Australian Government

Australian Fisheries Management Authority

Enhancing biological data inputs to Torres Strait Spanish mackerel stock assessment

2019/0832

June 2020

This report can be referenced as:

Langstreth J.C. and O'Neill M.F., 2020. *Enhancing biological data inputs to Torres Strait Spanish mackerel stock assessment.* Torres Strait AFMA Project Number: RR2019/0832. Department of Agriculture and Fisheries, Queensland Government.

This publication has been compiled by JC. Langstreth of Fisheries Queensland, Department of Agriculture and Fisheries.

1 Acknowledgements

The authors recognises and thanks the project team comprising of project partners:

- Andrew Trappett (Australian Fisheries Management Authority, AFMA), Allison Runck (Torres Strait Regional Authority, TSRA), Malcolm Pearce, Dr. Michael O'Neill, Tom Roberts and Sian Breen (Department of Agriculture and Fisheries, Queensland (DAF)) who provided an advisory and project steering role as well as provided a review and comments on the draft report;
- TSRA staff including Elizabeth McCrudden, Neville Johnston, and Selina Samai, for their extensive assistance in organising and facilitating inter-island travel and workshops;
- Dr. Michael O'Neill (DAF) for his input into the sampling design and knowledge of Torres Strait Spanish mackerel fisheries biology;
- DAF Fisheries Queensland staff Cassandra Peters, Michelle Stewart, Wayne Hagedoorn, Daniel McInnes, Jayden Zieth and Katrina Kaposi for their widespread support with data, fish ageing, sampling and laboratory processing;
- Cr. Rocky Stephen for his support to the project and assistance during workshops within island communities;
- Commercial Torres Strait Spanish mackerel fishers, fish buyers, processors and community members that collected biological data and samples for the project including: Egon Stewart, Brad Snow, John 'Freddy' Bennetts, Simon Naawi, Pau Stephens, Akasha Stephens, Melanie Karo, Dan Sailor, John Mosby, Hilda Mosby, Paul Lowatta.

We acknowledge and thank AFMA for funding the project and reporting through the Torres Strait Scientific Advisory Committee, in collaboration with additional funding and support from TSRA and DAF, and additional reviewers of this report including Jason McGilvray (DAF).

Many warm thanks to all the island communities and councils and Protected Zone Joint Authority members for allowing us to access the communities to conduct this research.

Ethical clearance and oversight was granted for this project by the Torres Strait Scientific Advisory Committee.

2 Acronyms

ABARES	Australian Bureau of Agriculture and Resource Economics and Sciences
AFMA	Australian Fisheries Management Authority
ALK	age length key
DAF	Department of Agriculture and Fisheries, Queensland
FL	fork length
FQ	Fisheries Queensland
JL	jaw length
n	number or count of samples
PZJA	Protected Zone Joint Authority
Sunset	Sunset licence holder/sector
TIB	Traditional Inhabitant Boat
TL	total length
TSRA	Torres Strait Regional Authority
TVH	Transferrable Vessel Holder

3 Summary

Torres Strait Spanish mackerel are harvested by line fishing from ocean waters between Cape York Peninsula (north-east Australia) and the western province of Papua New Guinea. Spanish mackerel are an iconic fish for Torres Strait communities and an important economic food source, with recent commercial harvests in the order of 82 t.

The commercial fishery is highly focused, with Spanish mackerel taken mostly between September and November. Commercial harvests are mostly from the eastern Torres Strait, and concentrated on north-eastern waters around Bramble Cay.

Two commercial sectors, a traditional inhabitant boat (TIB) and non-traditional sector (sunset licence sector) target Spanish mackerel. Fish catch and catch rate data from the two sectors support the stock assessment for Torres Strait Spanish mackerel.

Recent declines in Spanish mackerel catch rates have driven a need to collect new biological fish age-length information. This is to support future stock assessment investigations on recent declines, and help inform management decisions on sustainable levels of catch.

New biological sampling of Torres Strait Spanish mackerel was conducted in 2019-2020 to address a long-term critical need for updated fish age-length information. The data adds to the historical fish age-length data collected 15–20 years ago, in 2000-2002 and 2005.

A sampling program was employed to collect mackerel frames from both traditional inhabitant and non-traditional commercial fishing sectors. Many fishers and community members assisted to collect samples from fish frames and measure the lengths of fish in commercial catches.

Overall, an estimated 20 percent of the 2019–2020 fishery harvest was measured. Most of the sampling (80–90 percent) occurred between August 2019 to January 2020. Only two fishing areas outside of Bramble Cay were sampled, in the central and eastern Torres Strait.

The 2019–2020 patterns of Spanish mackerel age-lengths were truncated with few fish older than about five years of age. Most fish were aged between 2–4 years old. Results were similar to the data from 2000-2002 and 2005.

In 2019-2020, the oldest Spanish mackerel found was 13 years of age. This was one year older than the oldest fish previously recorded. Spanish mackerel were measured between 69 and 145 cm fork length (FL), with a majority between 88 and 106 cm.

Future sampling needs to build on the spatial coverage of sampling, particularly outside of the main Bramble Cay fishing ground. This is to test for any spatial bias, as most of the stock assessment information was from Bramble Cay. A finding of older fish from other

fishing grounds might suggest a higher abundance of Spanish mackerel, than as indicated from recent catch rates.

Continued annual fish age-length sampling is essential to monitor trends and patterns in the abundance of Spanish mackerel recruitment and cohort strengths. This is to improve stock assessment forecasts and management procedures.

Fishers from island communities within the eastern and central Torres Strait were key to the data gathering throughout the project. Participation of Traditional Owners and Inhabitants was fostered by community workshops which focused on opportunities for local involvement in sampling and data collection. Continued partnerships with key stakeholders, regular community engagement and feedback of project results will continue to build and promote trust to support effective working relationships between communities and researchers.

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4 Objectives

The objectives of the project included:

- Design a cost effective and efficient sampling program to collect the required fishery dependent biological data from fishers (ageing data and length frequency analysis) for informing the assessment of stock status and catch limits for Spanish mackerel in the Torres Strait.
- Engage with non-indigenous and indigenous fishing sectors to collect fish length measurements and determine length-frequency. Collect and process fish specimens and conduct ageing of fishes sampled as per existing standardised Spanish mackerel ageing protocols and quality assured methodologies.
- Construct and report on age and length-frequency.

5 Introduction

Australia's Spanish mackerel, *Scomberomorus commerson*, are large pelagic fish that are harvested by line and net fishing from tropical and sub-tropical ocean waters. They can weigh in excess of 30 kg, mature between two and four years of age and live for up to 26 years (McPherson 1992; McPherson 1993; QDAF 2018). Growth is extremely rapid in the first 2 years slowing with the onset of maturity (McPherson 1981; Mackie et al. 2003). Growth of Spanish mackerel appears to be sex specific after the first 2 years, with females growing faster, larger and living longer than males (McPherson 1992; Tobin and Mapleston 2004; McIlwain et al. 2005).

Current research identifies Spanish mackerel in neighbouring waters of the Gulf of Carpentaria and along the east coast of Australia as separate biological stocks from those in the Torres Strait and recommendations from this research are such that Torres Strait Spanish mackerel be regarded as a discrete meta-population for management (Buckworth et al. 2007).

Spanish mackerel are an iconic fish for Torres Strait communities and an important economic food source (Begg et al. 2006; Busilacchi et al. 2014; Williams et al. 2019). Within the Torres Strait Spanish Mackerel Fishery there are two commercial sectors: Traditional Inhabitant Boat (TIB) and Sunset Licence holders, both of which are line fisheries.

In 2008, the Australian Government funded a 100% buyback of Transferrable Vessel Holder (TVH) fishing licences, such that the catch entitlements in the fishery are 100% owned by the traditional inhabitant boat sector. As a condition of the buyout, the Protected Zone Joint Authority (PZJA) agreed that the TSRA would hold and lease out temporary licences until the TIB sector could increase its catch to the full allocation.

The TSRA manages the leasing out of fishing licences each fishing season on behalf of traditional inhabitants of the Torres Strait. The TIB sector has a large number of licenced operators (>200) harvesting a small amount of catch (2-11 t in 2017-18[1]). The non-traditional Sunset sector harvests most of the catch (77 t in 2017-18[1]) and consists of a small number of operators (<6), accessing the fishery through the temporary annual 'sunset' licence which is leased from the TSRA. These operators mainly target Spanish mackerel spawning aggregations around Bramble Cay during August to December and to a lesser extent target other fishing grounds around eastern Torres Strait. The sunset sector is regulated to no fishing within 10 nautical miles of the eastern Torres Strait communities of Masig, Ugar, Erub and Mer which drives some spatial differentiation in the use of the fishery by sector.

Previous monitoring of Torres Strait Spanish mackerel was conducted by the Queensland Government (DAF) between 2000 and 2002 to obtain biological information (O'Neill and Tobin 2016). The monitoring was conducted on board commercial non-traditional fishing operations, and focused on the main fishing grounds of Bramble Cay during October-November. The observer processed filleted fish frames to collect for length, otoliths, gonads and genetic samples, with most fish sampled from morning catches. See Begg et al. (2006), Langstreth (2015) and McPherson (unpublished) for more detail.

A research project conducted by the Cooperative Research Centre for the Torres Strait adopted similar protocols to sample Spanish mackerel in 2005 (Begg et al., 2006). There has been no length-age information collected from Torres Strait Spanish mackerel since this 2005 study.

The stock assessment for Torres Strait Spanish mackerel uses an integrated age-structured model and catch and effort data (O'Neill and Tobin 2016). The biological information used in the most recent assessment is based on early fishery-dependent surveys conducted in 2000 to 2002 (O'Neill and Tobin 2016) and in 2005 (Begg et al. 2006). In 2019 the Torres Strait Scientific Advisory Committee, on behalf of the Protected Zone Joint Authority (PZJA) together with the Torres Strait Regional Authority (TSRA), funded the identified need to update the age-length information for the fishery based on recommendations from the recent stock assessment (O'Neill and Tobin 2016) and supported by both the PZJA Torres Strait Finfish Fishery Resource Assessment Group and Working Group. Recent concerns in declining catch rates have also driven the collection of data as a high priority.

The results of project number 2019/0832 "*Enhancing biological data inputs to Torres Strait Spanish mackerel stock assessment*" are provided and will inform an updated stock assessment of the Torres Strait Spanish mackerel stock.

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1 https://www.pzja.gov.au/sites/default/files/2018_torres_strait_spanish_mackerel_stock_assessment_update.pdf

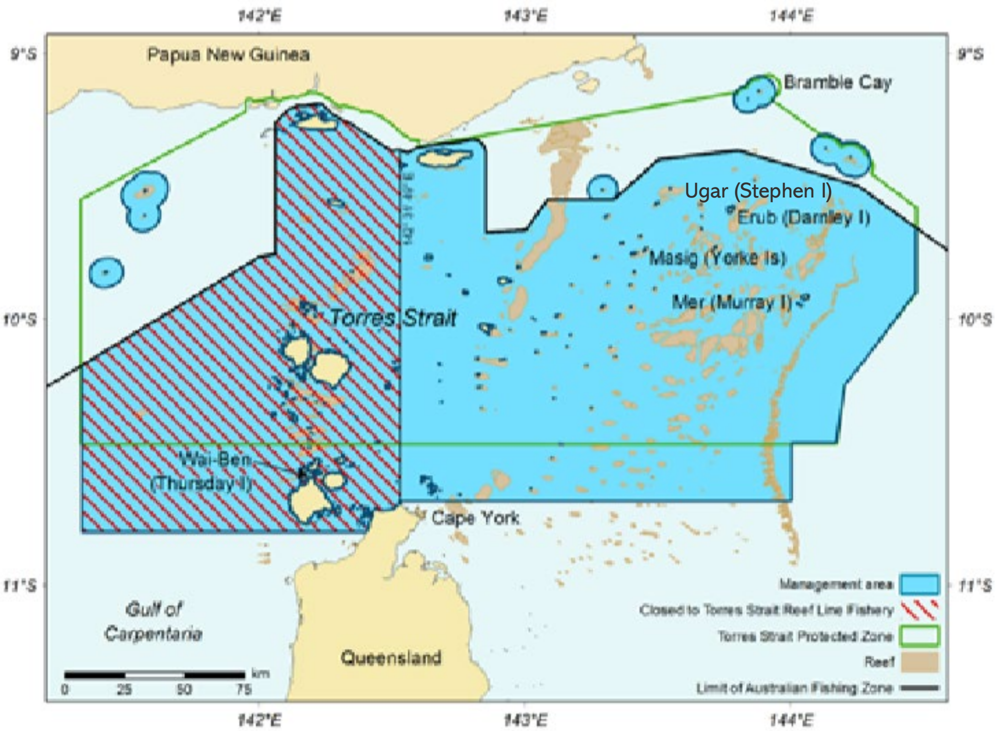
6 Methods

6.1 Engagement

The sampling program relied on the cooperation of commercial fishing sectors and community members to voluntarily allow access to their catches and to assist with data collection.

A process of engagement was conducted to directly involve the traditional inhabitants of central and outer eastern islands communities of Ugar, Erub, Masig and Mer (Figure 1), where the highest commercial TIB catches of Spanish mackerel are known to occur. The objectives of the engagement were to consult with the communities to inform about the research, seek input into the sampling strategies and design, seek involvement in the research, provide training and provide an opportunity for people to voice any concerns or objections relating to the research.

Figure 1. Area of the Torres Strait Finfish Fishery that includes the Torres Strait Spanish Mackerel Fishery. The management area for the Australian (Torres Strait) component is shaded blue. The map was sourced from the ABARES Fishery status report 2019 (Williams et al. 2019).



Project staff worked within the *Procedural Framework for Researchers in the Torres Strait* (Nakata 2018) and the *TSRA Cultural Protocols Guide* (TSRA 2011) when applying for project funding, and when planning and conducting visits to the Torres Strait to work with Traditional Inhabitants. Project staff sought advice from Torres Strait Regional Authority and PZJA consultative committees that regularly work within these cultural guidelines and have established relationships with key Torres Strait island contacts.

Additional to the human ethics considerations provided by the Torres Strait Scientific Advisory Committee research funding process, internal oversight was conducted by project staff. As stated in the Nakata framework (Nakata 2018), Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) maintain the *Guidelines for Ethical Research in Australian Indigenous Studies* (2012)(GERIAS)[1] which is the primary Indigenous research ethics guide used in Australia alongside the *National Health and Medical Research Council (NHMRC) Values and Ethics: Guidelines for Ethical Conduct in Aboriginal and Torres Strait Islander Health Research*[2] and the *National Statement on Ethical Conduct in Human Research 2007 (updated 2018)*[3].

These national guidelines (GERAIS) aim to improve the standards of engagement and benefits that research can offer Aboriginal and Torres Strait Islander peoples[2]. These guidelines were considered and a process for ethical oversight of the project established. Proposed actions against each of the 14 GERAIS principles were developed and these actions considered and approved by the Torres Strait Scientific Advisory Committee.

One of the key actions included ensuring that free prior informed consent is in place for the acknowledgement, attribution, and citation of local traditional knowledge and fisheries data. A copy of this project summary and informed consent form used to attain consent during initial engagement is provided in Appendix 2. Communities were advised of the community visits through notifications and discussions with island councils. All community members were invited to workshops using methods such as notices on community notice boards (example in Appendix 3).

A series of two workshops were conducted within each community between September and November 2019. Initial island workshops discussed the project objectives and sought involvement from traditional fishers, fish buyers and fish processors in the collection of fish samples and data. Follow-up workshops, approximately 6 weeks later, were conducted to continue discussions, progress sampling and solve data and logistic issues around collecting and freighting samples, and present project updates. Unfortunately, due to unexpected in-community events during scheduled visits, the two workshops in the community of Mer were unable to be conducted in 2019-20.

All members of each community were invited to workshops and participants were represented by commercial fishers and their families, fish buyers and processors, Torres Strait Island Regional councillors, traditional inhabitant members of PZJA advisory committees, council staff, and community members. Training on how to collect samples and record fish lengths was provided during these workshops, as well as provision of sampling kits.

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[1] https://aiatsis.gov.au/sites/default/files/docs/research-and-guides/ethics/gerais.pdf

[2] https://www.nhmrc.gov.au/research-policy/ethics/ethical-guidelines-research-aboriginal-and-torres-strait-islander-peoples

[3] https://www.nhmrc.gov.au/about-us/publications/national-statement-ethical-conduct-human-research-2007-updated-2018

2 https://aiatsis.gov.au/research/ethical-research

All five non-traditional Sunset fishers with 2019-20 Spanish mackerel catch allowance under a leased Sunset licence were consulted on the project and invited to be involved in data and sample collection. Four out of the five fishers were provided with sampling kits and training which represented the majority of fishing effort targeting mackerel in the fishery.

6.2 Data collection

6.2.1 Sampling design

Early length-age data collection for Torres Strait Spanish mackerel (2000-2002, 2005) was primarily focused on the main fishing grounds around Bramble Cay during the main fishing season (Oct-Nov) (Begg et al. 2006; O'Neill and Tobin 2016). These data were collected during on-board surveys of non-traditional fishing operations. This project aimed to collect updated length and age information and to increase the spatial and temporal representativeness of the Torres Strait Spanish mackerel fishery to capture information from catches of traditional fishing operations, from months outside of the main October-November fishing season, and from fishing grounds outside of Bramble Cay.

Target sample sizes were determined prior to the commencement of sampling and were based on knowledge of DAF's routine annual sampling programs of Spanish mackerel stocks along the east coast and in the Gulf of Carpentaria, together with advice from Torres Strait Spanish mackerel stock assessment scientists and discussions with the project team. Targets included a total of 1500 fish lengths from around 50 individual ungraded catches, and otoliths and sex information from around 500 fish.

Whilst targets had been set based on suitable yet realistic sample numbers, it was important to keep in mind that participation by commercial fishers and community members was voluntary. The success in the sampling design is underpinned by good levels of participation across both sectors and multiple participants within each sector. Furthermore, the majority of the harvest is taken by a small number of non-traditional operators. With this in mind, a significant focus of the first year of a fishery-dependent sampling program involved developing relationships with fishers and stakeholders to encourage participation.

Samples of fish tissue were collected opportunistically from fish frames/heads in order to start a collection of fine scale spatially representative genetic fish samples to further examine stock assumptions and boundaries (O'Neill and Tobin 2016) and close-kin genetic assessments.

Financial year, rather than calendar year, was used in the report as this period better depicts the fishing season as well as when spawning and recruitment to the fishery occurs.

6.2.2 Field collection

Length structure

Commercial fishers recorded the fork lengths of Spanish mackerel from whole unbiased (ungraded) catches onto waterproof measuring sheets with measurements to the nearest 1 cm. The measuring sheets were attached to a board with an aluminium end piece via two holes at one end. Where fishers could not measure an entire unbiased catch, they recorded the percentage of the catch. This representative length data was used to construct a length structure for the fishery.

Catches were defined as the fish from one morning or afternoon session or from a pooled number of dories or days, as long as the total number of fish caught, the proportion sampled, and the date(s) were recorded.

Age and sex-at length

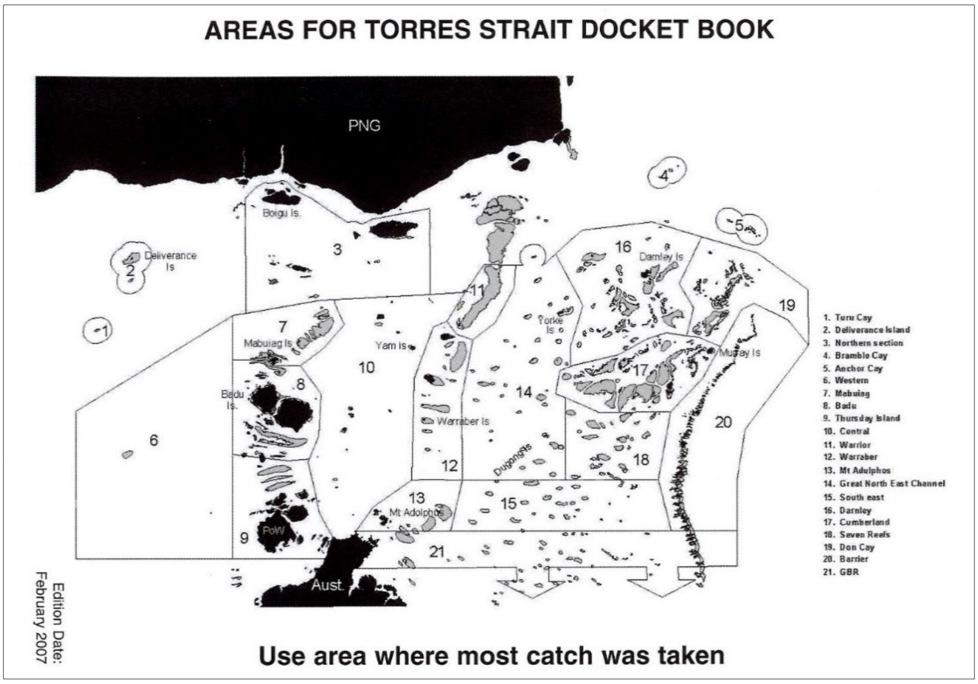
Commercial fishers collected samples of heads and gonads or whole filleted fish frames (with gonads) and were provided with equipment necessary to do this. Fish were selected randomly by sex, and therefore the sex ratio was representative of the catch within each length class.

Fish heads or frames provided were not all randomly selected by length, with the largest fish heads in the catch (fish weight >20 kgs) collected in order to sample larger and older fish. These samples are therefore biased by length, but not by age and sex within each length class.

Some fishers were asked to collect fork length measurements using a piece of cord cut to the fork length of each fish and provide these cords together with the head and gonads of the fish. The samples were freighted back to the laboratories in Cairns where they were processed by DAF staff. We removed otoliths and determined the sex of each fish provided in order to develop an age-at-length relationship (age-length key) that transformed the length structures into a representative age structure of the fishery.

Along with the biological material and length data, information on the catch including date caught, a general catch location and vessel name were provided by fishers with the fish samples and length data. Vessel name was recorded primarily to be able to track samples. Fishers were asked to provide position information as a general catch location that could include a reef or island name or a numbered region as per the Torres Strait fishery docket book (Figure 2).

Figure 2. Reporting areas for the Torres Strait docket book used by fishers to record the location of their sampled catch. Map sourced from the 2019 Torres Strait docket book.



6.2.3 Laboratory processing

Most of the fish samples were processed in the laboratories at the DAF's Northern Fisheries Centre in Cairns. Some of the samples were opportunistically processed in community during visits to conduct workshops.

Fish heads were measured by using callipers to measure the upper jaw length (Figure 3) of each fish to the nearest 1mm. If access to whole frames was possible, fork length and total length (Figure 4) were also measured to the nearest 1 mm. Where fishers had provided a cord cut to the fork length of the fish, this was measured on a measuring board in the laboratory also to the nearest 1 mm.

The otoliths (ear bones) are located in the cranial cavity and were accessed from the top of the head by making a dorsal transverse cranial incision with a saw or knife, cutting towards the back of the head (Figure 5). Otoliths were then removed using fine pointed forceps. Once removed, the sagittal otoliths were dried carefully with tissue and stored in a 5 ml plastic vial labelled with a unique sample number. Otoliths were left to further dry for around 48 hours with the cap removed before capping with a lid.

Sex information was recorded whenever it was available. Sex was determined by macroscopically examining the gonads, or the residual pieces of the gonads connected to the frame. If this was not possible, sex was recorded as unknown.

Genetic samples were opportunistically collected from samples during processing. For this a small piece of tissue (approximately 2 mm in diameter) was removed from the fleshy portion at the dorso-posterior of the fish's head. Each sample was placed in a 2 ml vial filled with ethyl alcohol, labelled with a unique sample number and stored in the laboratory freezer.

Ancillary data including catch date and location were recorded along with the biological data and all information was entered into an MS Access database and stored securely on the DAF server.

Figure 3. Upper jaw length measurement of a Spanish mackerel using Vernier callipers.

Figure 4. Position of fork and total length measurements collected from Spanish mackerel.

Figure 5. Stages of otolith extraction for a Spanish mackerel.

6.2.4 Fish ageing

Fisheries Queensland, part of the Department of Agriculture, Fisheries and Forestry, follows a standardised approach for routinely estimating the age of fish using otoliths (DPI&F 2007). For Spanish mackerel this process involves examining whole sagittal otoliths under a microscope and identifying alternating opaque and translucent zones on the otoliths. Fisheries Queensland routinely interprets otoliths collected from both the Australian east coast stock and from Gulf of Carpentaria waters (part of the northern Australian stock). Whilst the general otolith morphology is similar between the two stocks, there are subtle differences in the interpretation of the otolith and therefore separate protocols and quality assurance criteria are used for the two stocks (FQ. 2013).

A subset of Torres Strait otoliths collected were randomly selected and assessed for their similarity in macrostructures to otoliths from both Gulf of Carpentaria and east coast fish. They were observed to be more similar to those from the Gulf of Carpentaria across otolith clarity, increment patterns and formation (C. Peters, pers.comm., 2020). The standardised fish ageing methods for Gulf of Carpentaria Spanish mackerel (FQ. 2013) were used to interpret Torres Strait fish otoliths for this project.

A staff member experienced in reading Spanish mackerel otoliths trained on a reference set of otoliths with agreed interpretations. A competency test on 200 randomly selected otoliths from the reference set was then undertaken. The otoliths were interpreted for:

- increment count – the number of opaque zones counted between the primordium (nucleus) and the distal (outside) edge of the otolith,
- edge type - the edge of the otolith is classified as new, intermediate or wide. Intermediate and wide classifications are based on the relative stage of completion of the marginal translucent zone (Table 1), and
- readability - not-confident, confident, unreadable, processing error.

Otolith increment counts were tested for bias and precision and edge classifications were tested for overall agreement. These quality control measures are used during reader competency before a sample of otoliths are interpreted (DPI&F 2007, FQ. 2013) to ensure precise and unbiased results. Following this competency process, the 255 otoliths collected during the project were then interpreted followed by a re-read of a 200 randomly selected subset. Standard bias, precision and agreement measures were assessed and fell within acceptable levels.

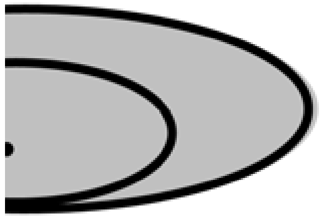
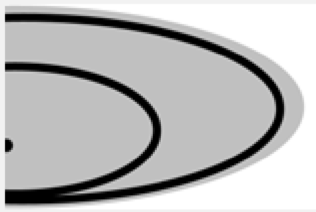
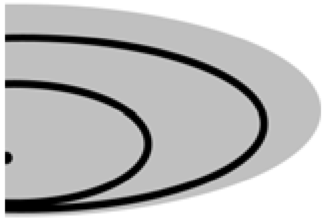
Edge type	Description	Example diagram
1 - new	Opaque material is visible on the otolith edge. The opaque material need not be continuous around the entire edge. A narrow amount of translucent material may be visible in some areas on the otolith edge.	
2 - intermediate	A continuous band of translucent material is visible on the outermost edge of the opaque zone. This marginal translucent zone is less than 2/3 complete.	
3 - wide	Marginal translucent zone is more than 2/3 complete.	

Table 1. Fish otolith edge type categories and descriptions assigned to each fish during ageing with example diagrams for each category.

6.3 Data analysis

6.3.1 Length and weight conversions

Multiple length measures from individual fish were collected where possible, elsewhere existing conversions were used to calculate values for other length types (Table 2).

Both fork length from the measured cord and a fork length derived from a jaw-fork conversion (Table 2) was collected if the fork length was not measured from the frame. The fork length derived from the jaw-fork conversion was used in the data analysis for this report. The additional fork length measures from the cord were retained for further comparative analysis given a jaw-fork conversion for Torres Strait Spanish mackerel stock is not currently available and the need for a feasible and appropriate method needs to be further investigated.

Individual fish weight was calculated using sex-specific total length-weight conversions for Torres Strait Spanish mackerel developed by Begg et al 2006 (Table 2).

Conversion	equation	source
Fork to jaw length (mm)	Pooled: $FL = 2193.05464879 - 2488.94980184*(0.99376283^{JL})$	DAF (2016) unpublished.
Fork to total length (mm)	Pooled: $TL = 4.274 + 1.06 \times FL$	Mackie et al. (2003)
Total length (cm) to weight (kg)	Female: $W = 2.960e^{-6} * (TL^{3.148})$ Male: $W = 4.224e^{-6} * (TL^{3.068})$ Pooled: $W = 2.718e^{-6} * (TL^{3.165})$	Begg et al. (2006)

Table 2. Equations and source of length and weight conversions used in data analysis. FL – fork length. TL – total length. JL – jaw length. F – female, M – male, P – pooled.

6.3.2 Length structures

Individual fish counts were scaled to the percentage of the catch to account for any subsampling. Individual adjusted lengths were allocated into a 2 cm length class. Summed scaled counts were then used to calculate the proportion of fish within each length class.

Length structures were pooled by sex and calculated for each sector. Due to representative lengths measured from a low number of primary vessels for each sector, data was also pooled across sector for reporting purposes.

6.3.3 Age allocation

The number and proportion of each otolith edge type were summarised to determine the distribution of each edge type across each month sampled between August 2019 and January 2020. This information was used to allocate each fish into an age group. Age group (cohort), which is expressed in whole years, was the maximum age a fish would reach during the 2019-20 sampling season.

Spanish mackerel growth is extremely rapid in the first few years of life, with annual growth in the first year averaging 93 cm TL (Begg et al. 2006). To adjust for growth of individual fish over the sample period, fish length was adjusted to the length at a nominal birthdate. Spanish mackerel have a protracted spawning season in the Torres Strait, between August and March (McPherson 1986). The nominal birth date assigned was 1 November as the middle of the 'expected' peak in the estimated spawning season. Adjusted length was calculated using the von Bertalanffy growth equation defined as:

$$L_t = L_\infty \left(1 - \exp^{-K[t - t_0]} \right) + \varepsilon ,$$

where L_t was the length at age t, L_∞ is the asymptotic mean length, K is the growth coefficient, t is the age of fish when captured, t_0 is the theoretical age of fish at which mean length is zero, and ε indicates that residuals are assumed to be distributed normally about the fitted growth curve. Growth coefficients from the 2019-20 individual length at age data were modelled using R program software package '*fishmethods'* utilising the '*growthmultifit*' and '*growth'* functions for male, female and pooled sex. Growth coefficient outputs from the model were utilised in the adjustment of length are provided in Table 3 with further results outputs provided in Appendix 4. It is noted that values of t_0 are highly negative for females and pooled sex. This is due to the nature of the fishery dependent sampling conducted that does not sample undersized fish and is biased for 0+ and 1+ age groups. These growth parameters are only used for the adjustment of length.

sex	Total n	L∞	K	t_0	standard error
female	152	150.1555 (10.2366)	0.1461 (0.0405)	-5.0628 (1.29719)	6.86
male	74	109.8319 (11.26920)	0.5697 (0.1520)	-1.3037 (0.6215)	5.14715
pooled	252	142.7557 (13.65983)	0.1604 (0.05749)	-4.7961 (1.63011)	7.14786

Table 3. Sex-specific von Bertalanffy growth parameters used to calculate adjusted length. The overall standard error of the observations for each sex are provided. Standard errors for each parameter estimate are provided in brackets.

6.3.4 Age length key

One age length key was generated for combined sexes for the 2019-20 samples using adjusted length allocated within a 2 cm length class and age group. The count of fish in each 2 cm length class was determined for each age group. From these, the proportion of fish in each length class was calculated for each age group to construct the age length key.

Gaps in the age length key were identified as missing rows in the matrix that had matching lengths in the length structure. Given the low sample sizes of fish ages in the smaller length classes and limited missing rows, these were filled manually following inspection of the length distributions of fish in the 1+ to 4+ year age groups. To do this, the proportion of selected age groups in the missing length classes (rows in the matrix) were filled with the appropriate allocation so that each row in the matrix added to 1.

Gaps in the upper distribution were not filled due to the low count of larger fish in the age length key and the low sample size of larger fish in the representative length structure. The number of fish in these larger size classes that are not included in the age structure is presented and the effect of this is discussed. This should be addressed with further consecutive years of sampling.

6.3.5 Age structures

Age structures were constructed using the pooled-sex 2 cm adjusted fork length structure and the constructed age length key described above. Fish within each length class were assigned to an age group based on the proportion of ages in the age length key. The proportion of fish in each age group were then calculated to develop the age structure for 2019-20.

7 Results and discussion

7.1.1 Data summary

From August 2019 to January 2020, the length measurements of 1,475 Torres Strait Spanish mackerel were recorded from 41 individual commercial catches (Table 4). Fish measured represented 1,571 fish lengths when subsampling was accounted for. All catches were randomly sampled at greater than or equal to a 50% subsample and were considered representative of the entire catch. Only 15% of catches were not fully recorded at 100% measurement.

The majority of fish lengths collected were from the Sunset sector (96.9%) with 49 fish (3.1%) from six catches sampled from the traditional TIB sector (Table 4). The majority of the commercial harvest is taken by the Sunset sector (55.6 t, 96.6% in 2019-20) with the remainder taken by TIB fishers (1.98 t, 3.4%) (AFMA 2020).

The proportion of sampling conducted in 2019-20 across each sector represents the contribution of each sector to the fishery. Based on estimates of total whole fish weight sampled in 2019-20 (11.8 t), the proportion of the commercial fishery reported through catch disposal records sampled was estimated at a total 20.5%, with 18.0% of the TIB and 20.6% of the Sunset sectors (Table 4). Although sample sizes reflect the sector catch share for the fishery and total fishery sampling was estimated at 20.5% in 2019-20, the sample size of fish lengths caught by traditional fishers may not capture the full variability in size of fish caught to enable length structure to be presented separately.

Length measurements were collected across three of the fishery areas. The majority (95.4%) were from catches at the Bramble Cay fishing grounds (Table 5) in Area 4 of the fishery (Figure 2) where the majority of the commercial catch is taken (e.g. 88 per cent of the fishery catches in the 2016-17 season (PZJA Finfish Resource Assessment Group

Meeting 1, November 2017[3])). A smaller sample size of 24 and 47 lengths were collected outside of these grounds within Area 14 and 16 respectively (Table 5).

A total of 255 Torres Strait Spanish mackerel otoliths were collected with assistance from seven individual commercial fishers (Figure 6). Sampling occurred between the months of August 2019 and January 2020. The greatest number of length and otolith samples were collected in November. Sex information was collected from 90% of the fish sampled for otoliths.

Future sampling would benefit from enhanced sample sizes within the TIB sector as well as increased sample sizes from areas outside of the Bramble Cay grounds, from both commercial fishery sectors. This would help to test for any spatial bias, as most of the information included in stock assessment was from Bramble Cay (O'Neill and Tobin, 2016). A finding of older fish from other fishing grounds might suggest a higher abundance of Spanish mackerel, than as indicated from recent catch rates.

[3] https://www.pzja.gov.au/sites/default/files/tsffrag_1_091117_papers.pdf

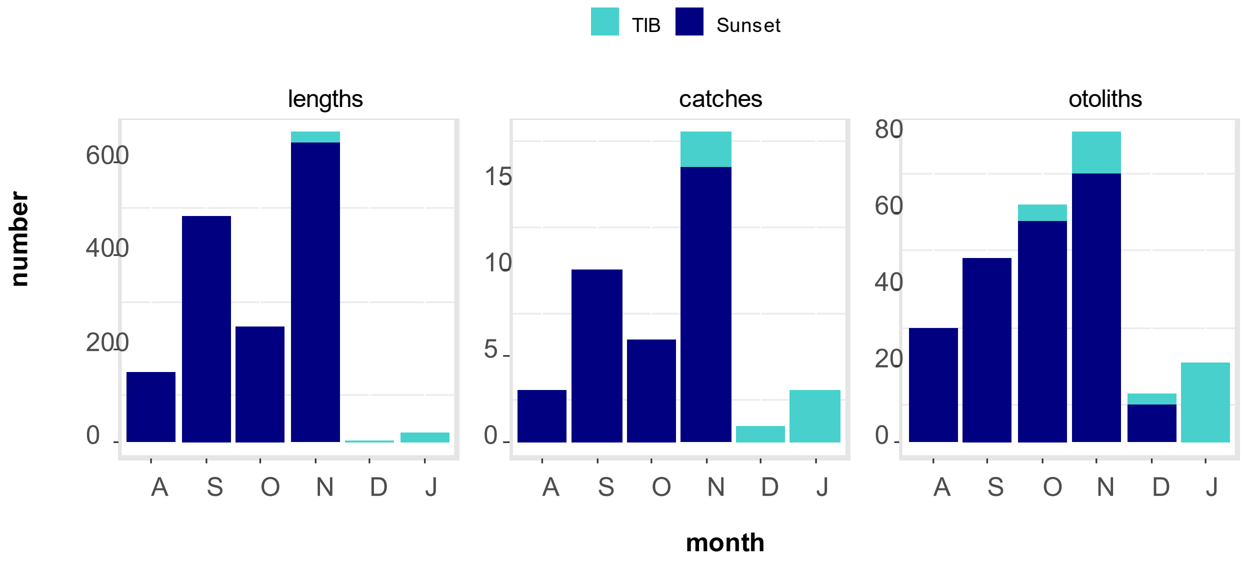
Data type	Total number	TIB	Sunset
Lengths (subsampled)	1,475	49	1,427
Lengths (scaled)	1,571	49	1,522
Catches	41	6	35
Number of primary vessels	5	3	2
Whole weight sampled*	11.8 t	0.36 t	11.43 t
Whole weight reported**	57.55 t	1.98 t	55.6 t
Proportion sampled***	20.5%	18.0%	20.6 %
Otoliths	255 (7)		
Sex data	230 (5)		
Genetic samples	125		

Table 4. Sample sizes of Spanish mackerel length and age information collected during 2019-20. Total samples sizes are provided for each data type as well as the number of representative lengths and catches per fishing sub-sector, Sunset and TIB. Numbers of individual fishers or primary vessels indicate the number from which the information was collected for representative fish lengths. * whole wet weight of sampled fish calculated from fork length. ** Commercial whole wet weight of Spanish mackerel reported via catch disposal records in 2019-20 (AFMA 2020) * represents proportion of the whole fish weight of fish sampled compared to the total catch estimate for 2019-20 fishing year.**

Data type	Area 4 (Bramble Cay)	Area 14	Area 16
Lengths (subsampled)	1,499 (1409)	24 (24)	47 (42)
Catches	34	4	3
Otoliths	198	27	30
Sex data	198	3	29
Genetic samples	103	22	

Table 5. Sample sizes of Spanish mackerel length and age information collected during 2019-20 across the Torres Strait docket book reporting areas (map of areas shown in Figure 1). Numbers in brackets represented the

Figure 6. Seasonal spread of Spanish mackerel sample sizes of lengths, catches and otoliths by month and fishing sub-sector collected between August 2019 and January 2020.



7.1.2 Length structures

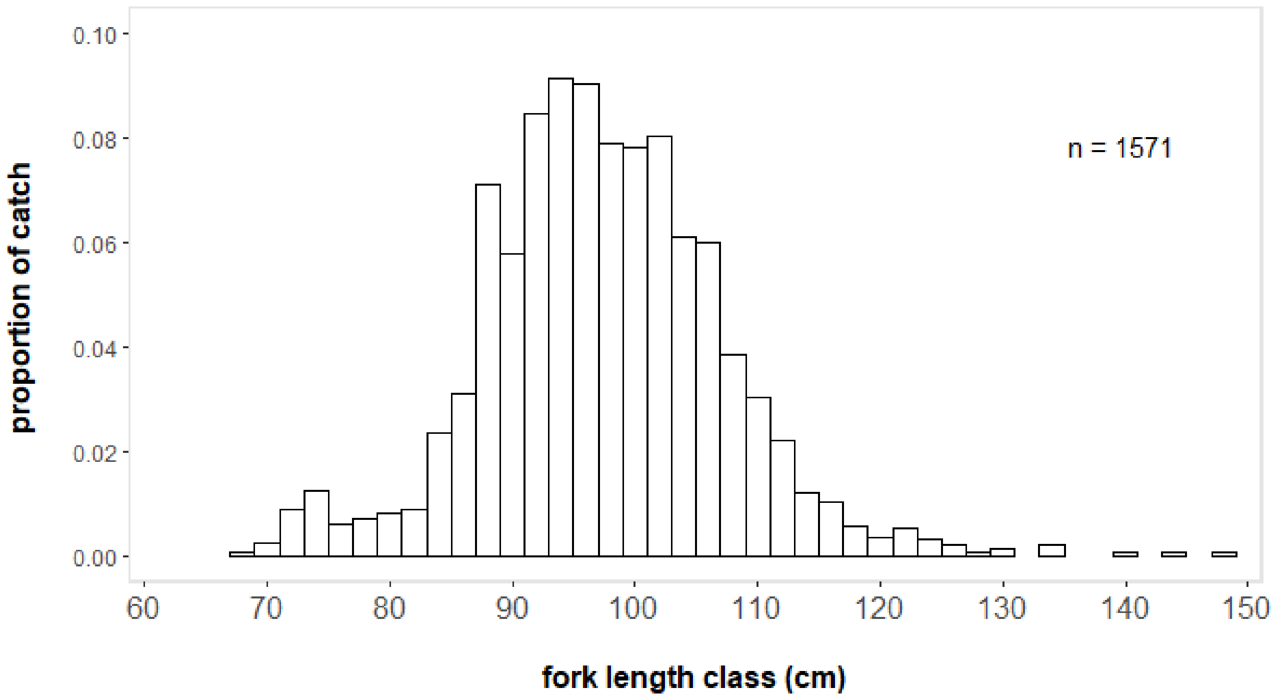
Torres Strait Spanish mackerel sampled from commercial catches in 2019-20 ranged in length between 69 and 145 cm FL (~ 77 - 158 cm TL). The majority of fish (75%) were between 88 and 106 cm (Figure 7), with an average fish length of 98 cm.

A small peak in the smaller fish between 69 and 75 cm FL, that are not fully available to the fishery were observed in catches (Figure 7). A similar peak was not observed in early sampling (Begg et al. 2006; O'Neill and Tobin 2016) and could indicate a stronger year class of small fish recruiting into the fishery in 2019-20 than in previously sampled years. Recruitment strengths of these smaller fish recruiting into and through the fishery can be identified and tracked with consistent annual sampling.

Length structures of Spanish mackerel in TIB and Sunset catches were viewed separately and were observed to be very similar. Average fish lengths were identical at 98 cm FL (~108 cm TL) for both Sunset (n= 1522) and TIB sectors (n=49). Increased sample sizes of fish lengths caught by traditional fishers would help to capture the full variability in length of fish caught. Due to privacy reasons, given the number of total primary vessels sampled within each sub-sector being less than five (Table 4), the length structures were grouped for reporting (Figure 7).

Length structures sampled in 2019-20 are very similar to those reported from on-board surveys conducted in 2000-2002 and 2005 (Begg et al. 2006; O'Neill and Tobin, 2016).

Figure 7. Length structure of the commercial Torres Strait Spanish mackerel catch in 2019-20. TIB and TVH sub-sectors combined. Number of individual primary boats = 5. N-value (n=1571) is number of fish represented.



7.1.3 Sex ratio

Sex ratios were biased towards females, particularly in the larger length classes (Figure 8). A breakdown of the sex ratios by length class demonstrate a change from a male to female bias as length increases (Figure 8). Smaller fish were biased towards males, although small sample sizes were recorded in length classes (<90 cm) and are likely to be influenced by sex and size specific selectivity in catches. The proportion of females increased with an increase in fish length at an average of 12.5% over each 5 cm length class between 85-89 and 120-124 cm. All fish longer than 120 cm were female.

This follows similar sex ratio by length class trends in early Torres Strait sampling (Begg et al. 2006), although the smallest and largest length classes with small sample sizes (Figure 8) are difficult to compare.

Sex ratio can vary with lunar cycle, with more males recorded over the first quarter and full moon periods and equal ratios over the new moon and last quarter periods (Mackie et al. 2003). Fish sampled for sex information were collected across the lunar cycle however this temporal variability could be investigated with additional years of sampling.

Figure 8. Sex ratio of Torres Strait Spanish mackerel in 2019-20 within each 5 cm length class 70-74 to 145-149 cm FL. Numbers on the bars represent sex-based sample sizes within length class.

7.1.4 Fish ageing

Otoliths were collected from a total of 255 Torres Strait Spanish mackerel and interpreted, recording increment count, edge type and readability. A subset of 200 randomly selected otoliths were re-read.

Standard bias, precision and edge classifications were tested for overall agreement between the two interpretations. Increment counts were tested for bias and precision, and edge classification was tested for overall agreement within each category. Quality control measures fell within acceptable levels as per existing measures for Gulf of Carpentaria Spanish mackerel (FQ. 2013). Calculated index of average percentage error (IAPE) was less than 6 (IAPE = 1.201) and edge type classification agreements were above the acceptable levels of correct otolith edge determination of 70% for new edge types, and 50% for intermediate and wide edge types. Edge type agreements were at 91%, 74% and 91 % for the new, intermediate and wide edge type categories respectively.

Three otoliths were classified as unreadable. The fish sampled ranged in length between 73 cm and 147 cm FL and in age groups from 1+ to 13+ (Table 6). Male fish were generally smaller and younger than the females sampled. The age group of each fish was determined using the methods described in 5.3.4.

Data type	Female	Male	Pooled
Min FL (TL)	89	73	73
Max FL (TL)	148	118	148
Avg FL (TL)	108	100	105
Min age	1	1	1
Max age	13	8	13
Avg age (years)	3.9	3.5	3.7
Sample size (n)	151	74	252

Table 6. Observed length and age group data summary of Torres Strait Spanish mackerel during 2019-20.

7.1.5 Age allocation

The edge type of Torres Strait Spanish mackerel otoliths demonstrated a peak in the proportion of new edge types in October (Figure 9). The proportion of new edge types decreased in November when the intermediate category increased as translucent growth increased on the otolith edge.

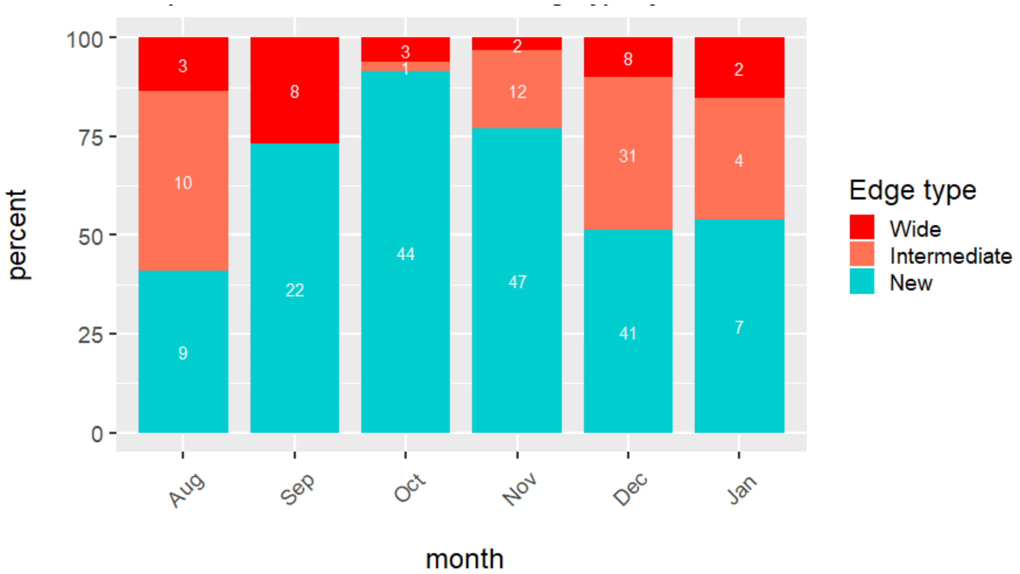
The timing for the period of opaque zone otolith formation was similar to that observed for Spanish mackerel in neighbouring waters which peaks in October for fish from east coast waters and September for fish from Queensland Gulf of Carpentaria waters (DAF 2013; O'Neill and Tobin 2016).

The observed fish-otolith increment counts were assigned to an age (cohort) group based on the otolith edge types and month of capture. For fish with an intermediate or wide edge type caught in August or September, one was added to the increment count for the calculation of age group (Table 7). It is expected that these fish would have laid down another opaque band during 2019-20 and therefore the maximum age they reach would be one more than their current count of increments. No other fish were adjusted as their increment count was expected to represent the maximum age they would be in 2019-20.

There was only one fish with no increment formed on the otolith (increment count = 0). This fish had a wide edge type and was caught in November at 73 cm FL (~ 82 cm TL), so it was allocated to the 1+ age group as it was assumed that it would be 1+ in the 2019-20 year.

A summary of the length at age results for male and female Spanish mackerel is provided in Table 8.

Figure 9. Monthly percentage of each otolith edge type for Torres Strait Spanish mackerel caught between August 2019 and January 2020. Data is pooled for sex and increment count. Number of samples is provided in each bar for each edge type.



Capture month	New	Intermediate	Wide
August	Increment	Increment + 1	Increment + 1
September	Increment	Increment + 1	Increment + 1
October	Increment	Increment	Increment
November	Increment	Increment	Increment
December	Increment	Increment	Increment
January	Increment	Increment	Increment

Table 7. Adjustment of otolith increment count to age group based on capture month of Torres Strait Spanish mackerel. Increment represents that the increment count was used as the value for age group. Increment + 1 represents that 1 year was added to increment count to calculate the value for age group.

Age group	Female FL (cm) Avg (range)	n females	Male FL (cm) Avg (range)	n males	n total
1+	95	1	78 (73-84)	5	6
2+	96 (89-104)	31	94 (86-105)	15	46
3+	105 (91-122)	35	98 (91-104)	19	54
4+	109 (100-128)	46	105 (94-118)	19	65
5+	115 (100-140)	21	107 (103-112)	8	29
6+	120 (110-139)	7	109 (108-110)	3	10
7+	122 (117-132)	4	107 (101-110)	4	8
8+	140	1	115	1	2
9+	131 (115-148)	2		0	2
10+	144	1		0	1
11+	14	1		0	1
12+	-	0	-	0	0
13+	117	1		0	1

Table 8. Adjusted fork length (FL) in cm at age (age group) data summary of Torres Strait Spanish mackerel during 2019-20, showing mean length and sample size for both males and females. Numbers in brackets are the range of lengths for each sex within each age group.

7.1.6 Age length key

The adjusted fork length and age group of 252 fish were used to construct an age length key to convert the length structures into an age structure for the fishery. All fish less than 82 cm were in the 1+ age group (Figure 10, Figure 11). The oldest fish was a female in the 13+ age group and measured at 117 cm FL (128 cm TL). Gaps in the age length key were identified as there were no fish aged in the 68, 70, 76, 78, 126 and 134 length classes (Figure 10).

Given the low sample sizes of fish ages in the smaller length classes and limited missing rows, gaps were filled manually following inspection of the length distributions of fish in the one to four year age groups (Figure 11). All missing length classes less than 80 cm were assigned as 1+ age group.

Gaps in the upper distribution were not filled resulting in these larger fish ‘falling out’ of the age structure. Fish in these missing upper length classes (126, 134 cm) comprised only 0.4% of the length structure (Figure 7). This had a limited result on the age structure given the low significance of these age classes. This may be addressed with further consecutive years of sampling and the use of a statistical model to estimate the age distribution within these missing lengths classes.

Figure 10. Plot of the observed age length key of Torres Strait Spanish mackerel sampled in 2019-20 using age group and adjusted fork length (cm). Number of fish = 252. Numbers shown on bars represent age group.

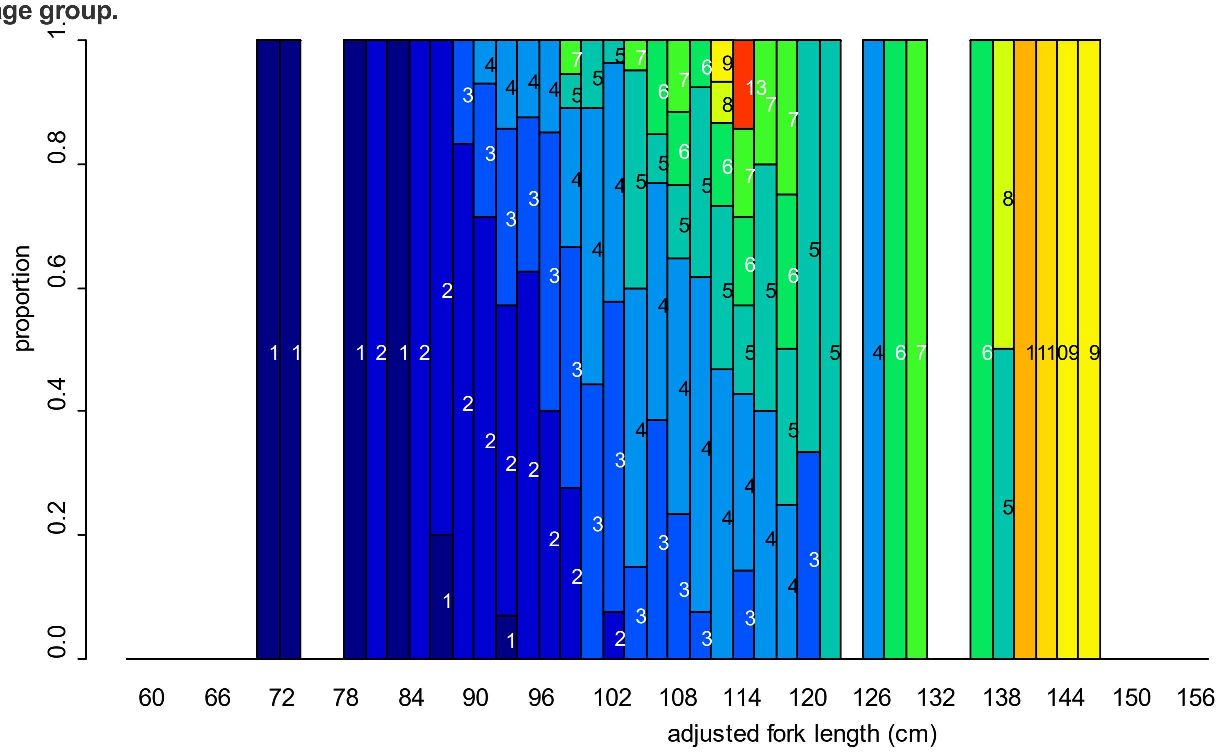
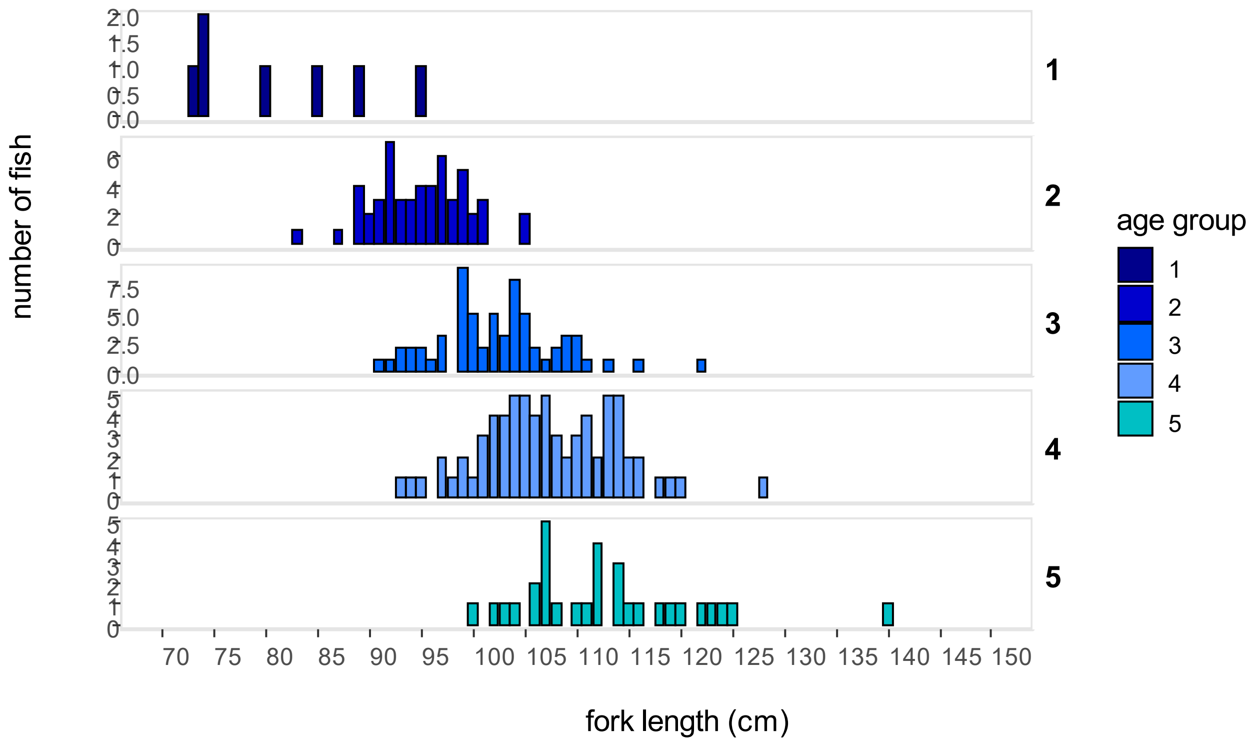


Figure 11. Length distribution of age groups 1 to 5 for Spanish mackerel sampled in 2019-20 used for filling gaps in the age length key.



7.1.7 Age structures

The age structure of Torres Strait Spanish mackerel in 2019-20 from Sunset and TIB sectors was grouped and is presented in Figure 12. Fish ranged between 1+ and 13+ with the catch dominated by fish in age groups 2+ to 4+ which comprised 83.0% of the catch. Age structures for the fishery are heavily truncated with only 3.8% of fish in age groups greater than 5+.

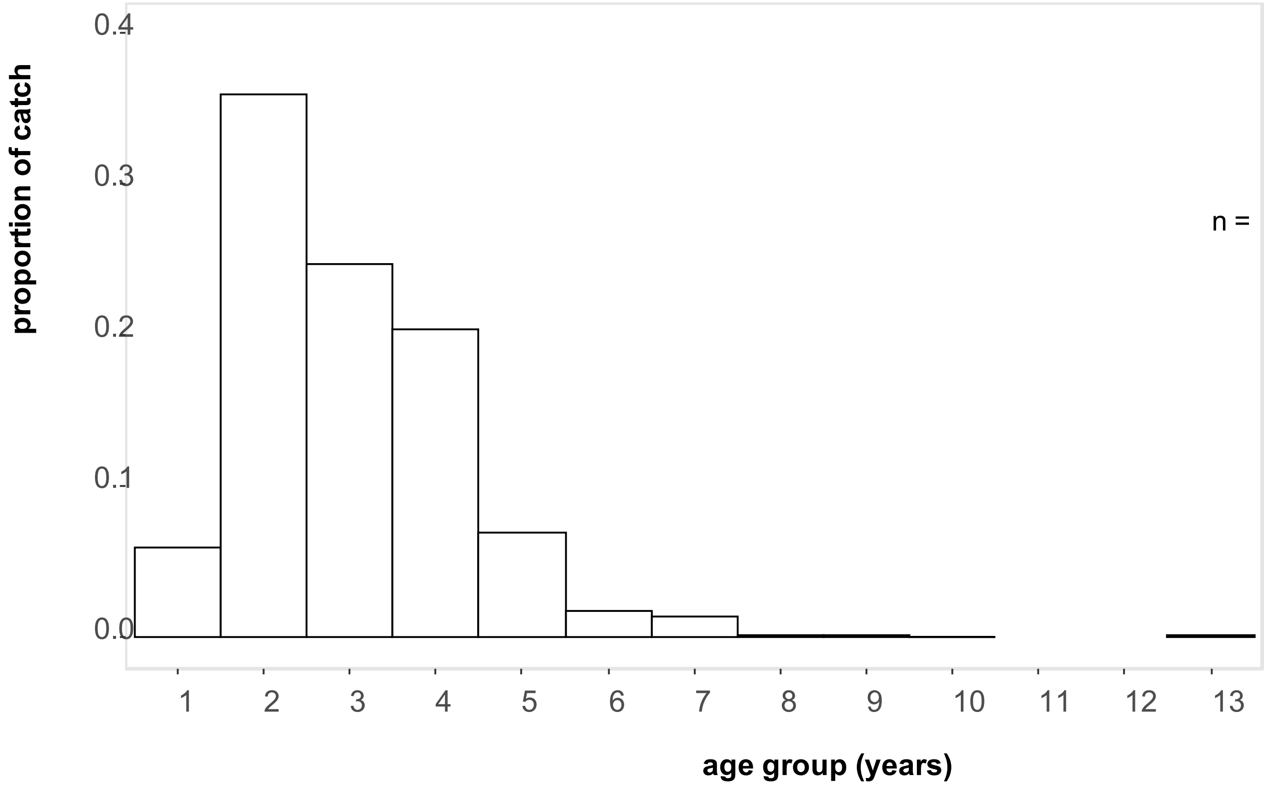
Age structures of Spanish mackerel in TIB and Sunset catches were viewed separately and were observed to be almost identical, although they could not be reported here due to a low number of primary vessels for each sector.

The combined age structure in 2019-20 (Figure 12) is similar to those reported from 2000 to 2002 (O'Neill and Tobin, 2016) and 2005 (Begg et al. 2006) showing truncated age structures from the 5+ age group. Spanish mackerel less than 2 years old (1+ age group), considered not fully recruited into the fishery (O'Neill and Tobin 2016; QDAF 2018), comprised 6.2% of the catch. The proportion of fish in 1+, which are not fully recruited into the fishery, was higher compared to the age structures from 2000-2002 (Begg et al. 2006) further suggesting a stronger recruitment into the fishery of small young fish in 2019-20.

There appears to be a large difference in the proportion of older fish (>5+ age group) and the maximum age of fish caught in the Torres Strait compared to fish caught in Queensland east coast and Gulf of Carpentaria fisheries (Langstreth et al. 2018; O'Neill et al. 2018; Bessell-Browne et al. in prep.). The maximum age of fish recorded in the Torres Strait prior to this study was 12 years (Begg et al. 2006) and age structures show that fish from the 5+ age groups comprise around 10% of the catch in 2019-20 (Figure 12), and an average 8% of the catch between 2000 and 2002 (Begg et al. 2006). Older fish in commercial catches along the neighbouring east coast where fish in age groups 5+ and older are more common in catches at an average 29% in the Gulf of Carpentaria and 22% on the east coast, with a greater maximum age recorded is 26 years (O'Neill et al. 2018; QDAF 2018; Bessell-Browne et al. in prep.).

Reasons for this large difference in the age structures are unknown. They may be linked to differences in available offshore reef habitats and food availability, total population size, fish movement patterns, fishing gears used, high fishing and/or natural mortality. Along the Queensland east coast, seasonal longshore movements allows Spanish mackerel to move south to feed over the summer period in southern Queensland and northern New South Wales (McPherson 2007, in Buckworth et al. 2007). Further widespread sampling is required to help understand and explain the differences.

Figure 12. Age structure of the commercial Torres Strait catch in 2019-20. TIB and Sunset sectors combined. Number of individual primary boats = 5. N-value (n=1571) is number of fish represented.



8 Conclusions

Biological sampling of Torres Strait Spanish mackerel conducted in 2019-20 addressed a long-term critical need for updated length-age information to inform stock assessment for the fishery.

Total sample sizes of Torres Strait Spanish mackerel collected were suitable to represent the length-age structures of the commercial fishery as a whole, sampling from both Sunset and TIB sectors as per each sector's annual catch share proportion. Increased sample sizes of measured catches from the TIB sector and increased participation (>5 primary vessels) in sampling from within each sector would allow construction and reporting of sector-based length-age structures for comparison.

The spatial and seasonal spread of sampling improved on previous sampling programs that were primarily conducted at the main fishery Bramble Cay grounds during October and early November (Begg et al. 2006; O'Neill and Tobin 2016) by sampling between August to January and sampling from two other fishery reporting areas in the central and eastern Torres Strait. Enhanced sample sizes in fishery areas around the eastern and central islands would improve the representation of the sex, length and age data by better capturing the variability in catches across this area. This will help to test for any spatial bias, as most of the stock assessment information was from Bramble Cay. A finding of older fish from other fishing grounds might suggest a higher abundance of Spanish mackerel, than as indicated from recent catch rates.

Length structures of commercial Torres Strait Spanish mackerel showed a majority (75%) of fish were between 88 and 106 cm FL. Age structures in 2019-20 were dominated by the 2+ to 4+ age groups (83%) and truncated from the 5+ age group, with limited numbers of older fish present. Age structures appeared highly similar to derived age structures from early sampling during 2000-2002 and 2005 (Begg et al. 2006; O'Neill and Tobin 2016). The oldest fish sampled was 13+, recording the oldest Spanish mackerel sampled from Torres Strait which was previously at 12+ (Begg et al. 2006).

The absence of older Spanish mackerel in fisheries within Torres Strait and Queensland Gulf of Carpentaria is of interest when comparing to age structures reported within east coast fisheries (Langstreth et al. 2014; O'Neill et al. 2018; Bessell-Browne et al. in prep.), that record much higher proportions of older fish and a maximum age at 26+. Reasons for this large difference in the age structures are largely unknown however may be linked to major differences in available offshore reef habitats and food availability, total population size, fish movement patterns to other areas, fishing gears, marketing or high fishing and/or natural mortality. Documentation of the differences in fishing gears and techniques used by commercial fishers and product form across these fisheries would assist to understand size selectivity influences on fishery length-age structures.

Age-length data from this project will inform future Torres Strait Spanish mackerel stock assessment and greatly inform management of this stock. Ongoing biological sampling will be critical in capturing inter-annual variability in age-length information and will benefit from increased sampling from the TIB sector and from areas outside of the Bramble Cay fishing grounds.

Relationships developed in 2019-20 will assist ongoing sampling to increase voluntary participation in data and sample collection. Continued partnerships with key stakeholders, regular community engagement and feedback of project results are recommended to continue to build and promote trust to support effective working relationships between communities and researchers.

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Appendix 1. Project information sheet

Department of Agriculture and Fisheries

Collecting biological data on Spanish mackerel in the Torres Strait

About the research project

Torres Strait Spanish mackerel are harvested from the ocean by line and troll fishing. They are an important traditional food source and income for communities.

The Torres Strait Spanish mackerel commercial fishery is very seasonal. Harvests are mostly taken between September and November from eastern Torres Strait and Bramble Cay waters.

The Protected Zone Joint Authority uses a stock assessment tool to set the amount of fish that are allowed to be caught each year by all fishers across the fishery. The most recent stock assessment for the Torres Strait Spanish Mackerel Fishery shows that catch rates in the fishery appear to be declining.

We need to update the length and age information used in the stock assessment. This information will help us understand more about the Spanish mackerel caught across different fishery areas.

The Department of Agriculture and Fisheries, Australian Fisheries Management Authority and the Torres Strait Regional Authority staff will work with commercial fishers and Torres Strait Islander communities to collect biological data from commercial catches of Spanish mackerel.

The Australian Fisheries Management Authority and the Torres Strait Regional Authority is funding this research.

Project objectives

The project will collect information on the age and length of Spanish mackerel caught by commercial fishers in the Torres Strait during 2019 and 2020. This information will be used in the Spanish mackerel stock assessment.

Research locations

Sampling will focus on the eastern areas of the Torres Strait, where commercial fishing operations target Spanish mackerel.

Project staff will aim to visit Erub (Darnley Island), Masig (Yorke Island), Ugar (Stephen Island), Mer (Murray Island) and Thursday Island to meet with fishers and representatives from fishing groups. They will discuss the project and ask fishers and staff at community freezer facilities to collect data and fish samples during the project period.

Figure 1 A Spanish mackerel

Data collection

The project will involve:

- collecting length, age and sex information of Spanish mackerel from commercial catches
- working with Indigenous and non-Indigenous commercial fishers and staff at community freezer facilities to assist in the collection of length data and fish frame samples. These samples will help determine the length, sex and age of each fish
- a stratified sampling design to make sure most of the fish length, sex and age information is collected at times and places where most of the fish are being caught

Australian Government
Australian Fisheries Management Authority
Torres Strait Regional Authority
Queensland Government

- freighting fish frames to Cairns to be processed in the Department of Agriculture and Fisheries Northern Fisheries Centre laboratories. The ear bones (otoliths) will be removed from the fish and used to determine the age of each fish (see Figure 2).

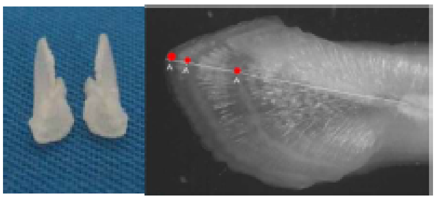

Figure 2 (left) A pair of whole otoliths (ear bones) from a Spanish mackerel

Figure 2 (right) An otolith under a microscope with three annual bands, each representative of a year of life, marked by red dots

Working with fishers and communities

Project staff will talk to Torres Strait Islander communities and fishers about the project. There will be opportunities for fishers and community freezer facilities staff to be involved in collecting data and fish samples.

Figure 3 Scientific staff member removing otoliths from a Spanish mackerel

How will the information be used?

The length, sex and age data will provide important insights into the structure of Spanish mackerel stock caught by the fishery. The data will be incorporated into future Torres Strait Spanish Mackerel Fishery stock assessments.

This project may provide more certainty in the catch levels set by the Protected Zone Joint Authority. This will assist the long-term health and sustainability of the fishery and will help to maximise the catch that can be taken in the fishery.

Summarised results will be available at the end of the project, and presentations will be conducted to communicate the major project findings.

For more information

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Appendix 2. Free Prior and Informed Consent: Information sheet and consent form

Department of Agriculture and Fisheries

Workshops for Torres Strait Spanish mackerel biological data project

You are invited to take part in a research project to collect length data and fish frame samples of Spanish mackerel caught in the Torres Strait. This research is helping communities, fishers, managers and scientists to learn more about the length, sex and age of Spanish mackerel caught within the commercial fishery in the Torres Strait. This knowledge is being used to maintain the health of the fishery into the future.

This one-year project is the result of a need identified by the Protected Zone Joint Authority (PZJA) Finfish Working group for updated information on the ages and lengths of Spanish mackerel. There is uncertainty in the condition of the Torres Strait Spanish mackerel stock and concern about declining catch rates. This information will be supporting the stock assessment for your Torres Strait Spanish mackerel fishery. The stock assessment is the tool being used by the PZJA in assessing the health of the fishery and in setting the amount of fish that are allowed to be caught each year by all fishers across the fishery.

The project is being led by **Jo Langstreth** from **Fisheries Queensland, Department of Agriculture and Fisheries (DAF)**, in collaboration with **Australian Fisheries Management Authority (AFMA)** and **Torres Strait Regional Authority (TSRA)**. Our project team brings fishery research, monitoring and assessment experience, with leaders from local fisheries management and the regional authority. This team is looking forward to working with fishers of the Torres Strait to collect fish length data and fish frame samples.

A series of workshops will be held in Erub, Mer, Masig and Ugar communities to discuss the project, seek input and provide an opportunity to train fishers and staff at community freezer facilities on how to collect the fish length data and fish frame samples.

The length and age data of Spanish mackerel is needed from across the fishery during times when most of the fish are caught. It is important to collect data from both the Indigenous and non-Indigenous commercial fishers. To explain how the project will work, two to three hour workshops will: a) discuss the aims of the research project, b) seek participation in the research for people interested in collecting data and samples of Spanish mackerel, c) seek knowledge and ideas, and d) discuss issues.

Taking part in this research is voluntary and you can stop taking part in the study at any time without having to give a reason or feeling like you are being judged.

Any contact details you provide will be strictly confidential to the project team. The data from the study will be used in the fisheries stock assessment project, research publications, presentations, and a summary report back to you and your community. Individuals will not be identified in any way in these reports, publications or presentations. Please be informed that confidentiality cannot be assured among members of the workshop sessions, although we ask participants to maintain confidentiality outside of the group.

If you have any questions about the study, including the ethical conduct of the study, please contact our Project Manager:

Jo Langstreth
Fisheries Queensland,
Department of Agriculture and Fisheries
Phone: (07) 4241 1245, 0429 029 625
Email: Joanne.Langstreth@daf.qld.gov.au

Queensland Government

INFORMED CONSENT FORM

Lead Researcher: Joanne Langstreth, Fisheries Queensland, Department of Agriculture and Fisheries
Research project: Enhancing biological data inputs to Torres Strait Spanish mackerel stock assessment

I understand the aim of this research project is to collect biological information on the length, sex, age and details of the catch (catch date, general location) of Spanish mackerel caught during commercial fishing in the Torres Strait. This information will provide important insights into the length and age structure of fish being caught across different areas of the fishery. This data is intended to be included in an update of the stock assessment for Torres Strait Spanish mackerel. Data from this project may provide more certainty in the catch levels that are set as a result of future stock assessments and will assist the long term health and sustainability of the fishery. If you decided to take part in the project and provide samples for the project, you will be provided a simple summary of our findings at the end of the project.

I acknowledge that:

- taking part in this workshop is voluntary and I am aware that I can stop taking part in it at any time without having to give a reason or feel like I am being judged.
- no names will be used to identify me in publications that results from this study without my approval;
- confidentiality cannot be assured in workshops.
- if I decide to assist with collecting fish samples or data for the project, I will receive $5 per fish frame and $40 per catch to cover the costs of my time. The number of samples that I can be paid for will be negotiated and agreed to with the project leader. All resources (such as bags and tags) and freight will be covered so I am not out of pocket.
- once my data and samples are submitted, even if I withdraw from providing further data, my previously submitted data will not be able to be withdrawn.

(Please tick to indicate consent)

I consent to participate in a workshop to discuss the research project		**Yes**		**No**
I consent to photographs being taken at the workshop		**Yes**		**No**
I consent that photographs of me may be used in project publications or promoting the project		**Yes**		**No**

Name: *(printed)*	
Signature:	**Date:**

Appendix 3. Example of community notice for island workshop

Australian Government | TSRA www.tsra.gov.au

COMMUNITY NOTICE

Protect Zone Joint Authority (PZJA)

Spanish Mackerel Sampling Workshop:

Training fisheries how to take age and length samples

What: The project is seeking Torres Strait fishers to collect the heads and frames of Spanish mackerel and take simple measurements. There are small payments available for samples provided to the project.

Why: There has been a declining catch rate in the Spanish mackerel fishery and more biological information is needed to understand why.

Who: Jo Langstreth - Fisheries Biologist - QLD Department of Agriculture & Fisheries

Elizabeth McCrudden – TSRA Fisheries Programme

Neville Johnston – TSRA Fisheries Programme

Andrew Trappett – AFMA

When: We encourage fishers targeting Spanish mackerel to attend the workshop on:

Masig Council Hall
Thursday 19 September
10:00am – 1:00pm

A second workshop will be held in November 2019

For more information please contact Elizabeth McCrudden from the TSRA Fisheries Programme on 4069 0700 or 0488044979

Appendix 4. Growth model results

Figure 13. Sex-specific von Bertalanffy growth model outputs of R-statistical package FishMethods '*growth'* function of age (decimal years) and fork length (cm) showing fit and residuals for a) females, b) males and c) pooled sex. Parameter estimates and model fit outputs are provided in Figure 14.

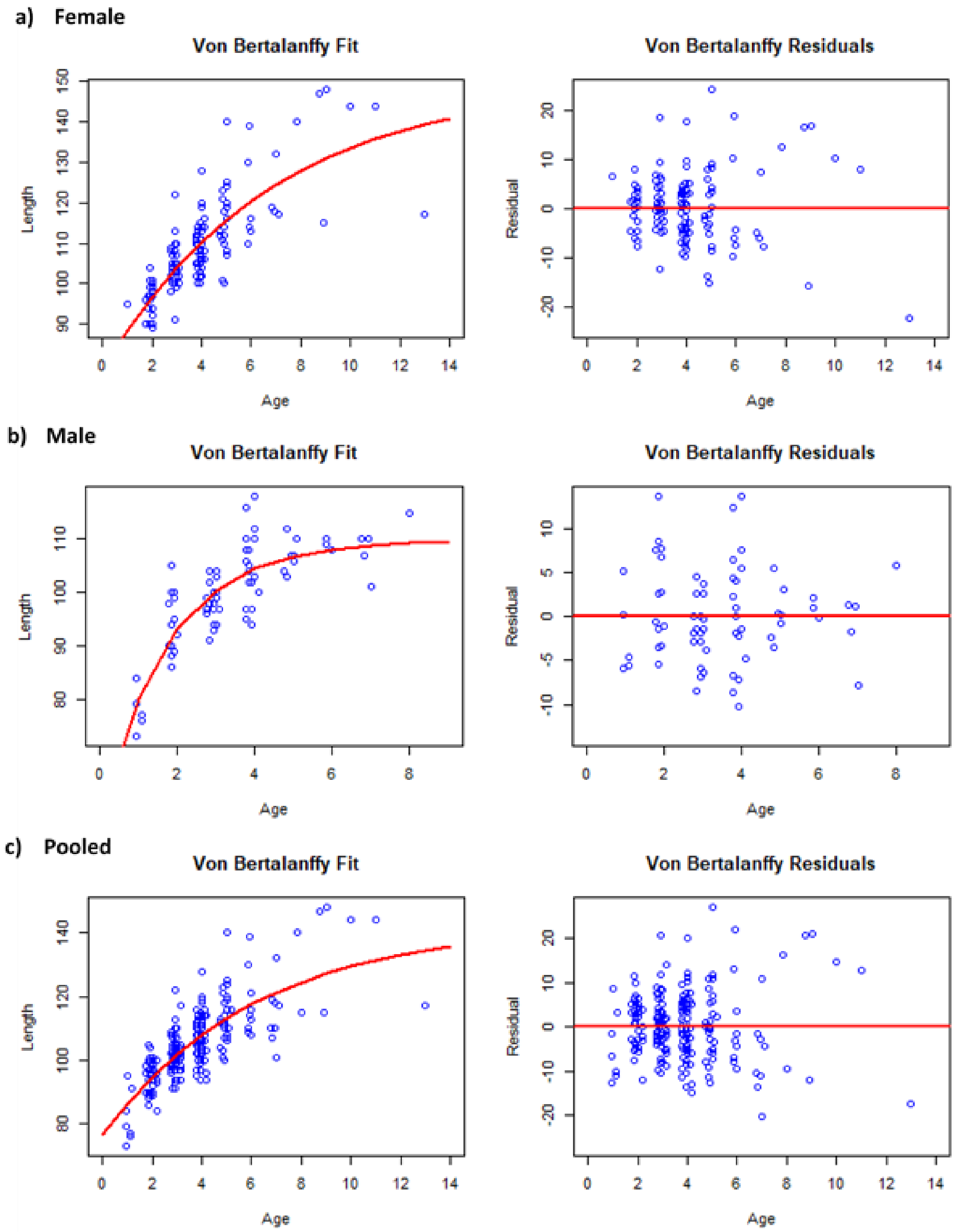

Figure 14. Results outputs of R-statistical package FishMethods '*growthmultifit*' and 'growth' function fitting von Bertalanffy growth model to age (decimal years) and fork length (cm) for 1) females, 2) males and 3) pooled sex. The model uses nonlinear least squares (nls) method. Parameter estimate, standard error, t-value and probability values are provided. Females were treated as the reference group in the multi-fit model and therefore estimates of Linf, K and t0 for male and pooled sex are added to the estimate provided for females. P-values are relative to the reference female dataset.

'*Multifit*' function

```
Formula: len ~ (Linf1 * F + Linf2 * M + Linf3 * P) * (1 - exp(-(K1 * F +
    K2 * M + K3 * P) * (age - (t01 * F + t02 * M + t03 * P))))
Parameters:
       Estimate Std. Error t value Pr(>|t|)
Linf1 150.15543   10.90442  13.770  < 2e-16 ***
Linf2 -40.32344   11.26920  -3.578 0.000382 ***
Linf3  -7.39990   13.65983  -0.542 0.588263
K1      0.14610    0.04292   3.404 0.000722 ***
K2      0.42360    0.15877   2.668 0.007894 **
K3      0.01427    0.05749   0.248 0.804111
t01    -5.06279    1.29719  -3.903 0.000109 ***
t02     3.75908    1.43982   2.611 0.009322 **
t03     0.26676    1.63011   0.164 0.870080
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.828 on 470 degrees of freedom

Number of iterations to convergence: 9
Achieved convergence tolerance: 4.18e-06

$vonbert
"Model: Sinf*(1-exp(-K*(t-t0)))+e", "Response: Individual Length", "Least Squar
es: Unweighted"
```

Female '*growth*' function

```
$vout
Nonlinear regression model
  model: size ~ Sinf * (1 - exp(-(K * (age - t0))))
   data: x
    Sinf        K       t0
150.1555   0.1461  -5.0628
 residual sum-of-squares: 7106

Number of iterations to convergence: 9
Achieved convergence tolerance: 7.065e-06
```

Male '*growth*' function

```
$vout
Nonlinear regression model
  model: size ~ Sinf * (1 - exp(-(K * (age - t0))))
   data: x
    Sinf        K       t0
109.8319   0.5697  -1.3037
 residual sum-of-squares: 1934

Number of iterations to convergence: 5
Achieved convergence tolerance: 2.942e-06
```

Pooled '*growth*' function

```
$vout
Nonlinear regression model
  model: size ~ Sinf * (1 - exp(-(K * (age - t0))))
   data: x
    Sinf        K       t0
142.7557   0.1604  -4.7961
 residual sum-of-squares: 12875

Number of iterations to convergence: 6
Achieved convergence tolerance: 1.43e-06
```