SIOFA | APSOI
Southern Indian Ocean Fisheries Agreement
Accord relatif aux Pêches dans le Sud de l'Océan Indien

10th Annual Meeting of the Scientific Committee (SC10)

Concarneau, France, 17-26 March 2025

SC-10-40

Age and growth of orange roughy (*Hoplostethus atlanticus*) from the southern Indian Ocean SIOFA Project ORY-2023-01

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Document type	Working paper ✔ Information paper ☐
Distribution	Public ✔ Restricted [1] ☐ Closed session document [2] ☐

Abstract

Otoliths of orange roughy (*Hoplostethus atlanticus*) from the southern Indian Ocean were prepared and aged for the Southern Indian Ocean Fisheries Agreement (SIOFA). Geographically separated areas (SouthWest Indian Ridge [SWIR] and Walter's Shoal) were identified by SIOFA as requiring age and growth information for this species; therefore, biological material (demographic data and otoliths) was provided (by SIOFA) to NIWA for otolith mass estimation, preparation, and ageing.

Growth and maturity analysis of these data is reported. The otoliths (n = 604) were prepared and read by one reader following the accepted ageing protocol. The aim was to provide otolith age as well as growth, maturity and otolith mass estimates of orange roughy from the Indian Ocean for SIOFA's research and monitoring programme. Age estimates ranged from 15 to 180 years and 21 to 116 years for SWIR and Walter's Shoal orange roughy, respectively. The von Bertalanffy growth function estimated asymptotic lengths (i.e., L_∞) were 53.53 and 57.55 cm, and generalised linear

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model estimated 50% maturity lengths (L50) were 42.24 and 41.11 cm (average when both sexes are combined) for SWIR and Walter's Shoal orange roughy, respectively. To improve the quality of age data it is recommended that an area-specific reference set of orange roughy otoliths be developed for the SIOFA area.

Recommendations

The authors of the report recommend that:

- Onboard observers from the SIOFA area should measure fish length using one method (e.g. standard length). For example, in the observer collected biological data there were at least two length measuring methods reported as used (i.e. the length measuring method differed between observers).
- During the current study there were whole trips where the data recorded on the otolith packets did not match that in the data files supplied. In these instances, the data recorded on the otolith packets was deemed to be correct, and the data in the files amended accordingly. Connectivity of raw sample data components should be improved between observer data sheets, otolith packets, and the electronic repository for monitoring of the SIOFA area.
- In the current study, a reference set consisting of orange roughy otoliths from New Zealand were used to ensure otoliths were read consistently. However, orange roughy in the SIOFA area display different biological characteristics compared to those from New Zealand (such as a lack of consistent TZs in the otoliths and large maximum sizes). If future ageing work is to be done on orange roughy in the SIOFA area, it is recommended that a reference set specific to the area be developed (see Saunders 2021).

NIWA
Taihoro Nukurangi

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Prepared for the Southern Indian Ocean Fisheries Agreement (SIOFA)

September 2024

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Climate, Freshwater & Ocean Science

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NIWA CLIENT REPORT No: 2024274WN
Report date: September 2024
NIWA Project: SIO24302

Revision	Description	Date
Version 1.0	Final version sent to client	02 September 2024

Quality Assurance Statement		
	Reviewed by:	Steven Holmes
	Formatting checked by:	Jess Moffat
	Approved for release by:	Alison MacDiarmid

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Executive summary

Otoliths of orange roughy (*Hoplostethus atlanticus*) from the southern Indian Ocean were prepared and aged for the Southern Indian Ocean Fisheries Agreement (SIOFA). Geographically separated areas (SouthWest Indian Ridge [SWIR] and Walter's Shoal) were identified by SIOFA as requiring age and growth information for this species; therefore, biological material (demographic data and otoliths) was provided (by SIOFA) to NIWA for otolith mass estimation, preparation, and ageing. Growth and maturity analysis of these data is reported. The otoliths (n = 604) were prepared and read by one reader following the accepted ageing protocol. The aim was to provide otolith age as well as growth, maturity and otolith mass estimates of orange roughy from the Indian Ocean for SIOFA's research and monitoring programme. Age estimates ranged from 15 to 180 years and 21 to 116 years for SWIR and Walter's Shoal orange roughy, respectively. The von Bertalanffy growth function estimated asymptotic lengths (i.e., L_∞) were 53.53 and 57.55 cm, and generalised linear model estimated 50% maturity lengths (L_{50}) were 42.24 and 41.11 cm (average when both sexes are combined) for SWIR and Walter's Shoal orange roughy, respectively. To improve the quality of age data it is recommended that an area-specific reference set of orange roughy otoliths be developed for the SIOFA area.

1 Introduction

The main objective of the SIOFA project "Age and growth of orange roughy (*Hoplostethus atlanticus*)" (Project ORY-2023-01) was the preparation and ageing of orange roughy otoliths sampled from the southern Indian Ocean (SouthWest Indian Ridge and Walter's Shoal) for the Southern Indian Ocean Fisheries Agreement (SIOFA). Otoliths were supplied by SIOFA and a subset selected for ageing by NIWA and SIOFA. The other objectives were to provide mass data for the aged otoliths, and to perform sex-specific growth and maturity analyses (both curve visualisations and parameters) on the aged fish. This is the third substantial set of age data produced for orange roughy from this area, the first being reported in Horn et al. (2018) and second in Saunders (2021). The specific objectives of this project were to:

1. Select 350 otoliths spanning the size range of fish caught at each of Walter's Shoal and the SouthWest Indian Ridge in the SIOFA area (a total of about 700 otoliths).
2. Weigh the otoliths and provide the weights and associated length and age data.
3. Develop sex separated and combined sex growth curves for orange roughy in both areas and as single SIOFA growth curves.
4. Use the biological sampling to develop maturity curves for each area.
5. Provide growth and maturity parameters for the stock assessments.
6. Develop age composition data using random age sampling for both Walter's Shoal and the Southwest Indian Ridge in the SIOFA area.

2 Methods

Otolith collection and selection

Otoliths were supplied by SIOFA and selected (subsampled) for ageing by NIWA, from collections made by observers and/or a dedicated crew member on Cook Islands flagged vessels fishing in the SIOFA area. Multiple years of collections were combined for the SouthWest Indian Ridge (SWIR) due to the small number of samples for a given year (*n*=~290 from 3 years [2019, 2020, and 2022]). This was done by consultation between the NIWA analysist and the SIOFA assessment scientist. A greater sample size was available for Walter's Shoal and it was possible to sample from a single year (2020) to produce a sex specific standard-length (length herein) frequency. The otolith subsample used all available otoliths from the tails of the length distribution, thus ensuring small and large fish were well represented in the subsample, with the remaining otoliths randomly sampled without replacement to complete the subsample (*n*=~320). Here tails were defined as <1st quartile – (interquartile * 0.5) for small fish and >3rd quartile + (interquartile range * 0.5) for large fish. Sex proportions were biased towards females (62%), as such, numbers of otoliths selected for ageing reflected this. Again, this was performed in consultation with SIOFA. All data work and analysis was performed using R statistical programming language (R Core Team 2020).

Otolith preparation for ageing

Otoliths were weighed in grams to four decimal places using a calibrated Mettler AE163 precision balance (with draft doors) and weights subsequently converted to milligrams for analysis. Otoliths were then prepared for ageing using the method described in Horn et al. (2016). One whole otolith from each of the selected fish was individually embedded in epoxy resin and cured in an oven. A thin section was cut along a line from the primordium (otolith nucleus region) through the most uniform (and usually the longest) antero-posterior axis using a sectioning saw with a diamond-impregnated wafering blade. The section was mounted on a glass microscope slide under a glass cover slip. When collected, some otoliths had been damaged such that the tips of the posterior-dorsal axes were missing on both otoliths. In these instances, it was possible to take complete, although sub-optimal, sections at other locations on the antero-posterior axis. For some sampled fish, both otoliths were too damaged or deformed and consequently neither otolith was prepared.

Reading and quality control

All otoliths were read once by one reader using the otolith interpretation and reading protocols described in Horn et al. (2016). In addition, a New Zealand exclusive economic zone fishing area reference set of 100 otoliths were read to provide estimates of precision (coefficient of variation [CV]) and bias. Precision must be below 6% CV for the reader to continue to routine ageing (Horn et al. 2016).

The data produced include counts of zones from the primordium to the transition zone (TZ), the zone that is considered to mark the onset of orange roughy maturity (Francis & Horn 1997), and from the TZ to the otolith margin. Also provided are readability codes for each of those readings provided on a 5-stage readability scale, as follows:

Primordium to TZ Readability / and TZ to Margin Readability

1. Otolith structure is exceptionally clear with unambiguous zones.
2. Sample may be ± one year from determined count.

3. Sample is difficult to interpret and subject to small interpretational differences.
4. Sample is difficult to interpret and subject to large interpretational differences.
5. Sample is unreadable due to failed preparation or unreadable structure.

Otolith data with a readability code of 5 (i.e., unreadable), for either the pre- or post-TZ readings, were excluded. The presence of a TZ was identified, ideally, by the following three criteria: a clear reduction in zone width, a marked change in the optical density of the otolith from dark to light, and a change in curvature of the posterior arm of the otolith (Horn et al. 2016). The readability of TZs were classified using a 4-stage scale, i.e.:

TZ Readability

0. TZ not believed to have yet been formed.
1. Clear and unambiguous, meets all three criteria. TZ count recorded.
2. Gradual transition, however at least two criteria met. TZ count recorded.
3. Gradual transition, none or one of the criteria met. TZ count not recorded.

For TZ readability code 3, only a total age was recorded by the reader as the likely location of the TZ was undefined. Note that the TZ of Indian Ocean orange roughy are not as defined as some other areas such as New Zealand (Peter Horn *pers. comm.*, Saunders 2021) therefore it is not recommended that the TZ value is used in further analysis (e.g. maturity).

Age data quality control (QC) was done visually by plotting the length-at-age for each aged individual to identify if any individuals were not the expected length-at-age. If outside the expected age, the otolith section was re-read to confirm the age.

Growth analysis

Growth was estimated using sex-specific and combined von Bertalanffy growth function models. This was performed for both areas separately and as a combined SIOFA area. The growth parameters were estimated using the non-linear least-squares estimates function (nls) (e.g. Bates and Chambers 2017). All models had starting parameters estimated using the Ford-Walford plot method (e.g. Walford 1946). Residuals were plotted to visually check model performance. Confidence intervals (95%) were bootstrap estimated (n=999).

Maturity analysis

Orange roughy maturity data was collected by SIOFA and consisted of estimates of gonad stage data. The methodology for this estimate is provided in detail in Brouwer et al. (2022). Briefly, the gonad stages range from 1–9, with stages 1–2 categorised as immature, 3–6 as mature and 7–9 as spent. The proportion of mature fish in each 1 cm standard length (SL) size class in the sample was estimated and a maturity ogive was fitted using a binomial generalised linear model. The length-at-50% maturity was then estimated. Gonads stages 7–9 or those without stage data were excluded from analysis (n=2), due to problems accurately staging spent gonads (Brouwer et al. 2022).

Otolith mass analysis

Otolith mass-at-age were analysed visually in a sex-specific scatterplots with fitted linear trendlines.

3 Results

Results from interpretation of the New Zealand reference set indicated excellent precision of the reader, with a CV of 3.56%. There was no age-associated bias in interpretation. Raw age data are provided in Appendix A and B for SWIR and Walter's Shoal respectively.

3.1 SouthWest Indian Ridge

Age and length

A subsample consisting of 290 individuals from SWIR in 2019, 2020, and 2022 were prepared for ageing. Of these, 10 otoliths were deemed unreadable (i.e., readability code = 5) and were removed prior to analysis, resulting in 280 age estimates used in the analysis (Table 1).

Table 1: Numbers of aged female, male, and sex undefined orange roughy from SouthWest Indian Ridge by year of capture.

	2019	2020	2022	Total
Female	78	54	25	**157**
Male	61	35	16	**112**
Undefined	2	5	4	**11**
Total	**141**	**94**	**45**	**280**

Age estimates ranged from 15 to 180 years. The median TZ age across both sexes was 31 years but only 59% had a TZ that was deemed robust (based on TZ readability score of 1–2). A small number of males (*n*=3) had smaller length-at-age than most data but upon review the ages appear robust. It is possible these are slower growing individuals or there was an error in the length data error (Figure 1).

Figure 1: **Sex-specific length-at-age of orange roughy from SouthWest Indian Ridge.**

The sample length range was greater for females (25 to 60 cm) than males (29 to 55 cm) and those fish for which sex was not determined (30 to 42 cm, Figure 2). All length distributions were slightly left skewed, with median standard lengths of 47 and 44.5 cm for females and males, respectively.

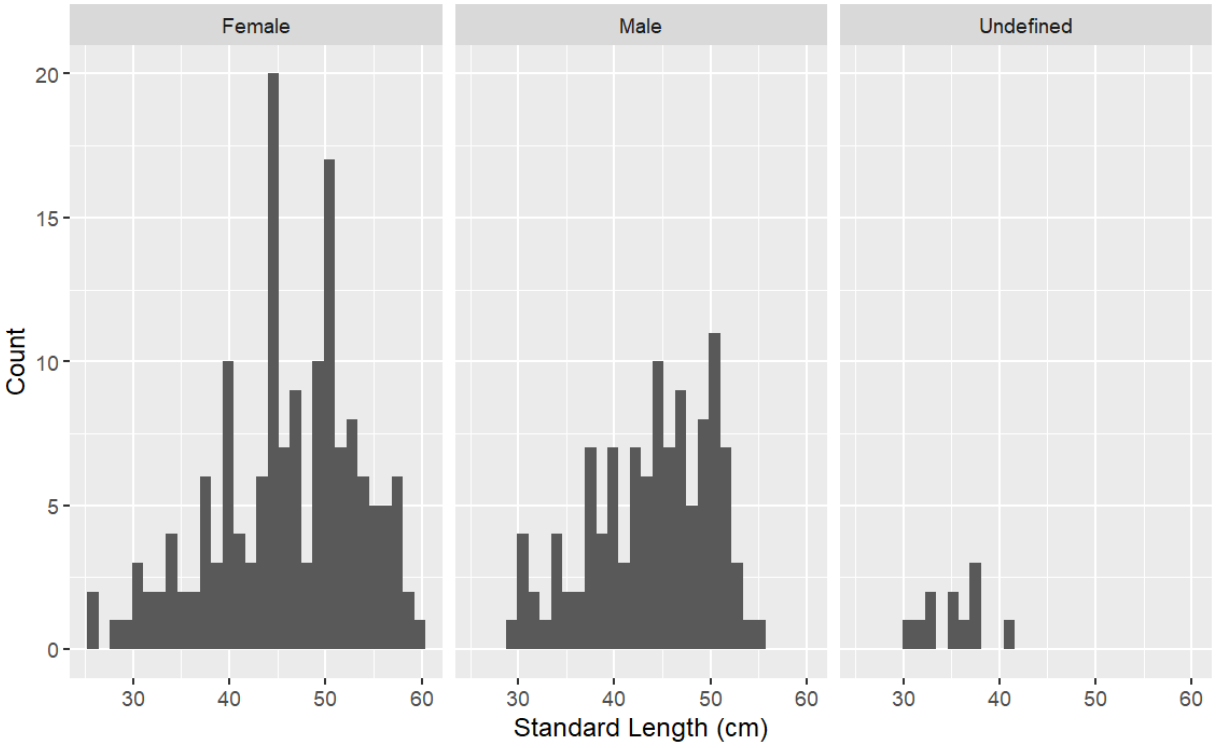

Figure 2: **Sex-specific sample-at-length distributions of orange roughy from SouthWest Indian Ridge.**

Excluding one male estimated as 180 years old, the sample ages were comparable between males and females (Figure 3). All age distributions were slightly right skewed.

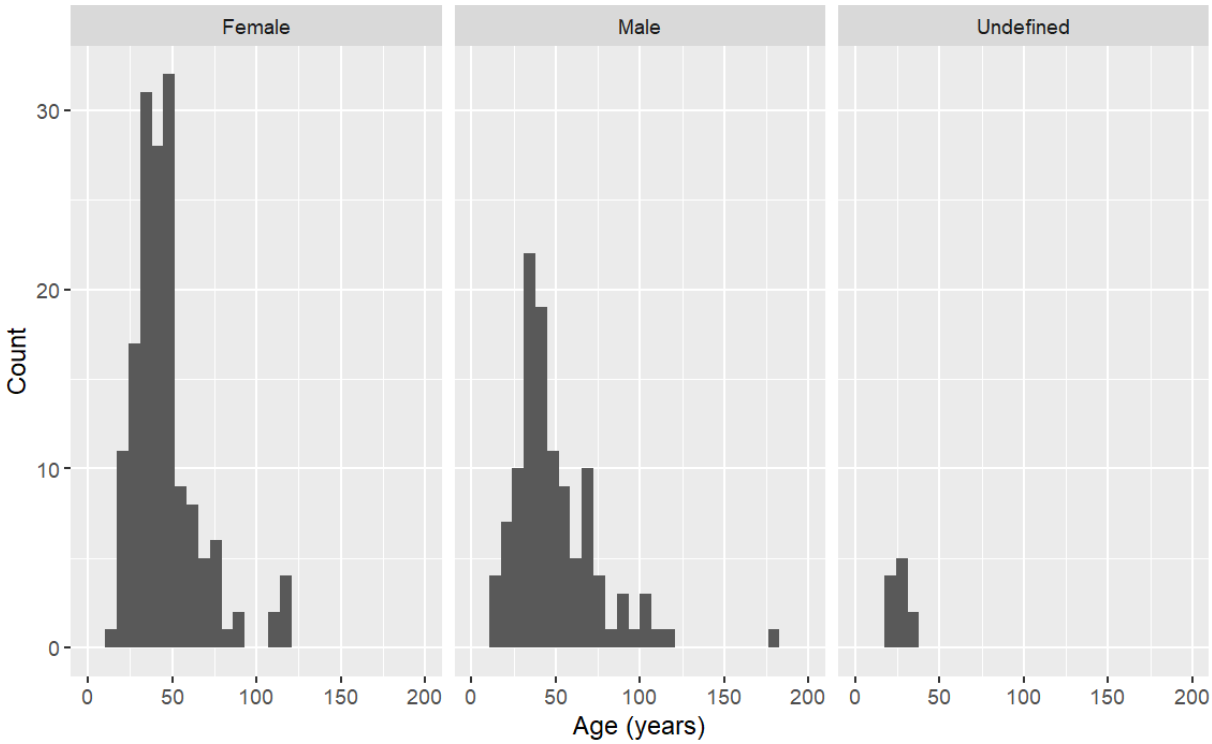

Figure 3: Sex-specific sample-at-age distributions of orange roughy from SouthWest Indian Ridge.

Growth

The estimated asymptotic length (i.e., L_∞) of female SWIR orange roughy from the von Bertalanffy growth function was 56.38 cm (Figure 4, Table 2). Examination of the distribution of residuals confirmed that assumptions for fitting models via least squares were satisfied (see diagnostic plots Appendix Figure C1). All other von Bertalanffy growth function parameters are presented in Table 2.

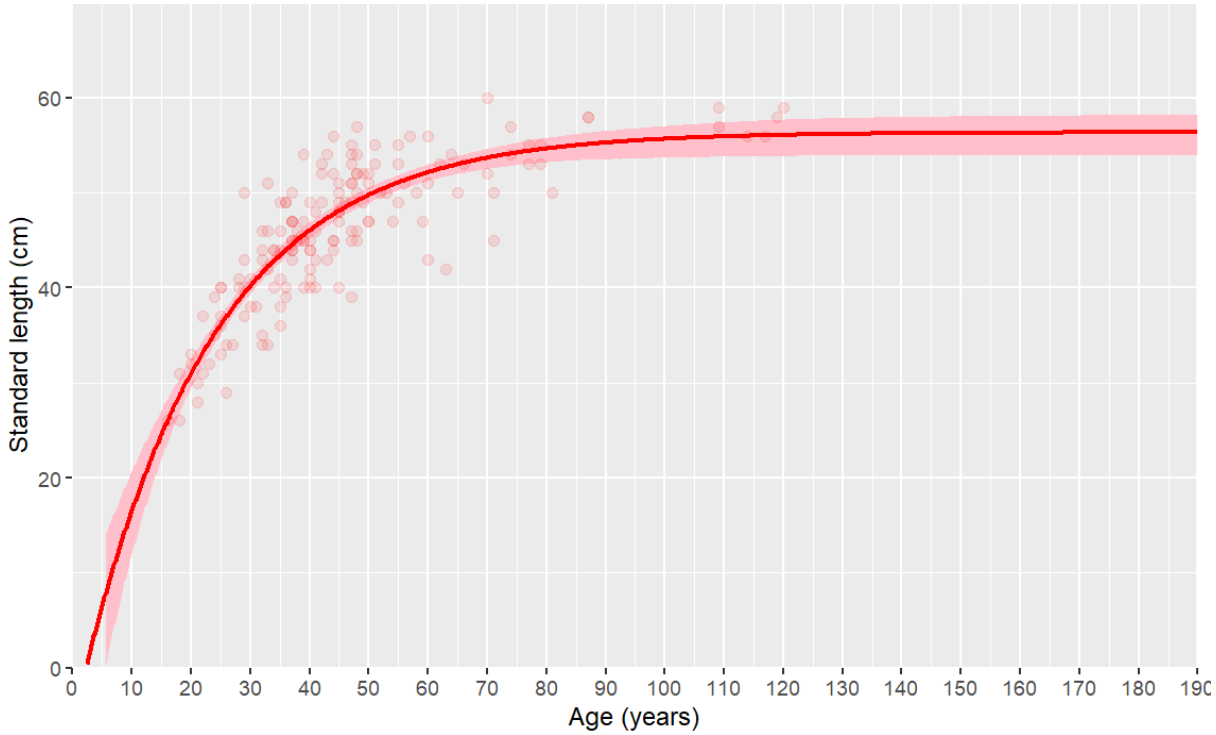

Figure 4: Length-at-age and fitted von Bertalanffy growth function curve of female orange roughy from SouthWest Indian Ridge.

Table 2: SouthWest Indian Ridge orange roughy von Bertalanffy growth function curve parameters with 95% confidence intervals for females and males and both sexes combined.

	L_∞	k	T_0
Females	56.38	0.05	2.23
2.5%	54.18	0.04	-1.87
97.5%	58.2	0.06	5.63
Males	50.85	0.05	-2.27
2.5%	49.20	0.04	-7.49
97.5%	52.28	0.06	1.91
Combined	53.53	0.05	1.33
2.5%	52.04	0.04	-2.23
97.5%	55.23	0.06	4.39

The estimated asymptotic length (i.e., L_∞) of male SWIR orange roughy from the von Bertalanffy growth function was 50.85 cm (Figure 5, Table 2). The distribution of length residuals showed a slight bias across fitted values (see diagnostic plots in Appendix Figure C2). All other von Bertalanffy growth function parameters are presented in Table 2.

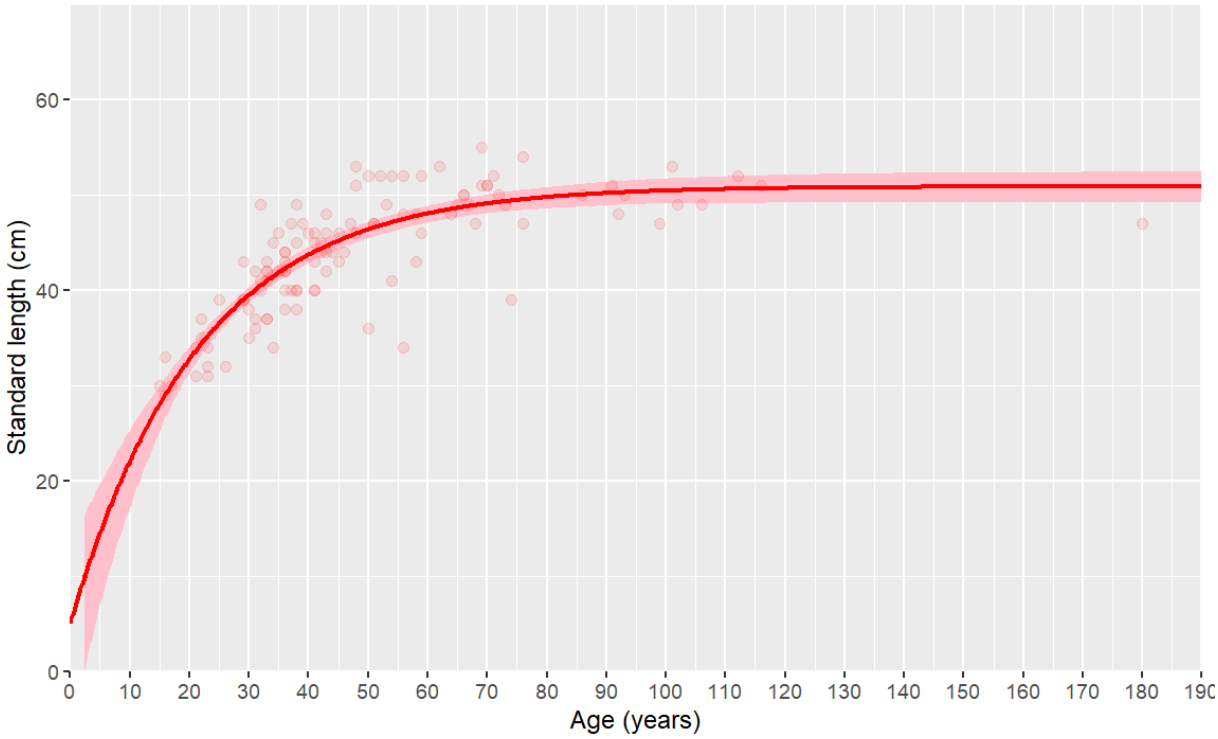

Figure 5: Length-at-age and fitted von Bertalanffy growth function curve of male orange roughy from SouthWest Indian Ridge.

The estimated asymptotic length (i.e., L_∞) of combined sex SWIR orange roughy from the von Bertalanffy growth function was 53.53 cm (Figure 6, Table 2). The distribution of length residuals showed a very slight bias across fitted values (see diagnostic plots Appendix Figure C3). All other von Bertalanffy growth function parameters are presented in Table 2.

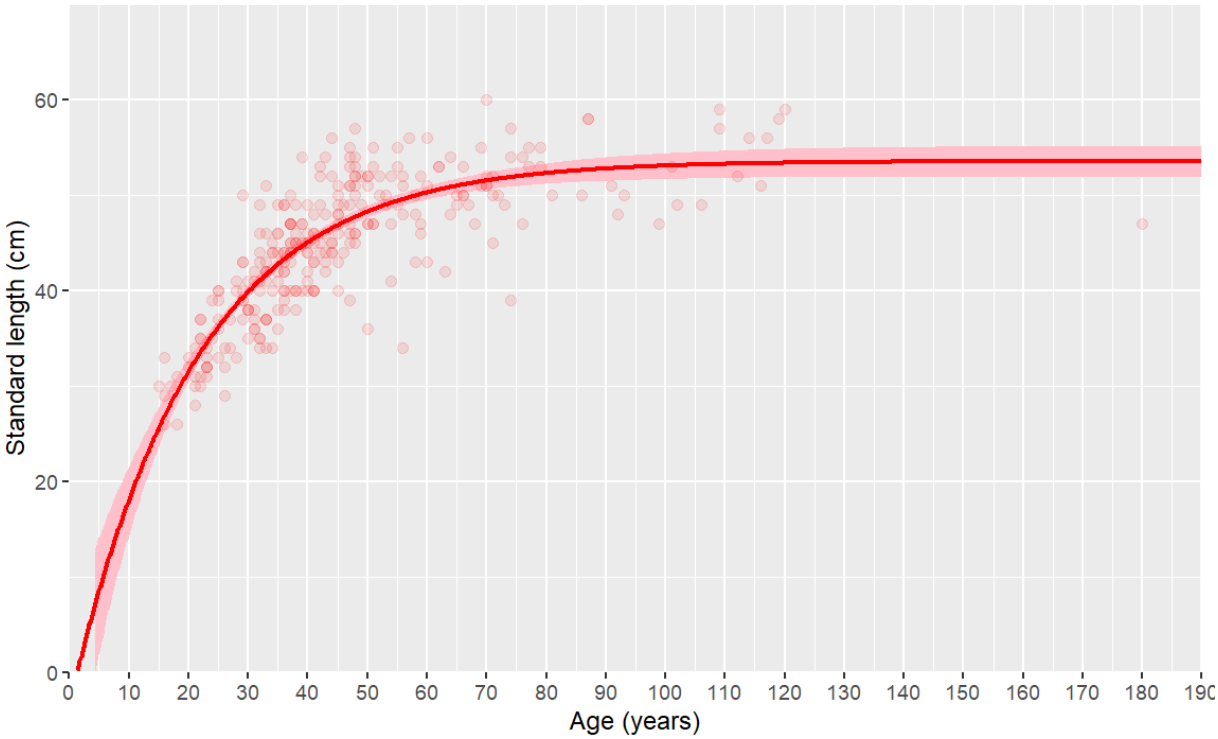

Figure 6: Length-at-age and fitted von Bertalanffy growth function curve of orange roughy (sexes combined) from SouthWest Indian Ridge.

Maturity

The estimated female size-at-50% maturity (42.96 cm, L_{50}) was nearly 1.5 cm longer than the males (41.52 cm) (Figure 7).

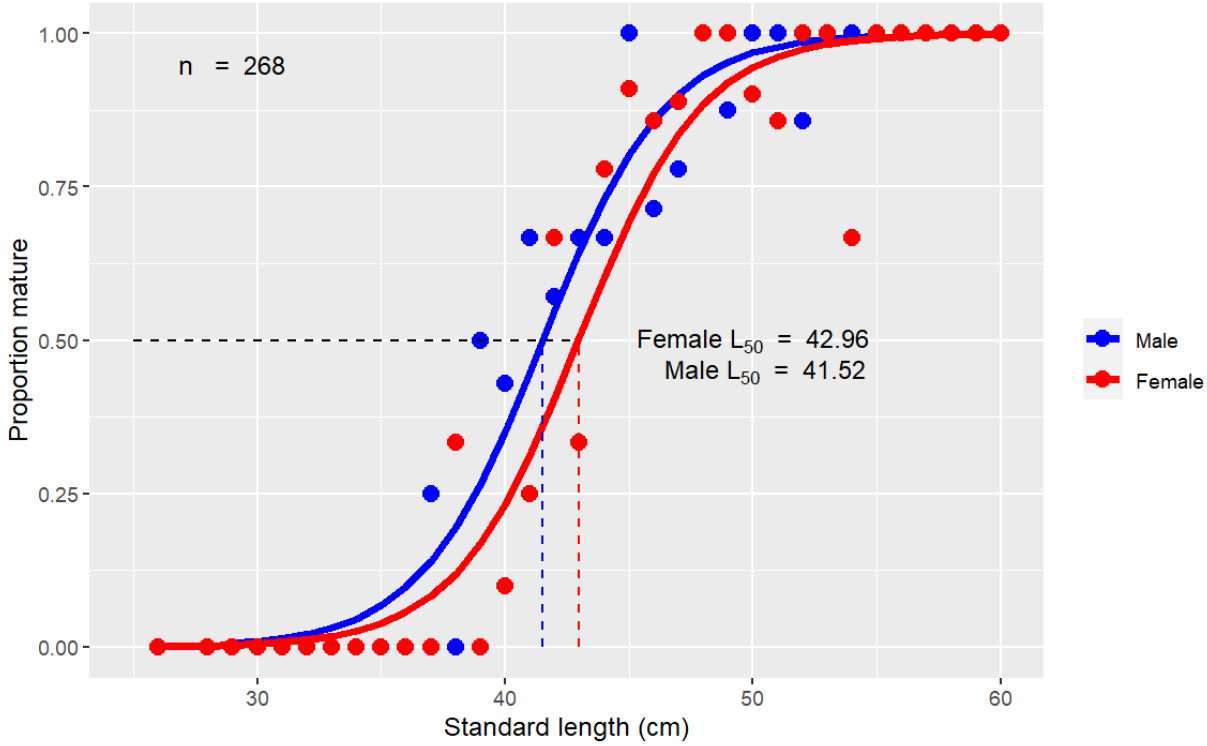

Figure 7: Sex-specific size-at-maturity curves and size-at-50% maturity (L_{50}) of orange roughy from SouthWest Indian Ridge. The dashed lines correspond to the L_{50}.

Otolith mass

A small number of otoliths could not be weighed due to damage (*n*=17). Otolith mass ranged from 46.1 to 1419.8 mg with the median 220.1 mg. There did appear to be a relationship between SWIR orange roughy otolith mass and age but with different positive trajectories depending on the sex (Figure 8). Trendlines suggest, females had slightly lighter otoliths compared to males until the age is greater than approximately 45 years, thereafter they become significantly heavier.

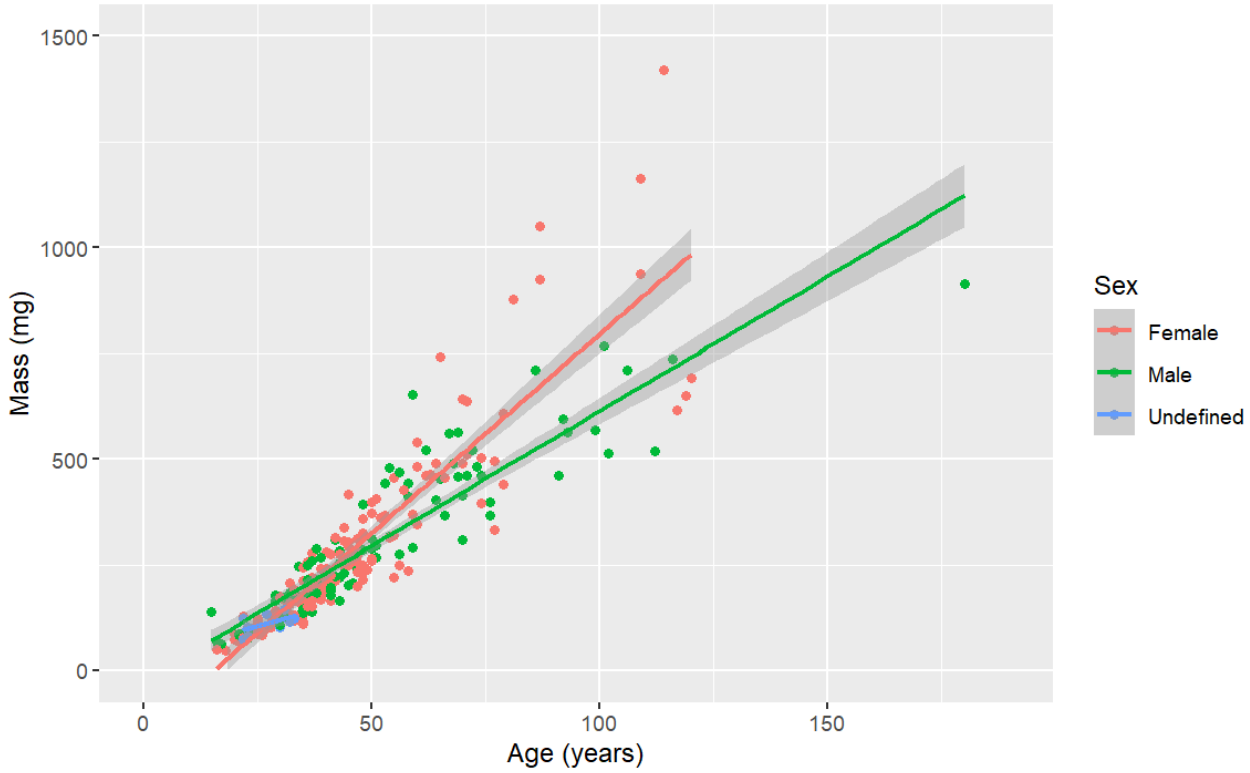

Figure 8: Sex specific otolith mass-at-age of orange roughy from SouthWest Indian Ridge. The trend lines are linear models with 95% confidence intervals.

3.2 Walter's Shoal

Age and length

A subsample consisting of 314 individuals from Walter's Shoal in 2020 were prepared for ageing. Of these, 23 were not deemed suitable for further analysis and were removed (e.g. readability code 5, Table 3). Of these 23, 10 appeared to be incorrect length data recordings. Also, the standard growth axis on the post-rostrum targeted for sectioning (and therefore reading) was highly variable which made these processes difficult and may have led to more than a typical number being rejected or judged as poor quality (Figure 9).

Table 3: Numbers of aged female and male orange roughy from Walter's Shoal.

Female	185
Male	106
Total	291

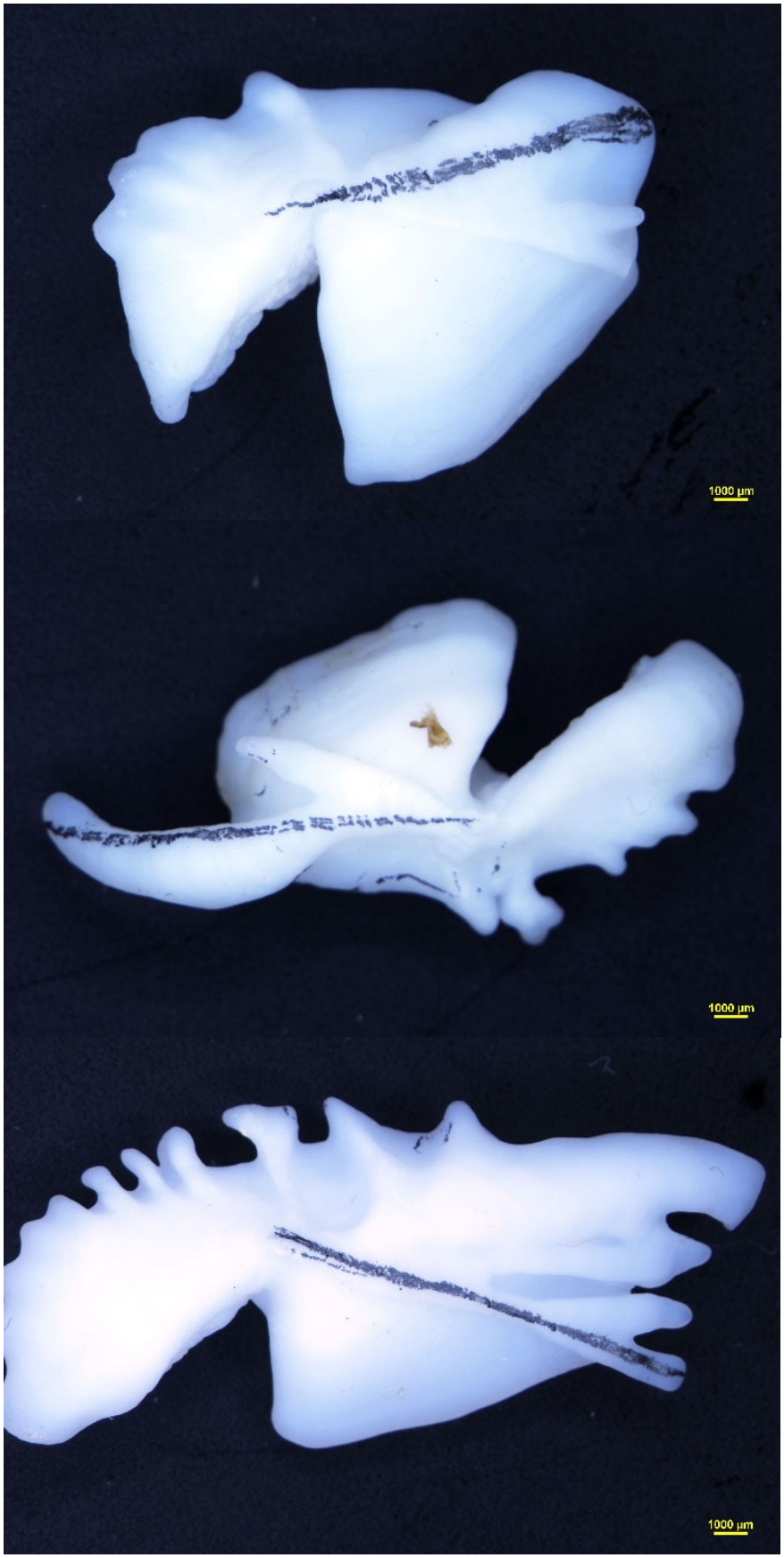

Figure 9: Whole otolith images (magnification 6.3 x) of orange roughy from Walter's Shoal with the pencil mark depicting the typical cutting plane (post-rostrum [opposite the sulcus]) and hence, the reading zone.

Age estimates ranged from 21 to 116 years. The median TZ age was 31 and 32 years (males and females respectively) but only 61% had a TZ that was deemed robust (based on TZ readability score). Post grooming, the age data was grouped as expected in a scatterplot (Figure 10).

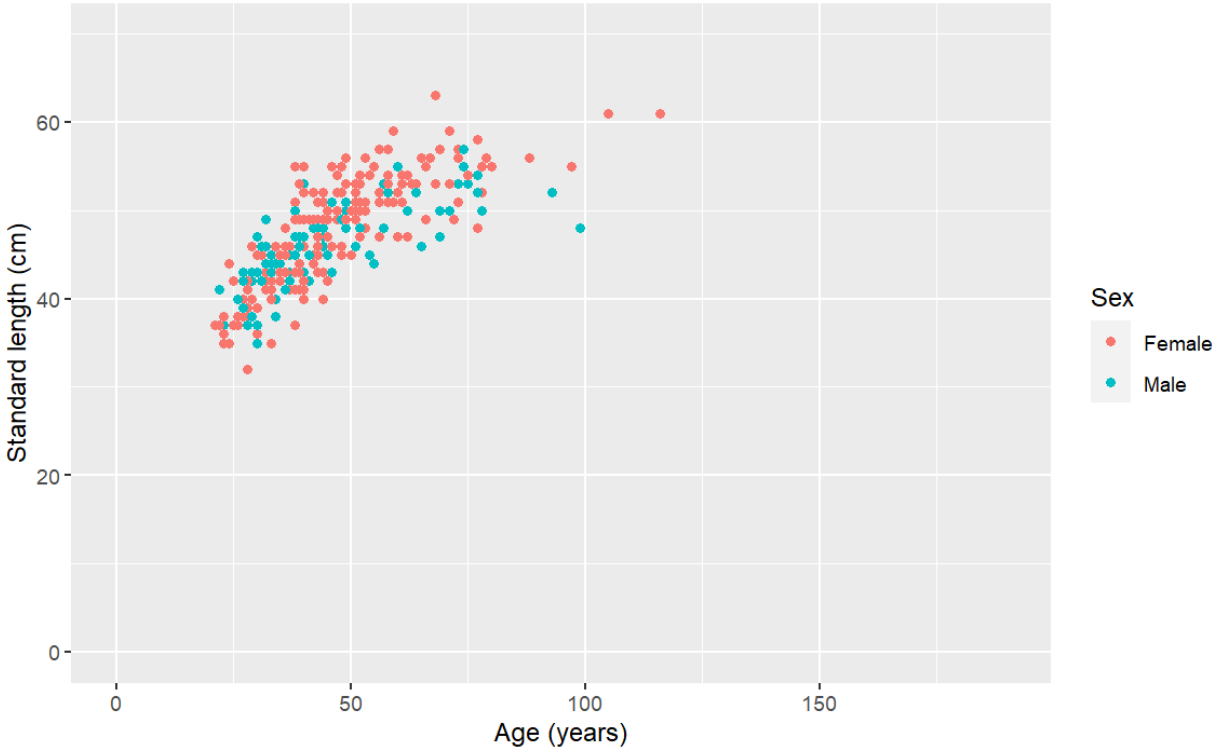

Figure 10: Sex-specific length-at-age of orange roughy from Walter's Shoal.

The sample length range was greater for females (32 to 63 cm) compared to males (35 to 57 cm) Figure 11). The female length distribution was slightly left skewed whereas the male lengths generally approximated a normal distribution. Median standard lengths were 48 and 46 cm for females and males respectively.

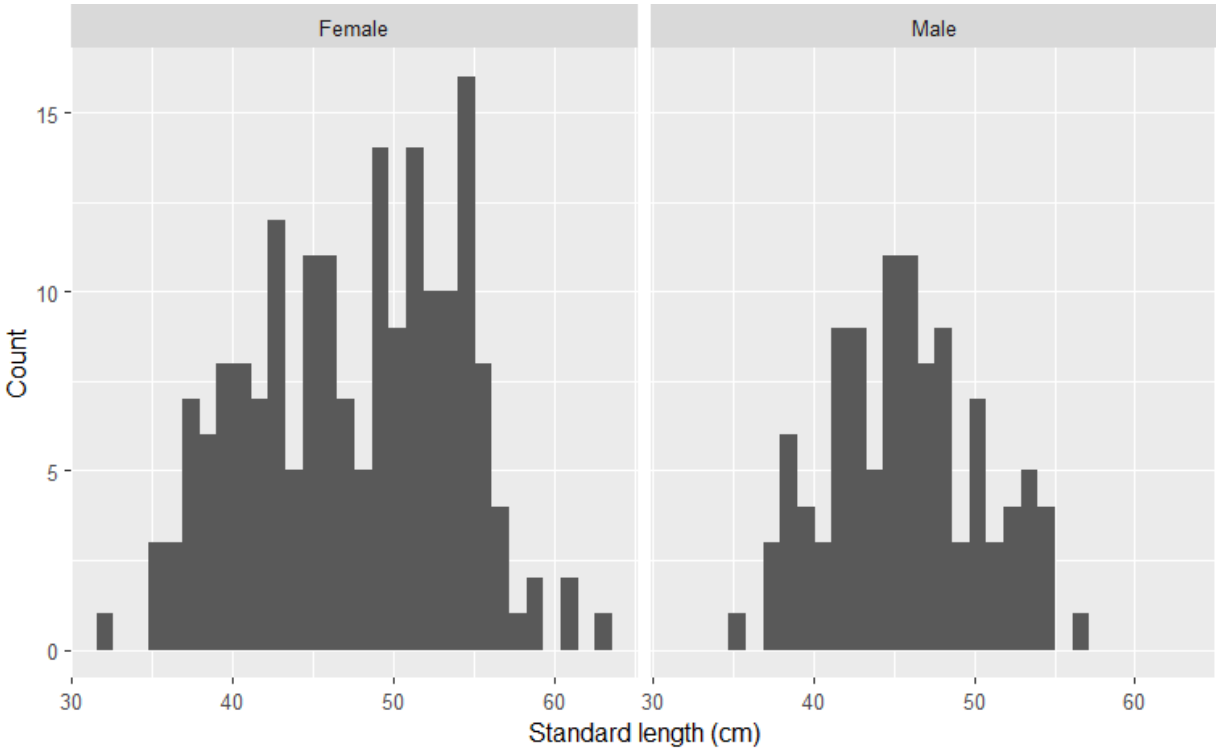

Figure 11: Sex specific sample-at-length distributions of orange roughy from Walter's Shoal.

The sample age range was greater for females (21 to 116 years) compared to males (22 to 99 years) (Figure 12). Both age distributions were slightly right skewed.

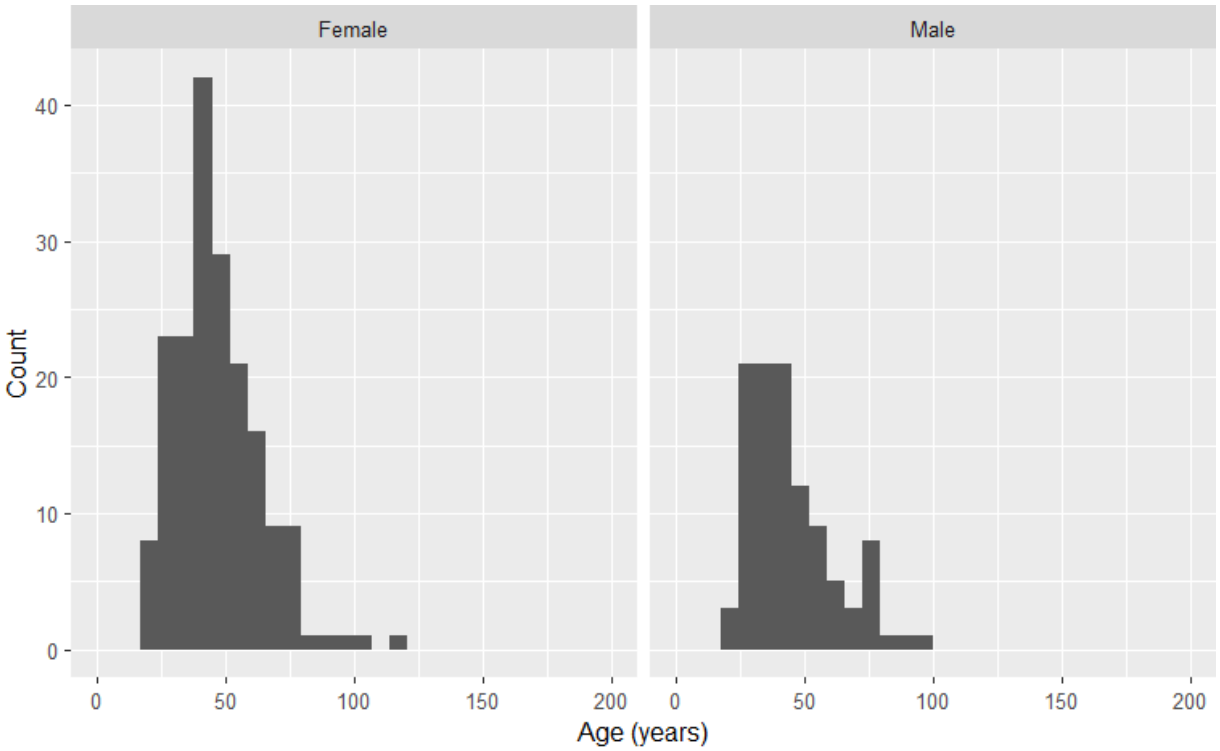

Figure 12: Sex specific sample-at-age distributions of orange roughy from Walter's Shoal.

Growth

The estimated asymptotic length (i.e., L_∞) of female Walter's Shoal orange roughy from the von Bertalanffy growth function was 59.73 cm (Figure 13, Table 4). Examination of the distribution of residuals confirmed that assumptions for fitting models via least squares were satisfied (see diagnostic plots Appendix Figure C4). All other von Bertalanffy growth function curve parameters are presented in Table 4.

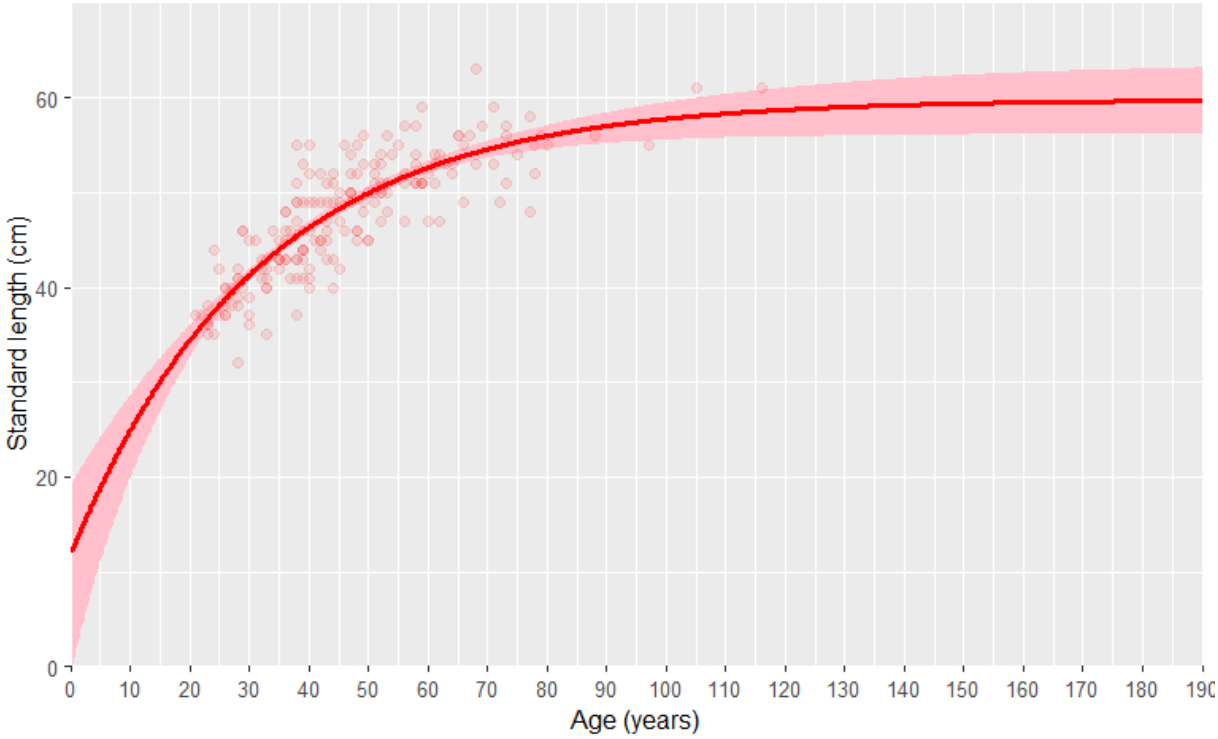

Figure 13: Length-at-age and fitted von Bertalanffy growth function curve of female orange roughy from Walter's Shoal.

Table 4: Walter's Shoal orange roughy von Bertalanffy growth function curve parameters with 95% confidence intervals for females and males and both sexes combined.

	L_∞	k	T_0
Females	59.73	0.11	9.76
2.5%	56.87	0.02	-15.41
97.5%	63.92	0.04	-0.382
Males	54.05	0.04	-12.26
2.5%	51.07	0.02	-35.73
97.5%	61.11	0.06	0.16
Combined	57.55	0.03	-8.13
2.5%	55.09	0.02	-17.8
97.5%	61.07	0.04	-1.53

The estimated asymptotic length (i.e., L_∞) of male Walter's Shoal orange roughy from the von Bertalanffy growth function was 54.05 cm (Figure 14, Table 4). Examination of the distribution of residuals confirmed that assumptions for fitting models via least squares were satisfied (see

diagnostic plots in Appendix Figure C5). All other von Bertalanffy growth function parameters are presented in Table 4.

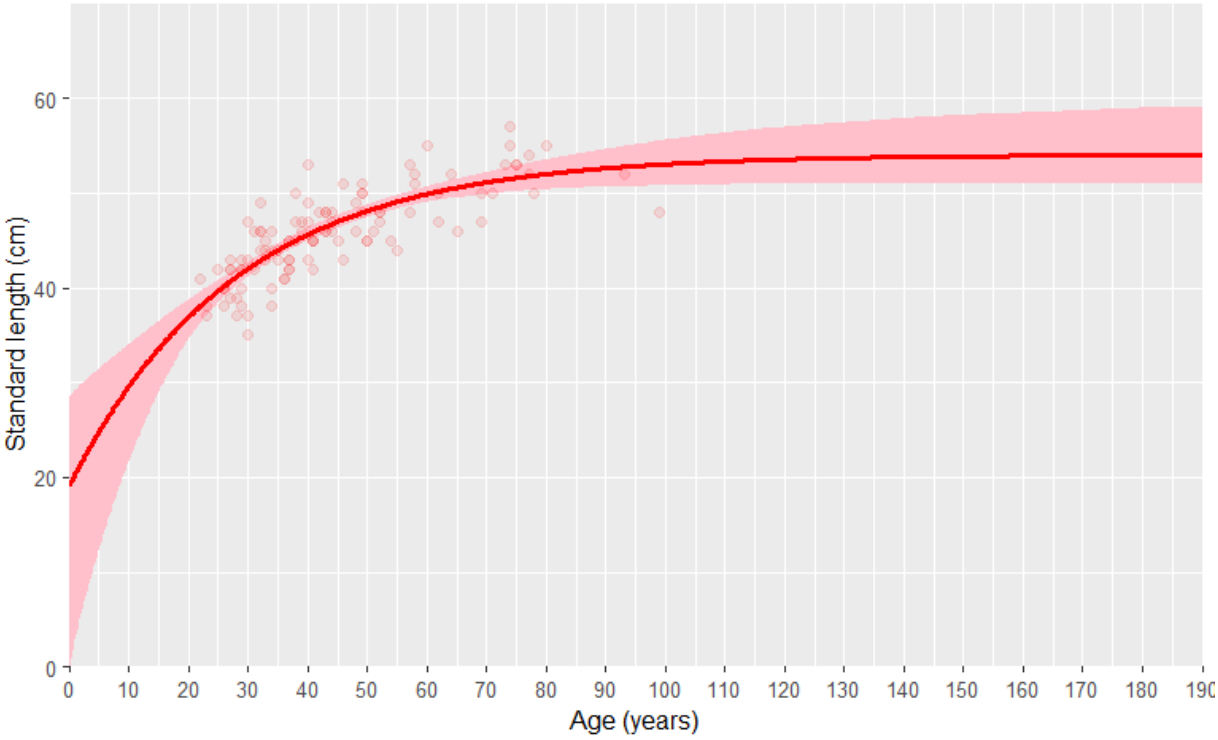

Figure 14: Length-at-age and fitted von Bertalanffy growth function curve of male orange roughy from Walter's Shoal.

The estimated asymptotic length (i.e., L_∞) of combined sex Walter's Shoal orange roughy from the von Bertalanffy curve was 57.55 cm (Figure 15, Table 4). Examination of the distribution of residuals confirmed that assumptions for fitting models via least squares were satisfied (see diagnostic plots Appendix Figure C6). All other von Bertalanffy growth function parameters are presented in Table 4.

Figure 15: Length-at-age and fitted von Bertalanffy growth function curve of orange roughy (sexes combined) from Walter's Shoal.

Maturity

The estimated size-at-50% maturity (i.e., L_{50}) was similar between females and males from Walter's Shoal (41.16 cm for females and 41.06 cm for males) (Figure 16).

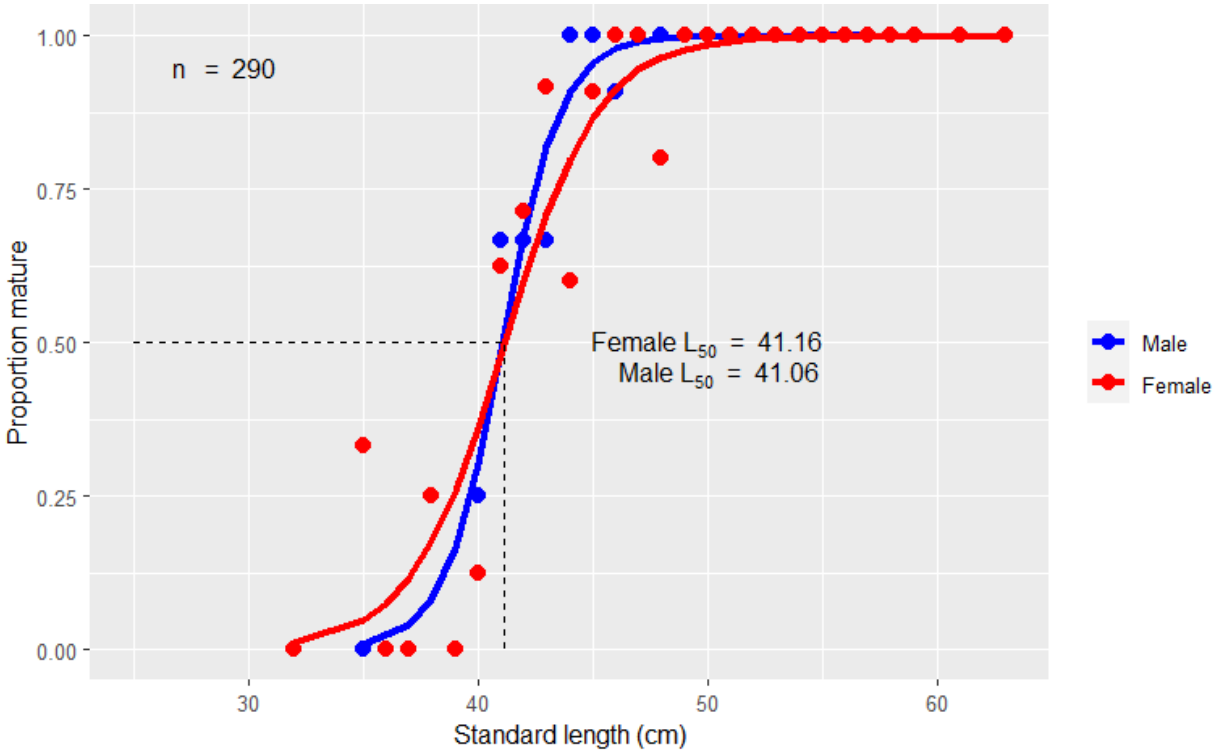

Figure 16: Sex specific size-at-maturity curves and size-at-50% maturity (L_{50}) of orange roughy from Walter's Shoal. The dashed lines correspond to the female L_{50}.

Otolith mass

A small number of otoliths could not be weighed due to damage (*n*=27). Otolith mass ranged from 108.9 to 1376.2 mg with the median 319.1 mg. Like the SWIR mass results, there does appear to be a relationship between Walter's Shoal orange roughy otolith mass and age with female otoliths significantly heavier, particularly when older than approximately 55 years (Figure 17).

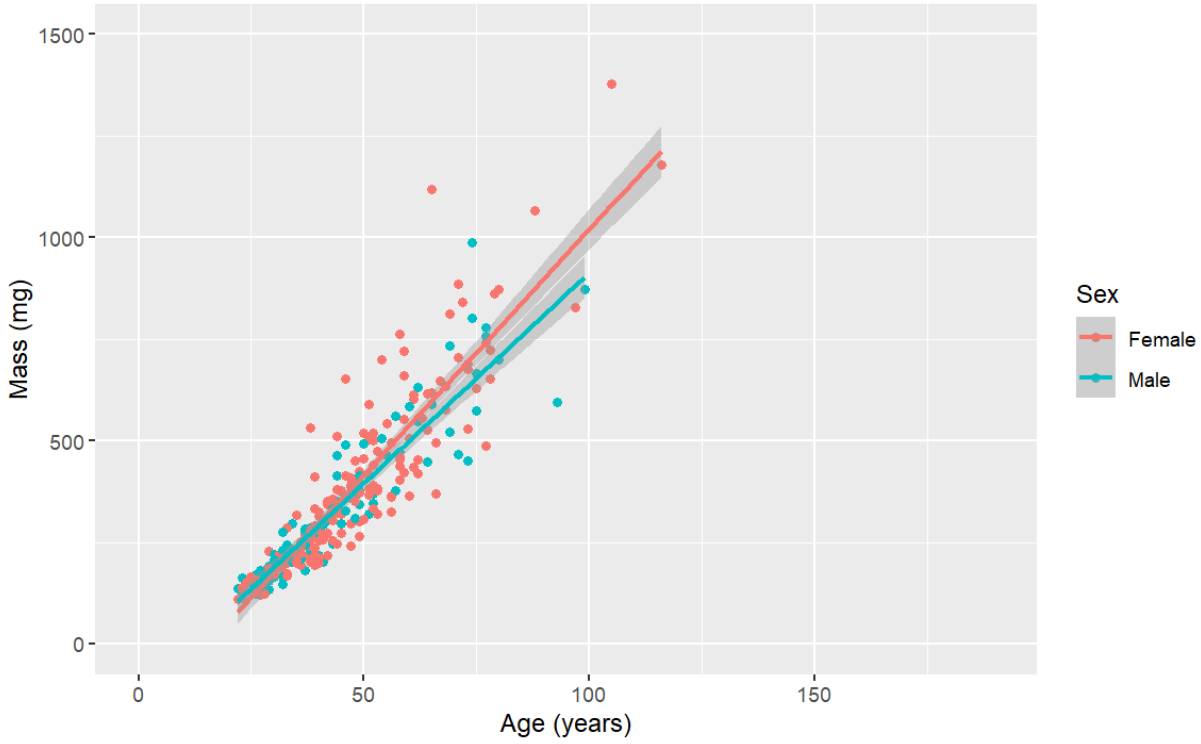

Figure 17: Sex specific otolith mass-at-age of orange roughy from Walter's Shoal. The trend lines are linear models with 95% confidence intervals.

3.3 Combined Southern Indian Ocean Agreement area growth curves

The estimated asymptotic length (i.e., L_∞) of female combined area orange roughy from the von Bertalanffy growth function was 57.41 cm (Figure 18, Table 5). Examination of the distribution of residuals confirmed that assumptions for fitting models via least squares were satisfied (see diagnostic plots Appendix Figure C7). All other von Bertalanffy growth function parameters are presented in Table 5.

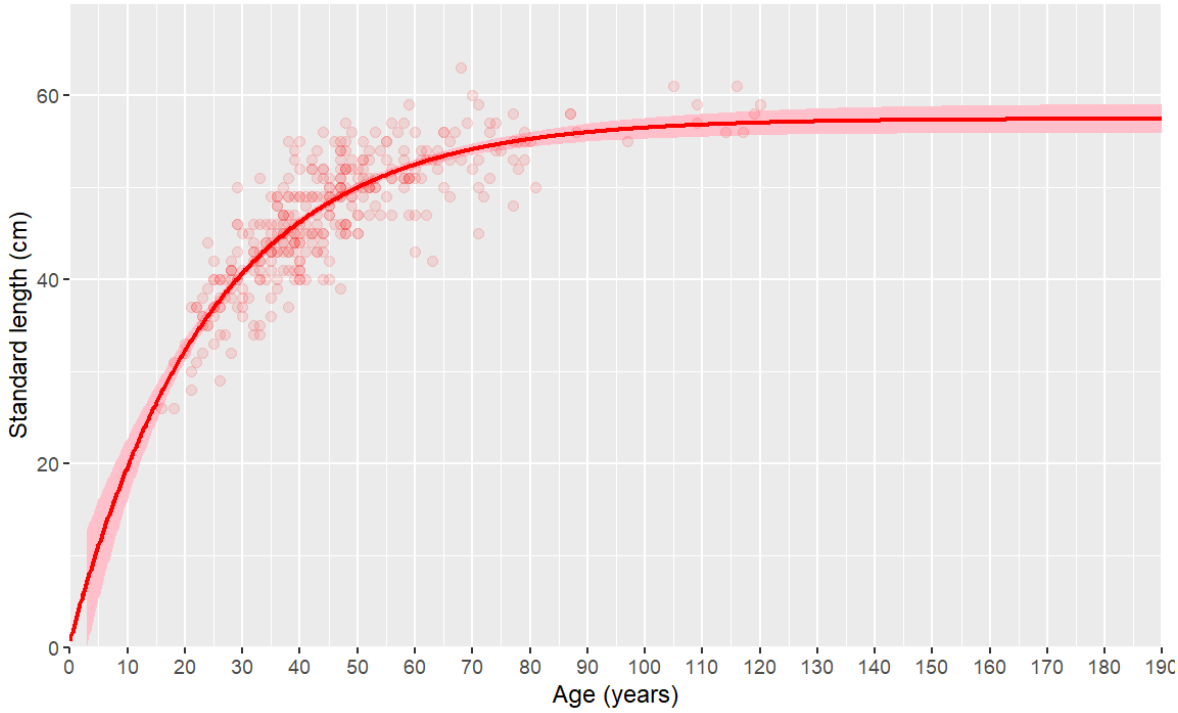

Figure 18: Length-at-age and fitted von Bertalanffy growth function curve of female orange roughy from the combined Southern Indian Ocean Agreement areas.

Table 5: Combined Southern Indian Ocean Agreement areas orange roughy von Bertalanffy growth function curve parameters with 95% confidence intervals for females and males and both sexes combined.

	L_∞	k	T_0
Females	57.41	0.04	-0.33
2.5%	55.74	0.03	-4.43
97.5%	59.05	0.05	2.74
Males	51.33	0.05	-1.91
2.5%	50.10	0.04	-6.48
97.5%	52.73	0.06	2.30
Combined	54.57	0.05	0.16
2.5%	53.35	0.04	-3.04
97.5%	55.95	0.05	2.77

The estimated asymptotic length (i.e., L_∞) of male combined area orange roughy from the von Bertalanffy growth function was 51.33 cm (Figure 19, Table 5). The distribution of length residuals showed a very slight bias across fitted values (see diagnostic plots Appendix Figure C8). All other von Bertalanffy growth function parameters are presented in Table 5.

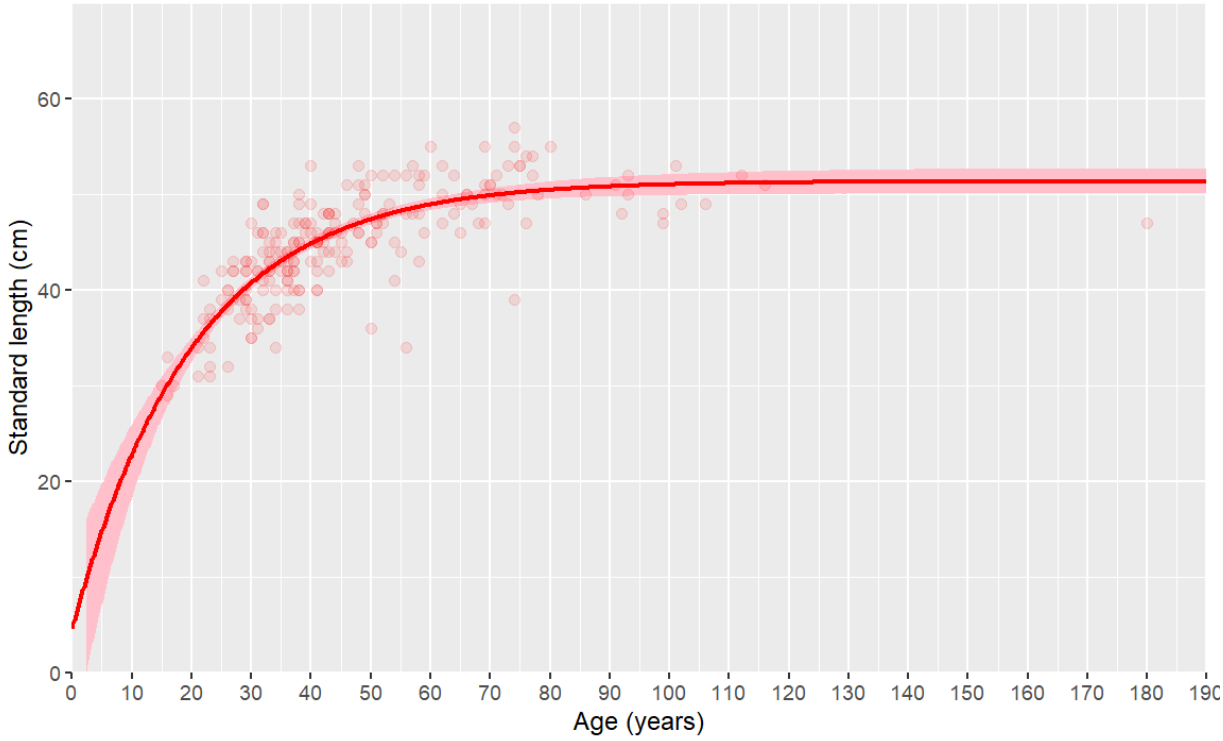

Figure 19: Length-at-age and fitted von Bertalanffy growth function curve of male orange roughy from the combined Southern Indian Ocean Agreement areas.

The asymptotic length (i.e., L_∞) of combined sex and area orange roughy estimated with a von Bertalanffy curve was 54.57 cm (Figure 20, Table 5). The distribution of length residuals showed a very slight bias across fitted values (see diagnostic plots Appendix Figure C9). All other von Bertalanffy growth function parameters are presented in Table 5.

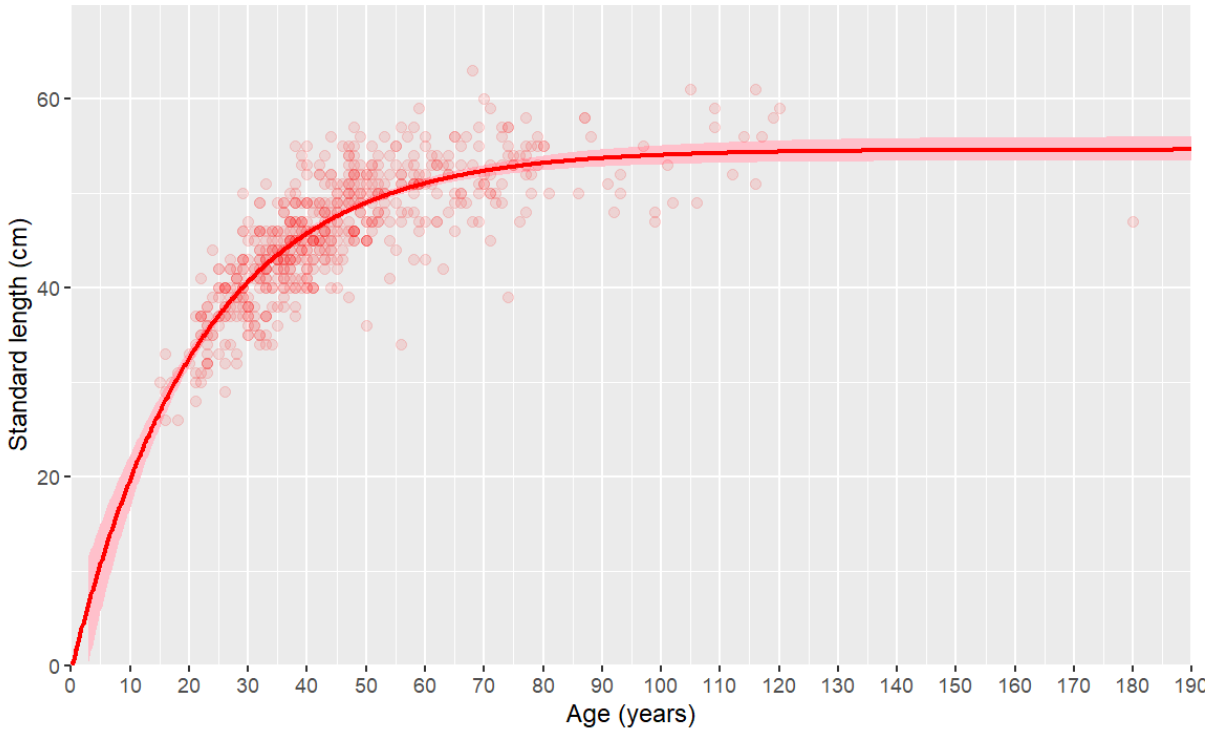

Figure 20: Length-at-age and fitted von Bertalanffy growth function curve of orange roughy (sexes combined) from the combined Southern Indian Ocean Agreement areas.

4 Discussion

The inconsistent structure pertaining to the TZ reiterates the findings of Saunders (2021) and suggests this may not be a useful structure to estimate biological age at maturity in the SIOFA area. However, the other readability indexes were reasonable for SWIR collected otoliths and suggest that otolith age estimation is viable here. The Walter's Shoal otolith structure, particularly the target post-rostrum, varied more than typically expected for orange roughy specimens. This has been noted for SIOFA collected orange roughy otoliths previously (see Saunders 2021) and may have led to more than usual technical problems (e.g. approximately twice as many Walter's Shoal individuals could not be accurately aged compared to SWIR).

4.1 Recommendations

Onboard observers from the SIOFA area should measure fish length using one method (e.g. standard length). For example, in the observer collected biological data there were at least two length measuring methods reported as used (i.e. the length measuring method differed between observers).

During the current study there were whole trips where the data recorded on the otolith packets did not match that in the data files supplied. In these instances, the data recorded on the otolith packets was deemed to be correct, and the data in the files amended accordingly. Connectivity of raw sample data components should be improved between observer data sheets, otolith packets, and the electronic repository for monitoring of the SIOFA area.

In the current study, a reference set consisting of orange roughy otoliths from New Zealand were used to ensure otoliths were read consistently. However, orange roughy in the SIOFA area display different biological characteristics compared to those from New Zealand (such as a lack of consistent TZs in the otoliths and large maximum sizes). If future ageing work is to be done on orange roughy in the SIOFA area, it is recommended that a reference set specific to the area be developed (see Saunders 2021).

5 Acknowledgements

We thank the Cook Islands Ministry of Marine resources and their fishing companies for collecting and Charles Heaphy for providing the otoliths, and Drs Steven Holmes and Bradley Moore for reviewing the manuscript. We also thank Drs Stephen Brouwer and Alistair Dunn for providing the analysis code used in this report. This work was funded by SIOFA under project ORY-2023-01 and managed under NIWA project code SIO24302.

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Appendix A Age data for SouthWest Indian Ridge

Table A1: Raw age data for SouthWest Indian Ridge. Note maturity is an index of reproductive stage, age is in years, R denotes readability, sex f and m is female and male (respectively), 0-TZ denotes birth to transition zone (TZ) age, TZE denotes TZ to otolith edge (time of sampling) age, total is grand age (often 0-TZ + TZE, except where young or no TZ present).

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
6	25/10/2019	56	5.27	f	10	6	616.3	27	3	2	90	3	117
6	25/10/2019	38	1.65	f	20	1	109	35	3	0	NA	NA	35
6	25/10/2019	34	1.3	m	30	1	131.1	34	3	0	NA	NA	34
6	25/10/2019	41	2.27	m	40	2	163.7	32	3	0	NA	NA	32
6	25/10/2019	41	2.05	m	50	3	317.9	28	3	2	26	3	54
6	25/10/2019	36	1.4	f	60	1	114.4	35	3	0	NA	NA	35
6	25/10/2019	34	1.35	f	70	1	133	32	3	0	NA	NA	32
6	25/10/2019	34	1.35	f	80	1	95.6	26	3	0	NA	NA	26
6	25/10/2019	40	2.12	m	90	1	139.8	37	3	0	NA	NA	37
6	25/10/2019	49	3.77	m	100	3	443.8	35	4	2	18	3	53
12	9/03/2019	46	2.66	m	10	3	214.6	30	3	2	18	2	48
12	9/03/2019	43	1.98	m	20	1	194.4	33	3	2	8	3	41
12	9/03/2019	46	2.4	m	30	4	258.1	45	3	3	NA	NA	45
12	9/03/2019	49	3.26	f	40	3	280.6	34	3	2	6	4	40
12	9/03/2019	46	2.58	f	50	3	184.5	35	3	2	3	3	38
12	9/03/2019	59	5.08	f	60	3	690.2	41	3	2	79	3	120
12	9/03/2019	52	3.74	m	70	3	459.7	29	3	2	42	3	71
12	9/03/2019	50	3.2	f	80	3	207.8	37	2	0	NA	NA	37
12	9/03/2019	45	3.1	m	90	3	245.7	25	3	2	9	3	34
13	26/10/2019	37	1.47	f	60	1	115.1	29	2	0	NA	NA	29
13	26/10/2019	50	3.96	m	90	3	365.9	24	3	2	42	3	66

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
13	26/10/2019	32	1.11	f	100	1	85.5	20	3	0	NA	NA	20
13	26/10/2019	32	1.03	m	80	1	NA	26	2	0	NA	NA	26
13	26/10/2019	53	4.46	f	20	3	608.2	35	3	2	44	3	79
13	26/10/2019	42	2.31	m	10	5	195.8	36	2	0	NA	NA	36
13	26/10/2019	32	1.19	m	50	1	80.7	23	2	0	NA	NA	23
13	26/10/2019	50	4.42	m	40	3	NA	27	4	2	39	3	66
13	26/10/2019	30	0.79	f	30	1	70.7	21	2	0	NA	NA	21
15	26/10/2019	51	4.08	f	70	2	482.7	27	2	2	33	3	60
15	26/10/2019	47	3.34	m	90	3	266.4	34	3	2	17	3	51
15	26/10/2019	40	1.63	f	100	2	NA	25	4	0	NA	NA	25
15	26/10/2019	53	3.58	f	80	3	456.2	23	4	2	32	2	55
15	26/10/2019	47	3.13	f	20	3	276.9	28	4	2	9	3	37
15	26/10/2019	48	3.57	m	10	5	402.2	30	3	2	34	3	64
15	26/10/2019	43	3.03	m	40	5	129	26	3	2	7	3	33
15	26/10/2019	43	2.6	m	50	5	412.1	23	4	2	35	3	58
15	26/10/2019	43	2.6	f	30	2	141.9	27	3	2	2	3	29
20	3/08/2022	49	3.41	f	24	4	256.2	30	3	2	6	3	36
20	3/08/2022	40	1.96	f	25	4	140.6	26	3	2	3	3	29
20	3/08/2022	38	1.825	m	6	2	NA	36	3	0	NA	NA	36
20	3/08/2022	45	2.895	m	8	5	289.2	32	3	2	6	3	38
20	3/08/2022	44	2.415	f	13	4	162.4	32	3	2	2	3	34
20	3/08/2022	42	2.355	m	7	5	196.8	24	3	2	12	3	36
25	11/03/2020	49	3.94	m	30	3	453	25	4	2	40	3	65
25	11/03/2020	49	3.9	f	10	3	274	46	3	3	NA	NA	46
25	11/03/2020	51	4.58	m	20	3	735	45	3	2	71	3	116
25	11/03/2020	41	1.88	f	80	2	212.8	31	3	2	4	3	35

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
25	11/03/2020	42	2.68	f	100	2	462.7	30	4	2	33	3	63
25	11/03/2020	49	4.14	f	60	3	243	35	4	0	NA	NA	35
25	11/03/2020	46	3.22	f	90	3	117.1	31	3	2	2	4	33
25	11/03/2020	39	2.16	f	50	2	92.6	24	2	0	NA	NA	24
25	11/03/2020	45	3.04	f	40	3	509.5	31	3	2	40	3	71
29	28/10/2019	46	2.23	m	70	3	187.2	30	3	2	10	3	40
29	28/10/2019	44	2.22	f	60	6	178.3	31	3	2	4	3	35
29	28/10/2019	46	2.58	m	80	2	226	31	3	2	10	3	41
29	28/10/2019	46	2.19	m	100	2	254.5	43	3	3	NA	NA	43
29	28/10/2019	37	1.44	f	90	2	112.8	25	3	0	NA	NA	25
29	28/10/2019	51	3.47	f	20	6	303.7	45	3	3	NA	NA	45
29	28/10/2019	47	2.78	f	10	3	254.3	35	3	2	10	3	45
29	28/10/2019	54	3.76	f	50	6	255.9	31	3	2	16	NA	47
29	28/10/2019	44	2.17	m	40	2	309.8	30	3	2	12	3	42
29	28/10/2019	47	3.46	f	30	3	370.3	27	3	2	32	3	59
38	29/10/2019	40	1.71	m	70	2	215.1	38	3	0	NA	NA	38
38	29/10/2019	46	3.12	f	60	2	132.3	31	3	2	4	3	35
38	29/10/2019	40	1.77	f	90	2	415.2	27	3	2	18	3	45
38	29/10/2019	44	2.72	m	50	3	205.9	36	3	2	10	3	46
38	29/10/2019	50	3.97	f	80	2	165.7	29	3	0	NA	NA	29
38	29/10/2019	43	2.59	f	20	2	200.1	35	3	2	6	3	41
38	29/10/2019	37	1.6	m	10	5	126.3	31	3	2	2	3	33
38	29/10/2019	43	2.7	f	100	2	193.1	37	3	0	NA	NA	37
38	29/10/2019	41	1.98	f	40	2	175.5	30	3	0	NA	NA	30
38	29/10/2019	48	3.21	f	30	3	NA	45	3	3	NA	NA	45
49	15/03/2019	26	0.62	f	80	1	46.1	18	3	0	NA	NA	18

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
49	15/03/2019	28	0.72	f	20	1	67.5	21	3	0	NA	NA	21
52	27/03/2020	38	1.4	m	60	2	207.4	30	3	2	8	3	38
52	27/03/2020	46	3.65	f	80	3	NA	35	3	2	13	3	48
52	27/03/2020	38	2.2	f	90	2	167.8	31	3	0	NA	NA	31
52	27/03/2020	45	3.28	f	10	3	181.9	30	3	2	7	3	37
52	27/03/2020	41	2.44	f	40	3	190.6	28	4	2	12	3	40
52	27/03/2020	44	2.84	f	30	3	193.5	28	3	2	9	3	37
52	27/03/2020	33	1.16	x	100	x	105.7	28	3	0	NA	NA	28
52	27/03/2020	35	1.29	x	20	x	115.5	30	3	2	2	NA	32
52	27/03/2020	36	1.61	x	50	x	125.8	28	3	2	3	3	31
59	28/03/2020	45	2.85	f	60	3	241.9	25	3	2	14	3	39
59	28/03/2020	37	1.64	m	50	1	138.9	30	3	2	1	3	31
59	28/03/2020	44	2.51	f	90	2	185.2	40	3	3	NA	NA	40
59	28/03/2020	47	3.37	f	80	3	259.2	35	3	2	15	3	50
59	28/03/2020	35	1.48	f	70	2	130.8	32	3	0	NA	NA	32
59	28/03/2020	45	3.22	f	20	3	259.8	33	3	2	11	3	44
59	28/03/2020	45	3.1	f	10	3	336.7	29	3	2	15	3	44
59	28/03/2020	36	1.57	m	40	1	129	31	3	0	NA	NA	31
59	28/03/2020	40	1.82	f	30	2	164.6	41	3	3	NA	NA	41
59	28/03/2020	40	1.94	f	100	2	209.8	40	3	3	NA	NA	40
71	30/03/2020	53	3.3	m	70	3	285	33	3	2	15	3	48
71	30/03/2020	34	2.73	m	60	2	468	24	4	2	32	3	56
71	30/03/2020	50	4.16	f	100	3	877.3	31	3	2	50	3	81
71	30/03/2020	47	3.4	m	80	3	367.8	36	3	2	40	3	76
71	30/03/2020	47	3.9	m	90	3	568.7	40	3	2	59	3	99
71	30/03/2020	39	2.89	m	20	3	461	27	3	2	47	3	74

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
71	30/03/2020	51	4.34	f	50	3	249.8	30	3	2	26	3	56
71	30/03/2020	53	4.15	m	40	3	768.5	33	3	2	68	3	101
71	30/03/2020	36	2.97	m	30	NA	287.4	33	3	2	17	3	50
77	19/04/2022	54	3.79	m	20	3	398.8	37	3	2	39	3	76
77	19/04/2022	57	4.72	f	30	3	394.6	48	3	2	26	3	74
77	19/04/2022	48	3.34	m	10	3	442.4	47	3	2	11	3	58
77	19/04/2022	45	2.07	f	80	3	152.1	33	3	2	4	3	37
77	19/04/2022	56	4.34	f	70	3	261.9	39	3	2	5	3	44
77	19/04/2022	46	2.11	m	100	4	135.1	35	3	0	NA	NA	35
77	19/04/2022	48	2.57	m	90	4	165.6	38	3	2	5	3	43
77	19/04/2022	50	3.63	f	50	3	236.1	35	3	2	23	3	58
77	19/04/2022	51	3.36	m	40	4	309	34	3	2	36	3	70
77	19/04/2022	49	2.59	m	60	4	178.1	35	3	2	3	3	38
87	12/11/2019	38	1.5	m	70	2	127.8	30	3	0	NA	NA	30
87	12/11/2019	39	1.76	f	60	2	168.7	36	3	0	NA	NA	36
87	12/11/2019	34	1.27	f	100	2	100	27	3	0	NA	NA	27
87	12/11/2019	56	5.28	f	80	6	1419.8	28	3	2	86	4	114
87	12/11/2019	41	2.13	f	10	2	125.6	28	3	0	NA	NA	28
87	12/11/2019	35	1.3	f	20	2	98.8	24	3	0	NA	NA	24
87	12/11/2019	37	1.92	m	50	1	124.3	33	3	0	NA	NA	33
87	12/11/2019	42	2.13	m	40	2	147.9	35	3	0	NA	NA	35
91	12/11/2019	54	3.9	f	100	2	502.6	30	3	2	44	3	74
91	12/11/2019	49	3.04	m	70	5	514	29	3	2	73	3	102
91	12/11/2019	49	2.65	m	90	2	183.6	26	3	2	6	3	32
91	12/11/2019	37	1.51	m	80	1	89	22	3	0	NA	NA	22
91	12/11/2019	48	2.9	m	10	5	595	33	3	2	59	4	92

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
91	12/11/2019	34	1.45	f	20	2	131.3	33	3	0	NA	NA	33
91	12/11/2019	50	3.94	m	50	5	710.7	86	3	3	NA	NA	86
91	12/11/2019	39	2	f	40	2	276.9	38	3	2	9	3	47
91	12/11/2019	47	3.06	f	30	2	168.7	35	3	2	4	3	39
100	15/11/2019	39	1.7	m	70	1	118.1	25	3	0	NA	NA	25
100	15/11/2019	55	3.93	f	60	6	319.5	55	4	0	NA	NA	55
100	15/11/2019	52	3.68	m	90	5	518	35	3	2	77	3	112
100	15/11/2019	51	3.54	m	100	5	392.8	31	3	2	17	3	48
100	15/11/2019	50	3.72	f	80	6	360.4	34	3	2	18	NA	52
100	15/11/2019	43	2.47	m	20	5	202.8	30	3	2	15	3	45
100	15/11/2019	53	3.63	m	10	5	521.2	25	3	2	37	3	62
100	15/11/2019	53	3.94	f	50	6	495.7	31	3	2	46	3	77
100	15/11/2019	47	3.34	f	40	6	313.6	38	3	2	16	3	54
100	15/11/2019	49	2.94	m	30	5	708.6	28	4	2	78	4	106
125	21/11/2019	47	2.72	m	70	2	240	31	3	2	16	3	47
125	21/11/2019	45	2.53	f	60	6	195.6	31	4	2	8	4	39
125	21/11/2019	50	3.69	f	100	6	230.6	30	3	2	18	3	48
125	21/11/2019	52	3.5	m	80	2	274.1	33	3	2	23	3	56
125	21/11/2019	47	2.74	m	90	5	296.3	33	3	2	18	3	51
125	21/11/2019	46	3.04	m	10	5	291.8	23	3	2	36	3	59
125	21/11/2019	44	2.47	f	20	2	245.4	35	4	2	9	3	44
125	21/11/2019	47	3.63	m	50	5	914.5	30	3	2	150	4	180
125	21/11/2019	51	3.32	m	40	5	457.1	33	3	2	36	3	69
125	21/11/2019	40	1.92	f	30	2	NA	34	3	0	NA	NA	34
126	29/03/2019	55	4.4	m	90	3	564.1	34	4	2	35	4	69
126	29/03/2019	54	3.82	f	60	2	248	48	4	3	NA	NA	48

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
126	29/03/2019	44	2.52	f	50	3	191.1	36	4	2	4	4	40
126	29/03/2019	39	1.74	m	80	2	164	29	3	0	NA	NA	29
126	29/03/2019	46	2.88	f	70	3	233.4	47	3	3	NA	NA	47
126	29/03/2019	51	3.08	f	20	3	272.7	32	3	2	15	3	47
126	29/03/2019	53	3.96	f	10	3	455.9	41	3	2	25	3	66
126	29/03/2019	40	1.6	f	40	2	101.4	28	3	0	NA	NA	28
126	29/03/2019	49	3.32	f	30	3	219.5	55	3	3	NA	NA	55
126	29/03/2019	37	1.48	x	100	x	122.1	33	3	0	NA	NA	33
130	23/11/2019	42	2.26	m	70	3	281.6	43	3	3	NA	NA	43
130	23/11/2019	43	2.32	m	60	3	182.8	36	4	0	NA	NA	36
130	23/11/2019	40	1.88	m	40	2	189.1	41	3	3	NA	NA	41
130	23/11/2019	49	3.64	m	90	3	480.6	38	4	2	35	3	73
130	23/11/2019	42	2.4	m	80	2	NA	33	3	0	NA	NA	33
130	23/11/2019	45	2.52	f	10	2	213.5	48	3	3	NA	NA	48
130	23/11/2019	40	1.88	f	50	2	179.7	39	3	0	NA	NA	39
130	23/11/2019	40	2.04	m	100	2	177.2	41	3	3	NA	NA	41
130	23/11/2019	44	2.28	m	30	2	219.8	43	3	3	NA	NA	43
131	23/11/2019	45	2.38	f	70	6	197.9	47	3	3	NA	NA	47
131	23/11/2019	33	0.84	f	90	1	72.7	20	3	0	NA	NA	20
131	23/11/2019	38	1.38	x	80	x	102.1	30	3	0	NA	NA	30
131	23/11/2019	51	3.22	f	100	6	255.8	30	4	2	17	3	47
131	23/11/2019	56	4.6	f	20	6	345.6	33	4	2	27	4	60
131	23/11/2019	55	3.8	f	30	6	273.7	33	4	2	14	3	47
131	23/11/2019	52	3.36	f	10	6	263.4	30	4	2	20	4	50
131	23/11/2019	29	0.74	f	60	1	84.6	26	3	0	NA	NA	26
131	23/11/2019	47	2.56	f	50	6	166.1	37	3	0	NA	NA	37

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
131	23/11/2019	54	3.76	f	40	6	174.3	39	3	0	NA	NA	39
140	18/04/2020	49	3.4	f	70	3	311.1	24	3	2	23	4	47
140	18/04/2020	50	3.93	f	60	3	259.6	45	4	3	NA	NA	45
140	18/04/2020	56	5.14	f	100	3	426.5	57	4	3	NA	NA	57
140	18/04/2020	52	3.91	f	90	3	213	30	3	2	12	3	42
140	18/04/2020	53	4.56	f	80	3	NA	30	3	2	12	3	42
140	18/04/2020	58	6.17	f	10	3	648.6	29	3	2	90	3	119
140	18/04/2020	52	4.4	f	50	3	325.9	30	3	2	18	3	48
140	18/04/2020	52	4.32	f	40	3	NA	38	3	2	10	3	48
140	18/04/2020	49	4.53	f	30	3	NA	30	3	2	19	3	49
142	25/11/2019	52	3.6	f	70	6	237.7	34	4	2	15	3	49
142	25/11/2019	48	3.22	m	60	5	NA	29	4	2	27	3	56
142	25/11/2019	52	4.12	m	80	5	480.3	38	3	2	16	3	54
142	25/11/2019	52	3.78	m	90	5	311.9	26	4	2	24	3	50
142	25/11/2019	52	4.08	m	100	5	NA	37	3	2	15	3	52
142	25/11/2019	54	4.7	f	50	6	276	35	4	2	8	4	43
142	25/11/2019	46	2.26	f	30	3	158	32	4	0	NA	NA	32
179	23/07/2020	31	0.79	f	80	1	NA	18	3	0	NA	NA	18
179	23/07/2020	29	0.78	m	60	1	NA	16	3	0	NA	NA	16
179	23/07/2020	30	1.12	m	70	1	138	15	3	0	NA	NA	15
179	23/07/2020	31	0.74	m	90	1	75.4	23	3	0	NA	NA	23
179	23/07/2020	34	0.95	m	100	1	86.6	21	3	0	NA	NA	21
179	23/07/2020	35	1.02	m	10	1	82.2	22	3	0	NA	NA	22
179	23/07/2020	31	0.77	m	20	1	83.9	21	3	0	NA	NA	21
179	23/07/2020	33	0.94	m	30	1	67.2	16	3	0	NA	NA	16
179	23/07/2020	35	1.24	m	40	1	108.6	30	4	0	NA	NA	30

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
179	23/07/2020	30	1.2	m	50	1	61.8	17	4	0	NA	NA	17
182	25/07/2020	39	2.07	m	70	3	175	29	3	0	NA	NA	29
182	25/07/2020	51	3.65	m	60	4	462.1	30	3	2	61	4	91
182	25/07/2020	44	2.73	m	50	3	229.4	33	4	2	11	3	44
182	25/07/2020	44	2.49	f	90	4	165.5	31	4	2	3	4	34
182	25/07/2020	40	2.05	m	20	3	201.5	29	3	2	7	4	36
182	25/07/2020	44	2.99	f	10	5	220.1	35	3	2	2	2	37
182	25/07/2020	45	3.07	m	100	3	196.4	30	3	2	11	3	41
182	25/07/2020	40	1.88	m	40	3	174.1	32	3	0	NA	NA	32
182	25/07/2020	45	2.19	f	30	5	194.2	28	4	2	10	3	38
192	28/07/2020	41	2.14	m	70	3	184.7	33	3	0	NA	NA	33
192	28/07/2020	51	3.88	m	100	3	412.9	32	4	2	38	NA	70
192	28/07/2020	40	2	m	80	3	182.7	38	3	0	NA	NA	38
192	28/07/2020	42	2.28	f	90	4	217.4	40	3	3	NA	NA	40
192	28/07/2020	50	4.34	f	10	5	636	38	3	2	33	4	71
192	28/07/2020	50	3.76	m	20	4	562.2	93	4	3	NA	NA	93
192	28/07/2020	45	2.74	m	50	3	223.6	42	3	3	NA	NA	42
192	28/07/2020	44	2.64	m	40	4	248.1	31	3	2	5	4	36
192	28/07/2020	47	3.24	f	30	4	165.1	37	3	0	NA	NA	37
198	11/05/2022	48	3.25	f	70	3	249.9	33	3	2	12	3	45
198	11/05/2022	50	3.89	m	60	3	522.3	32	3	2	40	3	72
198	11/05/2022	49	3.88	m	90	3	561.4	38	3	2	29	3	67
198	11/05/2022	58	5.6	f	100	3	925.3	40	3	2	47	4	87
198	11/05/2022	55	4.9	f	20	3	439.1	41	3	2	38	3	79
198	11/05/2022	57	5	f	10	3	359.7	48	3	3	NA	NA	48
198	11/05/2022	32	1.05	f	50	2	84.7	23	3	0	NA	NA	23

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
198	11/05/2022	47	3.65	m	40	3	490	36	3	2	32	3	68
198	11/05/2022	55	5.3	f	30	3	NA	26	4	2	25	3	51
217	6/05/2020	43	3.82	f	10	3	539.8	35	3	2	25	3	60
217	6/05/2020	43	2.69	m	30	2	179.2	29	3	0	NA	NA	29
217	6/05/2020	50	4.41	f	40	3	740.7	34	3	2	31	3	65
217	6/05/2020	47	3.54	m	50	2	259.8	27	4	2	10	3	37
217	6/05/2020	40	1.94	f	60	1	117.7	25	3	0	NA	NA	25
217	6/05/2020	41	2.08	x	70	x	145.2	31	3	0	NA	NA	31
217	6/05/2020	42	2.44	f	80	3	192.2	31	3	2	2	3	33
217	6/05/2020	37	2.75	x	90	x	133	27	3	0	NA	NA	27
217	6/05/2020	43	2.88	f	100	2	NA	43	4	3	NA	NA	43
218	15/05/2022	50	4.03	f	70	3	367.3	34	3	2	19	3	53
218	15/05/2022	48	3.22	f	60	3	225.6	34	3	2	7	3	41
218	15/05/2022	42	2.8	m	100	3	172	26	4	2	5	3	31
218	15/05/2022	40	2.12	f	80	1	152.3	36	4	0	NA	NA	36
218	15/05/2022	42	2.35	m	90	2	176.1	33	4	0	NA	NA	33
218	15/05/2022	58	6.08	f	10	3	1049.4	36	4	2	51	4	87
218	15/05/2022	47	3.21	f	20	3	373.1	36	3	2	14	3	50
218	15/05/2022	43	2.15	f	50	3	160.6	32	4	0	NA	NA	32
218	15/05/2022	44	2.77	m	40	4	214.3	30	3	2	6	NA	36
218	15/05/2022	44	2.66	f	30	3	206.1	32	4	0	NA	NA	32
221	6/08/2020	49	3.64	f	70	6	314.6	26	3	2	16	4	42
221	6/08/2020	55	5.72	f	60	6	332.8	31	3	2	46	3	77
221	6/08/2020	49	3.5	f	90	5	293.7	28	3	2	17	3	45
221	6/08/2020	57	5.19	f	80	6	1162.7	28	3	2	81	3	109
221	6/08/2020	45	2.64	f	100	6	240	33	3	2	7	3	40

Tow no	Date (new)	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
221	6/08/2020	60	5.5	f	10	6	640.4	30	3	2	40	3	70
221	6/08/2020	52	3.9	m	20	6	650.8	38	3	2	21	3	59
221	6/08/2020	52	5.16	f	50	5	489.8	39	3	2	31	3	70
221	6/08/2020	38	1.94	f	40	5	173.4	30	3	0	NA	NA	30
221	6/08/2020	53	4.78	f	30	6	405.2	32	4	2	19	4	51
229	7/08/2020	47	2.82	m	70	4	266.8	31	3	2	8	3	39
229	7/08/2020	54	5.26	f	60	5	490.5	35	3	2	29	3	64
229	7/08/2020	51	4.14	f	90	5	187.3	29	3	2	4	3	33
229	7/08/2020	53	4.88	f	100	4	281.3	36	3	2	11	3	47
229	7/08/2020	46	3.46	f	80	5	275.7	34	3	2	7	3	41
229	7/08/2020	59	5.26	f	20	6	937.2	34	3	2	75	3	109
229	7/08/2020	53	4	f	10	4	460.3	27	3	2	35	3	62
229	7/08/2020	49	3.28	f	50	4	196.4	32	3	2	4	3	36
229	7/08/2020	52	4.8	f	40	5	306	35	3	2	9	3	44
229	7/08/2020	51	5.04	f	30	4	398.5	28	4	2	22	3	50
244	19/05/2022	26	0.55	f	70	1	50.9	16	3	0	NA	NA	16
244	19/05/2022	33	1.15	f	100	1	87.6	25	3	0	NA	NA	25
244	19/05/2022	31	0.93	f	90	1	79.2	22	4	0	NA	NA	22
244	19/05/2022	37	1.48	f	20	1	129.6	22	3	0	NA	NA	22
244	19/05/2022	36	1.25	f	10	1	123.5	25	3	0	NA	NA	25
244	19/05/2022	34	1.14	m	40	1	90.7	23	4	0	NA	NA	23
244	19/05/2022	32	0.99	x	50	x	79.9	23	4	0	NA	NA	23
244	19/05/2022	30	0.84	x	30	x	72.5	22	3	0	NA	NA	22
244	19/05/2022	35	1.34	x	80	x	123.8	22	3	0	NA	NA	22
244	19/05/2022	33	0.76	x	60	x	101.2	23	3	0	NA	NA	23

Appendix B Age data for Walter's Shoal

Table B2: Raw age data for Walter's Shoal. Note maturity is an index of reproductive stage, age is in years, R denotes readability, sex m and f is male and female (respectively), 0-TZ denotes birth to transition zone (TZ) age, TZE denotes TZ to otolith edge (time of sampling) age, total is grand age (often 0-TZ + TZE, except where young or no TZ present).

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
1	3/06/2020	49	3.76	f	20	3	295.4	47	4	3	NA	NA	47
1	3/06/2020	45	2.85	m	40	3	NA	26	4	2	7	3	33
1	3/06/2020	51	4.47	f	60	3	318.2	39	3	2	14	3	53
1	3/06/2020	52	4.79	f	70	3	362.8	60	4	3	NA	NA	60
1	3/06/2020	48	3.65	m	80	3	246.6	31	4	2	12	3	43
1	3/06/2020	52	5.1	f	90	3	273.2	42	4	3	NA	NA	42
3	3/06/2020	49	3.65	m	20	4	217.9	31	4	2	9	3	40
3	3/06/2020	45	3.7	m	60	4	237	38	3	0	NA	NA	38
3	3/06/2020	48	3.65	m	70	3	368.4	52	3	3	NA	NA	52
3	3/06/2020	53	4.78	m	80	3	450.2	35	4	3	38	3	73
3	3/06/2020	53	4.73	m	90	4	573.7	37	4	2	38	3	75
3	3/06/2020	50	4.04	m	100	4	465.2	37	3	2	34	3	71
4	4/06/2020	61	7.95	f	10	4	1177.8	37	3	2	79	3	116
4	4/06/2020	56	6.05	f	20	3	265.2	36	3	2	13	3	49
4	4/06/2020	59	7.19	f	40	4	885.8	34	3	2	37	NA	71
4	4/06/2020	53	4.71	f	60	4	423.6	37	3	2	12	3	49
4	4/06/2020	49	3.98	f	70	4	252.9	34	3	2	9	3	43
4	4/06/2020	52	5.58	f	90	4	525.7	34	4	2	30	3	64
4	4/06/2020	47	3.27	f	100	3	218.8	38	3	0	NA	NA	38
5	4/06/2020	53	4.73	m	20	3	263	28	4	1	12	3	40

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
5	4/06/2020	52	4.74	m	40	3	593.9	39	3	2	54	3	93
5	4/06/2020	48	3.58	m	60	3	462.2	32	3	2	12	3	44
5	4/06/2020	54	5.81	f	100	3	601.8	41	4	2	20	4	61
23	8/06/2020	46	3.79	f	10	3	284.3	28	2	2	11	3	39
23	8/06/2020	37	1.91	m	20	1	162.9	23	3	0	NA	NA	23
23	8/06/2020	40	2	m	30	2	161	26	3	0	NA	NA	26
23	8/06/2020	55	5.33	f	40	3	723.8	25	3	2	53	3	78
23	8/06/2020	50	4.2	f	50	3	503.5	35	3	2	16	4	51
23	8/06/2020	42	2.55	f	80	2	180.2	32	3	0	NA	NA	32
23	8/06/2020	47	3.21	m	90	3	351.7	36	3	2	8	3	44
23	8/06/2020	48	3.65	f	100	3	378	33	4	2	20	3	53
32	10/06/2020	63	7.1	f	30	4	633.1	35	3	2	33	3	68
32	10/06/2020	53	4.63	m	40	3	560.6	35	4	2	22	4	57
32	10/06/2020	45	2.58	m	80	4	282.7	33	3	2	4	3	37
32	10/06/2020	55	4.86	m	90	4	583.9	38	3	2	22	3	60
32	10/06/2020	52	4.56	f	100	4	323.7	40	3	3	NA	NA	40
33	11/06/2020	38	1.6	f	30	1	121.2	27	3	0	NA	NA	27
33	11/06/2020	38	1.74	f	70	1	157	28	3	0	NA	NA	28
33	11/06/2020	43	2.57	f	80	5	225.5	32	3	0	NA	NA	32
33	11/06/2020	42	2.28	m	100	1	176.6	27	3	0	NA	NA	27
37	12/06/2020	42	2.45	m	20	3	190.3	29	3	0	NA	NA	29
37	12/06/2020	45	2.63	f	30	3	303.6	43	3	3	NA	NA	43
37	12/06/2020	42	2.65	m	50	4	274.9	26	3	2	11	3	37
37	12/06/2020	46	2.78	f	70	6	350.4	48	3	3	NA	NA	48
37	12/06/2020	49	3.27	f	80	6	368.9	37	3	2	29	3	66

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
38	11/06/2020	49	4.18	f	10	3	280.1	40	3	3	NA	NA	40
38	11/06/2020	54	5.3	f	20	3	389.9	29	3	2	23	3	52
38	11/06/2020	57	4.38	f	90	4	495	56	3	3	NA	NA	56
44	14/06/2020	51	3.8	m	10	4	472.3	38	3	2	20	3	58
44	14/06/2020	59	6	f	20	4	661	36	4	2	23	3	59
44	14/06/2020	55	6.15	f	30	4	828.5	35	3	2	62	4	97
44	14/06/2020	55	4.97	f	40	4	495	34	3	1	32	1	66
44	14/06/2020	46	3.01	m	60	4	318.6	34	3	2	17	3	51
44	14/06/2020	53	5.19	f	80	4	575	28	3	2	40	3	68
44	14/06/2020	56	5.36	f	90	4	382.1	25	3	2	28	3	53
48	16/06/2020	56	5.08	f	20	4	1065.8	31	3	2	57	4	88
48	16/06/2020	48	3.7	f	60	4	300.9	33	3	2	16	3	49
48	16/06/2020	54	5.2	f	70	4	452.1	32	3	2	26	3	58
48	16/06/2020	52	4.79	f	80	4	363.1	32	3	2	24	4	56
48	16/06/2020	58	5.73	f	90	4	741.6	32	3	2	45	3	77
48	16/06/2020	47	3.37	m	100	4	286	30	3	2	8	3	38
49	15/06/2020	46	4.04	f	10	3	227.7	29	2	0	NA	NA	29
49	15/06/2020	50	4.74	f	20	3	474	36	3	2	17	3	53
49	15/06/2020	46	2.96	m	40	2	146.9	32	3	0	NA	NA	32
49	15/06/2020	48	3.71	m	70	3	346	30	3	2	22	3	52
49	15/06/2020	57	6.35	f	90	3	812.6	41	3	2	28	2	69
49	15/06/2020	49	6.14	f	100	3	841.5	30	3	2	42	3	72
50	15/06/2020	51	4.97	f	20	3	324.5	24	3	2	19	4	43
50	15/06/2020	51	4.72	f	40	3	433.9	37	3	2	24	3	61
50	15/06/2020	49	4.45	f	50	3	NA	27	3	2	11	2	38

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
50	15/06/2020	55	5.13	f	70	4	313	40	3	3	NA	NA	40
55	14/06/2020	56	5.63	f	60	4	618.2	34	3	2	31	3	65
55	14/06/2020	51	3.79	f	70	4	269.9	38	3	0	NA	NA	38
55	14/06/2020	51	3.97	m	90	4	376.4	28	3	2	21	3	49
55	14/06/2020	50	3.6	m	100	4	734.1	44	4	2	25	3	69
57	16/06/2020	55	4.68	m	10	4	987	24	3	2	50	3	74
57	16/06/2020	52	5.07	f	20	4	394.3	29	4	2	19	3	48
57	16/06/2020	49	3.51	m	30	4	308.9	36	3	2	12	3	48
57	16/06/2020	50	3.56	m	40	4	399.2	33	3	2	16	2	49
57	16/06/2020	46	3.16	m	50	4	412.8	26	3	2	18	3	44
57	16/06/2020	53	4.25	f	60	4	613.5	31	2	2	30	2	61
57	16/06/2020	54	4.29	m	70	4	777.7	35	4	2	42	4	77
57	16/06/2020	48	3.4	m	80	4	315.2	29	3	2	14	3	43
64	18/06/2020	56	5.24	f	10	4	861.4	33	3	2	46	2	79
64	18/06/2020	48	3.49	m	40	4	412.5	28	3	2	21	3	49
64	18/06/2020	52	3.92	m	90	4	460.8	28	4	2	30	3	58
65	18/06/2020	57	6.41	f	10	4	528	32	2	2	41	2	73
65	18/06/2020	61	6.99	f	60	4	1376.2	37	3	2	68	4	105
65	18/06/2020	53	4.79	m	80	4	664.6	31	4	2	44	2	75
65	18/06/2020	48	3.37	m	90	3	302.8	29	4	2	13	3	42
70	19/06/2020	55	6.17	f	30	3	542.6	28	3	2	27	3	55
70	19/06/2020	54	5.47	f	40	4	627.8	26	3	2	49	4	75
70	19/06/2020	56	5.68	f	50	4	688.4	31	3	2	42	2	73
70	19/06/2020	53	5.8	f	60	4	403.9	30	3	2	28	3	58
70	19/06/2020	53	5.21	f	70	3	614.2	36	3	2	28	2	64

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
75	21/06/2020	47	3.19	m	30	4	521.5	36	3	2	33	3	69
75	21/06/2020	50	4.09	m	50	4	547.2	32	3	2	30	2	62
75	21/06/2020	46	3.29	m	90	4	588	31	3	2	34	3	65
75	21/06/2020	47	3.55	f	100	4	505.8	34	3	2	26	3	60
78	22/06/2020	47	3.56	m	30	3	344.5	33	3	2	19	3	52
78	22/06/2020	50	4.88	f	40	3	407.9	47	3	3	NA	NA	47
78	22/06/2020	45	3.48	m	50	3	NA	50	3	3	NA	NA	50
78	22/06/2020	47	3.41	m	70	3	286.5	34	4	3	5	4	39
78	22/06/2020	43	2.81	m	90	3	NA	27	2	2	13	3	40
78	22/06/2020	46	3.26	m	100	3	294.8	25	3	2	9	3	34
79	22/06/2020	45	3.3	f	10	3	456.4	31	3	2	19	4	50
79	22/06/2020	46	3.29	m	70	3	362.6	29	3	2	19	4	48
81	22/06/2020	52	4.37	f	10	4	589.2	27	4	2	24	3	51
81	22/06/2020	46	3.47	f	20	4	414	31	2	2	15	4	46
81	22/06/2020	52	4.63	f	30	4	653.2	78	4	3	NA	NA	78
81	22/06/2020	49	3.78	f	40	4	343.9	42	4	3	NA	NA	42
81	22/06/2020	53	5.06	f	50	3	554.5	36	3	2	27	3	63
81	22/06/2020	45	3.14	m	80	3	292.1	24	4	2	17	3	41
81	22/06/2020	43	2.65	m	90	3	171.2	30	3	0	NA	NA	30
83	24/06/2020	51	4.37	f	30	4	675.9	32	3	2	41	2	73
83	24/06/2020	52	4.34	m	40	4	446.6	35	3	2	29	3	64
83	24/06/2020	53	4.56	f	60	4	331.9	39	4	0	NA	NA	39
83	24/06/2020	47	3.31	m	70	4	631.6	34	3	2	28	3	62
83	24/06/2020	50	4.51	f	80	4	500.5	27	2	2	25	4	52
83	24/06/2020	56	5.7	f	100	4	646.7	37	3	2	30	4	67

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
85	24/06/2020	50	3.5	m	20	4	NA	26	4	2	52	3	78
85	24/06/2020	48	3.2	m	40	4	871.9	45	3	2	54	4	99
85	24/06/2020	43	2.49	m	50	4	NA	35	4	3	NA	NA	35
85	24/06/2020	49	3.7	f	60	4	366.5	32	3	2	19	3	51
86	26/06/2020	53	4.94	f	20	4	703.6	43	3	2	28	3	71
86	26/06/2020	52	3.87	m	30	4	755.8	51	3	2	26	3	77
86	26/06/2020	46	3.18	m	40	4	NA	38	3	2	5	3	43
86	26/06/2020	46	3.2	m	50	4	337.8	32	2	2	11	3	43
86	26/06/2020	50	3.75	m	60	4	342.9	36	2	2	13	3	49
86	26/06/2020	45	3.02	m	70	4	296.7	35	3	2	10	4	45
86	26/06/2020	44	3.06	m	80	3	NA	35	3	0	NA	NA	35
86	26/06/2020	55	5.18	m	90	8	699.7	29	4	2	51	3	80
87	26/06/2020	46	3.2	f	10	4	214.4	37	3	0	NA	NA	37
87	26/06/2020	54	4.84	f	20	4	358.1	33	3	2	14	3	47
87	26/06/2020	50	3.76	m	40	4	230.3	38	3	0	NA	NA	38
87	26/06/2020	47	3.1	m	60	4	NA	40	3	3	NA	NA	40
87	26/06/2020	40	2.15	m	90	4	157.5	29	3	0	NA	NA	29
87	26/06/2020	57	5.41	f	100	4	761.4	37	4	2	21	4	58
89	26/06/2020	47	2.94	m	10	4	220.7	30	3	0	NA	NA	30
89	26/06/2020	52	4.49	f	30	4	510.8	28	3	2	16	3	44
89	26/06/2020	57	5.2	m	80	4	801.6	37	3	2	37	3	74
89	26/06/2020	49	3.15	f	90	4	257.8	38	3	0	NA	NA	38
89	26/06/2020	55	5.11	f	100	4	349.8	29	3	2	19	3	48
90	26/06/2020	55	5.09	f	20	4	651.2	34	4	2	12	3	46
90	26/06/2020	55	5.13	f	40	4	532.8	38	3	0	NA	NA	38

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
90	26/06/2020	51	5.11	f	50	4	420.8	36	3	2	23	3	59
90	26/06/2020	54	4.92	f	60	4	452.9	34	3	2	28	3	62
90	26/06/2020	56	5.84	f	70	4	1116.9	25	3	2	40	3	65
90	26/06/2020	55	5.47	f	90	4	872.8	34	3	2	46	3	80
97	1/07/2020	46	2.76	f	60	4	233.8	29	3	2	5	3	34
97	1/07/2020	46	3.35	f	80	4	355.4	30	3	2	13	4	43
97	1/07/2020	51	4.39	f	100	4	380.4	28	3	2	16	3	44
99	2/07/2020	37	1.69	f	10	1	242.2	30	2	2	8	3	38
99	2/07/2020	42	2.62	f	20	4	286.2	33	3	2	NA	NA	33
99	2/07/2020	45	2.73	f	40	4	266	27	3	2	14	3	41
99	2/07/2020	42	2	m	50	3	202.9	27	3	2	14	3	41
99	2/07/2020	44	2.57	m	70	4	462.7	37	3	2	18	3	55
99	2/07/2020	45	2.95	f	100	4	218	38	3	2	4	3	42
100	3/07/2020	43	2.41	f	20	4	315.4	43	3	3	NA	NA	43
100	3/07/2020	43	2.21	f	50	4	197.9	33	3	0	NA	NA	33
100	3/07/2020	38	1.81	m	80	3	200.5	34	3	0	NA	NA	34
100	3/07/2020	40	1.88	f	100	1	142.4	26	3	0	NA	NA	26
101	3/07/2020	45	2.74	m	20	4	493.1	50	3	3	NA	NA	50
101	3/07/2020	41	2.21	m	50	4	235.7	36	3	0	NA	NA	36
101	3/07/2020	43	2.95	f	60	4	201.2	38	3	0	NA	NA	38
101	3/07/2020	47	3.2	f	80	4	376.3	22	3	2	23	3	45
101	3/07/2020	50	3.87	f	100	4	319.5	30	3	2	15	3	45
104	4/07/2020	41	2.51	f	10	4	131.4	28	3	0	NA	NA	28
104	4/07/2020	35	2.66	f	70	4	173.4	33	3	0	NA	NA	33
104	4/07/2020	44	2.68	m	90	4	244.5	33	3	0	NA	NA	33

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
104	4/07/2020	43	2.46	m	100	4	NA	33	3	0	NA	NA	33
108	5/07/2020	50	3.7	f	40	4	389	26	3	2	21	3	47
114	7/07/2020	42	2.41	m	10	4	198.7	31	3	0	NA	NA	31
114	7/07/2020	41	2.25	m	20	4	136	22	3	0	NA	NA	22
114	7/07/2020	46	2.98	f	40	4	NA	40	3	3	NA	NA	40
114	7/07/2020	41	2.14	f	50	5	179.7	28	3	0	NA	NA	28
114	7/07/2020	45	2.77	m	80	4	296.4	27	3	2	14	3	41
114	7/07/2020	42	2.07	m	100	4	180.3	26	3	2	11	3	37
120	9/07/2020	41	2.26	f	30	2	270.4	30	3	2	7	3	37
120	9/07/2020	46	3.23	f	50	4	NA	36	3	2	0	NA	36
120	9/07/2020	45	3.14	m	70	4	506.1	30	3	2	24	3	54
120	9/07/2020	47	3.59	f	80	4	302.6	43	3	3	NA	NA	43
120	9/07/2020	44	2.46	f	90	5	218	39	3	0	NA	NA	39
132	11/07/2020	41	2.31	f	10	5	263.8	34	3	2	4	3	38
132	11/07/2020	40	1.96	f	20	2	158.3	26	3	0	NA	NA	26
132	11/07/2020	45	2.9	f	30	3	218.1	27	3	2	4	3	31
132	11/07/2020	42	2.56	f	50	4	374.3	25	3	2	20	4	45
140	13/07/2020	50	4.22	f	20	4	386.5	28	3	2	19	4	47
140	13/07/2020	43	2.49	f	50	4	192.6	35	3	2	1	2	36
140	13/07/2020	45	3.38	f	60	4	311.1	22	3	2	20	3	42
140	13/07/2020	49	3.82	f	70	4	370.9	30	3	2	19	3	49
140	13/07/2020	51	4.19	f	100	5	719.8	29	3	2	30	3	59
141	5/11/2020	46	2.36	f	60	3	165.4	29	3	0	NA	NA	29
141	5/11/2020	44	2.56	f	70	3	410.4	39	4	0	NA	NA	39
141	5/11/2020	42	2.54	f	80	3	315.8	35	4	0	NA	NA	35

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
141	5/11/2020	40	2.12	m	100	1	224.6	34	3	0	NA	NA	34
143	14/07/2020	54	4.19	f	20	3	698.6	30	3	2	24	3	54
143	14/07/2020	48	3.2	m	30	4	377.6	31	3	2	26	3	57
143	14/07/2020	51	4.02	f	40	3	551.7	36	3	2	23	3	59
145	15/07/2020	51	4.06	f	10	5	416.3	27	3	2	24	3	51
145	15/07/2020	47	2.95	f	40	5	418.2	29	3	2	33	3	62
145	15/07/2020	43	2.39	m	50	2	244.3	37	3	0	NA	NA	37
145	15/07/2020	47	3.13	f	60	5	360.9	35	3	2	21	3	56
147	15/07/2020	39	2.11	m	30	1	122.2	28	3	0	NA	NA	28
147	15/07/2020	41	1.91	f	60	5	NA	29	3	2	3	3	32
147	15/07/2020	40	2.08	f	90	2	NA	27	3	0	NA	NA	27
148	15/07/2020	45	2.78	f	10	5	390.3	30	3	2	18	3	48
148	15/07/2020	43	2.24	f	20	5	245.6	33	3	2	11	3	44
148	15/07/2020	44	2.53	m	30	4	223	34	3	0	NA	NA	34
148	15/07/2020	42	2.36	f	50	5	255	40	4	3	NA	NA	40
148	15/07/2020	49	3.53	m	90	4	273.8	32	3	0	NA	NA	32
154	18/07/2020	40	2.06	m	80	1	169.9	26	3	0	NA	NA	26
154	18/07/2020	42	2.49	m	90	1	149.1	25	3	0	NA	NA	25
156	19/07/2020	43	2.16	f	40	2	222.1	35	3	0	NA	NA	35
156	19/07/2020	44	2.5	f	50	2	350.3	37	3	2	5	3	42
156	19/07/2020	48	3.14	f	60	2	250.2	35	3	2	1	3	36
156	19/07/2020	45	2.75	f	70	5	200	35	3	0	NA	NA	35
156	19/07/2020	46	2.88	m	80	5	NA	26	3	2	13	3	39
161	19/07/2020	43	2.75	m	10	4	276.5	29	3	2	8	2	37
161	19/07/2020	38	1.78	m	40	1	123.8	26	3	0	NA	NA	26

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
161	19/07/2020	44	2.37	m	60	4	164.6	30	3	2	2	3	32
161	19/07/2020	43	2.54	f	70	5	279.8	30	4	2	8	4	38
161	19/07/2020	40	3.7	f	80	5	NA	30	4	2	14	4	44
161	19/07/2020	35	1.43	m	100	1	164.4	30	3	0	NA	NA	30
163	24/04/2020	38	1.62	m	10	2	125.5	23	3	0	NA	NA	23
163	24/04/2020	44	2.43	f	30	2	151.6	24	3	0	NA	NA	24
163	24/04/2020	43	2.4	m	40	2	164.8	29	3	0	NA	NA	29
163	24/04/2020	43	2.24	m	60	2	161.3	27	3	0	NA	NA	27
163	24/04/2020	35	1.4	f	70	2	128.6	24	3	0	NA	NA	24
163	24/04/2020	40	2.01	f	100	2	187.1	29	3	0	NA	NA	29
163	20/07/2020	50	4.1	f	20	6	438.7	32	3	2	20	3	52
163	20/07/2020	45	2.92	f	30	6	305.7	34	3	2	16	3	50
163	20/07/2020	37	1.62	f	50	1	NA	21	4	0	NA	NA	21
163	20/07/2020	44	2.65	f	60	6	235.7	31	3	2	8	3	39
163	20/07/2020	43	2.54	m	80	4	327.1	46	3	3	NA	NA	46
163	20/07/2020	41	2.54	m	100	1	208.5	31	3	2	5	3	36
166	24/04/2020	39	2.18	f	10	2	NA	30	3	0	NA	NA	30
166	24/04/2020	40	1.9	f	30	1	NA	33	4	0	NA	NA	33
166	24/04/2020	43	2.79	f	40	3	240.5	33	3	2	3	3	36
166	24/04/2020	42	2.38	f	60	1	165.5	25	4	0	NA	NA	25
166	24/04/2020	41	2.43	f	80	2	211.6	34	3	2	6	3	40
166	24/04/2020	37	1.69	m	90	1	151.7	28	3	0	NA	NA	28
170	25/04/2020	38	1.8	f	20	3	157.2	26	3	0	NA	NA	26
170	25/04/2020	38	1.83	m	30	2	132.8	29	3	0	NA	NA	29
170	25/04/2020	42	2.12	m	50	1	154.2	29	3	0	NA	NA	29

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
170	25/04/2020	40	2.05	f	70	2	199.4	40	3	0	NA	NA	40
170	25/04/2020	43	2.73	f	80	3	NA	35	3	0	NA	NA	35
172	25/04/2020	49	3.07	f	10	3	272.7	37	3	2	8	3	45
172	25/04/2020	52	3.75	f	30	3	241.6	30	3	2	17	3	47
172	25/04/2020	48	2.87	f	100	3	NA	27	3	2	9	3	36
186	28/04/2020	45	2.87	m	30	4	NA	34	3	2	3	3	37
186	28/04/2020	48	4.5	f	40	3	487.3	30	3	2	47	3	77
186	28/04/2020	53	4.56	f	60	3	518.3	29	4	2	23	4	52
186	28/04/2020	46	3.18	m	90	3	231.2	32	3	0	NA	NA	32
202	1/05/2020	42	1.97	f	20	3	180.9	28	4	0	NA	NA	28
202	1/05/2020	46	2.8	m	80	3	197.6	27	3	2	4	3	31
202	1/05/2020	49	3.71	f	100	3	332.8	34	4	2	10	3	44
230	10/05/2020	37	1.86	f	20	1	125.7	26	3	0	NA	NA	26
230	10/05/2020	37	2.07	f	30	1	170.1	30	3	0	NA	NA	30
230	10/05/2020	41	1.95	f	40	1	NA	30	4	2	3	3	33
230	10/05/2020	39	1.97	f	80	1	124.3	28	4	0	NA	NA	28
230	10/05/2020	35	1.49	f	90	1	113.5	23	3	0	NA	NA	23
236	11/05/2020	32	1.4	f	10	1	NA	28	3	0	NA	NA	28
236	11/05/2020	36	1.84	f	30	1	135.3	23	3	0	NA	NA	23
236	11/05/2020	37	1.48	f	40	1	108.9	22	3	0	NA	NA	22
236	11/05/2020	37	1.68	f	60	1	163.4	25	3	0	NA	NA	25
236	11/05/2020	36	1.49	f	70	1	NA	30	3	0	NA	NA	30
236	11/05/2020	37	1.55	f	90	1	143.3	26	3	0	NA	NA	26
240	11/05/2020	40	2.1	f	70	1	167.2	33	3	0	NA	NA	33
240	11/05/2020	36	1.59	f	80	1	138.8	23	3	0	NA	NA	23

Tow no	Date	Length (SL cm)	Weight (kg)	Sex	Fish no	Maturity	Otolith weight (mg)	0-TZ	R (0-TZ)	R (TZ)	TZ-E	R (TZ-E)	Total
247	12/05/2020	42	2.3	m	30	3	181.6	26	3	2	1	2	27
247	12/05/2020	49	3.65	f	60	3	NA	29	4	2	10	3	39
247	12/05/2020	41	2.56	f	100	3	194.8	36	3	2	3	3	39
248	12/05/2020	49	3.86	f	20	3	257.9	32	3	2	9	3	41
248	12/05/2020	39	2.01	m	70	2	140.6	27	3	0	NA	NA	27
248	12/05/2020	45	3.05	f	80	3	222.4	33	3	2	3	3	36
248	12/05/2020	38	1.83	f	90	1	139.7	23	3	0	NA	NA	23
248	12/05/2020	43	2.35	f	100	3	291.1	26	4	2	13	3	39
255	13/05/2020	47	3.83	f	20	3	380.5	32	3	2	20	3	52
255	13/05/2020	45	2.79	f	60	2	180.4	28	3	2	2	2	30
255	13/05/2020	37	1.52	m	80	2	207.9	30	4	0	NA	NA	30
255	13/05/2020	43	2.96	f	100	3	203.1	35	3	0	NA	NA	35
270	15/05/2020	46	3.55	f	20	3	449.6	48	4	3	NA	NA	48
270	15/05/2020	51	4.47	f	60	3	437.8	38	3	2	20	3	58
270	15/05/2020	50	3.54	f	70	3	518.1	39	3	2	11	3	50
270	15/05/2020	45	2.76	m	80	3	NA	41	3	3	NA	NA	41
270	15/05/2020	53	5.49	f	100	3	381.4	29	3	2	22	3	51
271	15/05/2020	51	4.15	f	40	3	324.2	43	3	2	13	3	56
271	15/05/2020	51	4.32	m	60	3	490.3	31	3	2	15	3	46
271	15/05/2020	51	4.95	f	70	3	461.8	26	3	2	32	3	58
271	15/05/2020	51	4.5	f	80	3	332.6	52	3	0	NA	NA	52

Appendix C Growth model assumption checking

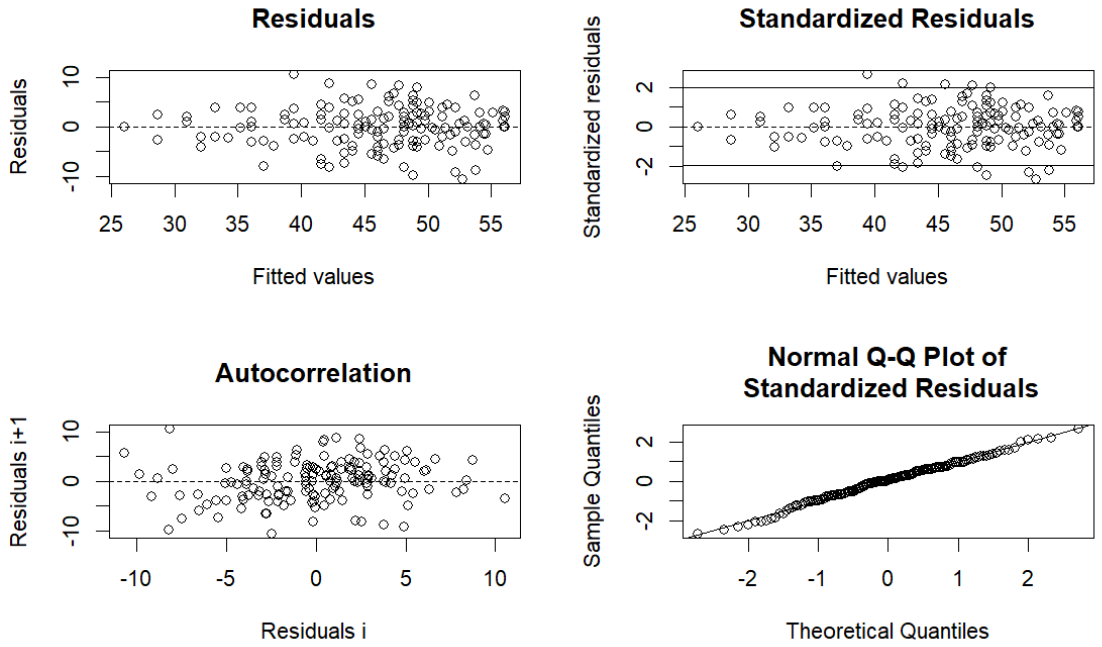


Figure C1: Residuals from the SWIR female growth model.

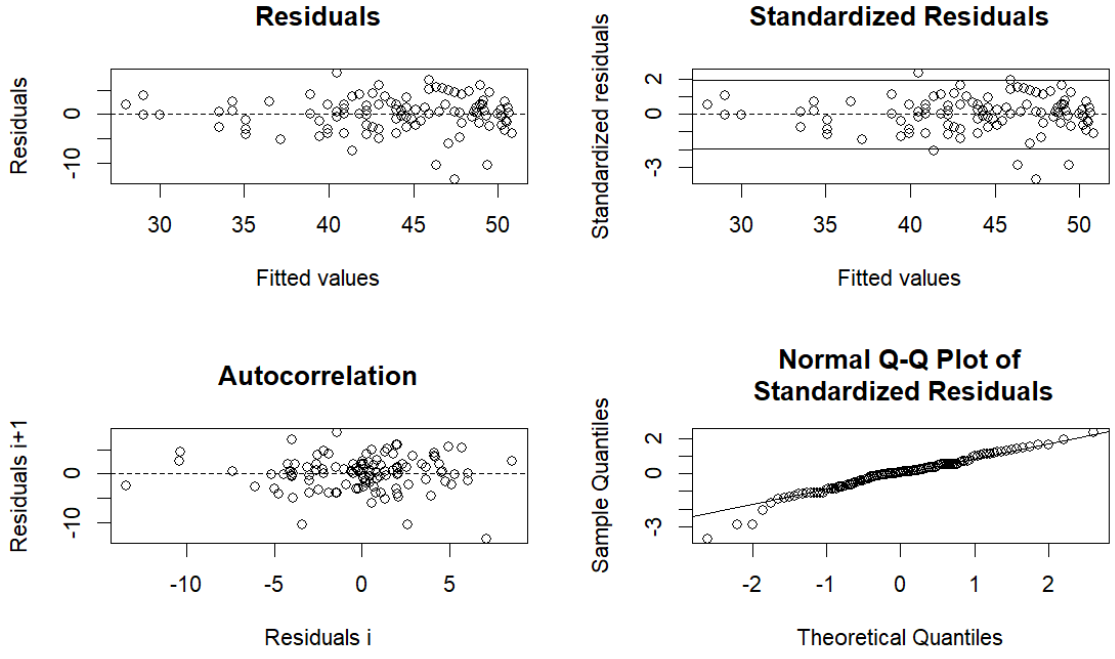


Figure C2: Residuals from the SWIR male growth model.

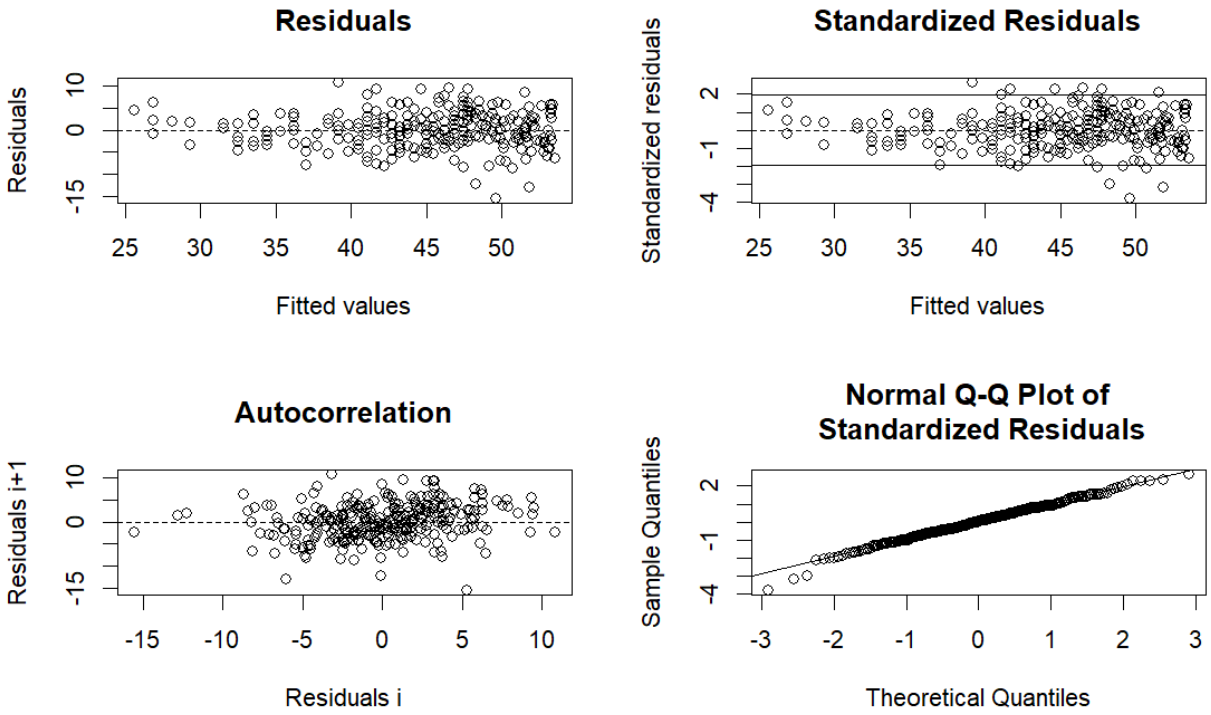


Figure C3: Residuals from the SWIR combined sex growth model.

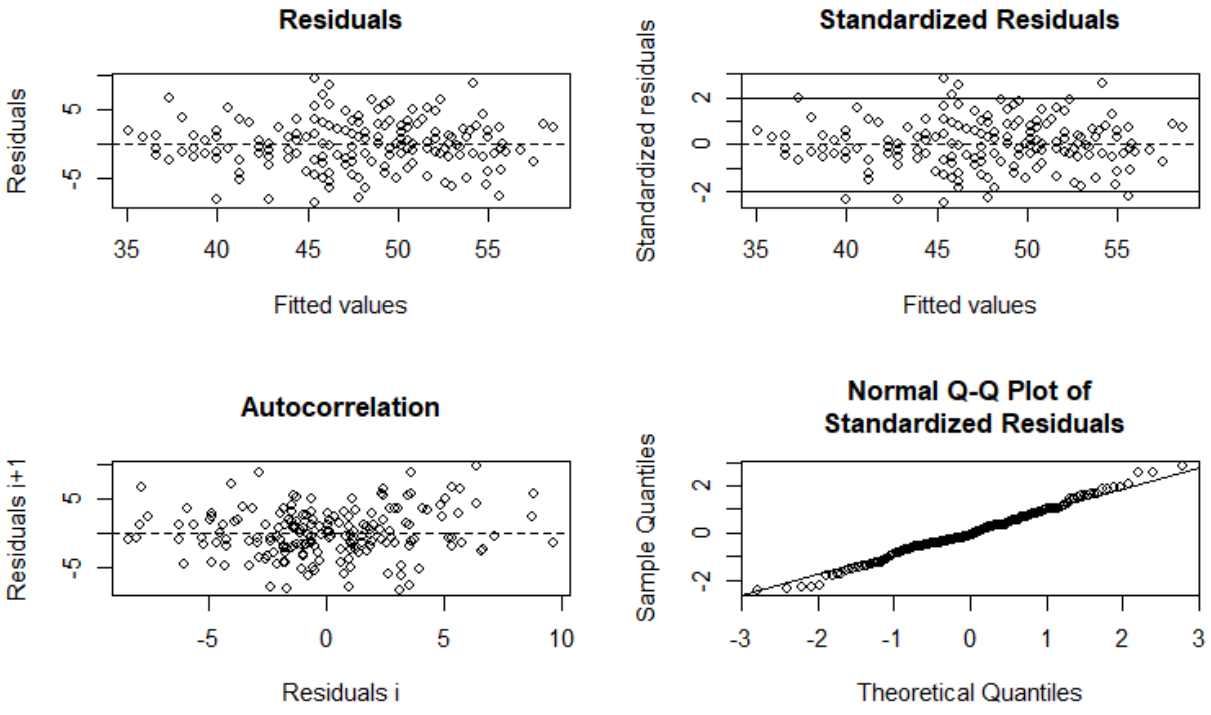


Figure C4: Residuals from the Walter's Shoal female growth model.

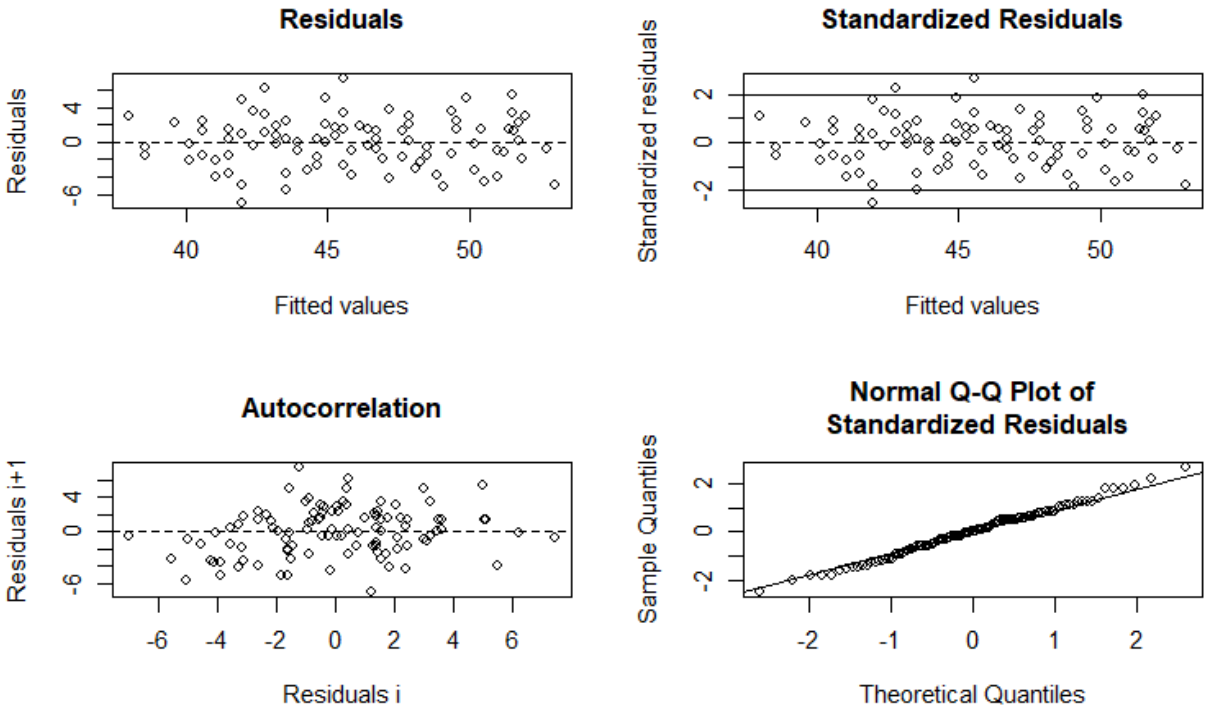


Figure C5: **Residuals from the Walter's Shoal male growth model.**

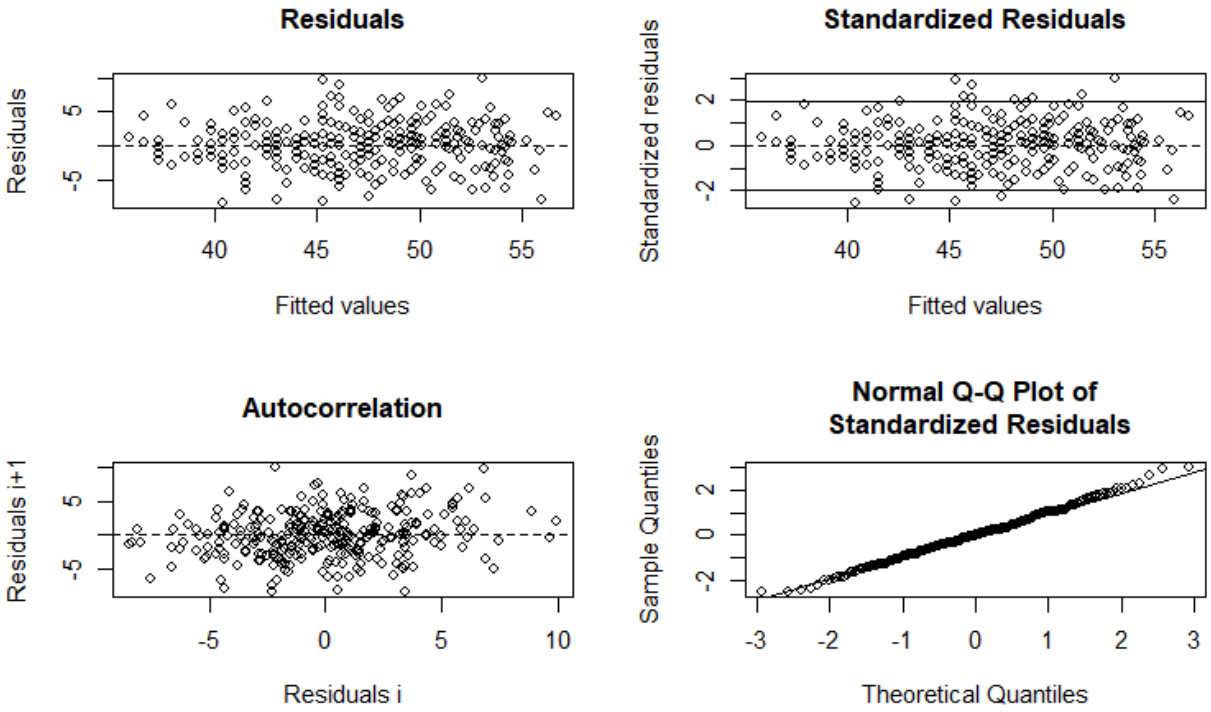


Figure C6: **Residuals from the Walter's Shoal combined sex growth model.**

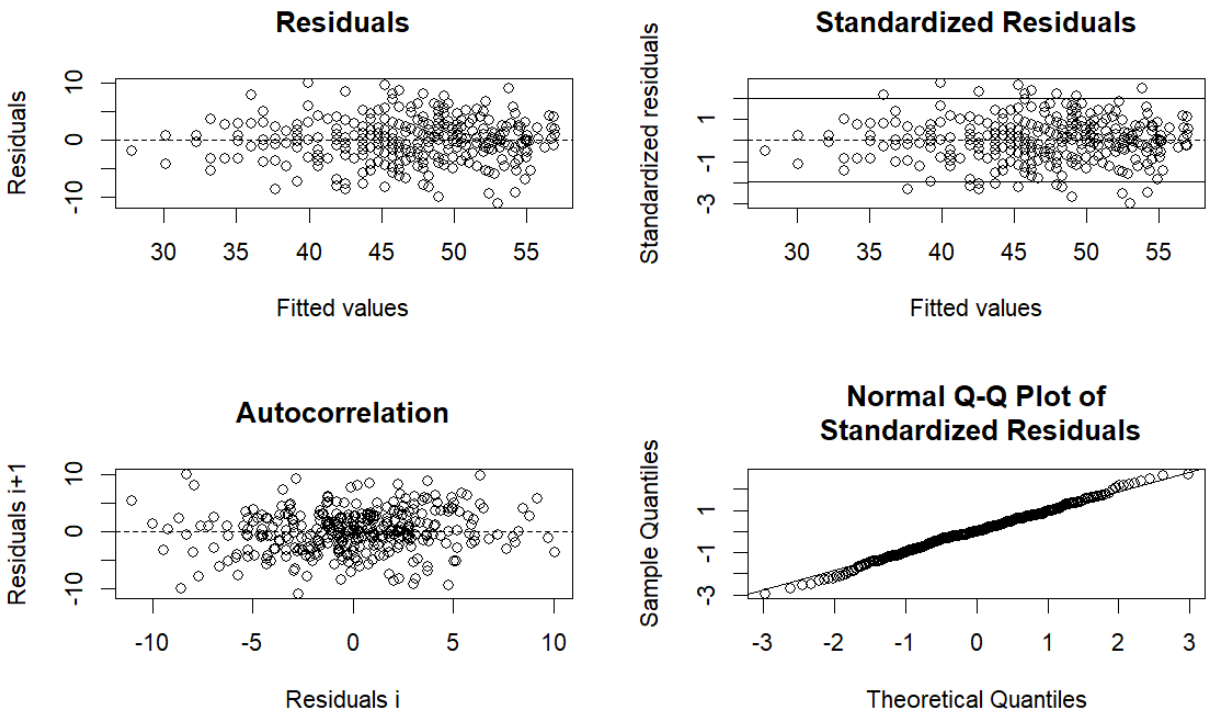


Figure C7: Residuals from the combined area female growth model.

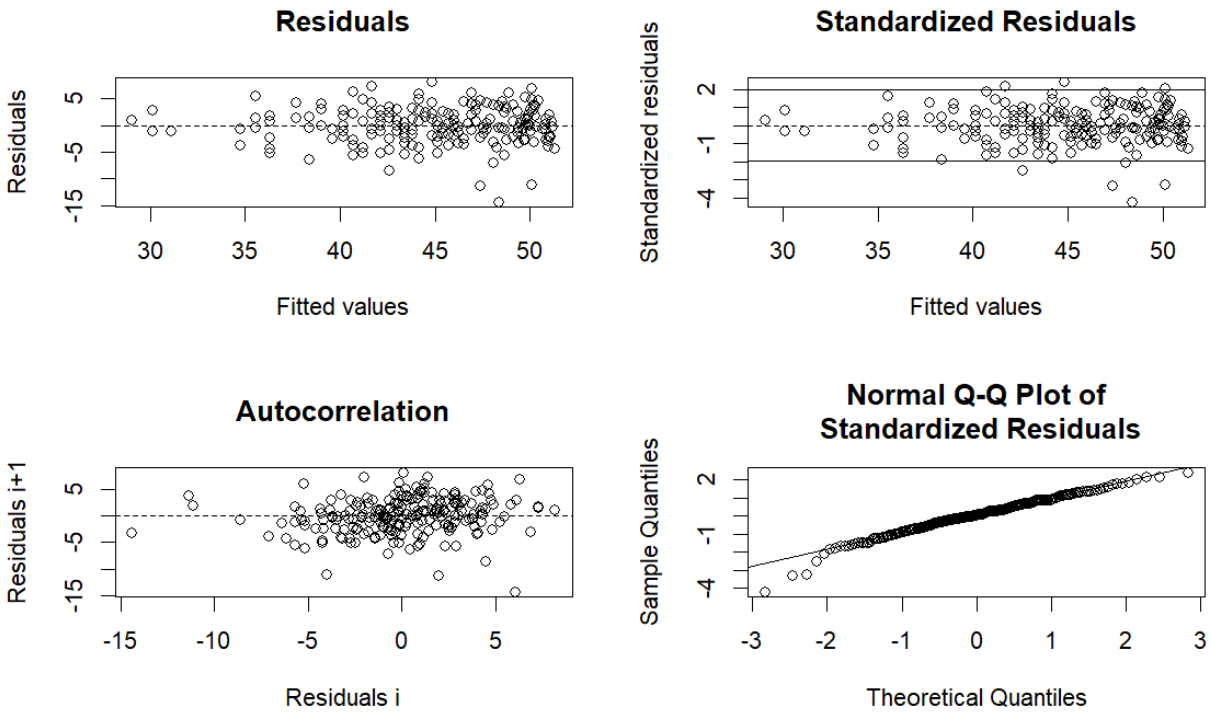


Figure C8: Residuals from the combined area male growth model.

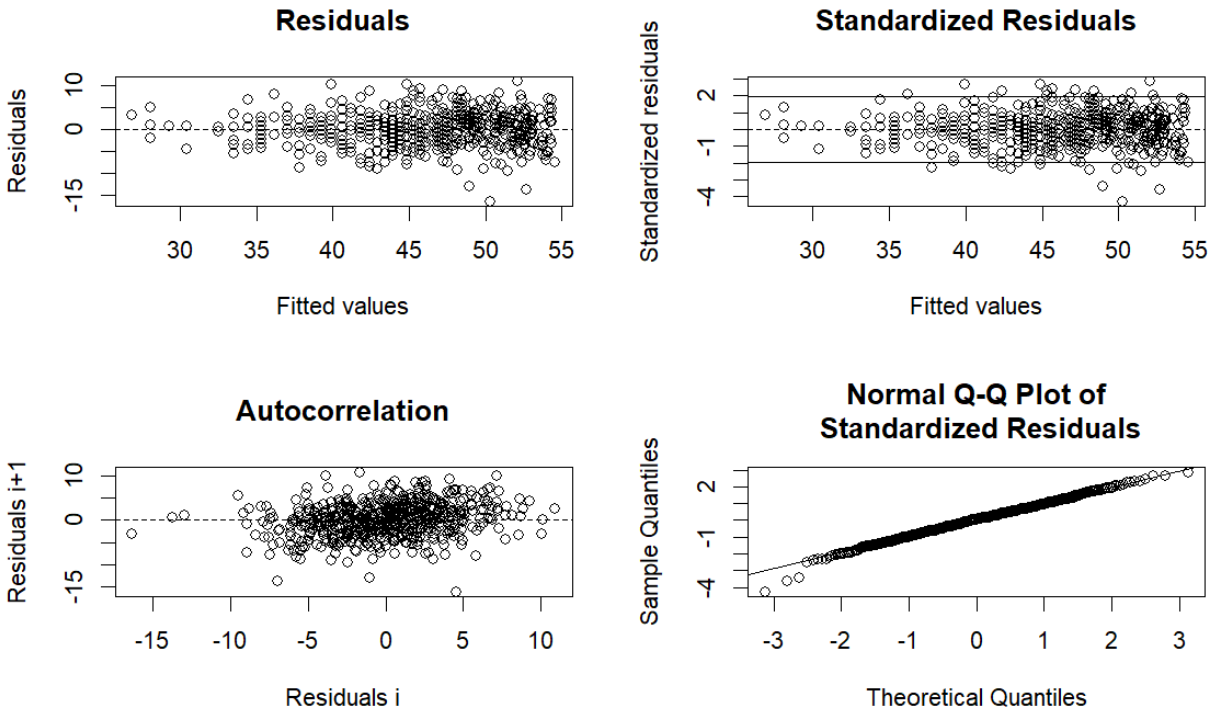


Figure C9: Residuals from the combined area and sex growth model.

Appendix D Terms or reference

Terms of Reference (ToR) for the provision of scientific services to SIOFA Scientific Committee

Project title: Age and growth of orange roughy (*Hoplostethus atlanticus*) Project Code: ORY-2023-01

1. INTRODUCTION

The SIOFA Scientific Committee (SC) is tasked to provide management advice for three important species (orange roughy, splendid alfonsino and Patagonian toothfish) to the Meeting of parties of SIOFA. CMM-15 (2020) paragraph 5 requires out that the orange roughy (*Hoplostethus atlanticus*) stocks shall assessed every three to five years. The first stock assessments of orange roughy were

conducted in 2018 (Cordue 2018a, 2018b) and the second assessments were in 2022 (Roa-Ureta 2022). The next stock assessment is scheduled for completion for SC10 in 2025.

There is some uncertainty in the growth curve estimates and maturity ogive for orange roughy, and particularly if there are differences between sexes and different areas in the SIOFA Area. In addition, age composition data are also required. Analyses of these data will be used to inform the next stock assessment of orange roughy.

This project builds on the work undertaken by Saunders (2021) and Brouwer et al. (2021) by developing age composition data and updating the growth and maturity curves for orange roughy (*Hoplostethus atlanticus*) on Walters Shoal (Walter's shoal, WSR and Seamounts) and on the southwest Indian Rise (Meeting, South Ridge, Middle Ridge and North Ridge) in the SIOFA area, using otoliths collected and held by the Cook Islands.

The previous age estimates will be made available to be included in this analysis to complement the data provided to this project and to evaluate differences in growth by sex, between these areas, and over time. Note, it is possible that not enough otoliths will be available from Southwest Indian Rise to produce sex separated growth curves for that area. In addition, age composition analyses may need to use otoliths aggregated over 2-3 years to obtain an adequate number of samples. The outcomes of this work should be collated in a preliminary report and presentation for SC9 in 2024 and a final report for SC10 in 2025.

2. TERMS OF REFERENCE

2.1. Objectives

1. Select 350 otoliths spanning the size range of fish caught at each of Walters Shoal and the Southwest Indian Rise in the SIOFA area (a total of about 700 otoliths).

2. Develop sex separated and combined sex growth curves for orange roughy in both areas and as single SIOFA growth curves.

3. Use the biological sampling to develop maturity curves for each area.

4. Provide growth and maturity parameters for the stock assessments.

5. Develop age composition data using random age sampling for both Walters Shoal and the Southwest Indian Rise in the SIOFA area.

2.2. Reporting Requirements

1. Provide updates and engage with the project advisory panel that will assist the consultant access and interpret reports, data, and to provide advice on relevant analyses or data interpretation for the project.

2. Present the preliminary methods and results of the project as indicated in Section 3. Take into account any comments made during this presentation in the following part of the work. 3. Provide a draft report detailing the methods, outcomes of project objective investigation as listed in the overall objectives, conclusions, and recommendations to the SIOFA project advisory panel for review by the dates indicated in Section 3.

4. Update the draft report in by considering any comments and advice from the project advisory panel and submit this final report to SIOFA Secretariat for submission to the following SIOFA Scientific Committee annual meeting.

5. Provide all the information collected to the SIOFA Secretariat (including that sourced from the Secretariat) before the final payment of the contract is made to the consultant. Such information includes electronic data files, analysis codes, biological samples, and other relevant data if applicable.

Presentations of reports to the Scientific Committee may be given virtually and travel to the meetings is not obligatory.

2.3. Confidentiality and distribution of project outcomes

The Consultant shall not release confidential data provided for conducting this study to any persons nor any organisations, other than SIOFA Secretariat. The consultant shall delete all the confidential data after the completion of the contract. Any arrangements for ownership, storage, or disposal of physical samples shall be agreed by SIOFA as a part of the contract.

All Intellectual Property generated as a part of this contract shall become the property of SIOFA unless otherwise excluded in the proposal and agreed by SIOFA in the contract.

All reports and presentations will be reviewed by the SIOFA Secretariat prior to any form of further distribution. The Consultant will revise the report according to comments received from the review process before the report or presentation is accepted as a submission against the requirements in these Terms of Reference.

2.4. Relevant SIOFA information

1. SIOFA data (provided by the SIOFA Secretariat upon request)

2. SIOFA spatial data layers. Available on

https://github.com/SIOFASecretariat/SIOFA_SC_Spatial_layers

3. SIOFA reporting templates. Available on

https://github.com/SIOFASecretariat/SIOFA_Reporting_templates

4. SIOFA reports:

a. SIOFA SC, SC Working Group, and National Reports. Scientific Committee Meeting | SIOFA (https://siofa.org/)

b. SIOFA MoP reports. Meeting of the Parties | SIOFA (https://siofa.org/)

c. SIOFA technical and scientific reports (public reports and abstracts of restricted reports are available from https://siofa.org/, and full restricted reports will be made

available by the SIOFA Secretariat to the project consultant upon request and after the approval of concerned CCPs.

3. WORK TIMELINE AND PAYMENT SCHEDULE

The funds for this project, budgeted under the SIOFA scientific funding scheme, allow for a maximum total budget of 40 000 Euro (including all costs and any travel related expenses).

The consultant shall follow the timeline described in Table 1 below.

Table 1: Timeline for payments, milestones, and report submission

Milestone	**Date**	**Activities**
Initiation of contract	30 September 2023	First instalment payment (30% of the total contract sum)
Presentation of preliminary results	18–27 March 2024	Presentation of preliminary methods and results to the SC9 meeting (virtual)
Delivery of draft report	15 April 2024	Second instalment payment (30% of the total contract sum) upon satisfactorily submission of a draft report, in a format suitable for submission to SC, to the project coordinator. The draft report must account for any comments received during SC9.

Delivery of final report	1 September 2024	Submission of final report in a format suitable for submission to SC10 and submission of project information to the project coordinator. Final instalment payment (40% of the total contract sum) on acceptance of the final report by the advisory panel and the final submission of project information

4. SUBMISSION OF APPLICATIONS

1. A current CV that summarises the applicant(s) relevant educational background and professional experience

2. A brief proposal (indicatively 1-2 pages) outlining the proposed methods and analyses, including a description of how the objectives of the ToR will be achieved

3. Any proposed exclusions to the intellectual property clause

4. The proposed consultancy price (including all consultant expenses and project related costs), noting that the available budget for this work indicated in Section 3

5. Identification of any project risks and associated mitigation and management required to successfully complete the project

6. A statement that identifies any perceived, potential, or actual conflicts of interest of the applicant(s), including those described in paragraph 4 of the SIOFA recruitment procedure (see Section 6), and

7. Any additional relevant information the applicant(s) wish to submit.

The applicants should have appropriate experience and knowledge of fish ageing, fitting of growth curves and maturity ogives, and their use for stock assessment, preferably for orange roughy.

Applications must be submitted to the SIOFA Science Officer Marco Milardi

(marco.milardi@siofa.org, CC secretariat@siofa.org). Only those applications received before 12:00 PM (9:00 AM UTC) on Friday the 1st of September, Reunion Island time, will be considered.

5. EVALUATION CRITERIA FOR THE SELECTION OF CANDIDATES

An evaluation panel, the SIOFA Secretariat, and the Chair and Vice-Chair of the SIOFA Scientific Committee will select one successful applicant for this contract. The selection criteria will include the following:

1. Adequate submission of information to allow the panel to evaluate the candidate 2. Evaluation of the proposal from the candidate, including the proposed contract price 3. Ability to undertake and complete the analyses or work required in this ToR 4. The candidate's agreement with confidentiality provisions required for the project 5. Acceptable conflict of interest statement

6. Agreement with the data submission and intellectual property terms required in this ToR, and 7. Financial and resourcing considerations.

6. CONFLICTS OF INTEREST. PARAGRAPH 4 OF SIOFA'S RECRUITMENT PROCEDURE

To ensure that situations relating to potential and actual conflict of interests are avoided, persons falling into the following categories may not normally be considered for SIOFA consultancy: (i). any person designated as a designated representative or alternate representative of a CCP to the Meeting of Parties (MOP) as per Rule 3.1 of the Rules of Procedure, and to the SC and any other subsidiary bodies of the MOP, as per Rule 21.3 of the Rules of Procedure; (ii). Any person fulfilling the function of Chair or Vice-Chair of the MOP or Chair or Vice-Chair of a SIOFA subsidiary body or working group; (iii). Any person acting as a member of a delegation involved in the SIOFA decision making process resulting in recommendations and/or approval for the SIOFA work requiring the engagement of a consultant; and (iv). Individuals who were SIOFA Secretariat staff members at the time when the recommendations and/or approval for the SIOFA works were adopted or who are members of immediate family (e.g., spouse or partner, father, mother, son, daughter, brother, or sister) of any Secretariat staff member or of the persons identified in 4 (i), (ii), and (iii).

7. CONTACTS

Project Coordinator – SIOFA Science Officer (Marco Milardi, marco.milardi@siofa.org)

Administration – SIOFA Executive Secretary (Thierry Clot, thierry.clot@siofa.org)

8. REFERENCES

Brouwer, S.; Wragg, C.; Dunn, A.; Saunders, R. (2022). Orange roughy age and growth in SIOFA from the Cook Islands fishery. SERAWG-04-09. Southern Indian Ocean Fisheries Agreement (SIOFA), 38 p.

Cordue, P.L. (2018a). Stock assessment of orange roughy in the Walter's Shoal Region. SAWG-01-05 rev 1. Southern Indian Ocean Fisheries Agreement (SIOFA), 57 p.

Cordue, P.L. (2018b). Assessments of orange roughy stocks in SIOFA statistical areas 1, 2, 3a, and 3b. SAWG-01-06 rev 1. Southern Indian Ocean Fisheries Agreement (SIOFA), 11 p.

Roa-Ureta, R., Wiff, R., Flores, A. (2022). Stock Assessment of the orange roughy (Hoplostethus atlanticus) under management by the Southern Indian Ocean Fisheries Agreement (SIOFA):2000 to 2020. SC-07-35. Southern Indian Ocean Fisheries Agreement (SIOFA), 63 p.

Saunders, R. (2022). Orange roughy otolith ageing (Project SER2021-02). SC-07-25. Southern Indian Ocean Fisheries Agreement (SIOFA), 18 p.

Appendix E Addendum to the terms of reference

ADDENDUM 1 To the

Short Form Agreement for Consultant Engagement SIOFA Project ORY-2023-01

Between: Southern Indian Ocean Fisheries Agreement (SIOFA), 13 Rue de Marseille, 97420 LE PORT, LA REUNION (UTC +4) *(Client)* **and:** National Institute of Water and Atmospheric Research Limited (NZBN: 9429038971433), 41 Market Place, Viaduct Harbour, Auckland 1010 (NIWA) *(Consultant)* Collectively referred to herein as the "Parties" and individually as a "Party"
Project: ORY-2023-01 *Age and growth of* **Location:** Wellington, New Zealand *orange roughy (Hoplostethus atlanticus)*

In the document referred above, please cancel to read

Objectives: 1. Select 350 otoliths spanning the size range of fish caught at each of Walters Shoal and the Southwest Indian Rise in the SIOFA area (a total of about 700 otoliths). 2. Weighing the otoliths and providing the weights and associated length and age data. 3. Develop sex separated and combined sex growth curves for orange roughy in both areas and as single SIOFA growth curves. 4. Use the biological sampling to develop maturity curves for each area. 5. Provide growth and maturity parameters for the stock assessments. 6. Develop age composition data using random age sampling for both Walters Shoal and the Southwest Indian Rise in the SIOFA area.

Deliverables:

1. Provide updates and engage with the project advisory panel that will assist the consultant access and interpret reports, data, and to provide advice on relevant analyses or data interpretation for the project.

2. Provide a final report detailing the methods, outcomes of project objective investigation as listed in the overall objectives, conclusions, and recommendations to the SIOFA project advisory panel for review. The draft report should be provided in a format suitable for submission to SC, to the project coordinator.

3. Update the final report in by considering any comments and advice from the project advisory panel and submit this report to SIOFA Secretariat for submission to the following SIOFA Scientific Committee annual meeting.

4. Provide all the information collected to the SIOFA Secretariat (including that sourced from the Secretariat) before the final payment of the contract is made to the consultant. Such information includes electronic data files, analysis codes, biological samples, and other relevant data if applicable. The Consultant shall not release

confidential data to any persons/organizations, other than SIOFA Secretariat, and shall delete all the confidential data upon contract completion.

Programme for the Services:

06/10/2023 Initiation of contract

1/09/2024 Delivery of final report

Fees & timing of payments:

Reports must be submitted to the SIOFA Secretariat and will be reviewed using procedures outlined in paper MOP-09-10 (Annex B), available at

https://github.com/SIOFASectetariat/SIOFA Reporting templates. Payment of contracts will be subject to satisfactory review and acceptance of the submitted reports by the SIOFA Secretaria**t**

€ 40,000 all tax included

06/10/2023 Initiation of contract First instalment payment (25% of the total contract sum)
15/05/2024 Progress payment Second instalment payment (25% of the total contract sum)
15/06/2024 Progress payment Third instalment payment (25% of the total contract sum)
1/09/2024 Delivery of final report Final instalment payment (25% of the total contract sum)

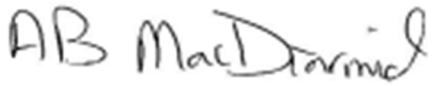
Additional Expenses:

2230 €: Weighing the otoliths and providing the weights and associated length and age data.

Any additional expenses will be paid with the final instalment payment once the final report will be validated by the Scientific Committee.

Client authorised signatory(ies):

Consultant authorised signatory(ies):



Print name: Thierry CLOT **Date:** 30/5/2024

Print name: Alison MacDiarmid -n Senior Regional Manager

Date: 30/5/2024