient (**b)** had a value of 2.82 with fork length and 2.97 with total length. This indicated that the Green jobfish has a negative allometric growth (Table 2). Negative allometric growth indicates that the fish have an elongated body type which is consistent with Green jobfish as they have long and narrow bodies.

Table 2: Estimated length weight parameters using fork length (FL) and total length (TL). TW is the total weight, a is the initial growth coefficient, b is the growth coefficient.

Equation	a	SE	b	SE	r^2
TW = aFL^b	0.000028	1.08	2.82	0.021	0.98
TW = aTL^b	0.00001	1.10	2.97	0.023	0.98

Size at maturity

A total of 95 fish ranging between 27 – 93 cm FL were used to determine the size of maturity microscopically for females. The samples were dominated with stage 2 regressing with only two fish samples obtained in the hydrated stage. The smallest mature female recorded was 34cm FL and the largest immature was 42cm FL. The estimated size at 50% maturity for females was 40.2 cm FL (CI 38.1 – 42.3 cm FL) (Figure 3). The size at maturity was also estimated macroscopically and it was 42.7cm FL (CI 40.5 – 44.9) for females (Figure 4) and 51cm FL (CI 48.4 – 53.6) for males (Figure 5). The smallest macroscopically mature female was 34 cm FL and the smallest mature male was 35.5 cm FL. The largest macroscopically immature female was 59.3 cm FL and largest immature male was 58cm FL. However, for both macroscopic models the R^2 was only 0.52 for females and 0.56 for males indicating that the model fit only around 50% of the actual values.

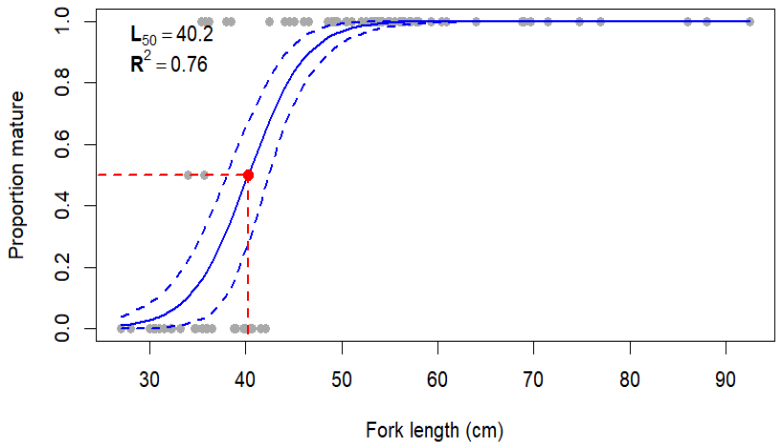

Figure 3: Proportion of mature female Green jobfish by fork length from the Mahe plateau (n=95). Maturity status was determined by microscopic examinations of gonads.

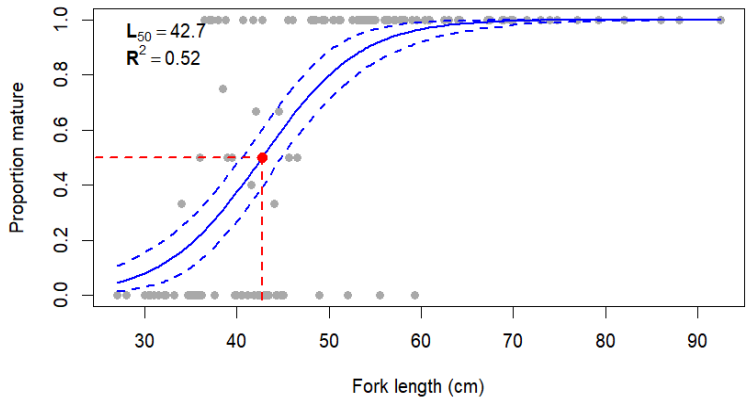

Figure 4: Proportion of mature female green jobfish by fork length from the Mahe plateau (n = 163). Maturity status was determined by macroscopic examination of gonads.

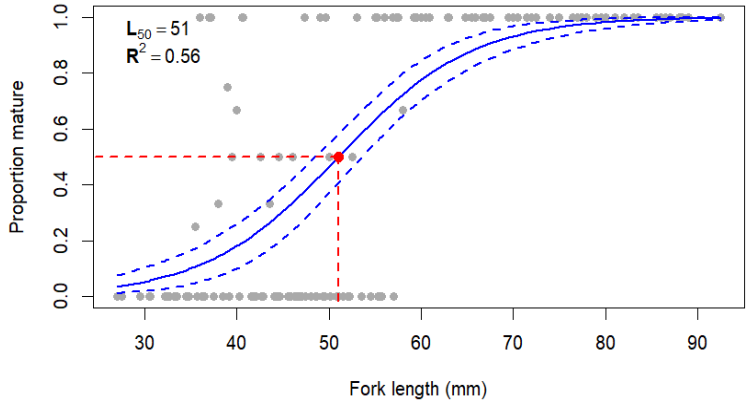

Figure 5: Proportion of mature for male green jobfish by fork length from the Mahe plateau (n = 196). Maturity status was determined by macroscopic examination of gonads.

Comparison with previous studies

Comparisons between this study and previous studies of size of maturity undertaken on the Mahe plateau indicates a shift in the size at maturity from 70cm in 1988 to 62-64cm in 1992 to 42.7cm obtained in this study (Table 3). Seychelles had a much higher length at maturity at 55.3cm TL compared to La Reunion which had a length at maturity of 32.03 cm TL (Mahé et al., 2024). A slight change was observed in the estimation of the growth coefficient between 1988 and this study, however b is still less than 3 indicating negative allometric growth

Table 3: Comparisons of length weight parameters and size of maturity with previous studies on Green jobfish

Area	Measurement type	a	b	Size at maturity (Lm50)	Reference
Mahe plateau (Seychelles)	Fork length (cm) Total weight (kg)	0.000028	2.82	F micro - 40.2cm FL F macro - 42.7 cm FL M macro - 51cm FL Mix macro - 55.3 cm TL	This study
Mahe plateau (Seychelles)	Fork length (cm) Total weight (kg)			F Macro - 62 - 64 cm FL	(Mees, 1992)
Mahe plateau (Seychelles)	Fork length (cm)	0.0000162	2.905	Macro - 70 cm FL	(De Moussac, 1988)
La Reunion	Total length			Mix macro - 32.03 cm TL	(Mahé et al., 2024)

Discussion

Size at maturity has been proven to be an important parameter in the management of fish stocks, especially when establishing a minimum landing size in a fishery (Pérez-Palafox et al., 2022). It is also important to have stock specific biological parameters so that the measures when applied are more accurate and targeted (Begg et al., 1999). The Green jobfish is currently being managed under the Mahe Plateau Trap and Line Co-Management Plan, with an established minimum landing size of 32cm fork length. This minimum size was established as a place holder pending further research to establish the actual size at maturity for the species on the Mahe plateau (Seychelles Fishing Authority, 2020). The results from the study have shown that the size at maturity determined through both microscopic and macroscopic methodology is far above the 32cm currently in place as minimum landing size for the species.

The difference observed in the estimates between macroscopic approach and microscopic approach provides an indication on the accuracy of the macroscopic method. Microscopic examination allows for more accurate identification of maturity markers that is difficult to pick up with the naked eyes during macroscopic analysis. However, in this study even with microscopic examination difficulty was encountered in differentiating between some immature and regenerating oocytes. Unfortunately, microscopic analysis on the gonads of jobfish in previous studies globally, have not revealed a similar issue and therefore it is unknown if this was a specific issue to the Seychelles Green jobfish (De Moussac, 1988; Everson et al., 1989; Mees, 1992).

A significant finding in the study is the observed shift in size at maturity compared to studies conducted on the same population in 1988 and 1992, indicating a reduction in the size at which Green jobfish reach maturity (De Moussac, 1988; Mees, 1992). Such changes in size at maturity is expected within fish population especially when there is exploitation on that population (Domínguez-Petit et al., 2008). Research has shown that size at maturity is density dependent, meaning that a reduction in population density can cause fish to mature earlier (Enberg et al., 2012; Morita & Fukuwaka, 2007).

Due to lack of ample sample size, further age-based parameters could not be determined for the species. These parameters are also as important when assessing the status of stocks and providing management advice. Therefore, it is highly required that further age studies on the species are undertaken. Additionally, due to gaps in some sampling months i.e. not all months were sampled and lack of variety in reproductive stages, knowledge on reproductive periods could not be obtained. These shortcomings highlight the gaps in the sampling protocol that should be addressed in future research. To improve sampling efforts, future studies should focus on collecting samples over consecutive months within a year and putting more effort in obtaining sizes in the extreme ends since they are rarer/fewer.

Based on the findings of this study, it is recommended that the most recent size at maturity estimates be considered in fisheries management decisions. Specifically, the regulation in relation to the minimum landing size should be updated to reflect the result of this study.

Acknowledgement

A special thank you goes to all fishers who assisted with the provision of fish during the sampling. Additionally, thank you goes to all research staff who in one way or another assisted with the sampling, data collection and analysis during all these years. This present work was funded by the Seychelles Fisheries Authority Recurrent budget and the European Union sectoral support fund under the EU Sustainable Fisheries Agreement (EU-SFA)

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Appendix I

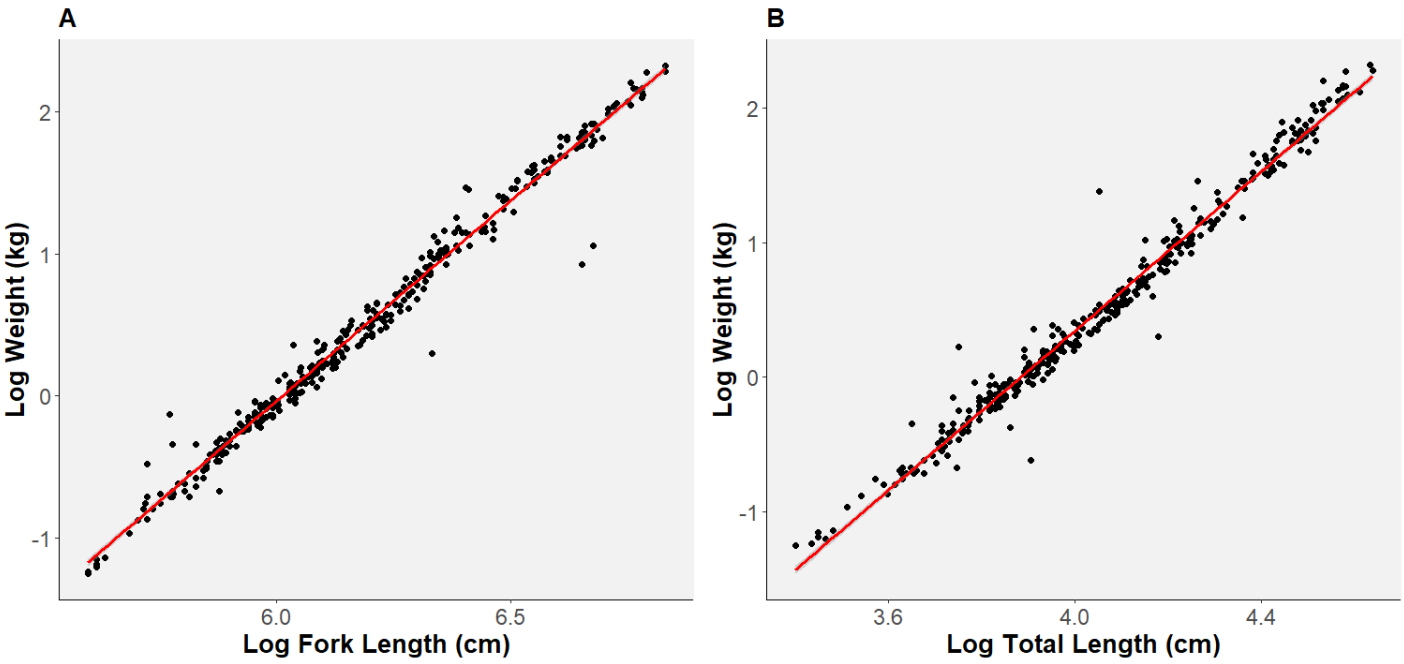

Figure 6: Length and weight relationship for Green jobfish by fork length (A) and total length (B) from the Mahe plateau