12th MEETING OF THE PZJA TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP (FFRAG 12)

Thursday 3rd November – Friday 4th November 2022

Face to Face Meeting

Venue: Pullman Boardroom 1 - Cairns

DRAFT AGENDA

1 PRELIMINARIES

1.1 Acknowledgment of Traditional Owners, Welcome and Apologies

The Chair will welcome members and observers to the 12th meeting of the FFRAG.

1.2 Adoption of Agenda

The FFRAG will be invited to adopt the draft agenda.

1.3 Declaration of Interests

Members and observers will be invited to declare any real or potential conflicts of interest and determine whether a member may or may not be present during discussion of or decisions made on the matter which is the subject of the conflict.

1.4 Action Items from Previous Meetings

The FFRAG will be invited to note the status of action items arising from previous meetings.

1.5 Out-of-Session Correspondence

The FFRAG will be invited to note out of session correspondence on FFRAG matters since the previous meeting.

2 UPDATES FROM MEMBERS

2.1 Industry & Scientific Members

Industry and scientific members will be invited to provide a verbal update on matters concerning the Torres Strait Finfish Fishery, in particular, providing comment on fishing patterns, behaviours, prices, and market trends this season.

2.2 Government Agencies

The FFRAG will be invited to note updates from AFMA, TSRA and QDAF on matters concerning the Torres Strait Finfish Fishery.

2.3 PNG National Fisheries Authority

The FFRAG will be invited to note a verbal update from the PNG National Fisheries Authority if a representative is in attendance.

2.4 Native Title

The FFRAG will be invited to note a verbal update from Malu Lamar (Torres Strait Islander) Corporation RNTBC if a representative is in attendance.

3 STOCK ASSESMENTS AND RBC ADVICE

3.1 Spanish Mackerel

The FFRAG will be invited to review the updated stock assessment outcomes and provide advice on a Recommended Biological Catch for Spanish mackerel for the 2023-24 fishing season.

3.2 Coral Trout

Having regard for new catch data, previous assessments and an updated CPUE data time series, the FFRAG will be invited to provide advice on a 2023-24 season Recommended Biological Catch.

4 MANAGEMENT

4.1 Harvest Strategy Development

The FFRAG will be invited to discuss and identify potential refinements to the draft harvest strategy (HS) for Spanish mackerel. This advice will be referred to a joint RAG/WG HS workshop in 2023. The HS workshop will seek to resolve all outstanding refinements to progress the development of a Management Strategy Evaluation for the fishery.

4.2 Management of the Take of Shark

The FRRAG will be asked to review the current measures applied to the management of the take of sharks in the Torres Strait Finfish Fishery and provide advice on whether they are in line with Commonwealth best practice.

4.3 Review of Barramundi Cod Management

The FFRAG are invited to review the recent take of Barramundi Cod in the Torres Strait Finfish Fishery and will be asked to discuss and provide advice on the potential risks to sustainability. This advice will be referred to the Finfish Working Group for consideration.

5 RESEARCH

5.1 Environmental Risk Assessments

The FFRAG will be invited to note a presentation from Dr Miriana Sporcic (CSIRO) on the draft Environmental Risk Assessment reports for the Torres Strait Spanish Mackerel and Reef Line fisheries. The FFRAG will then be asked to discuss and provide advice on these draft reports.

5.2 Biological Sampling Project

The FFRAG will be invited to note an update from the QDAF project team on the current project *Torres Strait Finfish Fishery Coral Trout and Biological Sampling 2021-2024* (project number 2020/0814).

5.3 Close-Kin Mark-Recapture Scoping Study

The FFRAG will be invited to note a presentation by Dr Ashley Williams on the status of the current project *Designing a Close-Kin Mark-Recapture study for Torres Strait Spanish mackerel* (project number 200817). This presentation will cover the draft project report, with FFRAG advice sought before the final report is completed.

5.4 Research Priorities

FFRAG members will be invited to discuss research priorities for the Finfish Fishery. This discussion will lead on from FFRAG 11 and will form the final advice from the FFRAG for 2022.

6 PRIORITIES FOR THE RAG / DATE AND VENUE FOR NEXT MEETING

FFRAG members will be invited to discuss other future priorities for management of the Finfish Fishery.

The FFRAG will confirm arrangements for FFRAG 13 and 14, tentatively scheduled for September and October 2023, and be advised of upcoming meetings of the FFWG (7-8 December 2022) and PZJA meeting to decide next season's sustainable catch limits (January 2023).

7 OTHER BUSINESS

FFRAG members will be invited to discuss other business for consideration.

8 CLEARANCE OF FFRAG ADVICE

The FFRAG will be asked to review and approve a written communique containing the key advice/outcomes from the current meeting.

The Chair must approve the attendance of all observers at the meeting. Individuals wishing to join the meeting as an observer must contact the Executive Officer – Chris Boon (chris.boon@afma.gov.au)

Torres Strait Finfish Fishery Resource Assessment Group	Meeting 12 3 - 4 November 2022
PRELIMINARIES Welcome and Apologies	Agenda Item 1.1 For Noting

- 1. That the Resource Assessment Group **NOTE**:
 - a) an acknowledgement of Traditional Owners;
 - b) the Chair's welcome address;
 - c) apologies received from members unable to attend.
- 2. As of 20 November 2022, no formal apologies have been received.

Torres Strait Finfish Fishery Resource Assessment Group	Meeting 12 3 - 4 November 2022
PRELIMINARIES Adoption of Agenda	Agenda Item 1.2 For Decision

1. That the Resource Assessment Group consider and **ADOPT** the draft agenda.

BACKGROUND

- 2. A first draft annotated agenda was circulated to members and observers on 6 October 2022.
- 3. As of 19 October 2022, no comments from members were received.

TORRES STRAIT ASSESSMENT GROU	FINFISH P	FISHERY	RESOURCE	Meeting 12 3-4 November 2022
PRELIMINARIES Declarations of Inte	rest			Agenda Item 1.3 For DECISION

- 1. That the Resource Assessment Group members:
 - a) **DECLARE** all real or potential conflicts of interest in Torres Strait finfish fisheries at the commencement of the meeting (**Table 1**).
 - b) **DETERMINE** whether the member may or may not be present during discussion of or decisions made on the matter which is the subject of the conflict;
 - c) **ABIDE** by decisions of the Resource Assessment Group regarding the management of conflicts of interest.
 - d) NOTE that the record of the meeting must record the fact of any disclosure, and the determination of the Resource Assessment Group as to whether the member may or may not be present during discussion of or decisions made on the matter which is the subject of the conflict.

BACKGROUND

- 2. Consistent with *Protected Zone Joint Authority (PZJA) Fisheries Management Paper No. 1* (FMP1), which guides the operation and administration of PZJA consultative forums, members are asked to declare any real or potential conflicts of interest.
- 3. Resource Assessment Group members are asked to declare all real or potential conflicts of interest or update the standing list of declared interests (**Table 1**) if required.
- 4. FMP1 recognises that members are appointed to provide input based on their knowledge and expertise and as a consequence, may face potential or direct conflicts of interest. Where a member has a material personal interest in a matter being considered, including a direct or indirect financial or economic interest; the interest could conflict with the proper performance of the member's duties. Of greater concern is the specific conflict created where a member is in a position to derive direct benefit from a recommendation if it is implemented.
- 5. When a member recognises that a real or potential conflict of interest exists, the conflict must be disclosed as soon as possible. Where this relates to an issue on the agenda of a meeting this can normally wait until that meeting, but where the conflict relates to decisions already made, members must be informed immediately. Conflicts of interest should be dealt with at the start of each meeting. If members become aware of a potential conflict of interest during the meeting, they must immediately disclose the conflict of interest.
- 6. Where it is determined that a direct conflict of interest exists, the forum may allow the member to continue to participate in the discussions relating to the matter but not in any decision making process. They may also determine that, having made their contribution to the discussions, the member should retire from the meeting for the remainder of discussions on that issue. Declarations

of interest, and subsequent decisions by the forum, must be recorded accurately in the meeting minutes.

Table 1. FFRAG member and observer Declarations of Interest to be updated at the meeting. Interests declared by those persons at the previous FFRAG meeting (12 October 2022) and FFWG meeting (25 November 2021) are shown.

Name	Position	Dec	laration of interest
Members			
David Brewer	Chair	•	Director – Upwelling P/L (David Brewer Consulting). Honorary Fellow - CSIRO Chair - Torres Strait Finfish RAG Scientific member – Torres Strait Finfish Working Group Scientific member – Northern Prawn Fishery RAG Current consultancies with Quandamooka YoolooburrabeeAboriginal Corporation, Newcrest Mining Ltd. Ex co-investigator on the completed Torres Strait 'Non-commercial catch' project. As a fisheries consultant, may apply for funds for Torres Strait fishery research projects in the future where consistent with hisrole as Chair.
Rocky Stephen	Industry member		Councillor for Ugar. Chairperson of Kos and Abob Fisheries Ugar. Works with brother in a commercial fishing business on Ugar (Brother Bear Fisheries). Eastern cluster representative on the PZJA Finfish RAG &Working Group. Traditional inhabitant member - Torres Strait Scientific AdvisoryCommittee. TSRA Board member for Ugar TSRA Finfish Quota ManagementCommittee. TSRA Board Fisheries Advisory Committee member. Member of Zenadth Kes Fisheries company.
Terrence Whap	Industry member.	•	Member of the PZJA TRL working group President of the local fisherman's association in Maluialgal PBC Director TSRA Board Member and Ranger
Harry Nona	Industry Member	•	Fulltime fisherman TIB licence holder
Benny Dau	Industry member	ТВС	
Gavin Mosby	Industry Member	ТВС	
Michael O'Neill	Scientific Member	•	Principal scientist for TSSAC recommended two- year project for Spanish mackerel stock

Name	Position	Declaration of interest
Ashley Williams	Scientific Member	 assessment work. Member of PZJA Finfish RAG and Working Group. Recently moved to CSIRO in 2020. Continued work with ABARES as a fishery scientist under Department of Agriculture and Water Resources. Involved in previous Torres Strait research.
Andrew Penny	Scientific Member	 Researcher and management scientist. Serves on six AFMA/PZJA advisory groups. Conducted research previously with the Torres Strait Prawn fishery and Tropical Rock Lobster fishery. No current Torres Strait projects. Is a consultant with a general interest in tropical fisheries. Researcher on current projects involving climate change/stock assessments.
Emma Freeman	AFMA Member	 Employed by AFMA, no pecuniary interests or otherwise
Chris Boon	RAG Executive Officer -AFMA	 Employed by AFMA, no pecuniary interests or otherwise
Nicholas Richards	Torres Strait Regional Authority (TSRA) Member	 Employed by TSRA – Project Manager (Fisheries). No pecuniary or vested interests in Torres Strait fisheries as an individual. Notes that TSRA holds finfish fishing licences on behalf of Traditional Inhabitants.
TBC	QDAF Member	TBC
Permanent Observers		
ТВС	Malu Lamar	TBC
Egon Stewart	Industry Observer	TBC
Casual Observers		
Ian Butler	ABARES	No pecuniary interests
Quinten Hirakawa	TSRA	 TIB licence holder with Spanish mackerel, Reef line, Tropical Rock Lobster and Beche-de-mer endorsements Has a background as a commercial Tropical Rock Lobster fisher. Co-investigator on the Spanish mackerel and coral trout biological sampling project.

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3 - 4 November 2022
PRELIMINARIES Actions arising & meeting record	Agenda Item 1.4 For NOTING

- 1. That RAG NOTE:
 - a) the progress of actions arising from previous FFRAG meetings; and
 - b) that the draft meeting record of the FFRAG 10 meeting on 18-19 November 2021 was circulated for member comment on 03 December 2021.

KEY ISSUES

Actions arising

2. Progress against the actions arising from previous FFRAG meetings are detailed in **Table 1**.

Meeting record

- 3. The draft meeting record from FFRAG 10 was circulated for member comment on 03 December 2021 with the period for comments to close on 17 December 2021.
- 4. Several comments were received from scientific members and TSRA members were received. The final record for FFRAG 10 meeting was cleared by the Chair on the 22 December 2021. The record was then uploaded to the PZJA website.
- 5. The draft meeting record for FFRAG 11 is scheduled to be circulated to members for comment on 27/10/2022.

Table 1: Status of previous outstanding FFRAG action items as of October 2022.

Number	Action	Status update
FFRAG 9, Action 2	AFMA to assess the feasibility of getting pre-1989 data digitised.	Actioned – It was deemed feasible to digitise this data, however the RAG advised that this would be of limited benefit to the stock assessment. Therefore this will not be progressed as a research priority.
FFRAG 10, Action 1	Dr Rik Buckworth to contact Geoff McPherson to confirm if he has copies of Mr Whitaker's logbooks for the <i>AFV Trader Horn</i> and if not, whether he knows where copies might be stored	Actioned – The logbooks are not available.
FFRAG 10, Action 2	AFMA to provide a summary of TIB CDR reporting by community.	Actioned – To be presented at FFRAG 12.
FFRAG 10, Action 3	Mr David Brewer to contact Brian Long, co-author of the '1995-1996 CSIRO fish dive survey' report (Influences of coastal processes on large scale communities of Torres Strait, Australian) to get further insight as to why coral trout were not observed at so many of the sites (zero counts).	Actioned – Update to be presented at FFRAG 12.
FFRAG 10, Action 4	Ashley Williams to circulate the following report The Effects of Line Fishing on the Great Barrier Reef and Evaluations of Alternative Potential management Strategies to the RAG.	Actioned – Recirculated to the FFRAG on 18/10/2022. The RAG may refer to this report when discussing an RBC for coral trout at FFRAG 12.
FFRAG 10, Action 5	AFMA to provide any available information on the spawning patterns of black jewfish to members out of session.	Actioned – Dr Michael O'Neill identified two relevant research papers which AFMA then circulated to the RAG on 25/11/2021.
FFRAG 8, Action 1	AFMA to complete project work with industry members in 2021 with a view to implementing a new logbook for the 2021-22 season.	Ongoing – This work is on track to be actioned for the 2023/24 season in line with a scheduled update to the Torres Strait Fisheries (Furnishing of Logbooks) Instrument 2020.
FFRAG 6, Action 1	AFMA to develop a work plan for the FFRAG to advise on best estimates of coral trout catches taken outside the commercial Torres Strait Finfish Fishery (Traditional take - kai-kai, recreational, charter sector).	Ongoing – The RAG agreed at FFRAG 9 to retain this action item, noting however, that progressing this action needs to be assessed against other RAG priorities and in light of any future research investment to develop an approach for measuring non-commercial fishing for the region.

FFRAG 5, Action 3	AFMA to update the FFRAG on the outcomes of Torres Strait case study, 'Fisheries adaptation to climate change' to be presented once complete (it was noted that it may be appropriate for AFMA to arrange an expert to present to the FFRAG on this report at an upcoming meeting).	Ongoing – The final case study report was circulated to the RAG on 13/10/21. Dr Beth Fulton has provided a pre-recorded presentation on this project. The FFRAG are welcome to view this presentation at FFRAG 12 or OOS.
FFRAG 5, Action 5	FFRAG are to work on forming a matrix of scenarios (different target reference points and building rates) to support RBC setting and deciding control rules for the harvest strategy. Matrix is to compare RBC, time to reach B Target and risk to stock (being number of model runs dropping below the limit reference point.	Ongoing – The RAG noted at FFRAG 9 that a matrix of scenarios has been developed and is currently being used to support setting the RBC. It was noted that the matrix will likely be reviewed alongside further work to develop a harvest strategy for the fishery. To be retained as an action item for further development.
FFRAG 5, Action 6	Obtaining accurate catch and effort data from the TIB sector is a key data need. AFMA and TSRA are to continue supporting industry in collecting voluntary effort data in catch disposal records and work on progressing compulsory logbook reporting as a priority.	Ongoing – The RAG noted AFMA advice that it remains an ongoing focus for AFMA to support the TIB sector to report accurate catch and effort data. AFMA further advised that it is continuing to work with the Commonwealth Department of Agriculture, Water and the Environment to progress legislative amendments. AFMA welcomed advice from members on any specific actions or initiatives to explore noting such requests would replace the current broad action. The RAG agreed to retain the action in its current form for the time being.
FFRAG 5, Action 7	FFRAG are to consider retrospective analyses for Spanish mackerel and how these can be built into the assessment	Ongoing – The RAG noted advice from Dr O'Neill that this analysis is to be built into the next stock assessment.

Torres Strait Finfish Fishery Resource Assessment Group	Meeting 12 3-4 November 2022
PRELIMINARIES Out of session correspondence	Agenda Item 1.5 For Noting

1. That the RAG **NOTE** the correspondence sent out-of-session since 23 September 2022.

BACKGROUND

2. The following correspondence was circulated out-of-session since 4 September 2022. Copies of this correspondence can be requested at any time from the FFRAG Executive Officer.

Date	Item
28/09/2022	FFRAG 11 Meeting Papers with attachments - 12 October 2022. DRAFT ERA documents to be provided separately
06/10/2022	FFRAG 12 Draft Agenda - and change of venue
06/10/2022	FFRAG 11 Meeting Paper attachments (Draft ERA documents)
10/10/2022	FFRAG 11 Meeting - 12 October 2022 (Teams Link & SA Report)
13/10/2022	FFRAG 11 - Key Recommendations.
18/10/2022	For FFRAG noting - The effects of line fishing on the great barrier reef and evaluations of alternative potential management strategies

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3 - 4 November 2022
UPDATES FROM MEMEBRS Industry and Scientific members	Agenda Item 2.1 For NOTING and DISCUSSION

- 1. That the RAG:
 - a) NOTE any updates provided by industry and scientific members;
 - b) **DISCUSS** strategic issues, including economic trends, affecting the management and development of Torres Strait fisheries.

Key Issues

- 2. Verbal reports will be provided by industry and scientific members under this item. The FFRAG Chairperson may also welcome a short report from any invited participants from industry at this agenda item.
- 3. It is important that the Finfish RAG (and also the Finfish Working Group (FFWG)) develop a common understanding of any relevant matters within adjacent jurisdictions and what issues if any, are having the greatest impact on industry and the management of fisheries. Such understanding will ensure proceedings of the FFRAG and FFWG are focused and may more effectively address each issue.
- 4. FFRAG members are asked to provide any updates on trends and opportunities in global markets, processing and value adding. Industry is also asked to contribute advice on economic and market trends where possible. Scientific members are asked to contribute advice on any broader strategic research projects or issues that may be of interest to the Torres Strait industry in future.

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
UPDATES FROM MEMBERS Government Agencies	Agenda Item 2.2 For NOTING

- 1. That the Resource Assessment Group (RAG):
 - a) **NOTE** the update provided by the Australian Fisheries Management Authority (AFMA) below;
 - b) **NOTE** the progress to date against the Wildlife Trade Operation (WTO) conditions for the Finfish Fishery as summarised in **Table 3**;
 - c) **NOTE** the update provided by the Queensland Department of Agriculture and Fisheries (QDAF); and
 - d) **NOTE** the update provided by the Torres Strait Regional Authority (TSRA).

AFMA UPDATE

TAC, Licencing, & Leasing

- 2. At its 11 February 2022 meeting the Protected Zone Joint Authority (PZJA) decided that the Total Allowable Catches (TAC) for the Torres Strait Finfish Fishery 2022/23 season will be 75 tonnes for Spanish mackerel and 135 tonnes for coral trout. The PZJA decision was in line with advice from the Torres Strait Finfish Resource Assessment Group and Torres Strait Finfish Working Group.
- 3. In line with advice from the TSRA Finfish Quota Management Committee (FQMC) and the TSRA Board, the following catch amounts were allocated to the Sunset sector (**Table 1**). These allocations were applied to sunset licence conditions by AFMA as the licencing Delegate.

Table 1: 2022-23 fishing season TACs and catch allowance by sector.

Species	Agreed TAC	Sunset Sector Catch Share	TIB Sector Catch Share
Spanish Mackerel	75	57	18
Coral Trout	135	35	100
Other reef line species	n/a	3.5	No Limit

4. As of 18 October 2022, the following number of licences were registered:

Table 2: Number of licenses issued for the 2021/22 and 2022/23 Torres Strait Finfish Fishery seasons.

	Nu	mber of TIB li	cences		Number of Sunset licences
Fishing season	SM	Reef line	Dual endorsed	Receiver licenses	SM/Reef line combined
2021/22	56	22	166	83	3
2022/23	34	20	107	66	3

Wildlife Trade Operation (WTO) Approval under the EPBC Act 1999

- 5. The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) requires the Australian Government to assess the environmental performance of all commercial fisheries, including those in the Torres Strait, and promote ecologically sustainable fisheries management. Approval under the EPBC Act is necessary for fisheries to be able to legally export commercially wild caught seafood from Australia. Such approvals may be subject to conditions applicable to the responsible management authority and fishers.
- 6. In October 2020 the Australian Fisheries Management Authority applied for export approval for the Torres Strait Finfish Fishery (TSFF) under the EPBC Act. The application was assessed and the fishery was declared by the Delegate for the Minister of the Environment, as an approved wildlife trade operation under Part 13A of the EPBC Act until 1 November 2023.
- 7. Live coral trout were exported for the first time in 2017¹. Maintaining a WTO approval for the fishery allows for the continued opportunity for live and frozen product to be exported, as well providing a sound basis for responsible fisheries management.
- 8. This approval was based on the 'Assessment of the Torres Strait Finfish Fishery December 2020', which was undertaken by The Department of Agriculture, Water and the Environment. This assessment contained 9 approval conditions to ensure ecological risks continue to be managed.
- 9. AFMA invites both the Finfish RAG and Finfish Working Group (WG) to monitor progress against each condition and provide advice on addressing conditions. To assist the RAG and WG, **Table 3** provides a summary of relevant actions taken or proposed to address each condition.

Table 3. Progress to date against the Wildlife Trade Operation (WTO) conditions for the Finfish fishery.

WTO Conditions for the Finfish Fishery	Progress as of October 2022
Condition 1: The Torres Strait Protected Zone Joint Authority must ensure that operation of the Torres Strait Finfish Fishery is carried out in accordance with management arrangements defined in the Torres Strait Fisheries Act 1984, Torres Strait Fisheries Regulations 1985, Torres Strait Finfish Fishery	On track: The Torres Strait Finfish Fishery continues to be managed in accordance with management arrangements in force under the <i>Torres Strait Fisheries Act 1984</i> .

¹ Fishery Status Reports 2021, Chapter 16 - ABARES

-

WTO Conditions for the Finfish Fishery	Progress as of October 2022
Management Plan 2013, Torres Strait Fisheries Management Instrument No. 14, Torres Strait Fisheries (Finfish) Management Instrument 2020, Torres Strait Fisheries (Furnishing of Logbooks) Instrument 2020 and in fishery permit conditions.	
Condition 2:	On track:
The Torres Strait Protected Zone Joint Authority must inform the Department of Agriculture, Water and the Environment of any intended material changes to the Torres Strait Finfish Fishery management arrangements that may affect the assessment against which <i>Environment Protection and Biodiversity Conservation Act 1999</i> decisions are made.	AFMA, on behalf of the PZJA, will provide an update on material changes to management arrangements in the annual report by 01 November 2022.
Condition 3: The Torres Strait Protected Zone Joint Authority must inform the Department of Agriculture, Water and the Environment of any intended changes to fisheries legislation that may affect the legislative instruments relevant to this approval.	On track: AFMA, on behalf of the PZJA, will inform the department of changes to the fisheries legislation and subordinate instruments in the annual report by 01 November 2022.
Condition 4:	On track:
The Torres Strait Protected Zone Joint Authority must provide reports to the Department of Agriculture, Water and the Environment annually as per Appendix B of the Guidelines for the Ecologically Sustainable Management of Fisheries - 2nd Edition.	AFMA, on behalf of the PZJA, will provide the second annual report by 01 November 2022.
Condition 5:	On track:
By 30 June 2023 the Torres Strait Protected Zone Joint Authority must complete an ecological risk assessment of the Torres Strait Finfish Fishery and develop an associated risk management strategy to address any risks identified in this assessment.	CSIRO are presenting the draft ecological risk assessment documents to the RAG at FFRAG 12 meeting. These documents were provided to the RAG for noting at FFRAG 11.
Condition 6:	In progress:
The Torres Strait Protected Zone Joint Authority must review the current measures applied to the management of the take of sharks in the Torres Strait Finish Fishery to ensure that they are in line with Commonwealth best practice.	To be reviewed at FFRAG 12 meeting on 3 -4 November 2022.
Condition 7:	Progressed:
The Torres Strait Protected Zone Joint Authority must review the appropriateness of the current minimum size limits for Spanish Mackerel in the Torres Strait Finfish Fishery.	Reviewed by the RAG at FFRAG 9 meeting on 14-15 October 2021. Current minimum size limit determined to be appropriate.
Condition 8:	In progress:
By 30 June 2023 the Torres Strait Protected Zone Joint Authority must develop a harvest strategy for the Torres Strait Finfish Fishery.	To be discussed/progressed at FFRAG 12 meeting on 3 - 4 November 2022.
Condition 9:	

WTO Conditions for the Finfish Fishery

The Torres Strait Protected Zone Joint Authority must ensure that there is a sufficient level of compliance measures in place to ensure the sustainable management of the Torres Strait Finfish Fishery, in accordance with the management arrangements in place for the fishery, including the reporting of interaction with protected species.

Progress as of October 2022

On track:

To ensure AFMA's compliance efforts are targeted in the right areas an intelligence driven risk based approach, using Compliance Risk Management Teams (CRMTs) will be applied under the 2020-21 National Compliance and Enforcement Program. The 2020-21 Program will focus on four key areas, one of which is compliance within Torres Strait Fisheries, focusing on quota evasion and reporting of threatened, endangered and protected (TEP) species. This document explains AFMA's compliance program priorities and objectives for the 2020-21 financial year (FY) and performance in the 2019-20 FY.

ABARES Fishery Status Reports

- 10. Each year, the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) compiles fishery status reports which provide an independent assessment of the biological status of fish stocks and the economic status of fisheries managed, or jointly managed, by the Australian Government (Commonwealth fisheries). The most recent ABARES Fishery Status Report was released in 2021 and summarises the performance of the finfish fishery in 2019 and 2020, against the requirements of fisheries legislation and policy.
- 11. In the 2021 report, both Spanish mackerel and coral trout are classified as not being overfished, and not subject to overfishing. The status of the Torres Strait Finfish and Fishery is summarised in the table below.

Table 4. Extract from Chapter 16 of the 2021 Torres Strait Finfish Fishery ABARES Fishery Status Report.

Stock	2019		2020		Comments	
	Fishing mortality	Biomass	Fishing mortality	Biomass		
Biological status						
Coral trout (Plectropomus spp., Variola spp.)	Not subject to overfishing	Not overfished	Not subject to overfishing	Not overfished	Recent catches are below levels that are likely to drive biomass below B _{LIM} .	
Spanish mackerel (Scomberomorus commerson)	Not subject to overfishing	Not overfished	Not subject to overfishing	Not overfished	Current catch is below the recommended biological catch. Most recent estimate of biomass is above 0.2B ₀ .	
Economic status						
The key objectives of the fishery are based on socio-economic outcomes. Catch has been relatively stable in the last decade and leasing revenue for the Traditional Inhabitant Sector has increased recently.						

Notes: $\mathbf{0.2B_0}$ 20% of unfished biomass. $\mathbf{B_{LIM}}$ Biomass limit reference point.

12. ABARES fishery status reports can be accessed on the ABARES website at:

https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/torres-strait-finfish-fishery

AFMA TI Compliance 2021- 2022

- 13. During the 2021 2022 reporting period AFMA conducted 17 at sea patrols and visited 34 ports. In addition, 37 boats were inspected and 64 fish receiver premises audited.
- 14. Overall compliance by stakeholders within all Torres Strait fisheries has improved markedly over recent years. AFMA has one matter currently before the court, with one other recent matter under investigation.
- 15. One matter dating back to 2018 was also decided in favour of AFMA by the court with fines and a conviction recorded.

Fin Fish Fishery specific

16. AFMA remind all fishers and receivers to accurately record catch weights and apply the conversion rate for processed catch. It is the responsibility of the licenced fishers to remain below any quota limits applicable.

<u>Update on Climate Change Work in Torres Strait Fisheries</u>

17. Following on from the Torres Strait Scientific Advisory Committee) (TSSAC) recommendations on the climate change scoping project (presented at FFRAG 9), a follow up call for research proposals (Attachment 2.2a) was made in February 2022 with one proposal received from CSIRO (Attachment 2.2b). Having regard to feedback from all PZJA advisory committee RAGs and Working Groups out of session, the TSSAC considered this research proposal at their meeting on 6-7 April 2022 (TSSAC 81).

18. The project is intended to:

- a) enable fisheries managers and communities to better prepare for climate change mitigation and adaptation, where possible;
- b) integrate new and existing fisheries and environmental data within an over-arching data framework;
- c) provide estimates of the impacts that different climate change scenarios could have on the marine ecosystem and associated fisheries/species;
- d) provide estimates of the economic, social and other fisheries-related livelihood impacts of climate change on communities in the short (2 yrs), medium (5 yrs) and longer term (10+ yrs), and suggest some possible actions for adaptation; and
- e) help differentiate between the relative effects of fishing and climate change on marine resources.
- f) provide results in formats (e.g. graphical, video, written) which can be communicated to stakeholders (Torres Strait Island Communities, Fishers, Fisheries Managers and local and regional organisations).
- 19. Due to limited AFMA funding available to support all recommended research projects in 2022-23, the climate change modelling project is to be partially funded through a \$500,000 co-contribution

- from the Torres Strait Regional Authority and the remainder of the project funds are being considered for funding through the Fisheries Research and Development Corporation (FRDC).
- 20. An outcome on FRDC funding is expected by the end of October 2022.

Building climate change information into fisheries management processes

- 21. In other Commonwealth fisheries (fisheries managed elsewhere in Australia by AFMA), a program of work is being undertaken to ensure that climate impacts are more strategically incorporated into the management of these fisheries to ensure that AFMA continues to meet legislative objectives relating to ecological sustainability. Structured integration of information, data and research on climate impacts into AFMA's decision-making processes is a necessary foundation to pursuing climate adaptive management across Commonwealth fisheries.
- 22. This work is a follow up action from the *Adaption of Commonwealth fisheries management framework to climate change project (FRDC 2016-059)* (the climate adaptation project) that looked at the readiness of Commonwealth Fisheries Management Arrangements to the potential impacts of climate change and options to adapt to changes. Its key output was a climate adaption handbook that provides detailed steps for fisheries and other stakeholders to conduct climate risk assessment of their fishery management arrangements and operations.
- 23. Recognising the priority that the Torres Strait community places upon management of climate change impacts and the vulnerability of Torres Strait fisheries to climate change, AFMA hopes to commence similar work for Torres Strait fisheries through the PZJA's advisory committees starting with the Tropical Rock Lobster fishery and gradually expanding to other Torres Strait Fisheries.
- 24. The RAG is invited to note this body of work that is looking to build climate change information into fisheries management advice and decisions in AFMA's other Commonwealth fisheries. The RAG is invited to consider how this may apply to Torres Strait Fisheries.

Other relevant research to date on climate change impacts on Torres Strait Fisheries

- 25. In terms of assessing the likely impacts of climate change on Torres Strait Fisheries the following has been undertaken:
 - a) Qualitative Sensitivity Analysis: Assessing the vulnerability of Torres Strait fisheries and supporting habitats to climate change (Welch and Johnson 2013);
 - b) Management Strategy Evaluation to integrate climate changes into the TRL Stock Assessment: An Integrated Management Strategy Evaluation (MSE) for the Torres Strait Rock Lobster *Panulirus ornatus* fishery (Plaganyi *et al* 2012);
 - c) System Modelling: Models of Intermediate Complexity of Ecosystems (MICE) applied to TRL in the Torres Strait. Used in the following projects:
 - AFMA project 2017/0816 Environmental drivers of variability and climate projections for the Torres Strait tropical lobster *Panulirus ornatus*. (Plaganyi *et al* 2018).

- ii. Decadal-Scale Forecasting of Australian Fish and Fisheries (Fulton *et al 2018*). A non-technical summary of the decadal-scale forecasting project² is provided at **Attachment 2.2c.**
- 26. In June 2018 the TSRA and National Environmental Science Programs (NESP) Earth Systems and Climate Change Hub convened a workshop on climate change implications for fisheries and marine ecosystems in the Torres Strait. The workshop identified initial thoughts on priority areas for research that may help fisheries and marine ecosystem management in the Torres Strait (Attachment 2.2d).

Adaption of Commonwealth fisheries management framework to climate change project (FRDC 2016-059) (the climate adaptation project)

- 27. The climate adaptation project was completed in 2021 and looked at the readiness of Commonwealth Fisheries Management Arrangements to the potential impacts of climate change and options to adapt to changes. Its key output is a climate adaption handbook that provides detailed steps for fisheries and other stakeholders to conduct climate risk assessment of their fishery management arrangements and operations. During the project, AFMA worked with the CSIRO, IMAS and other researchers to answer the following questions:
 - a. What changes does AFMA need to make to its regulatory system so that it can effectively deliver its management objectives?
 - b. What are the consequences of those changes for the fishing industry and other fishery stakeholders?
- 28. While AFMA's current management strategies have flexibility built in them, it was important to assess the extent to which the direct and indirect impacts of climate change will challenge Australian fisheries and the management framework that they are currently managed under. The climate adaptation project did this by developing a risk assessment approach that tests the adaptability of current and potential management arrangements to projected, climate driven, changes of fish stocks on three case study fisheries, the Northern Prawn, Heard and MacDonald Island and Southern Bluefin Tuna Fisheries as part of the project.
- 29. The project consulted with key stakeholders from those fisheries, as well as recreational, indigenous and state fishery stakeholders to develop the final approach.

-

² AFMA led project *Adaption of Commonwealth fisheries management framework to climate change project (FRDC 2016-059)*

TSRA UPDATE

- 30. A series of Torres Strait fishing workshops was recognised as a finalist at the National Seafood Industry Awards 2022 in Brisbane. The Torres Strait Regional Authority (TSRA) and Fishwell Consulting progressed from state to national finalists in the People and Development category for their fisheries workshops with Traditional Owners from across the region. They received the People Development Award for this work focussed on capacity building of local people and communities to support sustainable seafood stock and fishing industries in northern Australia waters. The workshops were funded by TSRA and the Department of Climate Change, Energy, the Environment and Water.
- 31. The WAPIL project (Fishing for our Future) has slipped significantly mostly due to land access issues for facilities and is being reviewed. Suggested improvements in implementation and approaches will be discussed at the WAPIL Steering Committee meeting November 17^{th.} The potential benefits for the FF and RL fisheries relate to improved and increased capacity for cold chain sea food storage, processing and transport; commercial fishing operations and skills development; business planning and development and increased employment opportunities.
- 32. The Torres Strait Regional Adaptation and Resilience Plan 2016-2021, is being updated and details how climate change will impact the region's communities and land and sea country, and what steps can be taken to reduce the likely impacts in order to ensure the region has a strong viable future. The report focuses on the impacts and vulnerabilities across five dimensions of climate change resilience including human, financial, natural, physical and social capital climate change adaptions and mitigations. This updated report will complement the CSIRO scoping study and proposal for funding on climate change and variability, and the AFMA planned climate change data incorporation into fisheries management.

QDAF UPDATE

Management Arrangement for east coast Spanish mackerel

New east coast Spanish mackerel fishery management arrangements are in place from October 2022, following significant consultation with stakeholders. The changes aim to strike a balance between rebuilding the stock and providing more controlled access for recreational and commercial fishers.

The management actions for the east coast Spanish mackerel include the following:

A northern closure in east coast waters north of 22°S (located slightly north of Stanage Bay, between Mackay and Yeppoon) for two three-week periods (six weeks total) around the new moons in October and November each year. The northern seasonal closures will provide vitally important protection for spawning aggregations. The first northern closure will run from 22 October 2022 to 12 November 2022 and 21 November to 12 December 2022.

A southern closure in east coast waters south of 22°S (located slightly north of Stanage Bay, between Mackay and Yeppoon) for two three-week periods (six weeks in total) in February and March each year. The first southern closure will run from 1 February 2023 to 21 February 2023 and 1 March 2023 to 21 March 2023.

Northern closure dates will be adjusted in subsequent years to align with new moon periods.

In consideration of pre-existing charter bookings made up to a year in advance, seasonal closures will not apply to recreational fishers on licensed charter fishing trips until the following season, starting on 1 July 2023.

Other key management changes:

On 1 July 2023, the recreational possession limit will change to one fish per person, or two fish per boat with two or more recreational fishers on board (the boat limit will not apply to licensed charter fishing trips).

On 1 July 2023, the extended charter trip limit will be removed (currently allows recreational fishers to take twice the in-possession limit for charter trips longer than 48 hours).

On 1 July 2023, the total allowable commercial catch will be adjusted to 165 tonnes for the 2023 fishing season.

A new smartphone app will be developed for recreational fishers to voluntarily report Spanish mackerel catches on the east coast and shark depredation. By supplying your catch information, you also improve our data, and the accuracy of our fish stock analyses.

A new education and awareness program will be introduced to promote best practice catch, release and handling techniques for recreational fishers.

Release of the East Coast Spanish Mackerel Harvest strategy (Attachment 2.2e)

The East coast Spanish mackerel harvest strategy: 2023-2028 has been released. This strategy sets out long-term objectives for the fishery, defining catch shares among fishing sectors and specifying decision rules for managing the fishery to achieve the ecological, economic, and social objectives of the fishery. It has just been published online here:

https://www.publications.qld.gov.au/dataset/queensland-sustainable-fisheries-strategy/resource/c4464bde-682c-4360-a63c-b33ef0f00f1d

The east coast Spanish mackerel fishery was assessed in 2021 as overfished, requiring urgent action to rebuild stocks. This harvest strategy aims to rebuild the stock to a level that achieves maximum sustainable yield, and subsequently, pursues the long-term goal of achieving maximum economic yield, while maintaining catch shares amongst the commercial, recreational, charter and Indigenous fishing sectors.

This strategy will manage fishing mortality of east coast Spanish mackerel stock, primarily through setting a total allowable catch for all sectors at a level that allows the stock to achieve defined biomass targets. Other management tools (e.g. size limits, spawning closures) may also be used to support the sustainable management of this stock under this harvest strategy.

The harvest strategy has been made following significant consultation with stakeholders and aims to strike a balance between rebuilding the stock and providing more controlled access for recreational and commercial fishers.

FRDC funded Spanish mackerel research

A new research project on Qld east coast Spanish mackerel has commenced in October 2022, with funding from the FRDC. The project follows strong calls from stakeholders for more research to address data gaps, including shark depredation, environmental factors, and coarse fishing effort data. This project will involve collaboration with CSIRO, NSW DPI, JCU and Sea Sense Australia consulting.

The project objectives include:

- Determining the feasibility of Close-Kin-Mark-Recapture (CKMR) for estimating absolute abundance of Qld east coast Spanish mackerel.
- Quantify shark depredation rates across the fishery.
- Determine post-release survival of undersize fish.
- Improve the fisheries-dependent abundance index through investigation of fine-scale effort data from vessel tracking.
- Quantify the influence of environmental factors on abundance and recruitment.

Expected outcomes include:

- Development of new knowledge and skills within DAF for the application of CKMR approaches and education of stakeholders around the use of this technique.
- The empirical data collected on shark depredation and post-release survival will increase the precision of, and stakeholder confidence in, stock assessments for Spanish mackerel.
- Generation of new knowledge around the concept of Effort Signatures and its role in improving and making more robust, fishery-data derived indices of abundance.
- Increased understanding of the environmental factors that influence Spanish mackerel recruitment, year class strength and abundance.

The project components were developed based on extensive feedback from members of the Qld Spanish mackerel fishery working group, GBRMPA, NSW DPI, and fishery stakeholders to ensure they deliver management benefits and provide long-term economic certainty to the fishery.

Torres Strait Scientific Advisory Committee 2022-2023 financial year research project scope

Project Title: Understanding climate variability and change relevant to key fisheries resources in the Torres Strait and adaptation and mitigation strategies.

Project Need:

Due to their strong connection to the marine environment, Torres Strait Island communities are uniquely reliant on their only significant renewable resource, fisheries. Key commercial species in Torres Strait fisheries, such as tropical rock lobsters, prawns, finfish and beche-de-mer, and the environment they rely on, will be influenced by current and future climate variability and change. These changes have the potential to disrupt fishers and fishing communities livelihoods and threaten food security, and understanding their likely extent is essential to enable mitigation and adaptation to occur, to secure the long term economic and social benefits for Torres Strait communities. There has been relatively little investment in research on fisheries-related climate change issues in the Torres Strait, compared to other areas of Australia.

Fisheries management and assessments will need to take account of the implications of future variability and change that may affect stocks. These may manifest through effects on recruitment pathways, mortality rates, and critical habitats among other processes. Previous reviews have qualitatively assessed the vulnerability of the Torres Strait to climate change effects; however, there is a need to account for these in a quantitative manner for fisheries management and communities to respond appropriately. A quantitative MICE model (Model of Intermediate Complexity) has already been completed in the Torres Strait region for tropical rock lobster, as a part of understanding the annual variability in abundance. Separate fishery specific assessment models for multiple species, will all require essentially the same over-arching regional-scale data. This data should cover future climate and environmental variability, including currents, winds, temperature, rainfall etc, at an appropriate spatial extent and grid-resolution.

If this project is funded, the model which is developed should be transferrable to other fisheries around Australia. The outcomes of the project will also provide climate variability information which is likely to have widespread benefits to support the communities of the Torres Strait to adapt, beyond just fisheries management.

Progress to date:

AFMA has completed a scoping study that has delivered an evaluation of the over-arching data requirements and framework that are needed to support a climate change model that will evaluate the implications of future climate variability and change scenarios on key fisheries. The study considered previous reviews of climate implications for Torres Strait, consulted extensively with relevant fishery researchers, managers and key stakeholders and convened a workshop, with relevant fishery modelling expert end-users and stakeholders. The final report provided a specification and preliminary costing for a climate change project on which this project scope is based.

Desired outcomes

The proposed project and resulting model and findings should:

- i) enable fisheries managers and communities to better prepare for climate change mitigation and adaptation, where possible;
- ii) integrate new and existing fisheries and environmental data within an over-arching data framework;
- iii) provide estimates of the impacts that different climate change scenarios could have on the marine ecosystem and associated fisheries/species;
- iv) provide estimates of the economic, social and other fisheries-related livelihood impacts of climate change on communities in the short (2 yrs), medium (5 yrs) and longer term (10+ yrs), and suggest some possible actions for adaptation; and

- v) help differentiate between the relative effects of fishing and climate change on marine resources.
- vi) provide results in formats (e.g. graphical, video, written) which can be communicated to stakeholders (Torres Strait Island Communities, Fishers, Fisheries Managers and local and regional organisations).

While the full proposed project would take 3-5 years to complete, there is an urgent need to gain early estimates of climate change impacts, noting that these estimates will be refined over time as the model is further developed and new data included.

Project outputs, time frame and cost estimates

The proposed project would consist of four stages/ components, which would be scheduled according to funding and researcher availability.

Steps 1 and 2 would need to commence simultaneously and be capable of providing preliminary estimates of climate change impacts within two years.

If funding was available, it would be preferred (but not essential) if Step 4 could be commenced at the start of the project. This will allow the project to be completed more quickly, which is the preference of Torres Strait communities and fishery managers.

Other than the data collected under Step 4, the proposed project could use existing and ongoing (funded) data, including those from global climate models, the Bureau of Meteorology and Torres Strait weather and marine monitoring data which has been collected by TSRA and AIMS. The already available data will allow the project team to begin modelling sooner if the project goes ahead. New data sources, including exploring opportunities to work with the Integrated Marine Observing System (IMOS) to establish sites within Torres Strait will also be considered.

- 1. Production of an over-arching data framework (approx. one year)
- 2. Development of an integrated modelling framework that would combine existing data and models (tropical rock lobster, beche-de-mer and dugongs) into an integrated MICE (approx. two years)
- 3. Development of a regional hydrographic modelling platform resulting in a high-resolution physical circulation model (approx. two years)
- 4. A short term data acquisition programme using moored data loggers and conductivity temperature depth (CTD) casts to collect additional physical data (including temperature, salinity currents and surface elevation) over at least one set of wet and dry seasons

Torres Strait Scientific Advisory Committee research application 2021

Please note TSSAC research applications have changed. There are no longer pre proposals. As such, please complete all sections of this proposal. You are also required to attach a copy of your stakeholder engagement strategy and community consultation plan with your proposal. See Attachment A for instructions on completing these documents.

SECTION 1 - ADI	MINISTRATIVE SUMM	1ARY				
Project title:	Understanding climate variability and change relevant to key fisheries resources in the Torres Strait and adaptation and mitigation strategies					
Applicant (organisation or person): CSIRO Oceans and Atmosphere						
Contacts						
<u>Administrative</u>						
Title/Name:	Sandie Cloos	Phone:	02 6246 4235			
Position:	Finance Advisor	Email:	sandie.cloos@csiro.au			
Organisation:	CSIRO Oceans & Atmosphere	Postal address:	GPO Box 1700			
Principal Investigator (po	erson)					
Title/Name:	Leo Dutra	Phone:	07 3214 2850			
Position:	Senior Research Scientist	Email:	leo.dutra@csiro.au			
Organisation:	CSIRO Oceans & Atmosphere	Postal address:	25S: Queensland BioSciences Precinct (QBP) 306 Carmody Rd, St Lucia, QLD 4072			
Co-investigator (s)						
Title/Name:	Eva Plaganyi	Phone:	07 3833 5955			
Position:	Senior Principal Research	Email:	eva-plaganyi-lloyd@csiro.au			
Organisation:	CSIRO Oceans & Atmosphere	Postal address:	Queensland BioSciences Precing 306 Carmody Rd, St Lucia, QLD			
Co-investigator (s):						
Title/Name:	Laura Blamey	Phone:	07 3214 2378			
Position:	Research Scientist	Email:	laura.blamey@csiro.au			
Organisation:	CSIRO Oceans & Atmosphere	Postal address:	Queensland BioSciences Precing 306 Carmody Rd, St Lucia, QLD			
Planned Start and End [Date					
Start Date:	01/07/2022	End Date: 01/03	3/2026			

SECTION 2 – PROJECT BUDGET

PROJECT BUDGET: (Excluding GST)

Financial Year	AFMA	Applicant (in kind)	Applicant	Other
2022-23	\$270,561	\$114,407		\$0.00
2023-24	\$405,687	\$171,545		\$0.00
2024-25	\$235,000	\$99,370		\$0.00
2025-26	\$137,711	\$58,231		\$0.00
Totals	\$1,048,959	\$443,553		\$0.00

SECTION 3 – PROJECT DESCRIPTION

Background and need (max 250 words) - detail any important background relating to the project. Why it is important and being proposed (need). Any related projects or other information the TSSAC should know when considering it for funding.

Fisheries in Torres Strait strongly support lifestyles, livelihoods and economic activities, but are at risk from climate change. Understanding the nature and extent of climate change impacts, and their socio-economic and livelihood consequences will help stakeholders better manage risks and adapt.

The research proposed will provide to fishers and managers up-to-date evidence-based information about current and future risks to fisheries associated with climate change. It will develop an integrated model of intermediate complexity for ecosystem assessment (i-MICE) to estimate climate change impacts on selected fisheries/species. Model development follows a stepwise approach. In Phase 1 available data and models will be combined in a data framework, i-MICEv.1 will be developed by extending and linking current biological models of key species (TRL, BDM, dugongs), known environmental drivers (SST) and habitat (seagrass). i-MICEv.1 will investigate the impacts of climate change scenarios on fisheries/species in the short (2yr), medium (5yr) and long-term (20 yrs), also considering socio-economic and livelihood metrics.

Phase 2 will develop a 3-dimensional ocean model to generate additional oceanographic data, based on climate change scenarios. The new data will feed into a refined i-MICEv.2 to investigate broader implications (i.e. not only related to SST) of climate change on the selected fisheries. Model results in both phases will be used to inform stakeholders and co-develop adaptation strategies via workshops.

Phases 1 and 2 are designed to be 'stand-alone' sequential exercises, but could be done in parallel which would allow the generation of timely results to stakeholders and development of adaptation strategies.

Objectives / performance indicators (max 250 words) - *list the major objectives or planned outcomes of the project. These will form your project milestones (Section 5):*

Phase 1

- 1. Establish a project steering committee (PSC) with guidance from AFMA and TSRA.
- 2. Develop data framework which will include collated fisheries and environmental datasets identified in the scoping study.
- 3. Integrate available data and models for Tropical Rock Lobster, bêche-de-mer, dugongs and seagrass into an integrated spatial MICE (i-MICEv.1) for the Torres Strait region and provide estimates of relative impacts from climate change (sea surface temperature for base case and a high emission scenario) on fisheries resources in the short (2yrs), medium (5yrs) and longer term (10+ yrs).
- 4. Refine social, economic and livelihood metrics (from previous Torres Strait Lobster MSE project) with PSC and link these metrics with the i-MICEv.1 model and present results from i-MICEv.1 to stakeholders and based on results, co-develop adaptation actions during workshops (if Phase 2 is funded, adaptation strategies will be finalized at a later stage (8).

Phase 2

- 5. Establish a monitoring program to collect physical data needed to calibrate the 3-dimensional ocean model of Torres Strait. Publish calibration data in Torres Strait data framework (2).
- 6. Develop and calibrate 3-dimensional ocean models (to cover the Torres Strait area). Generate outputs for physical processes for baseline and climate change scenarios. Deliver model outputs in the Torres Strait data framework (2).
- 7. Build i-MICEv.2 based on new variables from Torres Strait 3-dimensional ocean models and update estimated impacts.
- 8. Present results of the project to stakeholders and communities and co-develop adaptation strategies via stakeholder workshop(s).

Consultation and Engagement — Note: community consultation is required with key Torres Strait community stakeholders as a part of a TSSAC research project application being considered for funding.

This consultation will be required following conditional approval of a research proposal by the TSSAC. In order to facilitate this consultation, you are asked to develop a "stakeholder engagement strategy" and "community consultation package" as part of this research application. Please follow the instructions at Attachment A.

If there has been any initial consultation and engagement with Torres Strait communities already for this project, or for similar projects in the past, please outline with whom and the key outcomes. Please also outline any other consultation you have completed with other stakeholders too. (.

In 2021 CSIRO delivered the scoping study "Scoping a future project to address impacts from climate variability and change on key Torres Strait Fisheries" to AFMA which evaluated the availability and suitability of existing data required to develop future models to assess the impacts of climate change in Torres Strait fisheries. The findings from the scoping study included extensive consultation with fishery researchers, managers and key Torres Strait stakeholders, and included a technical workshop organised in October 2020 to present the proposed data and modelling frameworks, where input from participants were used in the final project scope specifications and preliminary costs provided.

The scoping study found that some datasets and models are available to start the modelling exercise. It recommended the consolidation of the available data into an overarching data framework and integration of existing data and models into a model of intermediate complexity for ecosystem assessment (MICE). The scoping study also recommended the construction of MICE in a stepwise fashion, adding new data and complexity as these become available or necessary, and engage with stakeholders to communicate model results at early stages and draw on local knowledge to further refine models. Also, given the paucity of hydrodynamic and physical data for the region, the scoping study recommended the development of a dedicated hydrodynamic model for Torres Strait because previous hydrodynamic models and supporting data are outdated. The Torres Strait hydrodynamic model would provide new oceanographic predictions at scales relevant to the management of fisheries by dynamically downscaling climate change scenarios that could then be used to refine and further develop MICE. As discussed during presentation of the scoping study with TSSAC in 2021, developing 3-dimensional ocean models and collecting the necessary data for its calibration and validation is expensive, but would be useful to investigate broader impacts of climate change in the region. For example, on other fisheries, different ecosystems and communities. The current proposal implements the recommended stepwise approach in the developments of models, also incorporating local knowledge, community and management needs via actively engaging with stakeholders.

Methods (max 250 words) – Detail the methods that will be used to undertake this project.

Phase 1

A project steering committee (PSC) will be established with support from AFMA and TSRA. The PSC will meet at least for 2h, 3 times/year to guide and advise on progress, stakeholder engagement, communication, adaptation strategies and other relevant matters.

The overarching data framework will use CSIRO IT infrastructure to collate, manage and describe datasets identified in the scoping study. These descriptions will be made public to allow non-CSIRO researchers to access and visualise data.

i-MICEv.1 will extend and link current biological models of key species (TRL, BDM, dugongs), known environmental drivers (sea surface temperature) and habitat (seagrass). The model will provide quantitative estimates of impacts from baseline and climate change scenarios on habitat and fisheries/species in the short (2yr), medium (5yr) and long-term (20 yrs). Previous social, economic and other fisheries-related livelihoods metrics will be refined with PSC and linked to i-MICE.

i-MICEv.1 results will be presented to stakeholders in a workshop, where adaptation strategies will be co-developed. Techniques such as scenario planning, impact and livelihood adaptation pathways will be applied in the workshop. Adaptation actions will only be developed here if Phase 2 is not funded.

Phase 2

Field work: Two moorings will be deployed for two months each over wet and dry seasons to collect the required physical data to extend boundaries, calibrate and validate a 3-dimensional ocean model of Torres Strait. The model will run baseline and climate change scenarios to generate new oceanographic data to develop i-MICEv.2, and updated results will be presented to stakeholders in a workshop where adaptation strategies will be co-developed.

Planned outcomes and benefits (max 150 words) – this should include how the research will be used by management to benefit the fishery and other stakeholders:

The research will integrate existing and new data and models into a data framework and develop i-MICE to estimate changes in fisheries and ecosystem resources due to climate change. It will integrate these results with socioeconomic and livelihood metrics, present research results back to stakeholders, and draw on local knowledge to further refine models. Model results will be presented and discussed with stakeholders and used to co-develop adaptation actions and to inform existing planning and adaptation processes. This will allow local communities and fisheries management to proactively prepare for short-long term changes anticipated under climate change. All data collected and produced in the project will be securely stored and managed via the proposed overarching data framework, where stakeholder information (e.g. local knowledge) will only be used with formal consent.

Project extension (max 100 words) - are there possible future research options that could result from this project?

Several research projects can result or benefit from this project. For example, the i-MICE modelling framework will allow the addition of complexity (e.g. new habitats, species and environmental conditions) depending on needs and data availability in the future. The combined i-MICE and ocean models will provide new hydrodynamic data and quantified impacts from climate change scenarios that could be used to support a broad range of further research on impacts and adaptation in Torres Strait. For example, they will allow the investigation of: (a) interactions between different fisheries and ecosystem functioning, (b) climate change impacts on abundance and distribution of a broader range of fisheries and species, (c) impacts of incidents (e.g. oil spills, ships running aground), (d) synergistic and cumulative climate and non-climate impacts on species, ecosystems and livelihoods, and e) the evaluation of alternative adaptation options.

Risk Analysis - be sure to consider risks specific to conducting research in the Torres Strait including community support or lack there-of.

The project team has a long history of research and stakeholder engagement in the region, and this considerably reduces the risk of a lack of support for the research. The project scope in which this proposal is based has invested time and effort to engage with stakeholders and the technical and fisheries management communities, inviting their inputs, and involving them in the research scope to the extent possible. As a result, there is strong interest and support from TSSAC to better understand climate change impacts in the fisheries of Torres strait and more broadly. There are a number of risks associated with conducting fieldwork in a remote region to collect the environmental data needed to develop the ocean model, such as strong currents, remote locations, and prevailing weather conditions, but CSIRO has strong expertise and experience in managing and avoiding any risks as they arise, plus stringent protocols in place to minimize these, which include mothership compliance with AMSA regulations, survey equipment inspection checklists, regular equipment servicing, and field work management.

Related Projects and Research Capacity (max 100 words) - *Are there any past or current projects relevant to this proposal funded through the TSSAC, TSRA, FRDC or other organisation? Outline the Investigators' experience in the proposed research and Torres Strait region.*

CSIRO has conducted research (e.g. surveys, assessment and harvest strategy development projects) on Rock Lobsters, bêche-de-mer and other fisheries in Torres Strait, including seabed habitat monitoring (including seagrass) and subsequent stock assessments since 1989 (PIs: Eva Plaganyi, Nicole Murphy et al.). This project builds also on a recent project led by Leo Dutra (CSIRO): Climate variability and change relevant to key fisheries resources in the Torres Strait and is also complemented by an FRDC project (led by Leo Dutra), which aims to build research capacity in the Torres Strait by engaging Torres Strait Islanders and CSIRO researchers in the coproduction and presentation of research at international conferences.

CSIRO has collaborated with Torres Strait islander communities, organizations and individuals throughout its history working in the area to ensure research outcomes are relevant to Torres Strait. Torres Strait islanders are provided with results of the research projects.

SECTION 4 - Schedule of Payments

As a general rule, up to 10% of the total project cost may be provided as an initial payment and a minimum of 30% of the total project cost must be left for the final report.

Milestones	Deliverable date (Please refer to instructions)	Schedule of AFMA payment(s) (excluding GST)
Initial payment on signing of contract	01/07/2022	\$0.00
Establish project steering committee	01/11/2022	\$0.00
PHASE 1		
Data framework	30/07/2023	\$87,356
Fisheries and socioecological estimates of climate change impacts on ecosystem and fisheries (iMICEv.1)	30/09/2024	\$360,107
Presentation of model results to stakeholders and adaptation strategies	30/10/2024	\$35,108
Phase 1 report	30/11/2024	-
PHASE 2		
Data collection to calibrate and validate hydrodynamic model	01/04/2025	\$157,929
Hydrodynamic model runs for climate change scenarios	30/07/2025	\$277,185
Assessment of climate change impacts using new oceanographic data from TS hydrodynamic model (i-MICEv.2	27/02/2026	\$95,460
Presentation of model results to stakeholders and development of adaptation strategies	31/03/2026	\$35,814
Draft final report	15/04/2026	-
Final report	30/04/2026	-
TOTAL		\$1,048,959

SECTION 5 - Description of Milestones

Details on each milestone must provide sufficient information to justify the milestone cost and should match the performance indicators. The description field will describe the work to be completed for that milestone with the justification field elaborating further on the categories of cost - for example salary.

Milestone:	Initial payment on signing of
	contract

Date:

01/07/2022

Financial Year	Salaries	Travel	Operating	Capital	Total
2022-23	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00

Description:

					- •			
	us	+.	+.	~~	+.	\sim	n	•
J	us	LI		La		u		•

Milestone: Establish project steering committee Date:

01/11/2022

Financial Year	Salaries	Travel	Operating	Capital	Total
2022-23	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00

Description:

A project steering committee (PSC) composed of fisheries managers, fishers, community members and other relevant stakeholders will be established at the beginning of the project. Lisa Cocking (AFMA) agreed to further discuss the process to establish a steering committee with TSRA and the project team if the project is funded. The PSC is expected to meet at least 3 times a year for 2h, where meetings can be conducted online or face-to-face depending on funds, time and needs of PSC members. Please note that no funds were budgeted in the proposal to cover travel, incidentals, sitting fees or any other costs for PSC members (assumed to be voluntary).

Justification:

Climate change is a contentious issue in Torres Strait and requires adequate mechanisms to ensure expectations about the project are adequately managed. A PSC will be important to address these issues by providing advice to the project team on research results, and guidance to select relevant metrics for fisheries and livelihood impacts that could be used to support management and planning processes. The PSC will also guide the project team about appropriate communication of research results and limitations, stakeholder engage during the development of the adaptation strategies and provide advice on extra-ordinary matters if they arise.

Milestone: Data framework Date: 30/07/2023

Financial Year	Salaries	Travel	Operating	Capital	Total
2022-23	\$60,098	\$0.00	\$2,108	\$0.00	\$62,206
2023-24	9,226				9,226
2024-25	9,486				9,486
2025-26	6,438				6,438
TOTAL					\$87,356

Description:

The proposed data framework identifies how the physio-chemical and ecological data will be managed and delivered to support the development of the proposed integrated MICE models and other research in Torres Strait. Datasets will be managed on CSIRO IT infrastructure, utilising relational database systems and enterprise file servers. Datasets will be described using geonetwork (www.marlin.csiro.au) and these descriptions will be made public to allow third parties (non-CSIRO) to access data depending on level of permission granted (i.e. licence restrictions). Datasets will be shared using Open Geospatial Consortium (OGC) standards where appropriate, by using a standards-compliant webserver (geoserver) linked to the collated data. This framework is scalable, robust and compliant with open data/metadata standards, allowing a flexible data delivery method to data visualisation portals, such as Torres Strait eAtlas and the Australian Ocean Data Network (AODN) portal (to be decided with PSC). The project will ensure confidentiality of local knowledge, which will only be used in the project or stored in the data framework with formal consent, following strict human ethics protocols.

Justification:

The data framework described will support the development of the integrated MICE model to investigate impacts of climate change on the selected fisheries, and other future research efforts in the region. It will also be the repository of data generated in the project, including calibration data for the hydrodynamic model and its outputs. The data framework will include metadata to allow the identification of datasets, access or permissions required to access data, restrictions, and spatial-temporal coverage of datasets. The data framework is flexible and has the potential to be deployed in other regions of interest.

Milestone: Fisheries and socio-

ecological estimates of climate change impacts on ecosystem and fisheries

(iMICEv.1)

Date:

30/09/2024

Financial Year	Salaries	Travel	Operating	Capital	Total
2022-23	\$125,430	\$0.00	\$2,109	\$0.00	\$127,539
2023-24	\$182,661	\$0.00	\$0.00	\$0.00	\$182,661
2024-25	\$49,907	\$0.00	\$0.00	\$0.00	\$49,907
TOTAL					\$360,107

Description:

i-MICEv.1 will extend and link current biological models of key species (TRL, BDM, dugongs), known environmental drivers (sea surface temperature) and habitat (seagrass). The model will provide quantitative estimates of impacts from baseline and climate change scenarios on habitat and fisheries/species in the short (2yr), medium (5yr) and long-term (20 yrs). Social, economic and other fisheries-related livelihoods metrics from previous Lobster MSE project will be refined with PSC and linked to i-MICEv.1. Risk statistics from climate change scenarios relative to base line will be produced. This will allow stakeholders to understand, for example, under climate change, how frequently the abundance or catch of a certain species might be expected to change compared to baseline scenario and to compare the relative risks for each spatial (e.g. fishing) region and socio-economic consequences.

The custom-designed modelling framework will be flexible and scalable, will account for uncertainty, and complexity could be added if needed by including additional species, and new climate, oceanographic and environmental data, as they become available (e.g. from Stage 2).

Justification:

i-MICEv.1 will provide the modelling framework linked to existing data and models to generate quantitative estimates of impacts from climate change scenarios on selected habitats and fisheries. This modelling framework will be extended into i-MICEv.2 if Phase 2 is funded which would allow the further investigation of climate change impacts considering a broader range of oceanographic conditions (e.g. currents, sea level, rainfall, etc.). Outputs will be presented and discussed with stakeholders during workshops and adaptation actions will be co-developed with them (adaptation actions will only be finalised here if Phase 2 is not funded).

Milestone: Presentation of Phase 1

model results to stakeholders and adaptation strategies Date:

30/10/2024

Financial Year	Salaries	Travel	Operating	Capital	Total
2024-25	\$22,106	\$8,082	\$4,920	\$0.00	\$35,108

Description:

Regular updates and results from i-MICEv.1 will be presented to PSC and to broader stakeholders at workshops to provide an opportunity for Q&A, feedback, and discussions including how to communicate results suitable to inform existing planning processes. Methods such as scenario planning and impact and livelihood adaptation pathways will also use i-MICEv.1 results to codevelop adaptation actions with stakeholders. Communication methods will be previously developed with PSC and discussed with broader stakeholder groups during the workshop.

If Phase 2 is funded, this workshop will involve: (a) information session to provide and discuss i-MICE results to guide the developments in the next phase, and (b) refinement of communication methods with stakeholders.

Justification:

There is a need to adequately and regularly communicate i-MICEv.1 results to PSC and broader stakeholders to inform the process to develop adaptation strategies. Stakeholders will have the opportunity to provide inputs into the delivery of climate change information to the different audiences in Torres Straits, thus making the information more salient to stakeholders.

Milestone: Phase 1 report Date: 30/11/2024

Financial Year	Salaries	Travel	Operating	Capital	Total
	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00

Description:

Final report containing results from assessment of climate change impacts on ecosystem and fisheries/species, feedback from stakeholders on results collected during workshop and adaptation strategies (if Phase 2 is not funded).

Justification:

This will be final report of project if Phase 2 is not funded and a preliminary report to inform development of models in Phase 2 if proposal is fully funded.

Milestone:

Data collection to calibrate and validate hydrodynamic model

01/04/2025

Financial Year	Salaries	Travel	Operating	Capital	Total
2022-23	\$42,317	\$5,271	\$33,228	\$0.00	\$80,816
2023-24	\$37,828	\$5,271	\$34,015	\$0.00	\$77,114
TOTAL					\$157,929

Description:

A monitoring program to collect physical data to calibrate the hydrodynamic model will involve 2 deployments of moorings (ADCP, CTD to collect physical data such temperature, salinity, currents (velocity, direction), surface elevation) at sea surface and bottom. Each deployment will last for 2 months over the wet and a dry seasons of years 2022-23.

Justification:

Developing the ocean model will require a data collection program for model calibration. The ocean model will provide valuable oceanographic data under different climate conditions that will improve our understanding about tides, currents sea temperature, salinity, pH and other physical drivers. Such data could be integrated in i-MICEv.2 to investigate, for example, the influence of physical drivers on reproduction, growth, larval dispersal and settlement, recruitment, abundance and distribution.

Milestone: Hydrodynamic model runs Date: 30/07/2025

for climate change

scenarios

Financial Year	Salaries	Travel	Operating	Capital	Total
2023-24	\$134,579	\$0.00	\$2,108	\$0.00	\$136,687
2024-25	\$138,390	\$0.00	\$2,108	\$0.00	\$140,498
TOTAL					\$277.185

Description:

CSIRO will apply a full 3 dimensional ocean model to simulate oceanographic conditions for a baseline and climate change scenarios. The ocean model will produce 3D hydrodynamic fields of the environment on a variable resolution grid that can be nested within operational Ocean models and CMIP style ocean models. The grid will be designed to resolve the area of interest for the MICE study. If needed, model resolution for specific fisheries areas will be increased by nesting high resolution models (10s to 100s of meters) inside the regional ocean model, through the relocatable coastal ocean model.

Outputs from the hydrodynamic model will be produced for the Torres Strait Region at a minimum of 1km grid cell resolution (finer in specific areas if required) as monthly averages for specific regions of interest (e.g. MSE sub-regions, or fishing sub-areas). New data generated will be used to add complexity to i-MICEv.2 to evaluate the effects of climate change on a broader range of oceanographic conditions and their impacts on the selected ecosystem and fisheries/species.

Justification:

Currently, only existing datasets for sea surface temperature have adequate spatial and temporal resolution to be used in i-MICE. Timeseries of other oceanographic variables exist but cover limited temporal or spatial scale. There are model outputs from downscaled models that are also available, but discrepancies between model outputs and observations were previously identified and need careful consideration and calibration before their use. Ocean model outputs will be used to extend the range of climate change variables to be explored in i-MICEv.2 to provide outputs that can support additional research in Torres Strait.

Milestone:

Assessment of climate change impacts using new oceanographic data from TS Hydrodynamic model (i-

MICEv.2)

Date:

27/02/2026

Financial Year	Salaries	Travel	Operating	Capital	Total
2025-26	\$95,460	\$0.00	\$0.00	\$0.00	\$95,460

Description:

Phase 1 is the starting point to initiate the investigation of climate change impacts in Torres Strait fisheries. Phase 2 is about generating new oceanographic data to allow for a more comprehensive investigation of climate impacts on physical variables and their effects on fisheries. New oceanographic data generated with the ocean model will be used to add complexity in the i-MICEv.2 to further investigate climate change impacts on the fisheries. Updated results will be presented to stakeholders.

Justification:

We use a step-wise approach in the development of i-MICE where in Phase 1, existing data are currently available to start modelling and investigate potential climate change impacts on the selected fisheries. In Phase 2, we add new data and complexity (from the ocean model) as these become available. This step-wise process allows time to obtain feedback from stakeholders on model development/assumptions/results in i-MICEv.1 and incorporate this into i-MICEv.2, allowing time to communicate model results, as well as drawing on local knowledge to further refine models and the information they generate.

Milestone:

Presentation of model results to stakeholders and development of adaptation strategies

Date:

31/03/2026

Financial Year	Salaries	Travel	Operating	Capital	Total
	\$25,623	\$5,271	\$4,920	\$0.00	\$35,814

Description:

If funds for Phase 2 are available, a second workshop will be organised to present and discuss updated results from i-MICEv.2 and to co-develop adaptation actions using scenario planning, and impact and livelihood adaptation pathways techniques.

_				_			
In	cti	ifi	ca	ti	n	n	

There is a need to adequately present and discuss research findings with stakeholders and identify ways of providing information to support existing planning and management process. I-MICEv.2 results will also support a process to co-develop adaptation strategies.

Milestone:	Draft report	Date:		15/05/2026	
Financial Year	Salaries	Travel C	perating	Capital	Total
	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Description:					
Justification:					
Milestone:	Final report	Date:		10/06/2026	
Financial Year	Salaries	Travel C	perating	Capital	Total
	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Description:					
Justification:					

Section 6 – Special Conditions

If relevant, this field will be used to assist in contract preparation for any special conditions. Examples of special conditions

may relate to marine spatial closures (including access) or any other clauses not specifically contained in the contract.

N/A

Section 7 - Data management

Identify the appropriate Intellectual Property category applicable to this application. Choose ONE from below:

Code	Description
1	Published, widely disseminated and promoted, and/or training and extension provided. Relates mainly to outputs that will be available in the public domain.
2	Published, widely disseminated and promoted, and/or training and extension provided. Related products and/or services developed. Relates mainly to outputs that will largely be available in the public domain, but components may be commercialised or intellectual property protected.
3	Published, widely disseminated and promoted, and/or training and extension provided. Related products and/or services developed. Relates mainly to outputs that may have significant components that are commercialised or intellectual property protected.

The following IP category applies to this application:

1. Published, widely disseminated and promoted, and/or training and extension provided. Relates mainly to outputs that will be available in the public domain.

I have searched for existing data (refer to guidelines on how to search the Australian Spatial Data Directory and Oceans Portal):

[Yes]

Provide a brief description of the data to be generated from the project and how this data will be stored for future protection and access, including:

• information on data security or privacy issues and applying to the data

Nominated data custodian

Physio-chemical data from monitoring program to calibrate ocean model (e.g. profiles of temperature, salinity, currents, etc) will be entered into and stored in the future overarching data framework that will also be delivered as part of the project. Data storage, protection and access is governed and managed according to CSIRO policy guidelines, in accordance with CSIRO rules and regulations.

- Document how research data, traditional knowledge and intellectual property will be handled during your project, including but not limited to:
- Acknowledging where the data or information used in research comes from, so that any income made from selling a concept in the future will be adequately linked to a community's contribution/ knowledge so they also receive financial or other benefit from "selling" a concept onward.
- How you will negotiate use and publish of traditional knowledge with communities. For example do
 traditional inhabitants allow public publication of information or only for project activities and
 reported on in internal reports? This will depend on data sensitivity and privacy (such as fishing
 grounds etc).
- Are there any other ethical considerations you have identified for this project which need to be managed?
- Are you committed to gaining ethics approval for this project from a suitable body such as a university or AIATSIS?

Acknowledging where the data or information used in research comes from, so that any income made from selling a concept in the future will be adequately linked to a community's contribution/ knowledge so they also receive financial or other benefit from "selling" a concept onward.

N/A – research will not include commercialisation of any products.

• How you will negotiate use and publish of traditional knowledge with communities. For example do traditional inhabitants allow public publication of information or only for project activities and reported on in internal reports? This will depend on data sensitivity and privacy (such as fishing grounds etc).

Special consideration will be taken with any Traditional Knowledge (TK) collected during the project. TK will only be used with the express permission and consent of the traditional owners. Guidance will be sought from local Island leaders and the TSRA to ensure full local support and agreement over the handling of TK information.

• Are there any other ethical considerations you have identified for this project which need to be managed?

Yes, participation in planned workshop sessions will be voluntary and participants will be given the opportunity to withdraw form participation at any time during or after the workshop. The project will follow established ethical guidelines prepared by the CSIRO Human Ethics committee.

 Are you committed to gaining ethics approval for this project from a suitable body such as a university or AIATSIS?

Yes – CSIRO has its own Human Research Ethics committee which considers the Code of Ethics for Aboriginal and Torres Strait Islander Research from AIATSIS. The project will seek human ethics approval from the CSIRO human ethics committee.

STAKEHOLDER ENGAGEMENT STRATEGY AND COMMUNITY CONSULTATION PACKAGE

Planning & development – who to engage and how

Researchers are required to develop a stakeholder engagement strategy as part of their TSSAC research proposal application process, which will include a short community consultation package which will be provided to the relevant stakeholders. This plain English package will be reviewed by the TSSAC along with your research application. You are required to work with the TSSAC Secretariat on the development of these documents. You **are not** required to undertake this consultation until conditional approval is given to your project and this engagement strategy. However, your full proposal submitted to the TSSAC can detail engagement and consultation undertaken with stakeholders and communities in developing the proposal to date, or relevant consultation from past projects, if this is an extension project, or continuing project.

Stakeholder engagement strategy

The stakeholder engagement strategy should detail the level of engagement required with the key stakeholders throughout the stages of the project (including the preliminary consultation phase as part of this research proposal, project implementation, updates about project progress and results dissemination following project completion).

The strategy should be no more than 2 pages and include:

- the areas in the Torres Strait region where the proposed research activities may occur (i.e. eastern or central communities, specific islands/ communities); and which Torres Strait community groups or individuals you will engage/involve from these areas during your research project? e.g. does your project involve community workshops or meetings? Will it employ any Torres Strait Islanders (paid or on a voluntary basis) and if not why not, will your project interview Torres Strait Islanders? Will your project require you to visit any Torres Strait communities (or is it solely at sea)?
- The types of engagement you plan to use during different phases of the project (e.g. during the initial consultation, for updates during the project, to disseminate results of the project). The project such as posting community notices, developing plain English summary reports, recording short educational videos or infographics, phone calls or emails);
- how research data, traditional knowledge and intellectual property will be handled during the project;
- how researchers will show respect for Traditional Inhabitant culture at all times.

The strategy should consider the projects' schedules and fieldwork and allow for extra lead-time, longer engagement periods in the community and appropriate response times when drafting milestones.

Note, depending on the level of engagement with the RNTBCs this may be on a fee for service basis. Researchers need to factor in any potential fee for service rates into the research project budget.

Example stakeholder engagement strategy

Timing	Task	Method of communication
March	Complete engagement with communities	Community notices, email to key
	about proposed project seeking feedback	stakeholders, follow up with phone calls at
		least twice if no response
August	Email key stakeholders to provide plain	email to key stakeholders with contact
	English project progress information	number if they wish to discuss.
December	Email key stakeholders to provide plain	email to key stakeholders with contact
	English project progress information	number if they wish to discuss.

June	Create and disseminate plain English summary of project outcomes.	Email to key stakeholders, community notice with QR code to website with summary.
June	Create short video with slides showing main project outcomes	Email video to key stakeholders, place community notice with QR code to website with the video link.

Community Consultation Package

The community consultation package should contain plain language information about the proposed research, be no more than two pages and may include:

- a process for clearly noting, upfront, that the project is in the application stage which is why you are seeking community views and consideration;
- the research objectives and timeframes;
- areas to be accessed for the study, and a detailed description of areas and details of what will be done there;
- materials, equipment and techniques to be used and how you will minimise risk of negative impacts on the area (environment and communities);
- involvement of key stakeholders (including local knowledge informants, local research assistants, and community information- sharing and research dissemination intentions)
 OR a brief explanation of why community involvement does not fit the nature of the project);
- anticipated outcomes including direct or indirect benefits* to key stakeholders such as any future benefit-sharing expectations, protections for traditional knowledge sources.
 AFMA may use the project summary for developing papers to communicate the research at relevant PZJA forums:
- likelihood and details of any extension activities following the research;
- how research data and intellectual property will be handled; and
- seeking advice about relevant traditional knowledge which could assist the project, or suggest changes to improve the projects' plan or success.

*For example, a) a greater understanding of a fishery through participation (potentially employment) in the research project and extension activities following the research (direct); b) improved understanding of stock status may lead to less precautionary Total Allowable Catch therefore increased utilisation of resource (indirect).

What happens following community engagement, as a part of my research application process?

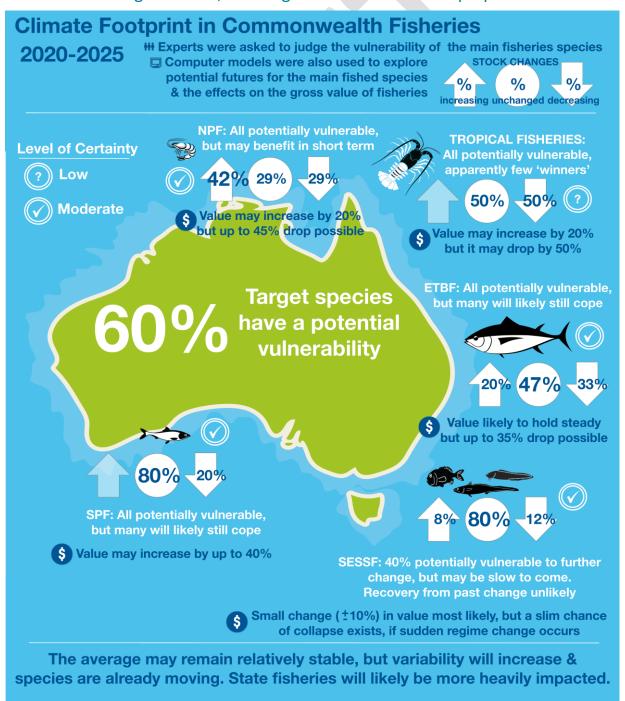
Once you have undertaken the community consultation (following conditional approval of your project), provide a clear summary of the results to the TSSAC secretariat detailing:

- A list of Torres Strait communities you consulted and how this occurred including engagement methods.
- The feedback provided by each individual or group (or the number of attempts of contact if you didn't not receive a response).
- Any perceived risks or stakeholder considerations with the project.
- Any changes to be made to the proposal based on feedback.
- How traditional knowledge might be considered or incorporated to enhance the project, its outcomes and benefits including IP issues associated with this
- How the research outcomes will benefit Traditional Inhabitants directly or indirectly, or why it is not relevant/applicable.



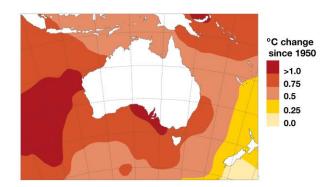
Australian fisheries stocks under climate change

Over the next twenty years Australia's marine ecosystems are expected to exhibit some of the largest climate-driven changes in the Southern Hemisphere. These changes will extend from the ecosystems to the local communities and businesses of the Australian fisheries sector. The CSIRO and its collaborators have pulled together all available information on how climate may affect fished species in Australia – identifying those most sensitive to climate. This information helps highlight those species that may be at risk and those that might benefit, allowing fisheries to be better prepared.



Climate change in Australian Waters

Australia's oceans are undergoing rapid change. The waters off south-east and south-west Australia are hotspots, warming much more rapidly than most of the world's oceans. Australia's tropical ocean is also warming rapidly, almost twice as fast as average for the rest of the world. It is important to understand what this means for the ecosystems in these warming waters if we are to continue to be sustainably manage Australian fisheries. Understanding the changes and being climate ready is important for both industry and management, because it allows them to plan their operations to avoid or mitigate negative impacts and to make the most of new opportunities that arise.



Water temperature change around Australia since 1950. Image updated from BOM data. These temperature increases mean water temperatures often record breaking.

Australian fish species have already begun to move. Over 100 Australian species have already started migrating south towards cooler southern waters. There have also been a series of marine heatwaves and other extreme events that have harmed Australia's seagrass, kelp forests, mangroves and coral reefs. These changes in the distribution, abundance and species composition in Australia's marine ecosystems mean that Australia's commercial fisheries are being affected by climate change. It is unavoidable. The ocean also has a long memory, which means that the effects of past and present human activities have already locked the world in to a further 0.5-1 °C warming. This is why fisheries managers (e.g. at AFMA) have asked for a rapid and thorough update of information so that they can base their strategic planning on the latest and best information.

Sensitivity of Australian Fisheries Target Species

Australian fisheries catch more than 100 species. There is not enough data or resources available to perform fine scale assessments for each species. Instead experts on the fisheries and target species were asked identify the key target species in State and Commonwealth fisheries. The experts then had to rank each species in terms of how sensitive it was to climate change. This sensitivity was judged in terms of factors that affect:

- abundance (how old they are when they mature, how often they reproduce, number of eggs, diet and habitat needs);
- movement and spatial distributions (distance they can move, how widely spread they are already, available habitats):
- behaviour (needing special triggers for reproduction or migration, having special behaviours that only happen for short periods)

Across all Australia 70% of all key target species are have moderate to high sensitivity in one of these factors. Within the AFMA managed fisheries at least 50% of the target species per fishery are moderately to highly sensitive and in many AFMA managed fisheries all the target species are sensitive in one way or another.

Most species were sensitive to factors determining their distribution or behaviour, while only about 25% were sensitive in terms of factors that directly influence abundance. The greatest sensitivity to the timing of key behaviours was along the coastline of eastern Australia (north and south), while shifts in distribution are the most likely responses in the west and in the tropical north. Invertebrates had higher sensitivity scores than other species. As a consequence, dive – and other gears targeting invertebrate – show the highest sensitivities. Purse seine fisheries for small pelagic species has the lowest sensitivities.

The sensitivity analysis suggests that fisheries should first consider how changes in distribution and the timing of key events affect them and their management and then consider potential than changes in abundance.

Sensitivity of Species Targeted by Australian Fisheries

Summary of sensitivity per fishery. Low sensitivity is for those species with a low rating across all 3 factors — abundance, distribution and behaviour. Moderate sensitivity indicates that a species had 1 factor that was scored as being moderately sensitive to climate change. High sensitivity covered both the case where a species was rated as having a factor that was highly sensitive to climate change or they had multiple factors rated as moderately sensitive. Sensitivity does not automatically indicate a likely decline it indicates the potential for change (including possible increases)

Commonwealth Fishery	Low	Moderate	High
Bass Strait Scallop			Scallops: behaviour and distribution
Coral Sea			Coral trout: distribution and abundance
Eastern Tuna and Billfish		Behaviour of all target species	
Northern Prawn			Behaviour and distribution of all target species
South and Eastern Scalefish and Shark	Species already showing shifts (warehou, morwong, redfish, ling) show low sensitivity to further climate driven change	Gemfish: abundance. Trevalla, flatheads, and whiting behaviour.	All/majority of properties of squids, sharks, blue grenadier and orange roughy.
Small Pelagics		Behaviour of sardine and blue mackerel	Jack mackerel and red bait behaviour and distribution
Torres Strait			All properties of tropical rock lobster
State Fisheries			
New South Wales, Victoria, South Australia		Behaviour of snapper, tuna and some small pelagics.	Many small pelagic, estuarine and invertebrate species (mainly via behaviour and distribution). All properties of sharks and blue grenadier.
Queensland		Behaviour of estuarine and shelf fish, as well as Spanish mackerel and billfish.	Behaviour and distribution of all reef fish. All properties of the majority of invertebrates and sharks.
Gulf of Carpentaria (Queensland and Northern Territory)	Bream and sharks	Majority of mackerels, estuarine fish and mangrove associated species (due to a mix of factors).	All/majority of properties of snappers, emperors and all valuable invertebrate species (prawns, lobster, sandfish).
Northern Territory and Western Australia	Many sharks, estuarine and large pelagic fish	Large sharks: abundance. Behaviour or distribution of fish non-reef shelf fish	All/majority of properties of reef associated fish and all invertebrates.
Western Australia		Distribution or behaviour of herring, reef associated predators, some abalone, octopus and sandfish.	All/majority of properties of prawns, crabs, many small pelagics, some abalone, oysters, bream and dhufish.

Fisheries projections

The other approach to consider the future climate change effects on Australia's fisheries was to take existing models of Australian marine ecosystems (which together cover the entire EEZ) and run them under the conditions that might exist over the next 40 years. The results of these models were then used to see how species abundance and distribution might change and how ecosystems might restructure.

The modelling work found that the different ecosystems around Australia face different types and levels of climate change – including temperature changes, changes in rainfall patterns, ocean acidification, shifting ocean oxygen levels. For fisheries as large as the SESSF different parts of a fishery will be undergoing different levels of change. In most instances, larger changes in the climate led to larger model responses. The tropics, however, might see some large changes despite only small shifts because those shifts will influence the productivity of phytoplankton that supports the entire food web.

Those models that only look at the physical environments preferred by species predicted there would be reasonably large declines for the majority of fish populations around Australia. However, once all the other processes that occur in ecosystems (e.g. feeding, movement, habitat use) were included in the models the picture is more complicated – some species decline, but others benefit and grow in abundance, though perhaps living in new locations.

The models also predict that the ecosystems will become more variable. The Tasman Sea, for example, could have strings of very productive years interspersed by series of years with exceptionally low production. This variability is reflected across the entire food web, with many of the species shifting their distributions in response – seeking out desirable habitats and food sources.

For many species the different models are in agreement, increasing confidence in the robustness of results. When the models disagree this highlights uncertainty and where more information is needed. Many of the species ranking highly in the sensitivity analysis also show enhanced responses to climate change in the models. In the short term many of the models predict little further change for most species (noting that this means that already depleted species do not show signs of recovery). Further in to the future (30-40 years) things become more uncertain, with the different models not always agreeing on whether species will increase or decrease in abundance. This is because simple physical responses alone may not dictate a species response to climate change. As abundances change, predation and competition within food webs will also change. This means that new or novel food webs may form, changing ecosystems unexpected ways. In some regions (such as south eastern Australia) the ecosystem may eventually shift into a new state that is quite different to today, though this will be dependent on exactly how the physical climate drivers interact with the many different responses of all the species making up the food web and habitats in that region.

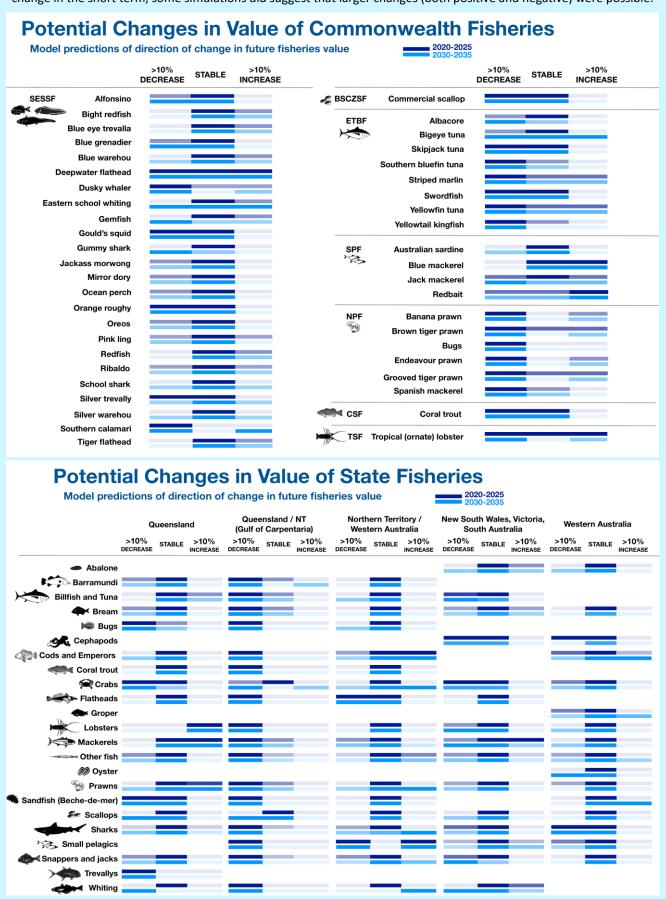
Implications of Climate Change

It is clear from the changes that have already occurred, and what the sensitivity and models predict, that there will be strong differences in the level of effects and responses across different species and food webs. Demersal food webs, those species that live near to or amongst habitats on the seabed, appear to be more strongly affected by climate change. Invertebrates, who are amongst Australia's most valuable target species, are particularly sensitive. Pelagic food webs, where species live up in the water column, appear less sensitive and may even benefit from the environmental changes.

This is a concerning finding as much of Australia's seafood is sourced from species that are members of demersal food webs or reliant upon them. Individuals in shallower (more effected) waters, or already living on the edge of what they can tolerate, will be the first to respond and will show the greatest magnitude of response. Some of these changes have already begun. The decline of species such as abalone associated with marine heatwaves and tens of species already observed to be moving south (e.g. into Tasmania and other places where they have not previously been recorded).

Invertebrates may be among the most heavily impacted species. They are often highly productive, but with relatively short life spans; meaning they can respond quickly, but often have little buffering capacity (they cannot ride out many poor years before suffering significant decline at the population level). Many invertebrates also have specific habitat requirements. Altogether these characteristics mean that invertebrates are more volatile and are quite sensitive to variation in climate and extreme events.

Both Commonwealth and State fisheries will face changes in gross value as a result of climate change effecting both the fish stocks and (potentially) the behaviour of the fishers. While the majority of the model results suggest little change in the short term, some simulations did suggest that larger changes (both positive and negative) were possible.



Ecosystem responses will not only respond to changes in temperature, precipitation or to ocean acidification. Variability in primary production (i.e. production by the plants and algae at the bottom of the food web) will also be important. For instance, if there is little change in primary production then ecosystems will likely show little change (so long as temperatures do not shift beyond what may species can physically tolerate). Unfortunately, it is not yet clear what future primary productivity will look like around Australia – as some important processes are still not completely understood. This means that understanding and predicting future changes in primary production remains an active area of research and updates will be provided as rapidly as possible.

Many mechanisms can lead to changes in ecosystems – whether through behaviour, distribution or abundance of the species and habitats in them. The drivers causing the changes can be different species to species. For some it will be due to changes in environmental conditions, this can cause the timing of seasonal events (like spawning) to move which can affect the success of those behaviours. If environmental conditions move beyond preferred ranges species will move to more favourable conditions or dwindle in abundance. For many species change will result from a loss (or shift) in habitat but for others changes will occur because the availability of their prey changes. For still other species it could be due to a shift in what their predator(s) are doing – if a predator moves away the prey abundance might grow, whereas if a predator starts to eat more of the prey (due to a shift in diet) then the prey population might decline. As frustrating as it may be for managers, industry and researchers looking for simple explanations and a way to make things more straight forward, it will likely come down to a case-by-case basis (which may even vary spatially across a species' geographic range).

Human responses to all these changes could also complicate things. Well informed decisions are one of the best ways of avoiding negative outcomes and maximising opportunities. A nested approach – where models and vulnerability assessments are used to identify the most at risk species and locations – appears to be the best way of targeting monitoring and management responses.

Given existing understanding of ecosystems, climate change and the sensitivities highlighted in this project a small set of management recommendations can be made:

- i. A staged response might be necessary, where fishing activities are first adjusted due to shifts in behaviour (e.g. changing the timing of seasonal closures to make sure they continue to line up with seasonal behaviours like spawning or migrations), before looking to respond to changes in spatial distributions.
- ii. Not all fisheries and operators will be exposed to the same level of change. Likewise, not everyone will have the same capacity to adapt. This will compound the differential outcomes seen across species and fisheries. One option is to simply accept uneven social and economic consequences. A more attractive alternative is to have information services (websites, newsletters, radio updates) to help explain what is going on, what the options are and the need for change as well as to provide support mechanisms to help those that are struggling to adjust.
- iii. Successful management will require a diverse set of good scientific tools. No single approach will be sufficient due to existing uncertainty and the interplay of climate and fishing with the ecosystem components and processes. New management and assessment tools will also be needed. The complexity of possible species responses and the increasing importance of environmental drivers means that current models used in stock assessments to advise on acceptable catch levels maybe insufficient for understanding stock patterns under climate change. Key interactions and dependencies may need to be included to better reflect how the species is responding. This means that models used in fisheries assessments will likely need to be extended along the lines of the approach known as "MICE", which are models that not only include the target species but also the most important environmental (and other) drivers that set the context for the species' responses.
- iv. Existing management strategies and objectives must be reviewed in terms of whether they help or hinder long term ecological and resources management objectives. Are they likely to deliver as desired into the future, if a stock is depleted can they rebuild it or help to recover degraded ecosystems? These considerations must go beyond focusing on fisheries to think about the structure of the whole ecosystem and which species are needed to maintain ore rebuild them. Such a rethink will require a greater coordination between conservation and fisheries management.
- v. Fisheries policy, management and assessment methods need to allow for the concept of regime shifts and extreme events and for contextual management decision making. Taking lessons from locations that have already faced such challenges suggests that indicators that can track what state the environment is in can be used to let managers know when they need to adjust acceptable levels of fishing pressure and protection.
- vi. Fisheries management methods should be made as flexible as possible, so they can change as rapidly as need to respond to changing system state. The speed of change means a no (or at least minimal) regrets approach to management needs to be taken, with updates as new information comes to light. Management instruments may also need to be adapted. Reference points defining an overfished state or a desirable state for target species might need to be modified if there is a regime shift in ecosystem state or stock productivity. Fisheries closures may need to be based on water bodies (large areas of water of a specific temperature) rather than simply relying on the protection of fixed geographic locations.

- vii. Management decision making will need to (i) more explicitly prioritize resources and awareness around vulnerable/ sensitive species and fisheries or (ii) have a clear discussion around whether some species are beyond management (as the environment has made it impossible for the species to recover). Such decisions can't be taken lightly but might be necessary if large environmental changes occur.
- viii. Australia-wide coordination of management will be imperative as species shift or environmental changes span State and Commonwealth boundaries. Without such coordination (or centralised management) local stress for fishing communities could become significant and new opportunities will likely be missed.
- ix. Fisheries management will need to interlink with the management of other uses of the marine environment that is Australia will need to use *integrated marine management*. The number of uses of the marine environment is rapidly expanding and growing to a scale not seen before in the oceans. Mining, energy generation, transport, aquaculture (farming), recreation etc. are now all competing for space and resources in the oceans and along increasingly crowded coastlines. It is important for fisheries to see themselves in the context of all of this activity so they respond appropriately given that bigger picture.

Providing information to industry operators and managers so they can address all these changes will require good data sources. There are still many things we do not know about Australia's ecosystems and how they respond. Fishers and managers (and the scientists helping them) will require as much information as possible if they are to understand what is happening and act wisely to mitigate undesirable outcomes and make the most of any new opportunities. Such a climate robust approach to fisheries will require the combination of a number of different sources of information, including:

- Measurements and forecasts of the physical environment (temperature, salinity, rainfall, storm patterns) extending what is already provided by the Bureau of Meteorology. Sharing the data from net net sensors (for example) can help provide a more accurate picture of the current conditions and the conditions fish prefer.
- Satellite images of ocean colour (which can be used to estimate how much plankton is in the water) can help
 predict where fish will be and can also forewarn of coming issues with stock productivity and recruitment. Plankton
 recorders voluntarily mounted on ships (e.g. tankers) can also help collect very useful information about what is
 happening at the bottom of the food web (this can help us understand how that effects the rest of the food web
 including those fish that are targeted by fisheries).
- Good quality catch and effort data is the longest and one of the best sources of information on target species in Australia.
- Survey data is also important as it helps give a more complete picture of what is going on. Catch data is very useful
 but having a second set of information from surveys helps to be sure about what is going on catches don't always
 reflect what the fish are doing, especially of the fishers have changed their behaviour in response to markets (for
 example).
- Citizen science data collected by Australians using smart phones and cameras represents a new source of potential
 data. Nearly every Australian citizen now owns a 'smart phone' which has sensors and an on-board computer that
 is more powerful than what was available to scientists as little as a decade ago. Data collected via photographs and
 voluntary reporting can be a very valuable source of information once it has been processed and scientifically
 collated. Australians see themselves as an ocean loving people so we shouldn't turn down any help they are eager
 to provide.

Looking Forward

Australian fisheries are in the midst of a period of rapid environmental change. This change is going to continue into the future and will differ place to place around Australia. Fishers and managers will need to be flexible if they are to cope with these changes. A failure to do so will bring economic (and likely social) hardship. Management will need to allow for spatial shifts and potentially for shifts in targeting and relevant management reference points. Management that is coordinated across State and Commonwealth fisheries and that links with the other users of marine waters is likely to do better than if those links are ignored. Healthy fisheries will also require good information services that are updated regularly with the latest understanding of what Australia's climate, fish, ecosystems and fisheries are doing. This is the summary of the latest (2018) update. If you would like more information please contact us (details below) or check out the websites listed below.

Useful Websites

Redmap (Range Extension Database & Mapping project) – www.redmap.org.au – this website invites the Australian community to spot, log and map marine species that are uncommon in Australia, or along particular parts of our coast. This helps keep everybody up to date on how Australia's species are moving. The website includes useful summarise on what climate change is and what it means for Australia's oceans.

BOM – www.bom.gov.au/climate – this website has a long list of climate time series and updates, including annual reports on what Australia's climate is doing.



Images: Shutterstock.com

CONTACT US

- t 1300 363 400 +61 3 9545 2176
- **e** csiroenquiries@csiro.au **w** www.csiro.au

We innovate for tomorrow and help improve today – for our customers, all Australians and the world.
We imagine. We collaborate. We innovate.

FOR FURTHER INFORMATION

CSIRO Oceans and Atmosphere Beth Fulton or Alistair Hobday

- t +61 3 6232 5222
- e beth.fulton@csiro.au
- w www.csiro.au







National Environmental Science Programme



WORKSHOP REPORT

Climate change in the **Torres Strait**

Implications for fisheries and marine ecosystems

June 2018

Earth Systems and Climate Change Hub Report No. 4





The Earth Systems and Climate Change Hub is supported by funding through the Australian Government's National Environmental Science Program. The Hub is hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and is a partnership between CSIRO, Bureau of Meteorology, Australian National University, Monash University, University of Melbourne, University of New South Wales and University of Tasmania. The role of the Hub is to ensure that Australia's policies and management decisions are effectively informed by Earth systems and climate change science, now and into the future. For more information visit www.nespclimate.com.au.

Copyright

© CSIRO 2018



Climate change in the Torres Strait: implications for fisheries and marine ecosystems is licensed by CSIRO for use under a Creative Commons Attribution 4.0 Australia licence. For licence conditions see https://creativecommons.org/licenses/by/4.0/

Citation

NESP Earth Systems and Climate Change Hub. 2018. *Climate change in the Torres Strait: implications for fisheries and marine ecosystems*, Earth Systems and Climate Change Hub Report No. 4, NESP Earth Systems and Climate Change Hub, Australia.

Contact

Enquiries regarding this report should be addressed to:

Earth Systems and Climate Change Hub PMB 1 Aspendale Vic 3195

info@nespclimate.com.au

Published: June 2018

This report is available for download from the Earth Systems and Climate Change Hub website at www.nespclimate.com.au.

Cover photo credit: AIMS/Ray Berkelmans, CC BY

Important disclaimer

The National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, the NESP ESCC Hub (including its host organisation, employees, partners and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

The ESCC Hub is committed to providing web accessible content wherever possible. If you are having difficulties with accessing this document, please contact info@nespclimate.com.au.

Contents

Introduction Background4 Torres Strait fisheries and marine ecoystems Understanding Torres Strait stakeholders......7 Climate change and impacts The climate context: variability, extremes, change and risk relevant to impacts on marine systems in the Torres Strait9 Climate trends and projections for the Torres Strait Islands......12 Vulnerability of Torres Strait fisheries to climate change.......15 Cascading consequences......18 Managing impacts Adapting to a changing environment: learning with the Torres Strait community to understand future impacts on wellbeing......21 Science to inform management Work being done in or relevant to Torres Strait fisheries and climate change26 Australian Fisheries Management Authority26 Torres Strait Regional Authority29 NESP Tropical Water Quality Hub......30 Science, data and research priorities31 Information to support management and adaptation Existing information and tools......32 **Appendices** Appendix 1: Workshop agenda34 Appendix 2: Workshop participants......37

AT A GLANCE

Key messages from the workshop

The climate is changing in the Torres Strait. Research shows that it is changing, communities see it on country (land and sea) and fishers see it in the changing state of natural resources.

Marine impacts from climate change in the Western and Central Torres Strait will include coastal erosion and declines in reef health and diversity, loss of critical inshore habitat, increased sea temperatures and sea levels and changes to currents and water quality; all of which will have a variety of direct and indirect impacts on fish stocks and marine ecosystems. Climate change will affect fisheries productivity, species distributions and seasonality, so subsistence and commercial fishery practices will need to be able to adapt to shifting circumstances.

It is important that all relevant parties are engaged in conversations about what climate change means for fisheries and marine ecosystems in order to prepare for the changes. Local traditional knowledge and scientific knowledge from the research community are important tools which can and should be integrated to help understand and prepare for future changes.

Torres Strait fisheries and marine ecosystems

- Torres Strait has diverse, productive and commercially, ecologically and culturally valuable fisheries and marine resources.
- There are complex traditional and regulatory management and resource sharing arrangements.
- Marine resources are likely to constitute a large proportion of protein for local communities.
- Traditional values of marine resources are very important to Torres Strait communities.

Climate change and impacts

- Being island based and heavily dependent on their marine resources, Torres Strait communities have certain inherent vulnerabilities in relation to climate change impacts compared to other parts of Australia.
- Climate change will strongly impact the Torres Strait marine environments and fisheries due to increased frequency and intensity of extreme events such as marine heatwaves, sea-level rise and changes to ocean oxygen content and ocean pH.
- Possible changes to ocean circulation and currents could have major ramifications fisheries and marine ecosystems.

Managing impacts

 Traditional fishers already practice many of the approaches needed to help ensure they can adjust to some of the likely impacts of climate change, such as providing

- spatial flexibility in fishing effort by observing Traditional boundaries between each community's sea country.
- Community values have an important role to play in determining management and adaptive responses to the impacts of climate change.
- Traditional cultural spatial management of resources between Australia and Papua New Guinea, while effective when observed and well supported, could contribute to conflict between the haves and the have-nots as climate change impacts increase.

Information to support management and adaptation

- There are already many climate projections data and information products available for the region, ranging from relatively large spatial scale (e.g. global and regional climate projections located at www.climatechangeinaustralia.gov.au) to smaller scale (e.g. downscaled CCAM projections for some parts of northern Australia and Papua New Guinea) and some regional ocean and fisheries modelling, but it is not necessarily accessible.
- Global model projections have limited value for the Torres Strait Islands because of the geography (small size and limited topography) of the islands and the poor resolution of El Niño-Southern Oscillation/Pacific Decadal Oscillation influences. Instead, higher resolution modelling (including ocean modelling and fisheries modelling) is needed to provide information at the appropriate spatial scale.
- Tidal dynamics need to be further taken into account to improve the climate downscaling in the Torres Strait region.
- Important oceanographic and environmental data are intermittent and/or absent, and there is a need for dedicated Torres Strait modelling across a range of applications related to fisheries.
- Although a lot of climate information is being continually generated, very little targeted information at required intervals is available to Torres Strait fishers to inform their seasonal fishing practices.
- Provision of regular climate, adaptation and management information via an annual forum or other updates may be useful.
- Managers seeking to adapt to climate/climate change issues in Torres Strait can glean valuable information from relevant projects around Australia and in the Pacific.
- Researchers need to have due diligence to present information appropriately for local communities so useful information can be placed in the hands of the local decision makers who are the traditional custodians of the resource.
- Communities in the Torres Strait are keen to be involved in discussions about how a changing climate affects fisheries.
- There is enough information now from studies in Torres Strait and adjacent areas (as proxies and examples) to make management decisions in the short term. Filling some key knowledge gaps and downscaling climate change projections will provide information to refine actions, but we don't need to wait for this information to act now.
- Consultation and engagement with traditional owners and fishers is paramount to appropriately target actions for key fisheries and vulnerabilities.

Background

The National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub and Torres Strait Regional Authority (TSRA) jointly convened a workshop in December 2017 to bring together key researchers and managers to review the current state of relevant scientific knowledge about climate change impacts on communities of the Torres Strait Islands, with a particular emphasis on inshore fisheries and marine ecosystems. This is the first time that climate and fisheries researchers and managers working in the Torres Strait have come together in this way.

The workshop is the first in a series of engagements that aim to:

- build relationships and raise awareness and understanding of key stakeholders (including traditional owners/local fishers, natural resource managers, other local communities of interest and scientists)
- identify data and information gaps and needs where appropriate
- develop options for the delivery of relevant science-based products and services to target end-users to inform policy development, management/adaptation planning and associated decision-making.

The objectives of this workshop are to:

- 1. Assess current state of knowledge and understanding on climate projections and impacts as they relate to the marine environment in the Torres Strait.
- 2. Capture knowledge of any observed or reported shifts in environmental variables
- 3. Identify key data and knowledge gaps and assess priority areas and issues from a scientific and managerial perspective and make recommendations for further focus or investigation
- 4. Determine communication products that should be developed to increase awareness and understanding of key stakeholders of climate change impacts on Torres Strait marine fisheries and ecosystems
- 5. Improve coordination and collaboration across relevant agencies and stakeholders and scope next steps in the proposed series of engagements.
- 6. Determine the nature of ongoing engagement with traditional owners on this issue. In practice, it will likely be facilitated through the TSRA and the fisheries working groups/management forums.

The workshop program and participant list are included in the appendices of this report.

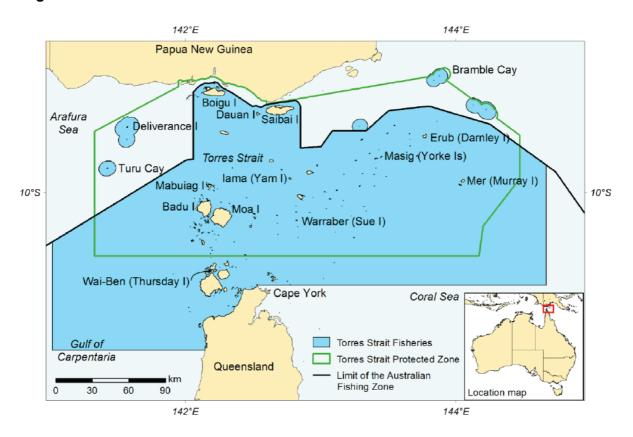
This report, which provides a brief synthesis of the workshop presentations and key discussion points, is the primary workshop output.

Fisheries in Torres Strait

Ian Butler, AFMA

- Torres Strait fisheries have complex arrangements for resource sharing.
- Torres Strait fisheries cover a diverse range of species.
- Historical catch data have been difficult to obtain, but improvements are being made (fish receiver data).

Region



The Torres Strait Protected Zone (TSPZ) is jointly managed by Australia and Papua New Guinea (PNG) through bilateral discussions. Within Australian waters in the TSPZ, traditional and commercial fishing are managed by the Protected Zone Joint Authority.

The fisheries in this region are shared between traditional inhabitant commercial fisheries, traditional artisanal fisheries, PNG fisheries and recreational fishers. Formal catch arrangements between Australian and PNG fishers are established under the Treaty.

The fisheries have commercial, cultural and lifestyle value.

Key fisheries

Torres Strait Finfish Fishery	Spanish mackerel but some other species	Trolling lure	2016 catch: 86.9 t Value: n/a (total finfish \$1.2 m)
Torres Strait Finfish Reef Line Fishery	Mostly coral trout but also other groupers, snapper, emperor, barramundi and trevally	Hook and line, spear, nets and traps	2016 catch: 38.7 t Value: n/a (total finfish \$1.2 m)
Torres Strait Tropical Rock Lobster Fishery	Tropical rock lobster	Hand diving (surface air supply, free diving); 306 commercial licenses (294 traditional inhabitants); artisanal; shared resource with PNG	2015–16 catch: 445 t Value: \$14.3 m
Torres Prawn Fishery	Brown tiger prawns, blue endeavour prawns, also other prawn species, bugs, octopus and squid	Caught at night using demersal otter trawl	2016 catch: 412 t Value: \$8.9 m
Torres Strait Beche-de-Mer Fishery	Sea cucumber (e.g. black teatfish, prickly redfish, sandfish, white teatfish, surf redfish)	Collected by hand free diving or on reef flats; scuba and hookah banned; traditional inhabitant and artisanal fishers only	2016 catch: 14.9 t Value: not assessed Illegal fishing from other countries
Trochus	Trochus	Collected by hand free diving or on reef flats; scuba and hookah banned; traditional inhabitant and artisanal fishers only	Catch: 0 t Illegal fishing from other countries
Pearl shell	Gold-lipped and black- lipped pearl shells	By hand for use in farming (Qld); traditional inhabitants only (with PNG)	Catch: limited to small amounts
Torres Strait Crab Fishery	Mostly mud crabs, some blue swimmer	Hand or scoop net; traditional inhabitants and artisanal fishers	Value: unknown
Turtle		Traditional artisanal fishers	Culturally important for food
Dugong		Traditional artisanal fishers	Culturally important for food

Understanding Torres Strait stakeholders

Charles David, TSRA

- The Torres Strait economy benefits significantly from the ocean. Jobs etc. often stem from the health of and access to fisheries - traditional fishing is commercial fishing.
- Climate change impacts shift movement patterns of fish and directly affect the health of coral and other less mobile aquatic resources.
- Wild stocks, in some cases, are at lower levels than recently observed and others are not recovering from past overfishing. To what degree these are attributed to or compounded by the impacts of climate change is unknown. Employment opportunities for Islanders could reduce as a consequence of continued decline in stocks.
- There are implications for ownership and management arrangements, aspiration and the current status of the fishery.
- Traditional knowledge considerations are important for management of Torres Strait Island fisheries.
- A summation of climate change in Torres Strait and what to expect in a given timeframe needs to be delivered to traditional owners and/or full-time commercial and community fishermen.

The Torres Strait Treaty and Torres Strait Fisheries Act 1984 (Commonwealth) are in place to acknowledge and protect the traditional way of life in the Torres Strait and the traditional inhabitants.

The Protected Zone Joint Authority (PZJA) is responsible for management of commercial and traditional fishing in the Australian area of the Torres Strait Protected Zone (TSPZ) and designated adjacent Torres Strait waters.

The PZJA is comprised of the Commonwealth and Queensland Ministers with responsibility for fisheries and the Chairperson of the TSRA. The PZJA is advised by a framework of management advisory committees made up of Torres Strait Islander fishers, commercial fishers, fishery managers and scientists. Recreational fishing is managed under Queensland law.

The Torres Strait fisheries management structure does not exist anywhere else in the country. The structure can make it seem difficult to get things done; however, this is not the case – you just have to have the traditional owners at the table.

There are five cluster groups in the Torres Strait. Traditionally you seek permission to go into someone else's sea country, but commercial fishing licences are for the whole zone so there's a disconnect between the two systems.

Roadmap to 100% fisheries ownership

The TSRA is working with key regional stakeholders and traditional inhabitants to achieve 100% ownership of the region's fisheries for traditional inhabitants. Both the finfish and bêche-de-mer fisheries are 100% owned by traditional inhabitants. The tropical rock lobster fishery is 66.18% owned by traditional inhabitants (at 20 November 2017, as reported on the TSRA website).

Traditional management of Torres Strait fisheries

Traditional areas and boundaries are important to traditional owners and their maintenance can be advantageous both culturally and for sustainability. Traditional owners want traditional boundaries and management to be recognised (which is why bringing traditional owners to the table is important).

Torres Strait Islanders have seen the changes, especially in fish stocks – and believe this is a strong reason why returning to traditional management (because it's more sustainable) is crucial. Turtle and dugong are success stories for traditional management.

Things in the past have resulted in some distrust of the science and 'westerners'; this is being overcome slowly.

The climate context: variability, extremes, change and risk relevant to impacts on marine systems in the Torres Strait

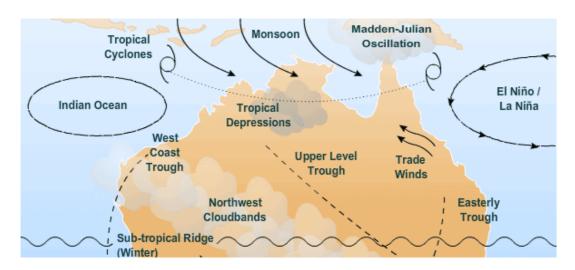
Neil Holbrook, ESCC Hub

- Torres Strait Islands are subjected to considerable ocean and climate variability (dominated by the monsoon and El Niño-Southern Oscillation) and extremes (including sea-level extremes, marine heatwaves, tropical cyclones and storms - and the associated winds, waves and storm surges – and extreme rainfall.
- Impacts of long-term changes in ocean temperatures (surface and deep), sea level and storminess will be both physical (e.g. inundation, erosion, coral damage) and ecological (affecting habitats, communities and species).
- Ocean acidification (reduction of ocean pH) affects calcifying organisms.

Variability

The climate of the Torres Strait is characterised by the monsoon wet season (December-April) with north-westerly winds and the dry season (May-November) with south-easterly winds.

The El Niño-Southern Oscillation (ENSO) contributes to year-to-year variability. During El Niño events, northern Australia is drier than normal, while during La Niña events it is wetter than normal. ENSO also plays a strong role in year to year variability of sea level.



(Source: Commonwealth of Australia 2010, Bureau of Meteorology. http://www.bom.gov.au/climate/about/)

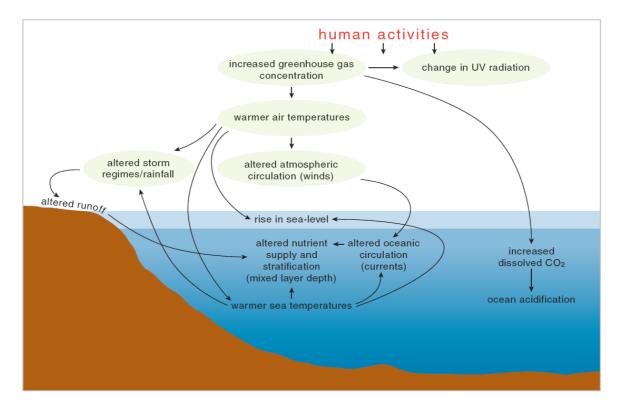
Extremes

By definition, extremes are rare and intense. They include tropical cyclones, storm surge, heatwaves (including marine heatwaves) and heavy rainfall.

Climate change, sea level rise and extremes

The impacts of sea-level rise will be felt most profoundly during extreme sea-level events. Increased sea level will increase the frequency of these events and the frequency of coastal inundation and erosion. Extreme sea levels may also change due to changes in storms (their frequency and intensity may change).

Climate change will also increase the frequency of extreme El Niño and La Niña events.



Physical and chemical changes in atmosphere and oceans due to climate change (Source: Poloczanska et al. 2007)

Implications

Coastal systems are particularly sensitive to sea-level rise, warming oceans and ocean acidification. The Intergovernmental Panel on Climate Change Working Group 2 contribution to the fifth assessment report gives examples of key risks.

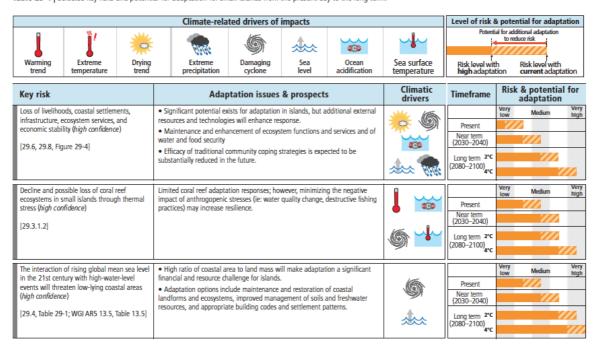


Table 29-4 | Selected key risks and potential for adaptation for small islands from the present day to the long term.

(Source: Table 29-4 in Nurse et al. 2014)

References/more information

- Nurse LA, McLean RF, Agard J, Briguglio LP, Duvat-Magnan V, Pelesikoti N, Tompkins E, Webb A (2014) Small islands. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [VR Barros, CB Field, DJ Dokken, MD Mastrandrea, KJ Mach, TE Bilir, M Chatterjee, KL Ebi, YO Estrada, RC Genova, B Girma, ES Kissel, AN Levy, S MacCracken, PR Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1613–1654.
- Poloczanska ES, Babcock RC, Butler A et al. (2007) Climate change and Australian marine life. Oceanography and Marine Biology 45, 407-478. doi:10.1201/9781420050943

Climate trends and projections for the Torres Strait Islands

Josephine Brown, ESCC Hub

- There is an observed warming trend in both air and sea-surface temperatures in the Torres Strait.
- Rainfall is highly variable, with a strong influence from the El Niño-Southern Oscillation. A trend due to global warming cannot be identified in the observations.
- Regional projections for the Torres Strait include warmer sea-surface temperatures and higher sea level. Rainfall will become more variable with more intense extreme events.

Climate projections

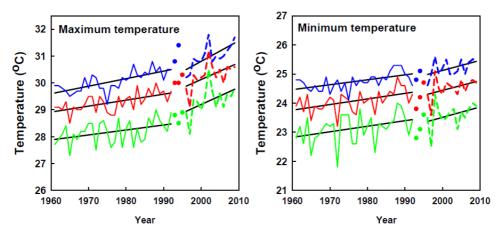
Projections based on global climate models generally cannot resolve the details of islands, topography or ocean currents in the Torres Strait. Global model information can be useful for some applications, while higher resolution (downscaled) model output may be needed for other applications. It is also important to evaluate whether the model can reproduce the observed present-day climate of the variable of interest (e.g. rainfall, temperature), and to consider the influence of model biases and errors on the climate of the Torres Strait.

Climate drivers

Climate in the Torres Strait is heavily influenced by the monsoon and the El Niño-Southern Oscillation (ENSO). In the future, monsoon rainfall is likely to be more variable than it is now and the influence of ENSO on rainfall will be greater.

Temperature

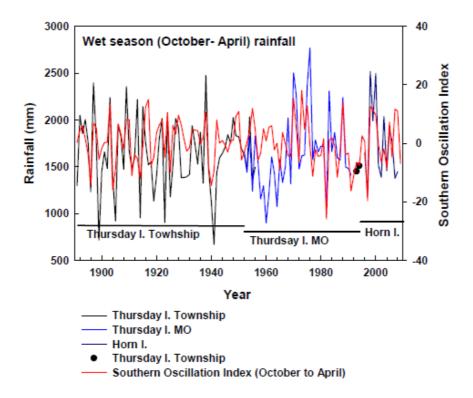
Mean temperature currently ranges annually from about 22–25 °C (min) to 28–32 °C (max). Temperatures have increased over the past century, with the rate of warming higher since 1960. Average temperatures will continue to increase in all seasons as a result of long term climate change, and there will be more hot days and warm spells.



Observed temperatures. Solid lines are records taken at Thursday Island MO. The observation site changed to Horn Island (dotted lines).

Rainfall

Rainfall has a strong seasonal cycle due to the influence of the monsoon. ENSO also influences rainfall, with drier years during El Niño events and wetter years during La Niña events. Changes to rainfall as a result of climate change are possible but unclear, but intensity of extreme daily rainfall events will increase.



Sea-surface temperature

The oceans around Australia have warmed. In the Torres Strait, this warming has occurred at 0.08–0.12 °C per decade since 1950. Sea-surface temperature will continue to increase as a result of climate change.

Ocean acidification

The pH of waters around Australia is decreasing (i.e. becoming more acidic). In the Torres Strait, the pH has dropped by 0.085-0.095 between 1880-89 and 2000-09, and ocean acidification will continue as a result of climate change.

Tropical cyclones

Tropical cyclones are generally located south of Torres Strait, but six have tracked through Torres Strait since 1906 and many more over Cape York. Since the 1970s there has been an overall trend for fewer tropical cyclones in the Australian region, and it is expected that there will be fewer but more intense tropical cyclones in the future as a result of climate change.

Sea level

In the period 1993–2015, sea level has increased in the Torres Strait by 6–7 mm per year. Mean sea level will continue to rise as a result of climate change, and height of extreme sealevel events will also increase.

References/more information

- Climate Change in Australia https://www.climatechangeinaustralia.gov.au/en/
- State of the Climate 2016 http://www.bom.gov.au/state-of-the-climate/index.shtml
- CoastAdapt https://coastadapt.com.au/
- Pacific Climate Futures https://www.pacificclimatefutures.net

Vulnerability of Torres Strait fisheries to climate change

Johanna Johnson, Tropical Water Quality Hub

- Torres Strait fishers already operate under climate variability and practice flexible approaches that will help with adaptation to future climate change impacts.
- There is enough information now from studies in Torres Strait and adjacent areas (as proxies and examples) to make management decisions immediately. Filling some key knowledge gaps and downscaling climate change projections will provide information to refine actions, but we don't need to wait for this information to act now.
- Consultation and engagement with traditional owners and fishers is important to target appropriate actions to key fisheries and vulnerabilities (and within the local/cultural context)

Potential climate change impacts on species

Species	Key potential impacts of climate change (2030)
Coral trout – common/barcheek/ passionfruit	 Reduced catchability after intense storms Reduced survival/development of early life stages due to increased sea-surface temperature (SST+) Adult movements into deeper waters due to SST+ Impacts on coral reef habitat may affect juvenile survival
Dugong	 Declines in seagrass negatively impact dugong due to: primary food source preferred habitat Increased stranding mortality due to intense storms
Blue endeavour prawn & brown tiger prawn	 Impacts on seagrass may decrease juvenile growth and survival Compromised growth and survival due to SST+ (near northern limit)
Turtle	 Female biased populations due to higher air temperatures during egg incubation Decrease in available nesting sites/disrupt successful nesting due to sea-level rise (SLR), more intense storms and extremes in rainfall Increased stranding mortality due to intense storms Impacts on seagrass may decrease growth and survival
Trochus	Unknown and previously assessed as minor
Sandfish	Generally unknown
Black teatfish	Reproductive success may be compromised (winter spawner) with SST+

Species	Key potential impacts of climate change (2030)				
Tropical rock lobster	 Faster growth and higher larval supply, but decreased juvenile survival due to SST+. Net result reduced spawning biomass Adult movement into deeper water due to SST+ Settlement areas and recruitment rates may change due to altered north-west Coral Sea currents 				
Mud crab	 Higher catch rates due to SST+ Possible population increases due to increases in rainfall 				
Spanish mackerel	Possible links between SST and larval survival but generally unknown				
Gold-lipped pearl oyster	Reduced larval growth due to increased rainfall/lower salinity				
Black-lipped pearl oyster	Lower abundance due to upper thermal limits of ~32 °C for adults and reduced larval growth >29 °C				

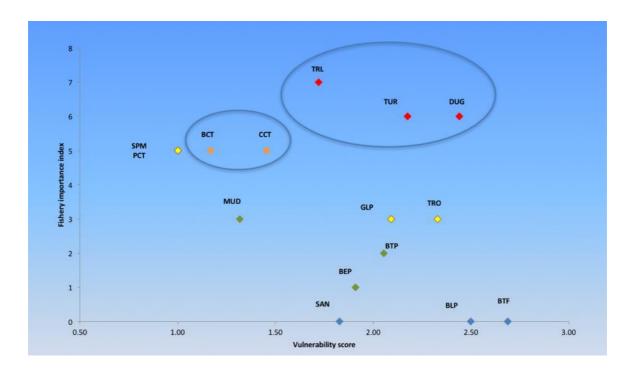
Vulnerability of supporting habitats

	SST	Rainfall/ river flow	Sea level	Cyclones & storms	Ocean pH	Solar radiation	Productivity /circulation
Coastal wetlands	very low	moderate	high – very high	moderate	very low	low	moderate
Seagrass	high	moderate	moderate	high	very low	high	moderate
Coral reefs	very high	high	low	high	very high	low	moderate

Prioritising species for management

Fisheries were ranked according to vulnerability and an 'importance' index that considered cultural and economic value. This process identified three species as management priorities - dugong, turtle and tropical rock lobster (red diamonds on the following figure). Second order priorities were coral trout (common and barcheek; orange diamonds on the following figure).

Importantly, any changes to fishing effort and therefore the pressure and value of fisheries could change the management priorities. For example, the reopening of the bêche-de-mer (specifically black teatfish) fishery since the assessment was conducted is likely to have increased the management priority of the main target species, and therefore requires a review and possible adaptations.



References/more information

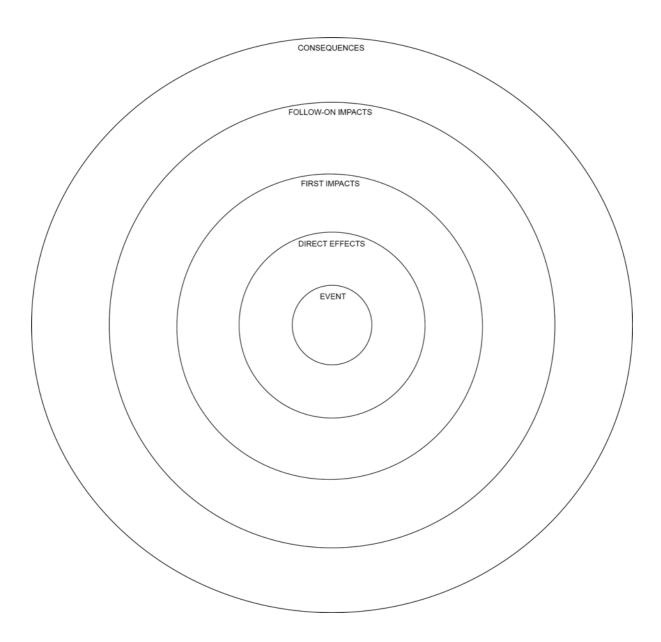
- Johnson JE, Marsh H, Hamann M, Duke N, Burrows D, Bainbridge S, Sweatman H, Brodie J, Bohensky E, Butler J, Laurance S (2015) Tropical Research in Australia's Torres Strait region. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns, 33 pp, DOI:10.13140/2.1.2391.1209
- Johnson JE, Welch DJ (2016) Climate change implications for Torres Strait fisheries: assessing vulnerability to inform adaptation. Climatic Change, 135(3): 611-624.
- Sweatman H, Johns K, Jonker M, Miller I, Osborne K. (2015) Report on Second Monitoring Field Trip to Torres Strait, January 2014. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (10 + iv pp.).
- Taylor HA, Carter AB, Davies J, McKenna SA, Reason CL, Rasheed MA. (2013) Seagrass Productivity, Resilience to Climate Change and Capacity for Recovery in the Torres Strait – 2011-2013 Report. JCU Publication 13/40, Centre for Tropical Water and Aquatic Ecosystem Research, Cairns, 80 pp.
- TSRA (2016) Torres Strait Long-Term Coral Reef Monitoring Project 2015–16. Land and Sea Management Unit, Torres Strait Regional Authority, Australia, 42 pp.
- Welch DJ, Johnson JE (2013) Assessing the vulnerability of Torres Strait fisheries and supporting habitats to climate change. Report to the Australian Fisheries Management Authority, C2O Fisheries, Australia.

Cascading consequences

The impacts of climate change in the Torres Strait are not limited to the direct impact of climate events, and the 'ripples' or flow-on effects can be more significant than the primary impacts – particularly when considering co-incident climate events or impacts.

The consequences of two climate scenarios were explored in a 'cascading consequences' exercise, where workshop participants split into groups to map the impacts and consequences of climate change on Torres Strait fisheries and marine ecosystems. The following template was used.

(This template is also a useful community engagement tool and can serve as the basis of insightful discussions when communities think about the consequences of climate events in their context.)



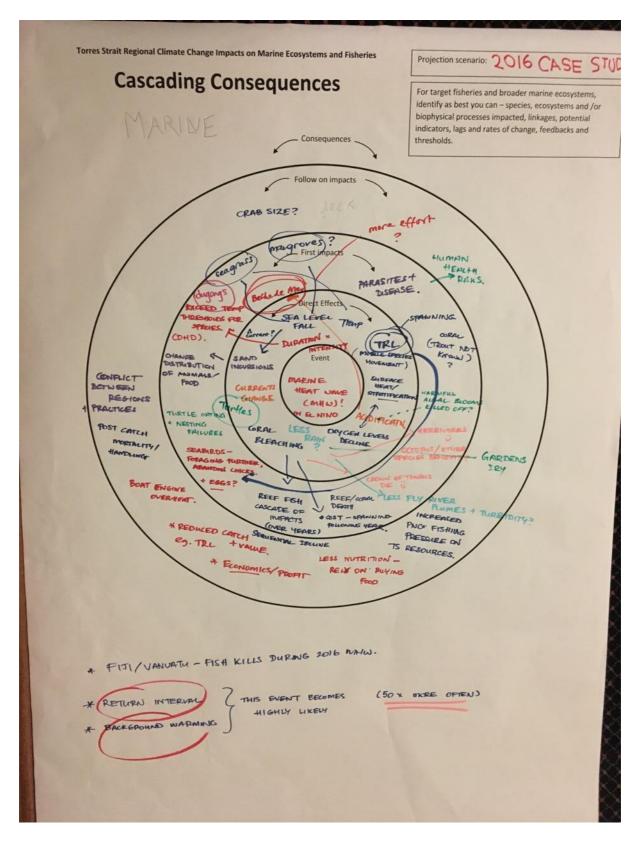
Torres Strait Regional Climate Change Impacts on Marine Ecosystems and Fisheries Projection scenario: **Cascading Consequences** For target fisheries and broader marine ecosystems, identify as best you can - species, ecosystems and /or biophysical processes impacted, linkages, potential indicators, lags and rates of change, feedbacks and thresholds. Follow on impacts Relocation of habitals and habital phase shifts (ommuna) Sustainability - altered larva impact community wellbeing Extreme sea level iomass, dive Reduced El nino Kangw rainfall Tropical cyclonel to the model response 1022 9 Ocean coral heatwave internation crime increas - Trophic cascades - Gailed existing manage Fish encrease disease
- a catchability mortality
a post catch mortality
- reduced recruitment - reduced incomes - loss of well-being - decision uncertainty

L) high risk

- effort shiff to other resources - loss of Food source - reduced public health

SCENARIO 1: Tropical cyclone occurring during an extreme El Niño event

SCENARIO 2: Marine heatwave during an El Niño event



This example was based on an event examined in this paper: Oliver ECJ, Perkins-Kirkpatrick SE, Holbrook NJ, Bindoff NL (2017) Anthropogenic and natural influences on record 2016 marine heat waves. Bulletin of the American Meteorological Society, 98(12), S44-S48, DOI:10.1175/BAMS-D-17-0118.1 (and 10.1175/BAMS-D-17-0118.1) 0118.2).

Adapting to a changing environment: learning with the Torres Strait community to understand future impacts on wellbeing

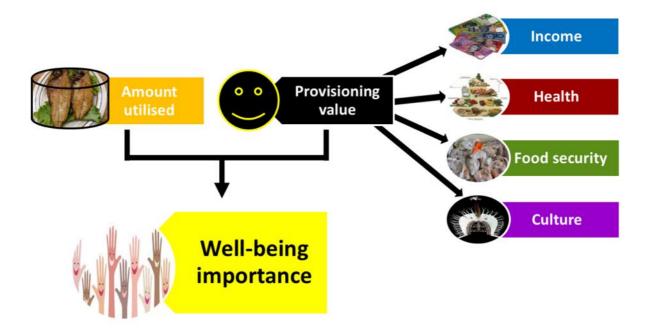
Cass Hunter, CSIRO

- Our science engagement and information needs to be relevant to communities by incorporating local views into the discussions
- Turning community visions about adaptation into reality involves being prepared to work across multiple sectors and the TSRA Climate Program
- Getting the right narrative for adaptation to climate change is about more than just our precision with science predictions.

Understanding impacts

- What are the drivers of change for livelihoods?
- What are the desired possible futures?
- What impact will the 'business as usual' (climate) future have on well-being?
- What is the resilience of the community today?
- What are the priority adaptation strategies to build resilience?

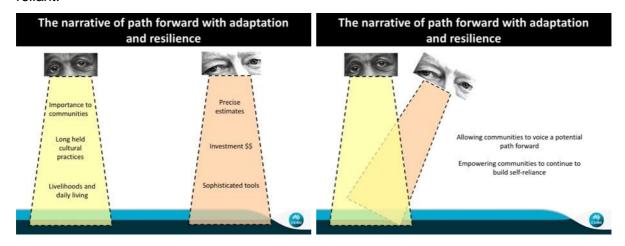
Understanding the importance of ecosystem goods and services



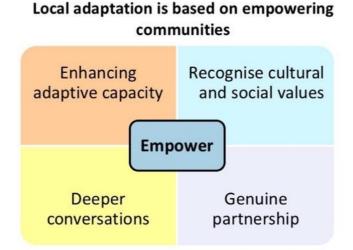
Adaptation strategies

Make it relevant – communities want to see their views and importance factored into climate conversations.

Culture is key – keeping culture strong helps the community to be sustainable and self-



Need collaborative partnerships to advance forward – to turn visions into reality (conversations into actions) we need to work across sectors (e.g. land use planners, renewables, sustainable housing, employment)



Lessons from the Pacific

Johanna Johnson, TWQ Hub and Mandy Hopkins, ESCC Hub

The Torres Strait is more like the Pacific than Australia – islands are geographically remote with decentralised and dispersed populations, and communities are critically dependent on marine resources for food and income.

In addition to the direct impacts, climate change is affecting habitats, which in turn affects fisheries, which in turn affects livelihoods and income, food security and economic development. It follows that Pacific Islands are highly exposed and vulnerable to climate change.

So, it is useful to consider how communities in the Pacific are using projections science to drive risk assessments, and how this informs adaptation planning and associated decisionmaking and on-ground actions.

Case studies

Food security

Pacific per capita fish consumption (98–147 kg/person/year) is 3–5 times the global average. Projected climate-related habitat declines (loss of coral cover, reduced seagrass, reduced mangrove area) will affect fisheries. Some Pacific nations are better placed than others to deal with this.

Food security implications



Group 1: Coastal fisheries are expected to meet the increased

- demand for fish Cook Islands
- Marshall Islands
- New Caledonia
- Palau
- Pitcairn Islands
- Tokelau



Group 2: Difficult to distribute fish to urban centres from remote islands & atolls

- FSM
- French Polynesia
- Kiribati
- Niue
- Tonga
- Tuvalu
- Wallis & Futuna



Group 3: Coastal fisheries cannot meet the increased demand

for fish

- · American Samoa
- Fiii
- Guam
- Nauru
- CNMI
- PNG
- Samoa
- Solomon Islands
- Vanuatu

Vanuatu has undertaken a number of adaptation activities in response, including:

- Structured monitoring of coastal fish habitats (reefs, seagrass, mangroves) commenced in 2015/16
- National Fisheries Policy 2016–2031 (ecosystem-based approach to coastal fisheries management)
- Trial of solar dryers for improved post-harvest fish preservation in north Efate and Santo
- New freshwater pond aquaculture for tilapia in villages
- Transfer fishing effort to target nearshore pelagic species using fish attracting devices (FADs); mostly local 'Vatuika' ('Fish and Wealth') design; 30 FADS installed/replaced since 2014

Papua New Guinea Treaty Villages

There are 13 Treaty Villages in the South Fly District of Papua New Guinea, where the low human development index is second only to the Congo. These villages are only 4 km from the northern Torres Strait Islands (Saibai and Boigu), and are highly exposed to climate variability and change.

Challenges for Treaty Villages include: water contamination, salinity intrusion, lack of sanitation, increasing demand/competition for natural resources (due to population growth), flooding and inundation during extreme sea level events, declining fisheries due to fish poaching, habitat loss and overfishing, high human disease prevalence (TB, malaria, cholera), isolation and lack of income opportunities - all serious cross-cutting issues that cannot be dealt with in isolation of climate change or each other.

A Community Ranger program is building a resilience platform for these villages with community-based and community-led activities to improve food security, water, health, livelihoods and well-being.

Outreach

The Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) program developed The Pacific Adventures of the Climate Crab, an animation and communication resource toolkit to raise awareness of the science and impacts of El Niño and La Niña to encourage Pacific Islanders to take early action in preparing for these extreme climate events.



The resource was developed in close consultation with in-country stakeholders, and its success as a community-level information tool demonstrates the importance of getting in the room and talking to people when developing content to facilitate outreach of the science.

The animation and toolkit are available on the Pacific Climate Change Science website at www.pacificclimatechangescience.org.

References/more information

- Johnson JE, Basel B (2017) Vulnerability Assessment & Local Early Action Planning (VA-LEAP): Community-based Assessments on Rendova Island, Solomon Islands. Report to the Pacific-American Climate Fund (PACAM), USAID Program, March 2017.
- Johnson JE, Waterhouse J, Devlin, MJ, Hooper E (2016) Marine Ecosystem Assessment: North Efate, Vanuatu. Report to the Pacific Community (SPC), Noumea, New Caledonia, and Agence Francaise de Developpement, Paris, France. Vanuatu RESCCUE project.
- Johnson, JE, Welch DJ (2016) Climate change impacts and adaptation actions in North Efate, Vanuatu. Report to the Pacific Community (SPC), Noumea, New Caledonia, and Agence Francaise de Developpement, Paris, France. Vanuatu RESCCUE project.
- Pacific Climate Change Science www.pacificclimatechangescience.org

Work being done in or relevant to Torres Strait fisheries and climate change

Australian Fisheries Management Authority

Ian Butler

AFMA's has a three-phase approach for adapting Commonwealth fisheries management to climate change.

1. Now

Industry perspectives - AFMA recently completed a survey of fishers in south-eastern Australia (Lakes Entrance) and found that climate change was not perceived as a major issue, even though the region is a climate change 'hot spot'. More important issues were economics, quotas, fishing costs and competition.

Non-recovering undercaught species – a collaboration between AFMA, Fishwell Consulting, CSIRO, the South East Trawl Fishing Industry Association and the Department of Agriculture and Water Resources is investigating the causes of undercaught total allowable catches (TACs) and non-recovering species in the Southern and Eastern Scalefish and Shark Fisheries.

Updated modelling - a CSIRO-led project involving AFMA, the University of Tasmania, the University of British Columbia and the Fisheries Research and Development Corporation is underway to update existing models to account for decadal and regional variation. The project will provide analyses of species sensitivity to climate change impacts and provide a set of recommendations based on findings.

2. 2018-20: Adaptation project

The objectives of AFMA's adaptation project are to:

- Determine how well the existing Commonwealth fisheries management framework copes with climate change impacts (i.e. risk assessment)
- Develop methodology and approach for AFMA (and other fisheries) to adapt the regulatory environment to climate change impacts.
- Develop strategies and priorities to account for the effects of climate change in management of fisheries.

This project does not directly apply to Torres Strait, but can fit in with some effort.

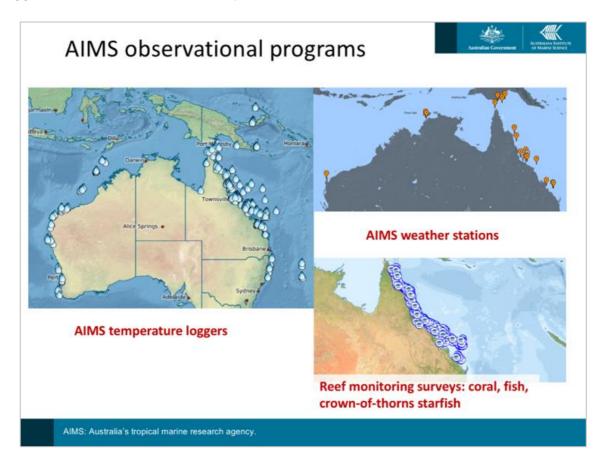
3. 2020+: Implementation

Flexible management is likely to be a key for future fisheries management with features such as a one-fishery approach (flexible management techniques with fewer boundaries) and mobile boundaries (e.g. Southern Bluefin tuna). Another feature is integration of forecasting of optimal fishing conditions.

Australian Institute of Marine Science

Craig Steinberg

One of AIMS's strengths is in its observational programs, which includes temperature loggers, weather stations and surveys of coral, fish and crown-of-thorns starfish.



Modelling currents, sea surface temperatures and sea-level anomalies allows analysis of marine heatwaves and coral bleaching events. Some results to come out of this work:

- The 2016 bleaching event on the Great Barrier Reef was the most severe on record and heat anomalies persisted to the following winter
- Micro-climates created by small scale upwelling can create persistent thermal refugia for coral from a variety of oceanographic processes
- The Gulf of Papua current can reverse, and the current is predicted to intensify in winter in the future. The fate of larvae will be dependent on these changes.

An environmental data gateway has been developed to bring together existing near-realtime data from many sources – IMOS, eReefs, NOAA, AIMS – into one location. The gateway is at http://eatlas.org.au/gbr-gateway-temp.

CSIRO

Eva Plaganyi

There is a long history of fisheries research in Torres Strait and several long time series of fisheries and habitat information collected as part of scientific surveys.

CSIRO has worked closely with traditional owners in the region for several decades in advancing fisheries science and management in the region, and there is a reasonably good two-way flow of information via workshops and meetings.

Torres Strait tropical rock lobster	 Biological and climate data (CSIRO/AFMA surveys since 1989) Mapping climate impacts on life history stages (2010 study) Use of management strategy evaluation (2010–13) Changes in oceanic currents and larval advection (current Environmental Influences project co-funded by AFMA & CSIRO) Model projections under future climate change (current project that links also with AFMA decadal projections project)
Bêche de mer	 Mapping climate impacts on life history stages (2011 study) Examples of the use of management strategy evaluation to test the performance of alternative marine monitoring and management strategies to detect and respond to ecological changes caused by climate change (2009–11, part of RUSS project)

There are gaps in some of the physical and oceanographic models that are needed to couple with the biological population dynamics for species of interest in order to reliably make predictions of impacts under climate change for fisheries and ecosystems (e.g. need to resolve tides in the region).

Management strategy evaluation as a risk management tool

Climate-smart strategies build resilience to multiple stresses. Management strategy evaluation (MSE) has been and continues to be used as one effective risk assessment method for road-testing the 'climate-smartness' of management strategies. This involves:

- Using climate risk assessment as an input to dynamic models
- Using a reference set of models (ensemble rather than single model) to capture key uncertainties
- Demonstration of use of MSE to test the performance (and adaptability), especially in the face of uncertainty, of alternative harvest strategies in meeting fishery management objectives, such as ensuring:
 - o low risk of stock depletion (overall and local)
 - o high probability of good catch / average profits
 - o low risk of changing the multi-species community composition
 - high probability of managing through climate variability and change.

Torres Strait Regional Authority

Andrew Simmonds

Climate change is impacting vulnerable species and habitats in the Torres Strait and Great Barrier Reef.

Seagrass meadows to date have not shown a negative response to climate change as trends in biomass and species diversity remain consistently high across the region. Seagrass could be vulnerable to climate extremes in the future and this would then impact the Torres Strait dugong population - currently low risk. Aerial surveys indicate the population is stable. There is a need to maintain five-yearly survey effort.

Isolated locations of mangroves on Torres Strait islands have shown local-scale dieback from coastal erosion/sea-level rise.

Hawksbill turtle nesting population in Torres Strait is in severe decline mostly due anthropogenic impacts of overharvest in neighbouring nations and potential overharvest of eggs in Torres Strait and in neighbouring nations.

Northern Great Barrier Reef stock of green turtles is likely heading for a steep decline as a result of failing hatchling production at key index sites at Raine Island and Moulter Cay. Targeting of adult females for harvest and overharvest of eggs in some locations in PNG, Solomons and Torres Strait are also primary contributors. Climate change is drastically skewing the sex of marine turtle hatchlings (all species nesting in Torres Strait) to female via the effects of increased temperatures on incubating eggs. This may lead to negative population outcomes once current hatchling cohorts reach maturity. Funding to support ongoing monitoring of vulnerable marine turtle species in Torres Strait is at risk. If monitoring of key nesting index sites were to cease, this would be a bad outcome for these stock as community-based management would cease to have access to population trends.

Impacts on coral reefs from broad-scale severe bleaching will likely have an impact on supporting habitat for commercial fish species. A fisheries management response may be necessary in the future if harvest levels decline. However, there is a lack of information in Torres Strait fisheries regarding amount and value of catches which limits certainty in accurate management responses. There may be refugia for corals at the north-eastern corner of the Torres Strait where waters remain cooler and this may need special management arrangements for future conservation.

Certain low-lying islands in Torres Strait are experiencing sea-level-related coastal erosion, which TSRA LSMU is monitoring. There are real concerns in these communities.

There is ongoing water quality research into the implications of sediment-related pollution originating from the Fly River. Saibai, Dauan and Boigu are most affected, though results are currently inconclusive. Working with JCU TropWater. Future directions may include investigation of common food sources for metal contamination as well as work to determine historical levels of metals in sediment and corals.

NESP Tropical Water Quality Hub

Johanna Johnson

Previous water quality research

- Torres Strait baseline study (1993) survey of trace metals in marine seafood, seagrass and sediments
- Apte & Day (1998) first accurate data on trace metal concentrations in waters (Cu, Cd and Ni only)
- Haynes & Kwan (2002) 28 sediment samples collected in 2000 and analysed for
- NERP WQ hazards (2011–13) hydrodynamic modelling, predictions of water flow, hazard assessment based on previous data

Current relevant Tropical Water Quality Hub projects

Influence of the Fly River on the Torres Strait region (Projects 2.2.1 and 2.2.2)

Runoff from the Fly River in Papua New Guinea influences water quality conditions in the Torres Strait region; however, the extent and frequency of this influence, and the potential ecological impacts, are not well understood. This project builds on previous efforts to determine the spatial extent, temporal patterns and constituent pollutants of Fly River discharge, and assess the vulnerability of ecosystems in the Torres Strait exposed to the discharge.

A related project is using state of the art procedures to determine trace metal concentrations in marine waters and sediments at locations across the Torres Strait. Chemical signatures of mine pollution are being measured in Torres Strait waters and sediments and hotspots of contamination identified. The water quality data generated will allow informed management decisions to be made on how to best address trans-boundary mining related pollution and potential ecological impacts.

Connectivity and inter-dependencies of values in the northeast Australia seascape: Great Barrier Reef, Torres Strait, Coral Sea, Great Sandy (Project 3.3.3)

This project is identifying and assessing the ecological, cultural, social and economic values of four marine jurisdictions - Great Barrier Reef, Torres Strait, Coral Sea, Great Sandy Straits – and characterising the processes and attributes that influence the values and their connectivity at a regional scale. In doing so, the project will deliver a resource that can inform cross-jurisdictional planning and management.

References/more information

NESP Tropical Water Quality Hub – www.nesptropical.edu.au

Science, data and research priorities

Workshop participants identified six priority areas for research that will help inform fisheries and marine ecosystem management in Torres Strait (and thereby to inform science-based adaptation response).

The following table summarises initial thoughts with regards to these priority areas. It is anticipated that ideas in this table will further refined over time.

Biological understanding	 Limited understanding of species responses to combinations of changing environmental variables (e.g. bêche-de-mer) (lab, desktop, field) Seagrass sensitivities
Monitoring	 Tidal gauges – to analyse and add Drifters – inform on complexity Integrated Marine Observing System Moorings (upwellings) – strings of loggers Himawari satellite information – 1 picture/10 minutes Turbidity using Secchi discs (cheap and easy)
Population modelling	 Coupling with high-resolution current/climate Follow similar approaches to those used for corals, crown-of-thorns starfish Additional models for species (e.g. turtles, dugongs) at appropriate spatial scales Coral trout correlations with coral abundance or habitat
Climate modelling	 Downscaling of projections for Torres Strait and in particular, tides Produce regional rainfall projections from CMIP5 models selected for skill/low biases (and maybe CCAM model runs)
Adaptation responses/ communities	 Communication Community consultation regarding adaptation Industry and traditional owner advice/experience with regard to fishing behaviour Management of fisheries – parallel AFMA projects, fishery by fishery; adaptation
Fly River	Plume predictionMetals/health risks

Science-based information products and services

Existing information and tools

While additional science will help inform management decisions in the Torres Strait, there is a great deal of information and a number of communication products and decision support tools currently available.

Data collected in the region	AIMS – in-situ collection (water temperature, weather) – online gateway
3	BoM – heatwave mapping
	AMSA – tide gauges
	AFMA – fisheries data
	Climate Change in Australia – climate projections
	 PACCSAP – climate projections for Papua New Guinea and various technical and non-technical climate change communication products and resources
	TSRA – reef monitoring, crown-of-thorns starfish monitoring, bleaching, beach profiling
	 TropWater (James Cook University) – in-situ seagrass surveys
	 CSIRO – annual habitat surveys (including numbers of pearl oyster, crown-of-thorns starfish and holothurians, and percent cover of standard substratum and biota (including seagrass and algae species) categories
Tools/ programs that make use of	ADWIM (impacts and wellbeing) -> CSIRO
the information	Torres Strait vulnerability assessment
	NESP ESCC Hub (www.nespclimate.com.au)

The challenge lies in identifying which information is most useful and delivering it to the people that need it in ways that they can use it.

Communication and outreach ideas

It was agreed that a useful communication and outreach model is needed to develop information resources for the communities and stakeholder groups to provide information that can be easily understood and delivered to stakeholders. A number of ideas for ways this might occur were identified at the workshop.

As is the case with the ideas for science, data and research priorities, it is anticipated that these ideas will be refined over time as follow-up to the workshop.

Support	Outreach specialist in climate supporting TSRA in disseminating information
Engagement/ outreach activities	TSRA staff discussing the outcomes of this workshop in fisheries working group meetings and canvasing interest in engagement
	 More targeted outreach effort to discuss key climate change messages in Torres Strait communities
	 Building local climate change capacity -> drive local adaptation plans -> climate champion -> who wants to be involved in the communities
	Annual event (pre-season gathering of key stakeholders) to provide timely climate information relevant to local communities/the fishery sector
Communication/ knowledge	Workshop report
brokering products	Climate change themed 'comic book' as a communication resource for local communities
	Video – explain the science and communicate traditional knowledge (communities explain what they see)

Appendix 1: Workshop agenda

Technical workshop

CLIMATE CHANGE IN THE TORRES STRAIT: IMPLICATIONS FOR FISHERIES AND MARINE ECOSYSTEMS

Pullman Cairns International, 17 Abbott Street, Cairns 7-8 December 2017

DAY 1: THU 7/12/17 13:00-17:30

Time	Agenda item	Who	Session purpose	
13:00	LUNCH			
Introdu				
14:00	Welcome	Geoff Gooley (ESCC Hub)		
14:05	Welcome to country	Gudju Gudju		
14:10	Introduction	Geoff Gooley (ESCC Hub)		
Setting	the context			
14:20	Overview: Climate change impacts on oceans, fisheries and marine systems Overview: Torres Strait	Neil Holbrook (ESCC Hub)	To ensure all workshop participants understand what aspects of climate change impact oceans and marine systems and what the impacts could be (starting with the global 'big picture' and including all aspects of climate change relevant to TS including SLR, coastal hazards, ocean temp extremes, acidification, extreme events, coral bleaching risk) To ensure all workshop participants	
	fisheries and marine ecosystems		understand the nature and extent of TS fisheries and marine ecosystems, including and key features and related considerations (e.g. social, political, economic).	
	Current and future climate in the Torres Strait			
15:20	Climate trends and projections for Torres Strait Islands	Jo Brown (ESCC Hub)	To provide an overview of the current climate of the TS, how it has changed and how it could change in the future, drawing on the latest climate change science. This information will provide an important basis for later discussions in the workshop.	

Time	Agenda item	Who	Session purpose
15:50	Climate change impacts on key TS resources – ADWIM model	Cass Hunter (CSIRO)	To share outputs from the CSIRO ecosystem goods and services model to show how climate change is likely to impact key marine resources for TS communities.
16:20	Vulnerability of fisheries to climate change – report summary	Jo Johnson (TWQ Hub)	To provide an overview of climate change hazards, vulnerability and risk specific to fisheries and marine ecosystems in the TS.
16:50	Day 1 wrap-up	Geoff Gooley (ESCC Hub)	
17:00	Close Day 1		

DAY 2: FRI 8/12/17 9:00-16:30

Time	Agenda item	Who	Session purpose		
Snapsh	ots: Understanding climate	change and impacts in			
9:00	Issues and impacts Including: impacts of the last coral bleaching event decadal scale projection of changes in fisheries stocks under climate change adaptation of fisheries to climate change	Craig Steinberg (AIMS) Eva Plaganyi (CSIRO) Ian Butler (AFMA) John Rainbird and Andrew Simmonds (TSRA) Jo Johnson (TWQ Hub)	To provide a brief overview of current projects and monitoring activities that are helping us to understand climate change and impacts in the TS, as well as discussion of current issues and impacts. Each presenter will have 15 mins to talk about work from their respective organisations, with time for discussion at the end. Outcomes/findings reported here will feed into the following discussions.		
10:40	Morning tea				
	g ahead: what does the futu				
11:00	Understanding TS stakeholders	Charles David (TSRA)	To identify TS stakeholder groups and their needs		
11:30	Activity: Cascading consequences	Facilitator: John Rainbird (TSRA)	To identify possible consequences of climate change and coincident events in TS. Participants will break into two groups for this activity.		
12:30	Discussion: Cascading consequences activity	Facilitator: John Rainbird (TSRA)	To discuss the outcomes of the previous activity. As well as being included in the workshop report, responses will inform post-workshop technical meeting discussions.		
13:00	Lunch				
-	Preparing for the future				
13:30	Lessons from the Pacific	Jo Johnson (TWQ Hub) and Mandy Hopkins (ESCC Hub)	To share how communities in the Pacific are using projections/science to drive risk assessments, and how		

Time	Agenda item	Who	Session purpose
			this feeds into adaptation planning
			and associated decision-making
14:00	Identified knowledge gaps	Facilitator: Geoff	To learn about some knowledge
	and prioritised needs	Gooley (ESCC Hub)	gaps and needs that have already
			been identified and prioritised. These
			will inform the following discussion.
14:20	Small group discussions:	Facilitator: Mariana	To identify knowledge gaps and
	Knowledge gaps and	Nahas (TSRA)	needs in light of what has been
	knowledge products		presented at the workshop, and how
			they may be able to be addressed.
			What [information] resources/
			knowledge products are needed to
			convey the learnings from this
			workshop to TS stakeholders (including TOs/local fishers, natural
			resource managers, other local
			communities of interest and
			scientists) and what information do
			we need from TOs?
15:00	Report back – Knowledge	Facilitator: Mariana	To record ideas for management
	gaps and knowledge	Nahas (TSRA)	responses and information needs. As
	products	,	well as being included in the
			workshop report, responses will
			inform post-workshop technical
			meeting discussions.
15:30	Group discussion:	Facilitators: Geoff	Emphasis on options for further
	Options for further	Gooley (ESCC Hub),	strategic engagement, collaborative
	engagement including	John Rainbird	partnerships and delivery
	priority actions and	(TSRA)	
	responsibilities		
	op wrap-up	0 - 11 0 - 1 - 15000	To an idea bid man of the
16:15	Closing remarks	Geoff Gooley (ESCC	To provide a brief recap of what has
	(including next steps)	Hub), John Rainbird	been covered and why, and what the next steps will be.
16:30	Workshop close	(TSRA)	next steps will be.
10.50	Workshop close		

Appendix 2: Workshop participants

- Shaun BARCLAY, TSRA (Day 2 only)
- Josephine BROWN, ESCC Hub
- Ian BUTLER, AFMA
- Charles DAVID, TSRA
- Geoff GOOLEY, ESCC Hub
- Rohan HAMDEN, Consultant (Day 1 only)
- Neil HOLBROOK, ESCC Hub
- Mandy HOPKINS, ESCC Hub
- Cass HUNTER, CSIRO
- Johanna JOHNSON, TWQ Hub
- Phil LAYCOCK, GBRMPA
- Mariana NAHAS, TSRA
- Karen PEARCE, ESCC Hub (Day 2 only)
- Eva PLAGANYI, CSIRO
- John RAINBIRD, TSRA
- Andrew SIMMONDS, TSRA
- Selina SOUTE, AFMA (Day 2 only)
- Craig STEINBERG, AIMS



National Environmental Science Programme

East coast Spanish mackerel fishery harvest strategy: 2023–2028



Business area owner Management & Reform

Endorsed by Deputy Director-General (Fisheries and Forestry) in accordance with delegated

powers under Part 2, Division 1 (Harvest Strategies) of the Fisheries Act 1994

Approved by Minister responsible for fisheries in accordance with section 16 of the Fisheries Act

1994

Revision history

Version no.	Approval date	Comments
0.1	July 2022	Draft harvest strategy for consultation
1.0	October 2022	Approval of final harvest strategy

Enquiries and feedback regarding this document can be made as follows:

Email: info@daf.qld.gov.au

Telephone: 13 25 23 (Queensland callers only)

(07) 3404 6999 (outside Queensland)

Monday, Tuesday, Wednesday and Friday: 8 am to 5 pm, Thursday: 9 am to 5 pm Department of Agriculture and Fisheries GPO Box 46 BRISBANE QLD 4001 AUSTRALIA

Website: daf.qld.gov.au

Interpreter statement



Post:

The Queensland Government is committed to providing accessible services to Queenslanders from all culturally and linguistically diverse backgrounds. If you need an interpreter to help you understand this document, call 13 25 23 or visit daf.qld.gov.au and search for 'interpreter'.

© State of Queensland, 2022

The Queensland Government supports and encourages the dissemination and exchange of its information. The copyright in this publication is licensed under a Creative Commons Attribution 4.0 International (CC BY 4.0) licence.

Under this licence you are free, without having to seek our permission, to use this publication in accordance with the licence terms.



You must keep intact the copyright notice and attribute the State of Queensland as the source of the publication.

Note: Some content in this publication may have different licence terms as indicated.

For more information on this licence, visit https://creativecommons.org/licenses/by/4.0/.

The information contained herein is subject to change without notice. The Queensland Government shall not be liable for technical or other errors or omissions contained herein. The reader/user accepts all risks and responsibility for losses, damages, costs and other consequences resulting directly or indirectly from using this information.

Contents

What the harvest strategy is trying to achieve	4
Fishery overview	4
Stocks covered by the harvest strategy	5
Management units for the harvest strategy	
Summary of management information	6
Fishery objectives	7
Catch shares	7
Managing the performance of the fishery	8
Management of target species	11
Management of ecological risks from fishing	12
Monitoring social and economic performance	13
Data collection, validation and assessment	14
Information and research priorities	15
Schedule of performance monitoring, assessment and review	
Acronyms and definitions	18
Appendix A: Overview of decision rules for east coast Spanish mackerel	20

What the harvest strategy is trying to achieve

This harvest strategy has been developed in line with the *Queensland harvest strategy policy* to manage harvest in the Queensland east coast Spanish mackerel fishery (ECSMF). The east coast Spanish mackerel stock was assessed in 2021 as overfished, requiring urgent action to rebuild stocks. This harvest strategy aims to rebuild the stock to a level that achieves maximum sustainable yield (MSY) and, subsequently, pursues the long-term goal of achieving maximum economic yield (MEY), while maintaining catch shares amongst the commercial, recreational, charter and Indigenous fishing sectors.

This harvest strategy will manage fishing mortality of east coast Spanish mackerel stock, primarily through setting a total allowable catch (TAC) for all sectors at a level that allows the stock to achieve defined biomass targets. Other management tools (e.g. size limits, spawning closures) may also be used to support the sustainable management of this stock under this harvest strategy.

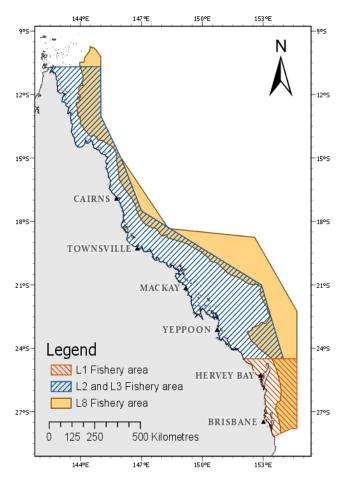
Fishery overview

The ECSMF is a line-only fishery that exclusively targets Spanish mackerel (*Scomberomorus commerson*) by trolling or towing lures and baited lines behind the vessel and near the surface of the water.

Recognised as a high-quality eating fish and for its status as a powerful sports fish, Spanish mackerel are targeted by Aboriginal and Torres Strait Islander fishers and the commercial, recreational and charter fishing sectors. The commercial fishery supplies domestic markets.

During September to November each year, Spanish mackerel school to form one of the most notable and predictable spawning aggregations of fish on the Great Barrier Reef. These spawning aggregations, primarily located in the Lucinda region in waters north of Townsville, support a disproportionate amount of fishing effort and catch (~40% of the Queensland commercial harvest is generally taken from the region during the spawning season).

The predictable schooling and aggregation behaviour of Spanish mackerel is a characteristic that has been



associated with vulnerability to overexploitation and rapid stock depletion. Schooling behaviour can often lead to issues of hyperstability, where catch rates remain generally stable as the fish population declines and fishery performance is overestimated. Long-term fishers' information suggests that the size of spawning aggregations and their reproductive capacity have diminished over time.

The stock is also fished in New South Wales, where approximately 9.5% of the total harvest is taken by commercial and recreational fishers each year.

Stocks covered by the harvest strategy

East coast Spanish mackerel form a single genetic stock between the Cape York Peninsula in north Queensland and Newcastle on the New South Wales mid-coast. This harvest strategy only relates to the management of Spanish mackerel in east coast Queensland waters (Table 1).

Table 1: Summary of fish stocks covered by this harvest strategy

Feature	Details
Target species	Spanish mackerel (Scomberomorus commerson)
Biology	Spanish mackerel are large pelagic fish and, on Australia's east coast, have been observed to live up to 26 years and weigh more than 30 kg. They reach sexual maturity above the minimum legal size limit of 75 cm between 2 and 4 years of age.
	Movement patterns are varied and depend on spawning and feeding behaviours, water temperatures and currents. Some fish can remain localised, whereas some fish move along the east coast. Spanish mackerel generally aggregate more in northern tropical waters during winter and spring for feeding and spawning, and some fish move to southern waters during summer and autumn to extend their feeding range. Seasonal and spatial patterns of fishing follow the predictable locations of schooling fish.
	Previous research has characterised east coast Spanish mackerel as an obligate transient aggregator, meaning their spawning—schooling behaviour was generally restricted to specific reef locations. Acoustic fish tag monitoring identified some fish as having strong reef fidelity during the spawning season. This predictable schooling and aggregation behaviour signified that east coast Spanish mackerel were vulnerable to overexploitation.

Management units for the harvest strategy

The management unit for this harvest strategy is all tidal waters in Queensland east of longitude 142°31'49" east.

Summary of management information

A summary of the management arrangements for the ECSMF is set out in Table 2. Copies of fisheries legislation are available at legislation.qld.gov.au, or visit fisheries.qld.gov.au for the latest information on fishing rules.

Table 2: Summary of management arrangements for the ECSMF fishery

Feature	Details	
Commercial access	Primary commercial fishing licence with:	
	a SM fishery symbol	
	 one or more of the following line symbols: L1, L2, L3 and L8 	
	sufficient SM individual transferable quota.	
Relevant fisheries	Fisheries Act 1994	
legislation	Fisheries (General) Regulation 2019	
	Fisheries (Commercial Fisheries) Regulation 2019	
	Fisheries Declaration 2019	
	Fisheries Quota Declaration 2019	
Other relevant legislation	Great Barrier Reef Marine Park Act 1975 and Great Barrier Reef Marine Park	
	Regulations 2019 (Cwlth)	
	Marine Parks Act 2004	
	Environment Protection and Biodiversity Conservation Act 1999 and	
	Environment Protection and Biodiversity Conservation Regulations 2000	
	(Cwlth)	
Working group	East coast Spanish mackerel fishery working group	
	Terms of reference and communiques are available at <u>fisheries.qld.gov.au</u>	
Gear	The following apparatus are permitted for use:	
	commercial – hook and line apparatus (additional restrictions	
	depending on fishery line symbol used)	
	recreational – recreational hook and line apparatus	
	Refer to fisheries legislation for specific gear requirements and rules.	
Main management	All sectors:	
methods	Gear restrictions	
	Minimum legal size limit	
	Spatial and temporal (seasonal) closures	
	Commercial only:	
	Individual transferable quota	
	Total allowable commercial catch (TACC)	
	Limited entry and defined fishery areas	
	Vessel and tender restrictions	
	Recreational only:	
	In-possession limits	
	Boat limits	
Fishing year	1 July – 30 June	

Feature	Details
Stock status	Stock status is assessed using the nationally agreed Status of Australian Fish Stocks (SAFS) classification framework (visit fish.gov.au) – east coast Spanish mackerel is listed as 'depleted' (SAFS 2020).
Accreditation under the	Part 13: Accredited
Environment Protection and Biodiversity Conservation Act 1999	Part 13A: Included in the list of exempt native specimens (LENS) (expires 28 August 2025) Visit environment.gov.au

Fishery objectives

The objective of the harvest strategy is to manage the fishery in accordance with the objectives of the *Fisheries Act 1994* and the *Queensland Sustainable Fisheries Strategy: 2017–2027*. Fishery objectives set out the direction and aspirations to be achieved in the long term.

The primary objectives for this fishery are to:

- rebuild the east coast Spanish mackerel stock within an appropriate timeframe (2TMIN) to an interim
 rebuilding target spawning biomass level that aims to maximise sustainable yield (Bmsy) for the fishery
 and
- once the east coast Spanish mackerel stock has been rebuilt to or above Bmsy, return it to, and
 maintain it at, a target spawning biomass level that aims to maximise economic yield (Bmey) for the
 fishery.

In pursuing the primary objectives, the harvest strategy aims to:

- minimise and mitigate any unacceptable ecological risks arising from fishing-related activities
- maintain appropriate sectoral allocations for the ECSMF
- maximise economic performance of the commercial sector
- monitor the broader social and economic benefits of the fishery to the community.

Catch shares

This harvest strategy aims to maintain the existing catch shares between sectors. The resource allocation arrangements set out in Table 3 overleaf ensure that catch shares among sectors can be maintained in response to changes in the TAC.

Future reviews of the TAC will consider the results from the latest statewide recreational fishing survey, any other available information relating to recreational harvest, and validated commercial catch over corresponding years. Table 3 outlines existing catch shares (rounded to nearest 5%) for all sectors based on available data up to 2020.

The traditional fishing rights of Aboriginal peoples and Torres Strait Islanders are protected under native title legislation and relate to harvest for domestic, communal and non-commercial purposes. Accordingly, traditional and customary fishing is recognised in Queensland and is not a defined allocation.

Aboriginal peoples and Torres Strait Islanders and their communities continue to express a desire for more economic opportunities through fishing, particularly in their own sea country. The *Aboriginal and Torres*

Strait Islander commercial fishing development policy provides for an Indigenous fishing permit to be issued, on a case-by-case basis and in accordance with section 54 of the Fisheries (General) Regulation 2019, to provide opportunities to take part in fishing-related business.

Table 3: Resource allocation arrangements for the ECSMF

Management unit	Commercial fishing ¹	Recreational fishing (including charter) ²	Indigenous commercial fishing development ³
East coast Spanish mackerel	60%	40%	Up to 2 tonnes

¹ Commercial catch share is informed by average harvest from 2004 to 2021, based on commercial logbooks and quota reporting.

Managing the performance of the fishery

Suitable performance indicators have been selected to describe fishery performance in relation to the objectives, with associated reference points identified to established acceptable performance. The primary performance indicator used to evaluate the status of the key species is spawning stock biomass. Spawning stock biomass is assessed periodically and is compared to the associated reference points.

The default biomass reference points identified in this harvest strategy are:

- an interim rebuilding target reference point of 40% of the spawning biomass (B₄₀) being the relative biomass level the harvest strategy aims to achieve in the short term this is considered a proxy for the biomass achieving maximum sustainable yield (B*msy*)
- an overarching target reference point (Btarg) of 60% of the spawning biomass (B₆₀) being the relative biomass level the harvest strategy aims to achieve in the long term this is considered a proxy for the biomass achieving maximum economic yield (Bmey)
- a limit reference point of (Blim) of 20% of the spawning biomass (B₂₀) being the biomass level that the harvest strategy aims to avoid if the stock is assessed to be below Blim, the risk to the stock is unacceptably high and the stock is defined as 'overfished'.

If a stock assessment provides a direct estimate of B*msy*, B*mey* or B*lim*, these may be used to replace the respective proxy values of B_{40} , B_{60} and B_{20} .

² Recreational catch share is informed by average harvest from 2004 to 2021, based on statewide recreational fishing surveys and charter logbooks.

³ Applications for an Indigenous commercial fishing developmental permit will be assessed on a case-by-case basis, but the total allocation across all active permits will not exceed the 2-tonne limit in any given fishing year.

Table 4: Performance indicators and reference points for the ECSMF

Performance indicator	Type of reference point	Reference level
	Interim rebuilding target reference point	40% spawning biomass (B ₄₀), proxy for biomass at maximum sustainable yield (B <i>msy</i>)
Spawning stock biomass	Target reference point (Btarg)	60% spawning biomass (B ₆₀), proxy for biomass at maximum economic yield (B <i>mey</i>)
	Limit reference point (Blim)	20% spawning biomass (B ₂₀), proxy for biomass at limit reference point

For Spanish mackerel, spawning stock biomass and sustainable harvests for all sectors will be estimated using a stock assessment. The aim is to measure the capability for the stock to attain the relevant target biomass level (40% and 60%), and at which point the harvest strategy will be considered as meeting its objectives.

Until the stock has been rebuilt to B_{40} (primary objective 1 achieved), the decision rules maintain the TACC at 165 tonnes and the recreational in-possession limit at 1 fish per person.

Once the stock is at or above B_{40} , the decision rules for setting a sustainable harvest to pursue Btarg are based on a 'hockey stick' approach. This is where the TAC is set based on a linear relationship between Blim, where the level of fishing mortality (F) is equal to zero, and Btarg, where the exploitation rate and TAC are set at the level to achieve MEY (Figure 1 overleaf).

The decision rules take into account the current biomass level of the stock for determining the TAC to achieve the Btarg. The recommended TAC is calculated by applying the rate of fishing mortality to achieve Btarg to the current spawning biomass level. As a result, the recommended TAC represents the total catch from all sectors that can be harvested in the following years to move the current biomass level towards the target level. A discount factor may also be included to account for uncertainty and to reduce the risk of a fishery not achieving its objectives.

If the spawning biomass falls below, or fails to rebuild above, *Blim* after four years of management intervention (1 July 2026), targeted fishing of the stock must cease and the decision rules of the harvest strategy will be reviewed to ensure that rebuilding will be achieved within the required timeframe. This period of time aligns with the age at which most Spanish mackerel are fully recruited and provides sufficient time for the effects of management intervention on spawning biomass to be observed.

In accordance with the *Queensland harvest strategy policy*, timeframes are specified relative to the minimum timeframe for rebuilding in the absence of fishing (TMIN). Timeframes are defined within the range of TMIN and 2TMIN, equating to a rebuilding timeframe for east coast Spanish mackerel of 7–14 years from 1 July 2023.

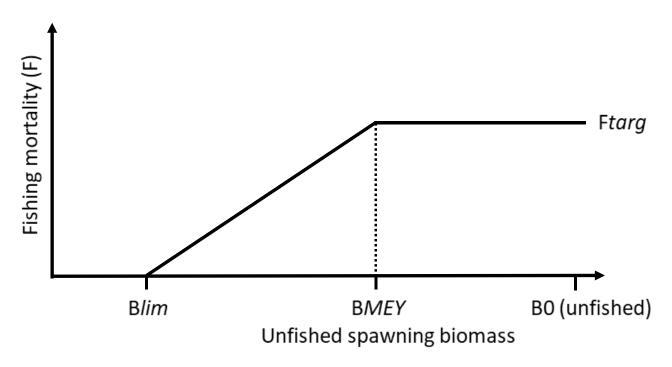


Figure 1: Showing the 'hockey stick' rule – Blim is limit reference point, Bmey is the biomass at MEY, B0 is the unfished biomass at 100%, F is fishing mortality and Ftarg is the level of fishing mortality for Bmey

The harvest strategy will also act to constrain all sectors within their allocated catch share. Should a new estimate of recreational harvest or catch from charter fishing logbooks indicate that a sector has increased their catch share outside of their allocated proportion, then decision rules are triggered to constrain that sector's harvest to within its share. Adjustments to the recreational fishing limits may be undertaken if large changes are made to the TAC for a species.

The decision rules, including those to rebuild the stock to B_{40} , are supported by spatial and temporal closures. These closures reduce overall fishing mortality and offer additional protection to Spanish mackerel during critical periods when the fish are aggregating (e.g. for spawning, feeding and migrating) and are vulnerable to overexploitation. The closures are necessary in combination with other measures, including the setting of a TACC and recreational in-possession limit, to rebuild the stock to B_{40} in the required timeframes and achieve the long-term target (Btarg) of B_{60} .

Management of target species

1.0 General decision rules

The decision rules below establish general conditions for all fishing sectors to prevent the TAC from being set at an unsustainable level that will not achieve the interim rebuilding target biomass of 40% (B_{40}) or the overarching target biomass (Btarg) of 60%. These rules also establish conditions that may trigger a closure of the fishery or a review of the decision rules, reference points or timeframes.

- 1.1 The rate of fishing mortality should not exceed that required to achieve Btarg.
- 1.2 The TAC should not exceed the level of fishing mortality required to maintain a stock at maximum sustainable yield (MSY) at equilibrium.
- 1.3 If the stock is at or below B*lim* after 1 July 2026, no targeted fishing for the species will be permitted for any sector until the biomass is at or above 30% of unfished levels (B_{30}).
- 1.4 If any new information becomes available indicating that the assessment and TAC-setting arrangements are not consistent with the sustainable management of the fishery or that the primary objectives of the harvest strategy will not be achievable, decision rules must be reviewed and, if appropriate, the reference points or timeframes should be adjusted.

2.0 Commercial decision rules

The decision rules below provide guidance to set the TACC using the outputs of a stock assessment, and aims to rebuild to the interim rebuilding target biomass of 40% (B_{40}) and subsequently achieve a target biomass (Btarg) of 60%.

- 2.1 If the biomass is below B_{40} and has not previously reached B_{40} under this harvest strategy (primary objectives 1 and 2 not achieved), maintain the TACC at 165 tonnes.
- 2.2 If the biomass is at or above Btarg (primary objectives 1 and 2 achieved), set the TACC at a level that maintains biomass at Btarg.
- 2.3 If the biomass is below Btarg and above Blim, and B₄₀ has been previously reached under this harvest strategy (primary objective 1 achieved but primary objective 2 not achieved), the TACC should be set as inferred by the hockey stick approach, where fishing mortality is reduced to the rate that allows the biomass to increase effectively back to Btarg.

3.0 Recreational and charter sector decision rules

The below decision rules have been designed to maintain catch shares between sectors (60% commercial; 40% recreational including charter) while rebuilding to the interim rebuilding target biomass of 40% (B_{40}) and achieving the long-term target biomass (Btarg) of 60%. If a new estimate of recreational or charter harvest indicates that either sector have increased their catch outside of their allocated catch share, then management action will be taken to constrain them within this share.

If the biomass is below B_{40} and has not previously reached B_{40} under this harvest strategy (primary objectives 1 and 2 not achieved), maintain the recreational in-possession limit of 1 fish per person.

- 3.2 If a recreational harvest estimate is no more than 10% above the allocated recreational catch proportion, then no management action is required.
- 3.3 If an estimate of recreational harvest exceeds the catch share by greater than 10%, the recreational inpossession limit will be decreased by an amount that will achieve the allocated recreational catch proportion.
- 3.4 If the commercia catch share increases by 10% or more according to the commercial decision rules, then the recreational in-possession limit will be increased to return catch shares to allocated proportions.

Management of ecological risks from fishing

4.0 Ecological risk decision rules

A foundation of sustainable fisheries management is managing the impact of fishing activities on non-target species and the broader marine ecosystem. Ecological risk assessments (ERA) identify and measure the ecological risks of fishing activity and identify issues that must be further managed under harvest strategies. The decision rules below are in place to minimise and mitigate high ecological risks arising from fishing-related activities.

4.1 If an ERA identifies fishing impacts that result in an unacceptable level of risk to any ecological component, a review is triggered to investigate the reason for the increased risk and appropriate management action taken to reduce the risk to an acceptable level.

A whole-of-fishery level 1 ERA for the ECSMF was completed in 2019 (visit era.daf.qld.gov.au) and identified one ecological component at higher risk – the target species (Spanish mackerel). As these risks were confined to the single target species, the ERA concluded that they would be best addressed through the harvest strategy framework.

Fisheries Queensland developed the <u>Ecological risk assessment guideline</u> to assess ecosystem impacts of fishing activities. Future risk assessments will be undertaken in line with the guideline to reassess any current or new ecological risks that may arise in the fishery. ERAs can be undertaken more frequently if there are significant changes identified in fishery operations, management activities or controls that are likely to result in a change to previously assessed risk levels.

Monitoring social and economic performance

The *Queensland Sustainable Fisheries Strategy: 2017–2027* outlines the target to set sustainable catch limits based on achieving B*mey* (around 60% of unfished spawning biomass) to support the most economically efficient use of the resource, improve the fishing experience for all sectors and promote resilience to adverse environmental conditions (e.g. floods, cyclones and bleaching). The harvest strategy rules have been set up to maintain the stock at target biomass level, once rebuilding is complete.

The objectives listed in Table 5 will be used to monitor the social and economic performance of this fishery. The management options outlined are intended to provide some guidance on the options that could reasonably be considered alongside the decision rules if fishery trends are of concern.

Table 5: Social and economic indicators for the ECSMF

Objective	Performance indicators	Management options
Maximise economic performance of the commercial sector	 Potential indicators to monitor include: catch per unit effort (average per day/hour fished) costs, earnings and net financial and economic profit net economic returns, gross state product, gross value of production quota sale and lease price profit decomposition (using profit or lease price) to determine impacts of prices, costs and stock/catch rates on changes in profits 	Consider regulatory and non-regulatory options Adjust management as needed Options include minimum quota holding and latent effort review
Monitor the broader social and economic benefits of the fishery to the community	 Potential indicators to monitor include: fisher satisfaction (with their fishing experience – commercial and recreational) recreational fisher participation and economic information percentage of quota/licences that are owned (rather than leased) Gini coefficient of quota owner (measure of concentration) percentage of total costs/inputs purchased from local businesses/residents income generated (crew plus profit – gross value added) proportion of catch sold locally fish prices number of platforms / number of active licences / total capacity community satisfaction (with their fisheries and the way in which they are managed) 	Consider regulatory and non-regulatory options Adjust management as needed

Data collection, validation and assessment

The catch and effort data required to inform harvesting of Spanish mackerel is obtained through commercial logbook returns. For the Queensland east coast line fin fish fisheries logbook, visit business.qld.gov.au.

As the ECSMF is quota-managed, real-time reporting and catch disposal records are also required to provide an accurate record of catch. All vessels in the fishery are required to have a vessel tracking unit installed and operational on all primary and tender vessels to verify fishing effort reported in commercial fishing logbooks. Commercial catch rates are standardised to account for a range of potential influencing variables. The current catch rate standardisation considers fishing year, latitude band, seasonal variables, wind component variables, lunar phase variables, number of fishing operations and individual fishing operations through time, as well as annual changes in fishing power to account for increased fishing effort and improved gear technology. The data collected via boat ramp surveys and the statewide recreational fishing survey helps provide important information on recreational fishing, including total recreational harvest and discarding behaviour. Charter operators also record catch information in logbooks, which is included as recreational harvest.

Fisheries Queensland also collects biological data on Spanish mackerel from commercial and recreational fishers to measure long-term trends in length, age and rate of total mortality, and address emerging knowledge requirements. Biological sampling of Spanish mackerel is separated into distinct regions along Queensland's east coast to account for any substantial variations in the population characteristics of the species over the whole region.

The Australia east coast Spanish mackerel stock assessment uses an annual time-step, two-sex, age-structured population model within Stock Synthesis software. The model incorporated data from 1911 to 2020, including annual estimated commercial, charter and recreational harvest (including recreational released fish mortality), commercial standardised catch rates, fish age—length frequencies and key long-term fishery information on fishing power changes and catch rates. The assessment was conducted at the whole-stock level, including data from across jurisdictions and fishing sectors.

Information and research priorities

Key information and research priorities have been identified in Table 6 to help meet the objectives of this harvest strategy. These will be updated as required.

Table 6: Information and research priorities for the ECSMF

Project description	Explanation of need	Priority
Identify suitable and feasible fishery-independent indices of abundance	Assessment of the east coast Spanish mackerel stock relies on fishery-dependent data, and there are uncertainties around the use of standardised catch rates as an index of abundance (due to hyperstability, different targeting practices, complex fishing effort dynamics, etc.) as well as input parameters. A robust means of assessing abundance and/or recruitment without using fishery-dependent data will reduce uncertainty in the stock assessment and provide a better understanding of how environmental factors influence spawning and recruitment. Due to the range of potential survey options (e.g. Close-Kin Mark-Recapture, egg density surveys) with varying levels of cost-effectiveness depending on species biology and other factors, a feasibility study may be required to consider and compare options.	High
Quantify depredation rates and other sources of fishing mortality (e.g. post-release mortality)	Depredation (typically by sharks) and post-release mortality are both sources of mortality in the Spanish mackerel fishery that have yet to be quantified. This remains a significant data gap and source of uncertainty for future stock assessments in the fishery, and may represent a significant component of mortality contributing to stock decline. Additionally, fishers across all sectors report that depredation is an important issue affecting their catch rates, profit margins and fishing experience.	High
Improve catch-rate standardisations using vessel tracking data	Concerns have been raised regarding the robustness and coarse resolution of catch and effort metrics used in the Spanish mackerel stock assessment process. Consistent high catch rates at spawning aggregations may be masking an overall decline in abundance of the stock due to hyperstability, which is known to occur in fisheries that target spawning aggregations. Improved fishing effort datasets with higher spatial and temporal resolution are necessary to identify if hyperstability is occurring in this fishery and to increase the robustness of the catch-rate standardisations used in stock assessments.	High
Measure the effect of environmental variables on recruitment success and variability	' ' '	

Schedule of performance monitoring, assessment and review

Annual performance monitoring and assessment

Fishery performance will be reviewed against this harvest strategy annually. This review will include convening the Spanish mackerel fishery working group to provide operational advice on the fishery's performance.

The primary performance measure is spawning biomass, which will be used to review the TAC approximately every three years. In the intervening years, a review of standardised catch rate information will also inform fishery performance and if management action is required between scheduled stock assessments. If a stock assessment biomass estimate becomes available prior to the scheduled timeframe that indicates the TAC should be adjusted in order to meet the objectives of the fishery, then the TAC should be reviewed.

While harvest strategies provide certainty and transparency in terms of management decisions in response to certain fishery information, there must also be flexibility to allow new information or changing circumstances to be appropriately considered. There may be instances in which a stock assessment may need to be available prior to, or delayed beyond, the scheduled date. Any change to the stock assessment schedule should be considered by the working group and decided on by the chief executive based on the below conditions:

- If during the period between scheduled stock assessments the chief executive is concerned that a performance indicator (e.g. stock status, standardised commercial catch rate, total harvest) suggests the stock is not performing in a way that will achieve the target biomass level, the chief executive may decide that a stock assessment will be undertaken before the scheduled timeframe.
- If the chief executive is satisfied that (1) indicators for the stock suggest it is achieving, or rebuilding to, target biomass levels and that there is a low ecological risk to the stock under the current management arrangements, or (2) if resourcing requirements prohibit the ability for an assessment to be delivered in the scheduled timeframe, the chief executive may decide that a scheduled stock assessment will be delayed.

Table 7: Schedule of performance monitoring, assessment and review

Activity	Year 1 2023–24	Year 2 2024–25	Year 3 2025–26	Year 4 2026–27	Year 5 2027–28
Monitoring and assessment	Catch, effort and biological monitoring	Catch, effort and biological monitoring	Catch, effort and biological monitoring	Catch, effort and biological monitoring Modelled assessment	Catch, effort and biological monitoring
Management	Review of catch, effort and biological data	Review of catch, effort and biological data	Review of catch, effort and biological data	Review performance against primary objectives	Review of catch, effort and biological data Review harvest strategy

Harvest strategy review

This harvest strategy will remain in place for a period of five years, after which time it will need to be fully reviewed in accordance with the *Fisheries Act 1994*.

The harvest strategy may be subject to further review and amendment as appropriate within the five-year period if any of the following circumstances arise:

- there is new information that substantially changes the status of the fishery, leading to improved estimates of indicators relative to reference points
- drivers external to management of the fishery increase the risk to fish stock
- a new recreational harvest estimate becomes available that suggests the defined sectorial catch shares may have been set incorrectly or may be unrepresentative
- it is clear the harvest strategy is not working effectively, and the intent of the *Queensland harvest* strategy policy is not being met.

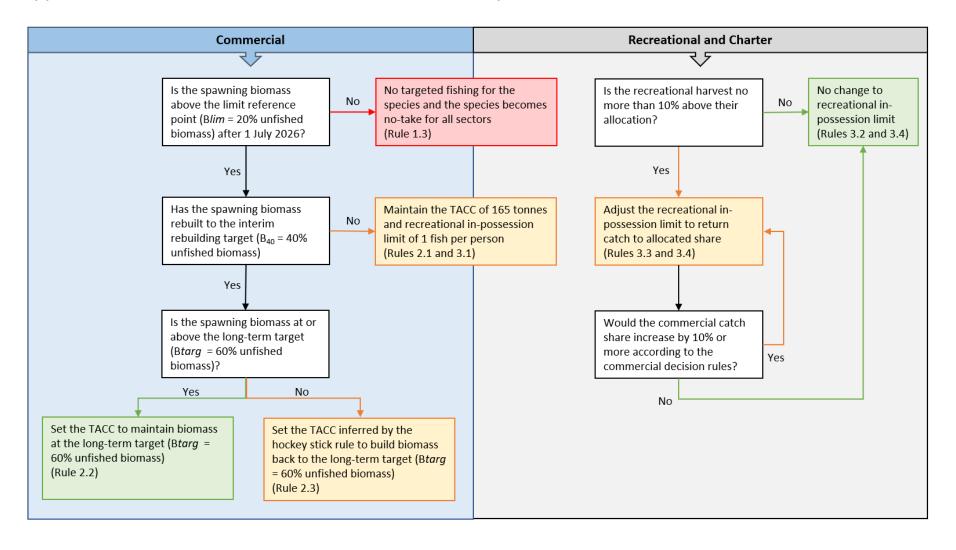
For more information on the processes for amending harvest strategies, refer to the Queensland harvest strategy policy available at <u>publications.qld.gov.au</u>.

Acronyms and definitions

Acronym/term	Definition				
Biomass (B)	Total weight of a population or of a component of a population, usually expressed as a ratio that indicates the biomass as a percentage of the unfished biomass (B_0).				
	East coast Spanish mackerel is assessed in terms of spawning stock biomass, which is measured by spawning egg production.				
Unfished biomass (B₀)	Mean equilibrium virgin unfished biomass, meaning the average biomass level if fishing had not occurred. For east coast Spanish mackerel, this is currently taken to be the spawning stock biomass in 1911 and prior to the commencement of the commercial fishery.				
40% unfished biomass (B ₄₀)	The biomass at 40% of unfished levels. Used by default as a proxy for the biomass at maximum sustainable yield (B <i>msy</i>) and as the interim target biomass reference point for rebuilding.				
Biomass at maximum sustainable yield (B <i>msy</i>)	Biomass at maximum sustainable yield (MSY). Without a specific estimate, the default B <i>msy</i> is taken to be 40% of unfished biomass.				
Biomass at maximum economic yield (B <i>mey</i>)	Biomass at maximum economic yield (MEY). Without a specific estimate, the default B mey is taken to be 60% of unfished biomass (B ₆₀).				
Biomass limit reference point (Blim)	The point below which the risk to the stock is regarded as unacceptably high and urgent management action must be taken to rebuild the stock. The default limit reference point is 20% of unfished biomass (B ₂₀).				
Target biomass (Btarg)	The target reference point in terms of the stock's biomass.				
Ecological risk assessment (ERA)	An analysis of the best available information about fishery impacts on target species, non-target and protected species (e.g. dugongs, turtles, dolphins and protected fish) and the broader ecosystem. ERAs identify and measure the ecological risks of fishing activity and identify issues that must be further managed under harvest strategies.				
Fishing mortality (F)	Describes the part of the stock's total mortality rate due to fishing, often expressed as a rate that indicates the percentage of the population caught in a year.				
Fishing mortality target (Ftarg)	The fishing mortality that achieves the target biomass (Btarg).				
Individual transferable quota	A fully tradeable catch share allocated to individual fishers or companies that allows the holder to catch a portion of the total allowable commercial catch (TACC) each fishing season. Usually assigned a weight value in kilograms that will change as the TACC is set for each season.				
Maximum economic yield (MEY)	The sustainable level of annual harvest that allows net economic returns to be maximised (the largest positive difference between total revenue and total costs of fishing, which equals the maximum profit).				

Maximum sustainable yield (MSY)	The maximum annual harvest that can be removed from the stock over an indefinite period under prevailing environmental conditions.			
Spawning stock biomass	An indicator of the status of the stock and its reproductive capacity. It can be defined as total egg production or the combined weight of all individuals in a fish stock (usually females only) that have reached sexual maturity and are capable of reproducing.			
Status of Australian Fish Stocks (SAFS)	A series of assessments of the biological sustainability of a broad range of wild-caught fish stocks against a nationally agreed framework. Reports are published that determine whether the abundance of fish and the level of harvest from the stock can be considered sustainable.			
Total allowable catch (TAC)	A harvest limit that is set as an output control on fishing for all sectors, specifying the total amount of fish that can be taken from a fishery each year.			
Total allowable commercial catch (TACC)	The harvest limit set for the commercial fishing sector is usually achieved through setting TACC, but sometimes through input controls			
TMIN, 2TMIN	Rebuilding timeframes specified relative to the minimum timeframe for rebuilding in the absence of fishing.			

Appendix A: Overview of decision rules for east coast Spanish mackerel



TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3 - 4 November 2022
UPDATES FROM MEMBERS Papua New Guinea National Fisheries Authority	Agenda Item 2.3 For NOTING

1. That the RAG **NOTE** the update to be provided by the PNG National Fisheries Authority (NFA).

BACKGROUND

2. A verbal report will be provided under this item.

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
UPDATES FROM MEMBERS Native Title	Agenda Item 2.4 For NOTING

1. That the RAG **NOTE** any updates on Native Title matters from members, including representatives of Malu Lamar (Torres Strait Islanders) Corporation RNTBC (Malu Lamar).

BACKGROUND

- 2. On 7 August 2013 the High Court of Australia confirmed coexisting Native Title rights, including commercial fishing, in the claimed area (covering most of the Torres Strait Protected Zone). This decision gives judicial authority for Traditional Owners to access and take the resources of the sea for all purposes. Native Title rights in relation to commercial fishing must be exercisable in accordance with the *Torres Strait Fisheries Act 1984*.
- 3. Traditional Owners and Native Title representative bodies have an important role in managing Torres Strait fisheries. It is important therefore that the RAG keep informed on any relevant Native Title issues arising.

Torres Strait Finfish Fishery Resource Assessment Group	Meeting 12 3-4 November 2022
STOCK ASSESSMENTS AND RBC ADVICE Spanish mackerel	Agenda Item No. 3.1 For Discussion and Advice

That the Resource Assessment Group (RAG):

- REVIEW the results of the updated Spanish mackerel stock assessment and Recommended Biological Catch (RBC) estimates to be presented by FFRAG Scientific Member Dr Michael O'Neill and Coinvestigator Dr Rik Buckworth under the funded project "Torres Strait Spanish mackerel stock assessment" (project number 200815); and
- 2. Having regard for the stock assessment outcomes, RBC estimates and advice on a harvest strategy for the fishery, **DISCUSS** and **PROVIDE ADVICE** on an RBC for Spanish mackerel for the 2023-24 season.

KEY ISSUES

- 1. In preparation for updating the stock assessment and estimating an RBC for the 2023-24 fishing season, at its last meeting¹, the RAG reviewed the new data catch and age data available from the 2021-22 fishing season and provided recommendations on:
 - a) treatments to be applied to data inputs;
 - b) specific model analyses and sensitives to be undertaken; and
 - c) the RBC calculation method.
- 2. Key advice received at FFRAG 11 meeting (12 October 2022) on data treatments for the 2022 assessment were:
 - Retain 'standardised catch rates' in line with the 2021 assessment.
 - Do not include TIB catch rates in the assessment (as per previous assessment). However, the stock assessment team will include this as a sensitivity analysis in line with 2021.
 - Incorporate the historical G McPherson data into the assessment. This data will be entered into the 2022 assessment as an additional input compared to 2021.
 - The RAG recommended to run 6 core analyses in line with the 2021 assessment (**Table 2**). These include the 3 defined natural mortality rates, and two harvest scenarios. The average output from these 6 analyses will be used for the Recommended Biological Catch (RBC) calculation.
 - The RAG recommended to run 4 sensitivity analyses (**Table 3**).
 - The RAG agreed to include newly available commercial catch-weight data from the 2021/22 season, which comprised 5.8 tonnes from the TIB sector, and 47.3 tonnes from the sunset sector. In

¹ FFRAG 12 meeting, 12th October 2022

addition to an estimate of non-commercial catch, this brings the total catch for the 2021/22 season to **73.1 tonnes**.

- The RAG also agreed to an expected harvest for the 2022/2023 season. This was calculated to be **81 tonnes** (sunset = 57 t , TIB = 4 t, 15 t kai kai, 5 t rec, and 0 for charter and PNG). This expected harvest will be entered into the stock assessment to calculate an RBC for the 2023/24 season.
- 3. **Table 1** provides a summary of RAG advice to date, and highlights amendments / new data for the 2022 stock assessment.
- 4. Although a harvest strategy for the Spanish mackerel fishery is yet to be completed, progress has been made by the RAG and Finfish Fishery Working Group (WG) on several components of a potential harvest strategy for the species. This work has sensibly guided both RAG and WG advice on recent RBC and TACs. In particular,
 - a) the guiding principles and key fishery attributes (factors that should help shape the development of the harvest strategy); and
 - b) target and limit reference points.
- 5. **Attachment 3.1a** provides a summary of RAG advice on relevant components of Spanish mackerel draft harvest strategy from its meeting on 31 October 1 November 2019 (meeting 5). Based on this advice, the FFRAG commenced the current RBC setting process in 2020² in preparation for the 2021-22 season.
- 6. This process demonstrates how the RAG and WG applied the harvest strategy guiding principles and was subsequently followed by the FFRAG in 2021. This resulted in a 'matrix of scenarios' to assist in setting an RBC (**Table 4**).
- 7. The RAG at FFRAG 11 meeting recommended to follow the same RBC setting process for the 2023/24 season.

Table 1: Summary of RAG advice to date on Spanish mackerel stock assessment data inputs.

Assessment item	RAG Recommendations								
1. Total annual	1. Total annual harvest tonnes								
Annual average fish weights in Sunset tonnages	 To support the 2020 stock assessment the RAG recommended: changing the constant assumed average fish weight data rule to apply a weighted mean value to the years for which a mean fish weight was not available from catch sampling; and that the project team use total harvest values available from Catch Disposal Records (CDRs) from the 2018-19 season onwards noting these were verified weights in port. The RAG recommended to retain these values for the 2021 & 2022 stock assessments. 								
Harvest estimates 1940-1988	Table 2 summarises RAG advice on 1940-1988 harvest tonnages. Sunset sector historic harvests • These figures are based on available data from McPherson et al. (1986). Retained for the 2021 & 2022 stock assessments. 'TIB' sector historic harvests								

² Attachment 3.1a of FFRAG 10 Papers (18-19 November 2021)

_

 On the basis of the advice from the Traditional Inhabitant industry members, the RAG (at FFRAG 7) recommended the table of catches be amended to reflect zero tonnes of harvest from the TIB sector prior to 1975 as an input to the 2020 stock assessment model. The RAG supported the assumption of 3 t harvest to be input into the model per year for TIB sector from 1975 to 1988. the 2021 & 2022 stock assessments.

'TIB' sector historic harvests

 The RAG (at FFRAG 7) accepted advice from the Traditional Inhabitant industry members and agreed to recommend that the traditional harvest of mackerel be revised from 10 t down to 2 t prior to 1975 as an input to the 2020 stock assessment model. Retained for 2021 stock assessment.

Recreational Fishing

• The RAG noted at FFRAG 7 that the 2 t estimate for recreational catches is based on modern QDAF led survey techniques and is applied consistently across all years as an input into the model. The RAG had no basis to deviate from this approach. The RAG therefore recommended maintaining a 2 t recreational take of Spanish mackerel for all years in the 2020 stock assessment model. Retained for the 2021 stock assessment.

Options for connecting the older historical catch data with the modern logbook time series

At FFRAG 7 the project team presented the RAG with four options (logistic, polynomial, log-linear and weighted mean) available to fit the assumed total harvests in the model to the pre-1989 data points of harvest estimates available from older sources (1957-1962 data from a single boat and 1975-1979 data from the Queensland Fish Board and some processors).

RAG scientific members advised that the log-linear and weighted-mean models should be disregarded as these approaches placed too much emphasis on the older uncertain points (1957- 1962 and 1975-1979) in the time series.

Based on this advice the RAG recommended that both the logistic and polynomial approaches should be used as inputs to the 2020 stock assessment as they appeared to fit the available data historic data points well.

Retained for the 2021 stock assessment.

The RAG recommended for the 2019 assessment to inflate the time series of total harvests by 100 t for the years 1979 to 1989 to include this estimate of mortality on the stock in the model.

Upon review in 2020, the RAG agreed:

100 t Taiwanese gillnet harvest 1979-1986

- there was a sufficient weight of evidence to show that IUU fishing of Spanish mackerel did occur. This was chiefly based on the 1992 Joint Advisory Council advice of an apprehension of a drift net boat with a large quantify of catch in its hold and reported take of mackerel in March 1992 and reports from McPherson 1986.
- that the IUU catches should be accounted for in the stock assessment. If IUU
 catches are not accounted for, the stock assessment may overestimate the current
 biomass estimate through time which could then lead to over-harvesting.
- for the time series of harvests from Taiwanese IUU to be extended from 1986 to 1992-93 and to taper the catch down to zero by this point (i.e. extending harvest into 1990, 1991, 1992 reducing to zero tonnes to blend into the existing time series by 1993). Tapering was agreed based on the assumption that IUU fishing decreased as the presence of Australian fishing boats on the fishing grounds increased.

Retained for 2021 stock assessment.

Assess logbook over reporting of

At FFRAG 6 meeting in 2019 the RAG concluded that, as an issue, paper fish was not substantially influential on the model outcomes and scientific efforts should be placed on other areas in future assessments. The stock assessment team advised that paper fish could be left in the model for future analysis (in 2020) as a post-analysis sensitivity approach rather than including as part of the core assessment model runs. FFRAG supported this

fish harvest (paper fish)	approach to leave these data in the model and that there would need to be a clear justification to remove or alter these values.
2. Standardise	d catch rates
Number of dories reported	The available data on the historical number of dories used by primary boats was analysed during the 2020 stock assessment. The RAG recommended not including the factor of number of dories in the 2020 stock assessment until further fact finding and investigation on the older data could be conducted. Retained for the 2021 & 2022 stock assessments.
Fishing Power (FP)	The RAG noted at FFRAG 7 that the FP in the Torres Strait model was a calculation carried over from the Queensland East Coast stock assessment and, if applied yearly, would mean about a 23 per cent increase in FP from 1989 to present (0.955 to 1.187). The RAG noted advice from industry that prior to 1989 no one had GPS units, but by the mid 90's this technology was common across the fleet; meaning that FP has indeed been changing across the time series. Based on this advice the RAG recommended that, for the 2020 stock assessment, fishing power should be included as a factor in the model in all model runs i.e. no model runs will be performed excluding FP. Retained for the 2021 & 2022 stock assessments.
Categorise fishing skippers and dory drivers	Outstanding assessment item to review
GLM influences – effects of model terms on sunset catch rates	The RAG noted that the generalized linear model accounts for certain factors such as seasonal changes, wind strength and direction, spatial variation, variations between operators, lunar cycle. The key factor which was included in the 2020 and 2021 stock assessments was the Qld north east coast 'fishing power' offset. Retained for the 2022 stock assessment.
3. Biology	
Age frequency data	At FFRAG 7 the RAG recommended that all years of available fish age and length data below should be included as inputs into the 2020 stock assessment.
Natural mortality rates	Retained for the 2021 & 2022 stock assessments – now includes 13 years of data. At FFRAG 7 the RAG recommended that the 2020 assessment model conduct model runs reusing the Natural Mortality (M) value of 0.3 from the 2019 stock assessment (which was considered as a good logical lower value estimate), 0.45 as a higher range. This was amended for the 2021 assessment to values of 0.3, 0.35, 0.4 per year. Retained for the 2022 stock assessment.
Spawner – recruitment steepness	At FFRAG 9 the RAG recommended the following to be applied to the 2021 stock assessment: a) that the estimated steepness parameter of 0.4 be used in the model; and

	b) two sensitivities to be run using 0.6 and 0.7. The sensitivity runs will assist the RAG to learn how the model performs using higher steepness parameters and therefore to undertake a more detailed review in the future.						
	Retained for the 2022 stock assessment.						
4. Stock assess	ment model						
	FFRAG 9 advice on stock assessment analyses data treatments is as follows:						
	1. Total harvests:						
	Apply two models of historical estimates 1940-1988						
	 Apply the agreed tapered estimate of Taiwanese IUU harvests to these models. 						
	2. Standardised catch rates:						
Data	Do not apply tender/dory data						
treatments	 Apply the Qld north east coast 'fishing power' offset to the GLM 						
for Stock assessment	 Incorporate available TIB CPUE data into a 'sensitivity analysis' for 2021. 						
analyses	3. Fish age frequencies:						
(summary)	Utilise all years with fish age or length data						
	4. Natural mortality rate						
	 Apply a natural mortality rate of 0.3, 0.35, and 0.4 						
	5. Steepness parameter						
	 Estimate steepness, and sensitivity test higher fixed steepness values of 0.6 and 0.7. 						
	Retained for the 2022 stock assessment.						
	At FFRAG 9 the RAG recommended the following method for calculating an RBC. This was in line with the method used for the 2020 assessment.						
	 a) Forecasting the RBC to account for the time lag between the stock assessment and the beginning of the 2021/22 fishing season. This is where stock recruitment and mortality for the 2020/21 season was accounted for. Average recruitment was assumed, removing natural mortality, and removing predicted fishing 						
	b) Producing a range of RBC values which corresponded with biomass target reference points (also referred to as target fishing mortality rates: 'F-values). These F-values ranged from 'maximum sustainable yield' (MSY) to 'F ₆₀ ' (to maintain a stock that is at 60% of virgin biomass)						
Method for calculating	c) Running simulations to assess risk to the stock over 12 years against each RBC value.						
RBCs	Retained for the 2022 stock assessment.						
Design RBC	The RAG noted the approach used in the 2019 assessment, where a range of target reference point fishing mortalities were considered in recommending an RBC (F MSY, F 40, F 48, F 60), with the median value of all agreed model runs (analyses) being used to select the RBC.						
decision tables	This decision table design was retained for the 2020 and 2021 stock assessment.						
เฉมเซง	Retained for the 2022 stock assessment.						

Dissect the depletion levels up to 1989 and catch history	Outstanding assessment item to review
	Outstanding assessment item to review
Retrospective	
analyses	
	Outstanding assessment item to review

Table 2. Analyses / model runs agreed to be applied to the 2022 Torres Strait Spanish mackerel fishery.

Label	Catch rate series	Natural mortality rate (M)	Steepness parameter	Harvest pre-1989	Ageing data	Start year for data*
1	No tender data. Fishing power included.	0.3	Estimated	Historic catches actual + polynomial model + IUU tapered	All years	1941
2	No tender data. Fishing power included.	0.35	Estimated	Historic catches actual + polynomial model + IUU tapered	All years	1941
3	No tender data. Fishing power included.	0.4	Estimated	Historic catches actual + polynomial model + IUU tapered	All years	1941
4	No tender data. Fishing power included.	0.3	Estimated	Historic catches actual + logistic model + IUU tapered	All years	1941
5	No tender data. Fishing power included.	0.35	Estimated	Historic catches actual + logistic model + IUU tapered	All years	1941
6	No tender data. Fishing power included.	0.4	Estimated	Historic catches actual + logistic model + IUU tapered	All years	1941

^{*} Start year is 1940-1941, now labelled as 1941. Previously this was labelled as 1940.

Table 3. Sensitivity analyses / model runs agreed to be applied to the 2022 Torres Strait Spanish mackerel fishery.

Label	Catch rate series	Natural mortality rate (M)	Steepness parameter	Harvest pre- 1989	Ageing data	Start year for data	Comments
7	TIB data included No tender data. Fishing power included.	0.35	Estimated	Historic catches actual + polynomial model + IUU tapered	All years	1941	TIB catch rate in. Compared to analysis 2.
8	No tender data. Fishing power included.	0.35	Estimated	Historic catches actual + polynomial model + 0.5 IUU tapered	All years	1941	Illustrate 1/2 IUU. Compared to analysis 2.
9	Tender data and fishing power both included.	0.35	Estimated	Historic catches actual + polynomial model + IUU tapered	All years	1941	CPUE with tenders. Compared to analysis 2.
10	No tender data. Fishing power included.	0.35	Estimated	Historic catches actual + polynomial model + IUU tapered	All years	1941	New growth curve. Compared to analysis 2.

Table 4. Summary of options presented to the FFRAG as outputs from the 1940 model runs in the 2021 Spanish mackerel stock assessment update. Green highlighted approaches in column 4 were those considered by the RAG as potentially appropriate RBCs for the 2022/23 season.

No.	Name of RBC approach 1940 custom model	Fishing year for the RBC calculation	% of <u>all</u> simulations below S ₂₀ over 12 years and 6 analyses Assuming average recruitment, and the constant RBC	% of <u>feasible</u> simulations below S ₂₀ over 12 years and 6 analyses Assuming average recruitment, and the constant RBC	Median RBC tonnes Over 6 analyses
1	Constant F _{MSY}	2022-23	12.8%	8.4%	131
2	Constant F ₄₀	2022-23	12.6%	8.2%	129
3	Constant F ₄₈	2022-23	10.4%	5.8%	102
4	Constant F ₅₀	2022-23	9.9%	5.3%	95
6	Constant F ₆₀	2022-23	8.6%	3.9%	68

Status of Spanish mackerel draft harvest strategy components as reviewed by FFRAG at its meeting on 31 Oct- 1 Nov 2019 (meeting 5)

Guiding principles and key fishery attributes - factors that helped shape the development of the Harvest Strategy

Recommended

Consistency with the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (HSP, 2018). This is consistent with objectives of the *Torres Strait Fisheries Act 1984* (the Act).

Have regard for traditional knowledge and the ability of communities to manage fishery resources locally, through acknowledging and incorporating customary and traditional laws, recognising; Malo Ra Gelar, Gudumalulgal Sabe, Maluailgal Sabe, Kulkalgal Sabe.

Recognise commercial fishing by traditional inhabitants is important for local employment, economic development and for the passing down of traditional knowledge and cultural lore. Enough fish need to be left in the water for future fishers to make money and to protect the traditional way of life, livelihoods and cultural values.

Spanish mackerel are a shared resource important for subsistence, commercial, traditional, charter and recreational sectors. Shared stock under the Torres Strait Treaty with PNG, stock to be shared if PNG nominate to do so.

TACs should vary according to stock status (up and down):

- If biomass decreases be cautious. Stock is not to go below the limit;
- If biomass is increasing be conservative; 'bank' fish.

RAG noted that 'banking' fish was challenging to capture in the decision rules of a harvest strategy with stocks generally building towards a target reference point in a prescribed way based on assessment outcomes.

RAG noted that the prescription for this in-principle objective from traditional owners was in regard to when the stock was increasing, to not necessarily increase the TAC but possibly only after a trend/consecutive years of increasing stock. RAG also advised that this approach and wording should also consider the level of certainty and precaution underlying future decision making. RAG suggested that this wording required greater clarity in the final harvest strategy but the spirit of the objective was understood and would likely only apply to the fishery when the stock has eventually build above the Target Reference Point and increases in TACs (via a potential fish-down of the stock to B Target by increasing harvests) are suggested by the assessment estimate of biomass. It was considered

that clear decision rules to implement this stakeholder desire would need to be developed with stakeholders, potentially as the Strategy is reviewed over time.

Having regard for the current stock size (B_{31}) and that B_{60} is not quickly achieved (possibly greater than 12 years) without significant reductions in catch which may in turn cause significant economic and social impacts on the Fishery, a shorter-term target reference point is first required.

Torres Strait Spanish mackerel stock are assumed separate from other regional stocks. They have limited mixing with the Queensland East Coast and the Gulf of Carpentaria stocks (see Buckworth et al. 2007 and Newman et al. 2009).

There is potential for variations in availability and abundance of Spanish mackerel in the Fishery, due to their movement, schooling and aggregation patterns for feeding and spawning, recruitment and mortality.

Spanish mackerel are a shared resource important for subsistence, commercial, traditional, charter and recreational sectors.

Operational objectives

What we want the harvest strategy to achieve.

Recommended

Maintain the stock at (on average), or return to, a target biomass point (B_{TARG}) equal to a stock size that aims to protect the traditional way and life and livelihood of traditional inhabitants and is biologically and economically acceptable.

Maintain stocks above the limit biomass level (B_{LIM}), or an appropriate proxy, at least 90 per cent of the time.

Reduce fishing levels if a stock is below B_{TARG} but above B_{LIM}.

Implement rebuilding strategies, if the stock moves below B_{LIM}.

Reference points

A reference point is a specified level of an indicator used as a basis for managing a stock or fishery. Reference points will generally be based on indicators of either the total or spawning stock size (biomass) or the amount of harvest (fishing mortality). Reference points show where we want (target) and don't want (limit) the stock levels in the fishery to be.

Recommended	Unfished biomass (B_0) = B_{1940} = 100%.	The year 1940 is considered the start of the commercial operations in the Fishery. The unfished biomass B0 therefore is the model-estimate of spawning stock biomass in 1940.	
Target (B_{TARG}) reference point = B_{48} B ₄₈ ³ is the default target (a proxy for Policy.		B_{48}^{3} is the default target (a proxy for B_{MEY} - biomass at maximum economic yield) in the Commonwealth HS Policy.	
	Limit reference point $(B_{LIM}) = B_{20}$	B_{LIM} is the spawning biomass level below which the ecological risk to the stock is unacceptable and the stock is defined as 'overfished'. This is an agreed level which we do not want the stock to fall below. B_{20} is the default limit proxy in the Commonwealth HS Policy ⁴ .	
Outstanding	Long term B TARG = B ₆₀	TARG = B ₆₀ Further analysis and advice is required on the suitability of B60 as a long-term B TARG, in compariso other target biomass levels above BMSY having regard for the biology of the species and performance of Strategy in meeting its objectives.	
		Stakeholders have recommended that the Strategy ensures enough fish are left in the water to support commercial fishing but also protect the traditional way of life and livelihoods of traditional inhabitants.	
		Advice to date is that a higher target biomass level (referring to 60%), would increase catch rates and improve profits in the fishery over other lower reference points, such as B48. RAG advice on the suitability of B60 against other possible higher target biomass levels is necessary. There are likely to be trade-offs between medium-term returns from the fishery (significantly reduced TAC) and longer-term returns (more	

³ Comm HSP: The target reference point for key commercial fish stocks is the stock biomass required to produce maximum economic yield from the fishery (BMEY). For multispecies fisheries, the biomass target level for individual stocks may vary in order to achieve overall maximum economic yield from the fishery. In cases where stock-specific BMEY is unknown or not estimated, a proxy of 0.48 times the unfished biomass, or 1.2 times the biomass at maximum sustainable yield (BMSY), should be used. Where BMSY is unknown or poorly estimated, a proxy of 0.4 times unfished biomass should be used. Alternative target proxies may be applied provided they can be demonstrated to be compliant with the policy objective.

⁴ Comm HSP: All stocks must be maintained above their biomass limit reference point (BLIM) at least 90 per cent of the time. Where information to support selection of a stock-specific limit reference point is not available, a proxy of 0.2 times unfished biomass should be used.

fish in the water meaning less cost to catch and therefore higher returns. Also, there would be more fish in the water for other users).
Quantitative analysis and/or evidence from comparable fisheries may enable more evidence-based advice and decision making on the longer-term target.

Torres Strait Finfish Fishery Resource Assessment Group	Meeting 12 3-4 November 2022
STOCK ASSESSMENTS AND RBC ADVICE Coral trout	Agenda Item No. 3.2 For Discussion and Advice

That the Finfish Fishery Resource Assessment Group:

- REVIEW the updated coral trout Catch Per Unit Effort (unstandardised) data series to be presented by AFMA; and
- Having regard for new catch data, previous assessments, and the updated coral trout CPUE data time series, **DISCUSS** and **PROVIDE ADVICE** on an RBC for Coral trout for the 2023-24 fishing season.

KEY ISSUES

- 1. The status of coral trout has been assessed against both the results of a Management Strategy Evaluation (MSE) undertaken in 2006 (Williams et al. 2007, 2011) and more recently, a preliminary stock assessment undertaken by Dr George Leigh (QDAF) and Dr Matthew Holden (University of Queensland) under the previously funded project "Harvest strategies for the Torres Strait Finfish Fishery'.
- 2. At its 31 October-1 November 2019 meeting (FFRAG 5) the RAG recommended that a stock assessment be conducted during the 2021-22 fishing season, once further data is available. At the time, the FFRAG considered that postponing the stock assessment for three years would allow enough time for additional data to be included. The additional data priorities identified being:
 - a) Review and possible inclusion of data from a 1994-95 CSIRO fish survey data in the Torres Strait (*Influence of Coastal Processes on Large Scale Pattern in Reef Fish Communities of Torres Strait, Australia*, Milton & Long, CSIRO 1997);
 - b) Improved catch and effort data from TIB fishers; and
 - c) Fishery independent data such as an underwater survey or biological sampling.
- 3. Biological sampling for coral trout commenced in the 2020-21 fishing season for the first time.
- 4. At its meeting (14-15 October 2021, meeting 9), the FFRAG did not recommend undertaking a stock assessment for coral trout as an immediate research priority for funding in 2022-23 nor did the FFRAG support a fishery-independent-survey at that time.
- Dr Trevor Hutton summarised coral tout data from the 1995-1996 CSIRO dive survey and
 presented to the RAG at FFRAG 9. The RAG considered this summary along with an updated
 standardized CPUE timeseries when formulating an RBC for the 2022/23 season. The RAG did not

consider the substantive annual RBC of 135 tonnes to be a risk to sustainability based on the available information.

- 6. AFMA will present an updated unstandardised CPUE timeseries to the RAG at FFRAG 12.
- 7. The RAG is asked to note that the previously identified research priority to update the standardised CPUE timeseries is on track to be presented out-of-session in November 2022. The RAG will be invited to provide final advice on an RBC for the 2023/24 season before the Finfish Fishery Working Group meets on 7-8 December 2022.

BACKGROUND

- 8. At the RAG's meeting on 31 October 1 November 2019 (meeting 5) the RAG identified, two triggers that may indicate changes in the risk profile for the stock:
 - a) Catches from TIB + Sunset sector exceeding 90 t (being two thirds of the constant catch TAC of 134.9 t); and
 - b) If the standardised catch rate per day drops below 90.6 kg per primary vessel day¹.
- 9. The RAG advised that either of these two triggers being met would flag a change in the stock status and will mean a stock assessment is to be carried out to investigate. FFRAG considered that further work would be required to develop decision rules based on the outcomes of this assessment if triggered; i.e. how are the outputs of the assessment used to then move the stock relative to the reference points.
- 10. Relevantly the RAG also recommended that an alternative, robust indicator of stock status, other than CPUE from the small number of sunset boats targeting coral trout, needs to be developed to track the stock status over time.
- 11. At FFRAG 9 meeting on 14-15th October 2021, the RAG noted the 2020 *ABARES Fishery Status Report* for the Torres Strait Finfish Fishery. It was raised by a scientific member that although coral trout are currently classified as not being overfished, and not subject to overfishing, due to the increasing length of time since the last evaluation of the coral trout stock, there is an increasing risk of it becoming unknown what the productivity of the stock is.
- 12. The RAG noted unless a stock assessment can be endorsed, then there is a risk that the fishery may be classed as 'status uncertain' for being over-fished/subject to overfishing.
- 13. The RAG at FFRAG 11 meeting on 12 October 2022 provided preliminary advice that a stock assessment for coral trout is an essential research priority for the finfish fishery.
- 14. Recent commercial catches of Coral trout in the Fishery are summarised below:
 - 21 tonnes in 2014-15
 - 38.4 tonnes in 2015-16.
 - 25.7 tonnes in 2016-17
 - 27.3 tonnes in 2017-18
- 17.3 tonnes in 2018-19
- 32.5 tonnes in 2019/20
- 18.9 tonnes in 2020-21
- 41.9 tonnes in 2021-22

¹ The catch rate associated with B80 was determined to be 120 kg per day based on an average from 2012-2017 advice is that if it falls below 90 kg per day (as a proxy for B60) it would trigger an assessment.

- 15. A coral trout TAC of 135 tonnes has been in place since 2007–2008 (note historically the TAC was 134.9 tonnes but the PZJA agreed to simplify the TAC for the 2019-20 fishing season). This TAC was based on the average catch between 2001 and 2005 and included historic high catches reported in the fishery.
- 16. In the absence of a formal stock assessment, the status of the coral trout stock has been evaluated against the results of a Management Strategy Evaluation (MSE) undertaken in 2006 (Williams et al. 2007, 2011). In this MSE exercise, four constant catch scenarios of 80, 110, 140 and 170 tonnes were tested which all achieved a biomass for the fishery of at least 60 per cent of virgin total biomass by 2025. The biomass in 2004 was estimated to be more than 60 per cent of unfished levels (Williams et al. 2011, 2007). Commercial catch in recent years has been below historical catch levels and well below the lowest catch level simulated in the MSE (80 t per year).
- 17. At its meeting on 13-14 March 2019 the FFRAG considered a preliminary stock assessment for coral trout. The FFRAG accepted the assessment as preliminary noting the stage of development of the assessment and the range of uncertainties within the assessment. The FFRAG noted the results of the preliminary stock assessment suggest the coral trout stock is healthy with around 80 per cent of virgin biomass available. The RAG noted that all of the model estimates of current spawning biomass were above 65 per cent estimated virgin biomass.
- 18. At meeting on 18-19 November 2022 the FFRAG again recommended maintaining the coral trout TAC at 135 t for the 2022-23 season noting, catches remain low in the fishery (catches for the 2019-20 fishing season were 32.34 tonnes), the 2019 preliminary stock assessment outcomes, and industry advice that catches were unlikely to increase significantly in next fishing season.
- 19. At its meeting on 25 November 2021 the FFWG supported the FFRAG advice and also recommended that the coral trout TAC remain at 135t for the 2022-23 fishing season.

Non-Commercial Catch

- 20. To date, the TAC has not been calculated with an explicit deduction to account for likely catches taken outside the fishery (kai kai, recreational, charter). This is because it has not been a high priority to undertake work to determine catch estimates whilst catches remain very low compared with the TAC.
- 21. At its meeting on 27-28 November (meeting 6), the RAG recommended that AFMA undertake a work plan to support RAG consideration of likely catches ahead of the following fishing season. To date, this work has not been actioned due to the underutilised nature of the fishery (catches far below the available TAC).
- 22. The RAG agreed to retain this action item, noting however, that progressing this action needs to be assessed against other RAG priorities and in light of any future research investment to develop an approach for measuring non-commercial fishing for the region.
- 23. At its meeting on 14-15th October 2021 the RAG noted the progression of the project *Developing* an approach for measuring non-commercial fishing in the Torres Strait in order to improve

fisheries management and promote sustainable livelihoods, which was completed in 2021. This project proposed a timeline of future monitoring projects to measuring non-commercial catch, including coral trout.

- 15. As of October 2022, 'Phase 2' of the non-commercial catch project (*Measuring non-commercial fishing catches (traditional subsistence fishing) in the Torres Strait in order to improve fisheries management and promote sustainable livelihoods*) has been supported by the FRDC for funding, subject to conditions.
- 16. This project will seek to quantify the levels of non-commercial take of a wide range of fisheries resources, including finfish.

Torres Strait Finfish Fishery	Meeting 12
Resource Assessment Group	3 - 4 November 2022
MANAGEMENT	Agenda Item No. 4.1
Harvest Strategy Development	For Discussion and Advice

That the Resource Assessment Group (RAG):

- 1. **REVIEW** work to date on developing harvest strategies for Spanish mackerel and coral trout;
- 2. AGREE on outstanding harvest strategy components to be progressed and tested; and
- 3. **DISCUSS** and **PROVIDE ADVICE** on a work plan to develop RAG advice on final draft harvest strategies for Spanish mackerel and coral trout.

KEY ISSUES

Spanish mackerel

- 1. At FFRAG 10 (18-19 November 2021) the RAG reviewed the work to date on a draft harvest strategy for Spanish mackerel. This included advice from FFRRAG 5 based on the outcomes of the AFMA funded project *Harvest Strategies for the Torres Strait Finfish Fishery* project (Project number 2016/0824) which was completed in 2019 (Table 1). Table 2 provides a summary of progress for coral trout however the RAG has not reviewed this table given the need for focus on Spanish mackerel.
- 2. Progress made on the harvest strategies is also the result of recommendations from the RAG, Working Group (FFWG) and broader industry members that participated in several harvest strategy workshops.
- 3. The RAG agreed that objectives (including guiding principles), indicators (biomass) and reference points (target and limit reference points) for a future Spanish mackerel harvest strategy were well progressed. The RAG recommended that a Management Strategy Evaluation (MSE) be undertaken to finalise a harvest strategy for Spanish mackerel that meets Traditional Owner objectives and is robust to uncertainties.
- 4. The RAG developed a scope for the MSE project which was then released in a public call for research for the 2022/23 financial year in December 2021.
- 5. There were no proposals received for the MSE of Spanish mackerel for the Torres Strait Finfish Fishery for the 2022/23 financial year.
- 6. As this research project remained a high priority for the fishery, a RAG sub-group of scientific members met in September 2022 to refine technical aspects of the previous MSE scope. A direct call for a research proposal was then progressed for the 2023/24 financial year. The refined scope can be found at **Attachment 4.1a.**

- 7. The RAG will be asked to review a research proposal for an MSE project should one be submitted before 3 November 2022.
- 8. AFMA proposes to convene a joint FFRAG / FFWG harvest strategy workshop in March 2023 to refine all components of a harvest strategy in anticipation of a streamlined Management Strategy Evaluation in 2023/24.
- 9. The RAG is asked to identify all outstanding refinements and develop specific agenda items to be actioned at the proposed harvest strategy workshop. This will enable all required considerations to be provided to a future MSE project team.

Coral Trout

- 10. At FFRAG 10 meeting, the RAG agreed to defer further discussion on coral trout until its next meeting. In doing so the RAG agreed that:
 - a) based on stock status and fishing levels, the highest priority for the fishery should be to progress a harvest strategy for Spanish mackerel; and
 - b) consistent with its advice on 14-15 October 2021 (meeting 9), the highest immediate research priority for coral trout is to progress a CPUE standardisation methodology and analysis. Given the likely status of the stock, the size of the fishery in terms of catch, the level of information available for the fishery, and the costs involved in undertaking fishery independent surveys, it is likely that CPUE analysis will be central to harvest strategy options in the short to medium term. The RAG also noted that biological and catch composition data is now being collected for the fishery. These data will support future stock assessments.
- 11. The RAG developed a research scope for a coral trout CPUE standardisation project which was subsequently released in a public call for research in December 2021. A proposal was received however was not able to be progressed for funding.
- 12. This work will instead be conducted by Dr Michael O'Neill, with outcomes to be presented to the RAG out-of-session in November 2022. This will provide the RAG with a current index of abundance which will guide future advice on the progression of a harvest strategy for coral trout.

Table 1. Status of Spanish mackerel draft harvest strategy components as reviewed by FFRAG at its meeting on 31 Oct- 1 Nov 2019 (meeting 5). Note this table is an updated version to that attached to the record for the FFRAG meeting 5.

Guiding principles and key fishery attributes – factors that helped shape the development of the Harvest Strategy

Recommended

Consistency with the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (HSP, 2018). This is consistent with objectives of the *Torres Strait Fisheries Act 1984* (the Act).

Have regard for traditional knowledge and the ability of communities to manage fishery resources locally, through acknowledging and incorporating customary and traditional laws, recognising; Malo Ra Gelar, Gudumalulgal Sabe, Maluailgal Sabe, Kulkalgal Sabe.

Recognise commercial fishing by traditional inhabitants is important for local employment, economic development and for the passing down of traditional knowledge and cultural lore. Enough fish need to be left in the water for future fishers to make money and to protect the traditional way of life, livelihoods and cultural values.

Spanish mackerel are a shared resource important for subsistence, commercial, traditional, charter and recreational sectors. Shared stock under the Torres Strait Treaty with PNG, stock to be shared if PNG nominate to do so.

TACs should vary according to stock status (up and down):

- If biomass decreases be cautious. Stock is not to go below the limit;
- If biomass is increasing be conservative; 'bank' fish.

Having regard for the current stock size (B_{31}) and that B_{60} is not quickly achieved (possibly greater than 12 years) without significant reductions in catch which may in turn cause significant economic and social impacts on the Fishery, a shorter-term target reference point is first required.

Torres Strait Spanish mackerel stock are assumed separate from other regional stocks. They have limited mixing with the Queensland East Coast and the Gulf of Carpentaria stocks (see Buckworth et al. 2007 and Newman et al. 2009).

There is potential for variations in availability and abundance of Spanish mackerel in the Fishery, due to their movement, schooling and aggregation patterns for feeding and spawning, recruitment and mortality.

Spanish mackerel are a shared resource important for subsistence, commercial, traditional, charter and recreational sectors.

Operational objectives

What we want the harvest strategy to achieve.

Recommended

Maintain the stock at (on average), or return to, a target biomass point (B_{TARG}) equal to a stock size that aims to protect the traditional way and life and livelihood of traditional inhabitants and is biologically and economically acceptable.

Maintain stocks above the limit biomass level (B_{LIM}), or an appropriate proxy, at least 90 per cent of the time.

Reduce fishing levels if a stock is below B_{TARG} but above B_{LIM} .

Implement rebuilding strategies, if the stock moves below B_{LIM} .

Indicators

Indicators provide information on the state of the stock and how the stock is doing against agreed reference points (reference points are addressed below and are a specified level of these indicators)

Recommended

Biomass – Catch and effort data from daily fishing logbooks is used as a proxy for abundance in the stock assessment model which is used to calculate biomass of the stock as a proportion of unfished biomass (B₀).

Outstanding

Fishing mortality (B) based indicators. The stock assessment model can estimate a level of F to move the stock towards the target. There was some consideration from the FFRAG of using an F-based indicator in the harvest strategy. Advice is sought from the FFRAG on whether there is value in further exploring this as an option.

Reference points

A reference point is a specified level of an indicator used as a basis for managing a stock or fishery. Reference points will generally be based on indicators of either the total or spawning stock size (biomass) or the amount of harvest (fishing mortality). Reference points show where we want (target) and don't want (limit) the stock levels in the fishery to be.

Recommended	Unfished biomass (B_0) = B_{1940} = 100%.	The year 1940 is considered the start of the commercial operations in the Fishery. The unfished biomass B0 therefore is the model-estimate of spawning stock biomass in 1940.
	Target (B_{TARG}) reference point = B_{48}	$B_{48}{}^1$ is the default target (a proxy for $B_{MEY}{}^-$ biomass at maximum economic yield) in the Commonwealth HS Policy.
		FFRAG supported the B48 target reference point and outlined the following rationale for adopting this value.
		FFRAG noted that the most recent assessment update was estimating B MSY for the stock as being close to the Commonwealth Harvest Strategy Policy of B40 which is a commonly accepted indicator in fisheries as a target reference point for maintaining a level of biomass (not catches) focused on maximising sustainable harvest (yield) from the fishery.
		Noting identified uncertainty in our data and stock assessment model there is a need to be precautionary and apply a 'buffer'. Traditional owners have also advised an objective for the fishery is

¹ Comm HSP: The target reference point for key commercial fish stocks is the stock biomass required to produce maximum economic yield from the fishery (BMEY). For multispecies fisheries, the biomass target level for individual stocks may vary in order to achieve overall maximum economic yield from the fishery. In cases where stock-specific BMEY is unknown or not estimated, a proxy of 0.48 times the unfished biomass, or 1.2 times the biomass at maximum sustainable yield (BMSY), should be used. Where BMSY is unknown or poorly estimated, a proxy of 0.4 times unfished biomass should be used. Alternative target proxies may be applied provided they can be demonstrated to be compliant with the policy objective.

	Limit reference point (B _{LIM}) = B ₂₀	to have a target biomass level that supports good catch rates. For these two reasons, a multiplier is applied to set the target biomass at a higher level than B MSY. It was noted in other fisheries this may be considered as a B MEY target reference point or proxy (to maximise economics from harvest taken) but in this fishery, B MEY is unable to be calculated without reliable price data from catches. The RAG agreed that a 20 per cent buffer would be applied to B MSY in order to set B TARG (1.2 times B MSY of B40 = B48), though consideration (based on QDAF experience) was given to alternative multipliers given work undertaken by Pascoe et al. to estimate the best proxy economic target reference point in data-poor fisheries. FFRAG considered comparisons of costs to revenue ratios and appropriate multipliers from the research but noted that the examples were not comparable with the Torres Strait Finfish Fishery. It was noted that a desktop study could be funded to calculate this optimum B MSY: B MEY point noting that setting a biomass level that is high will trade off available harvest and the number of boats active in the fishery. Bum is the spawning biomass level below which the ecological risk to the stock is unacceptable and the stock is defined as 'overfished'. This is an agreed level which we do not want the stock to fall below.
Outstanding		B ₂₀ is the default limit proxy in the Commonwealth HS Policy ² .
Outstanding	Long term B TARG = B ₆₀	Further analysis and advice is required on the suitability of B60 as a long-term B TARG, in comparison to other target biomass levels above B_{MSY} having regard for the biology of the species and performance of the Strategy in meeting its objectives.
		Stakeholders have recommended that the Strategy ensures enough fish are left in the water to support commercial fishing but also protect the traditional way of life and livelihoods of traditional inhabitants.
		Advice to date is that a higher target biomass level (referring to 60%), would increase catch rates and improve profits in the fishery over other lower reference points, such as B_{48} . RAG advice on the suitability of B_{60} against other possible higher target biomass levels is necessary. There are likely to be

² Comm HSP: All stocks must be maintained above their biomass limit reference point (BLIM) at least 90 per cent of the time. Where information to support selection of a stock-specific limit reference point is not available, a proxy of 0.2 times unfished biomass should be used.

trade-offs between medium-term returns from the fishery (significantly reduced TAC) and longer-term returns (more fish in the water meaning less cost to catch and therefore higher returns. Also, there would be more fish in the water for other users).
Quantitative analysis and/or evidence from comparable fisheries may enable more evidence-based advice and decision making on the longer-term target.

Decision Rules (also called Harvest Control Rules)

These rules are designed to maintain and/or return the stock to the target reference point.

Recommended	If stock falls below the limit reference point (B _{LIM}).	The Fishery is closed (all commercial fishing for Spanish mackerel is to cease) and subject to a rebuilding strategy. The nature of the rebuilding strategy will be determined on the basis of the stock assessment (to be applied immediately) and the rate of recovery (i.e. number of years to achieve a biomass greater than B_{LIM}).
	Re-opening the Fishery ³	Following closure of the Fishery, the Fishery can only be re-opened when a stock assessment determines the Fishery to be above the biomass limit reference point.
Outstanding	If the stock is above the limit reference point but below the target reference point.	The RBC is to be set at level that allows for the stock to build towards the target. Importantly the decision rule can be designed to build the stock at different rates (e.g. the number of years for the stock to build to the target reference point or the rate of building near the target or limit). An outstanding action has been for the FFRAG to consider scenarios with multiple timeframes to build the stock to reach B ₄₈ .
Outstanding	If stock is overfished (below B _{LIM})	Consistent with the Commonwealth HS policy the FFRAG and FFWG have recommended that commercial fishing for Spanish mackerel should cease if the stock falls below B _{LIM} . Further FFRAG discussion and advice is now sought to consider additional decision rules and actions required to

³ Comm HSP: Once a stock has been rebuilt to above the limit reference point with a reasonable level of certainty, it may be appropriate to recommence targeted fishing in line with its harvest strategy, which will continue to rebuild the stock towards its target reference point.

		guide rebuilding and to trigger any necessary reviews of the HS, noting the HS should be designed to avoid the stock breaching the limit. FFRAG are to note and discuss the HS policy requirements to be included in the Spanish Mackerel HS if the stock falls below B _{LIM} :
		a) that targeted commercial fishing for Spanish mackerel will cease
		b) a rebuilding strategy will be developed to build the stock above B _{LIM} with a reasonable level of certainty
		c) if B_{LIM} is breached while the fishery is operating in line with HS, the HS must be reviewed.
		FFRAG to provide advice on:
		a) A process to understand how the stock has rebuilt above B _{LIM} with certainty in the absence of commercial fishing e.g. model projections.
		b) whether a decision rule with a lower level of fishing pressure would be appropriate if the stock is above but close to B _{LIM} .
		FFRAG noted that four years would likely be the minimum possible recovery time (based on biology of the animal) to rebuild the stock back above B LIM and the existing model could be used to forecast how the stock would respond with zero catches if closed to commercial fishing.
Outstanding	Utilisation related Decision Rules (desired fishing intensity) noting a fishery may have indicators and reference points including spawning stock size (biomass) or the amount of harvest (F or fishing mortality i.e.	Decision rules have yet not been established for harvest related performance metrics such as future 'target' catches or 'target' catch rates desired by industry per primary vessel or per TIB dory day. Given that limited catch and effort data has only recently become available from TIB sector, the HS focus has been on agreeing biomass-based reference points and decision rules. Additionally, at the last FFRAG/FFWG meeting with regard to considering various longer-term target biomass reference points, industry expressed a strong preference for management to focus on building the biomass back to BTARG in the coming years, before exploring any other scenarios.

	utilisation of the resource).	FFRAG are asked to confirm this approach and consider how future decision rules may incorporate increased growth of the TIB sector.
Outstanding	Precautionary increases to total allowable catches.	Stakeholders recommended that if the stock assessment outcomes suggested increases in the TACs, these increases should only occur slowly through some kind of change limiting rule, noting that an increased TAC would likely not affect the TIB sector with the low present level of utilisation. Stakeholder advised a preference for 'banking' these fish to contribute to the biomass and future catch rates rather than harvesting this extra stock. At a previous FFRAG/WG meeting a number of challenges were identified with applying a change limiting rule for possible TAC increases. Instead the RAG/WG placed priority on examining different building rate scenarios which may achieve this desired precautionary outcome. FFRAG are asked to confirm this approach and provide advice on how to progress change-limiting rules if necessary.

Monitoring and assessment cycle		
Recommended	Based on the most recent estimate of the stock status (0.31 times unfished biomass) and declining biomass (and CPUE) trend, a stock assessment should be performed annually until the biomass is estimated to be above B ₄₀ .	
Outstanding	Subject to any further advice from the HS project team, FFRAG advice is sought on: a) An appropriate assessment cycle when the stock is above B40 and/or methods for evaluating future assessment cycles. b) Likely data needs to support monitoring stock performance under the Strategy over time. c) Standard procedures for applying the decision rules to the stock assessment outcomes, and, any other minimum stock assessment scenarios, and/or, sensitivities. FFRAG noted that although other options balancing risk and cost might be considered, given the decline in catch rates, transitional nature of the fishery, lack of fishery independent monitoring and suggestions of environmental influences on the fishery, there is a strong rationale to conduct yearly stock assessments for Spanish mackerel.	

FFRAG considered that examining CPUE in intervening years between full assessments (as an alternative) would be possible as an indicator of stock health but running a full assessment using the model would be more cost effective - given that running CPUE standardisations alone does require time and resources and the accepted full model can be run.

FFRAG recommended that until MSE testing had been conducted, and the stock could be demonstrated to be at or above B40 (as a B MSY proxy), yearly stock assessments are required.

Table 2. Status of Coral trout draft harvest strategy components tabled at RAG 5.

Guiding principles and key fishery attributes

Factors that helped shape the development of the Harvest Strategy

Recommended

Consistent with the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (HSP, 2018). This is consistent with objectives of the *Torres Strait Fisheries Act 1984* (the Act).

Have regard for traditional knowledge and the ability of communities to manage fishery resources locally, through acknowledging and incorporating customary and traditional laws, recognising; Malo Ra Gelar, Gudumalulgal Sabe, Maluailgal Sabe,

Kulkalgal Sabe.

Recognise commercial fishing by traditional inhabitants is important for local employment, economic development and for the passing down of traditional knowledge and cultural lore. Enough fish need to be left in the water for fishers to make money and to protect the traditional way of life, livelihoods and cultural values.

Coral trout are a shared resource important for subsistence, commercial, traditional, charter and recreational sectors.

TACs in the Torres Strait Finfish Fishery should vary according to stock status (up and down):

- If biomass decreases be cautious. Stock is not to go below the limit;
- If biomass is increasing be conservative; 'bank' fish.

Since the 2007 Government funded licence buyback there has been limited effort in the fishery and the available total allowable catch has been under-caught.

Four coral trout species commercially caught in Torres Strait. These four species (Common, Islander, Passionfruit and Bluespot) are managed under a 'species group arrangement with a shared total allowable catch. There is a risk of local depletion of any of the four species in the Coral trout 'species group' as the existing assessment model assumes all four species are one stock.

Operational objectives

What we want the harvest strategy to achieve.

Recommended

Maintain the stock at current levels given:

- the assessment is preliminary meaning it does not supply enough evidence to support changing the TACs without further development and catch data to support it; and
- noting the present high estimate of biomass and recent low harvests, industry are supportive of a conservative B_{TARG} for the stock to manage the fishery at a level which leaves more fish in the water than a straight MSY target rate⁴.

Maintain stocks above the limit biomass level (B_{LIM}), or an appropriate proxy, at least 90 per cent of the time.

Reduce fishing levels if a stock is below B_{TARG} but above B_{LIM}.

Implement rebuilding strategies, if the stock moves below $B_{\text{\tiny LIM}}.$

Indicators

Indicators provide information on the state of the stock and how the stock is doing against agreed reference points (reference points are listed below and are a specified level of these indicators)

Recommended

Biomass – Catch and effort data from daily fishing logbooks is used as a proxy for abundance in the stock assessment model which is used to calculate biomass of the stock as a proportion of unfished biomass (B_0).

Outstanding The current stock assessment is considered preliminary and as a result, the biomass calculation is not yet relied on as an accurate indicator of abundance or biomass. The FFRAG/FFWG did recommend a CPUE proxy for B80 to be used as a trigger for future stock assessment (see *Monitoring and Assessment* below). Further discussion and advice is sought from the FFRAG on development of these and other indicators.

Reference points

A reference point is a specified level of an indicator used as a basis for managing a stock or fishery. Reference points will generally be based on indicators of either the total or spawning stock size (biomass) or the amount of harvest (fishing mortality). Reference points set out where we want (target) and don't want (limit) the desired stock levels in the fishery to be.

Recommended	Unfished biomass (B_0) = B_{1950} = 100%.	The year 1950 is considered to be the start of the commercial operations in the Fishery. The unfished biomass B0 therefore is the model-estimate of spawning stock biomass in 1940.
	Target (B _{TARG}) reference point = B ₆₀	The target biomass B_{TARG} is the spawning biomass level equal to 60% of B_0 to take account of the fact that the resource is important for the traditional way of life and livelihood of traditional inhabitants, is leased to sunset licence holders and the target biomass level must be biologically and economically acceptable.
		The current agreed B_{TARG} is based on the assumption that B_{MSY} is 50% of B_0 for this species and B_{TARG} should be set at 1.2 B_{MSY} .
		Stakeholders were supportive of a target that can take into account the patchiness of the stock (small areas with good trout catch rates separated by large areas of desert), the preliminary nature of the stock assessment, the risk of localised depletion, the basket of four species and that a proportion of the stock is not available.
	Limit reference point (B _{LIM}) = B ₂₀	B _{LIM} is the spawning biomass level below which the ecological risk to the stock is unacceptable and the stock is defined as 'overfished'. This is an agreed level which we do not want the stock to fall below. B20 is the default limit proxy in the Commonwealth HS Policy ⁵ .

⁵ Comm HSP: All stocks must be maintained above their biomass limit reference point (BLIM) at least 90 per cent of the time. Where information to support selection of a stock-specific limit reference point is not available, a proxy of 0.2 times unfished biomass should be used.

Outstanding	Consideration of alternative approaches to guide decision	Reference points for coral trout have been agreed though, as per below, additional work is required on development of decision rules to move the stock relative to these points.
	making in the fishery.	Given that the initial stock assessment model does not provide a sufficient basis to support formation of decision rules, FFRAG advice is sought on possible alternative approaches for a strategy to guide decision making, for example the FFRAG may want to consider tiered harvest strategies approaches from data-poor fisheries. Such tiered strategies may set out a precautionary base-level (or status quo) position, outline what data are required to progress the fishery and what the next tier may mean for a fishery in terms of improved understanding/decreased risks to the stock and less precautionary catch levels.

Decision rules (also called harvest control rules). These rules are designed to maintain and/or return the stock to the target reference point.				
Recommended	Maintain current TAC until next Stock assessment	There is no current agreed decision rule for setting catch limits. The FFRAG/FFWG meeting recommended that the current constant RBC of 134.9 tonnes be adopted as the interim RBC until the stock assessment is updated. The current preliminary assessment indicates the stock is likely to be greater than 80% of the unfished biomass level. In the future the decision rules would recommend a harvest level (as a recommended biological catch -RBC) on the basis of evaluating the resource status.		
	If stock falls below the limit reference point (B_{LIM}).	The Fishery is closed (all commercial fishing to cease) and subject to a rebuilding strategy. The nature of the rebuilding strategy will be determined on the basis of the stock assessment (to be applied immediately) and the rate of recovery (i.e. number of years to achieve a biomass greater than B_{LIM}).		
	Re-opening the Fishery ⁶	Following closure of the Fishery, the Fishery can only be re-opened when a stock assessment determines the Fishery to be above the biomass limit reference point.		

⁶ Comm HSP: Once a stock has been rebuilt to above the limit reference point with a reasonable level of certainty, it may be appropriate to recommence targeted fishing in line with its harvest strategy, which will continue to rebuild the stock towards its target reference point.

Outstanding	Maintain current TAC until next Stock assessment	FFRAG are to provide further advice on the operational objective for maintaining the stock at present levels, specifically what an appropriate level of harvest might be to maintain the present impact on the stock, noting: a. while the available TAC has been 134.9 t a maximum of 46 t of harvest has been reported taken per year since the 2007 buyout; b. potential risks to individual species within the species basket (the four different coral trout species) noting the species distribution and catch composition is not well understood which add uncertainty around the biomass estimates; c. there is no absolute certainty as to when additional data will be available to Fishery (improved TIB data, independent dive survey).
Outstanding	If stock falls below B LIM	Consistent with the Commonwealth HS policy the FFRAG and FFWG have recommended that commercial fishing for coral trout should cease if the stock falls below B _{LIM} . Further FFRAG discussion and advice is now sought to consider additional decision rules and actions required to guide rebuilding and to trigger any necessary reviews of the HS, noting the HS should be designed to avoid the stock breaching the limit. FFRAG note and discuss the HS policy requirements to be included in the Spanish Mackerel HS if the stock falls below B _{LIM} : a) that targeted commercial fishing for Spanish mackerel will cease, b) a rebuilding strategy will be developed to build the stock above B _{LIM} with a reasonable level of certainty. c) If B _{LIM} is breached while the fishery is operating in line with HS, the HS must be reviewed. FFRAG to provide advice on: c) A process to understand how the stock has rebuilt above B _{LIM} with certainty in the absence of commercial fishing e.g. model projections. a) whether a decision rule with a lower level of fishing pressure would be appropriate if the stock is above but close to B _{LIM} .

Outstanding	If the stock is above the limit reference point but below the target reference point.	The RBC is to be set at level that allows for the stock to build towards the target. Importantly a decision rule must be designed and agreed to build the stock at different rates (e.g. the number of years for the stock to build to the target reference point or the rate of building near the target or limit). FFRAG are to advise on a process for this decision rule to be developed.	
Outstanding	Harvest based decision rules (desired fishing intensity) a fishery may have indicators and reference points including spawning stock size (biomass) or the amount of harvest (F or fishing mortality).	Decision rules have not yet been established for harvest related performance metrics (measuring how the stock is being used) such as future 'target' catches or 'target' catch rates desired by industry per primary vessel or per TIB dory day. The focus so far has been placed on agreeing biomass based reference points and decision rules.	
Outstanding	Precautionary increases to total allowable catches.	Stakeholders recommended that if the stock assessment outcomes suggested increases in the TACs, these increases should only occur slowly through some kind of change limiting rule, noting that an increased TAC would likely not affect the TIB sector with a low present level of utilisation. Stakeholder advised a preference for 'banking' these fish to contribute to the biomass and future catch rates rather than harvesting this extra stock. At the last FFRAG/WG meeting a number of challenges were identified with applying a change limiting rule for possible TAC increases. Instead the RAG/WG placed priority on examining different building rate scenarios which may achieve this desired precautionary outcome. FFRAG are asked to confirm this approach and provide advice on how to progress change-limiting rules if necessary	
Monitoring and asse	essment cycle		
Recommended	available, ahead of setting cat	FFRAG has recommended that a stock assessment should be conducted during the 2021-22 season, once further data is available, ahead of setting catch limits for the 2022-23 season. Postponing the stock assessment for three years would allow enough time for additional data to be included. The additional data priorities identified are:	

- a) the 1994-95 CSIRO fish survey data which may form a valuable baseline datum;
- b) improved catch and effort data from TIB fishers; and
- c) fishery independent data such as an underwater survey or biological sampling.

Trigger reference points (or breakout rules) were recommended for the years between stock assessments. The agreed trigger reference points will use standardised CPUE data as a proxy for biomass and the yearly fishery catch data to ensure the maximum yield of the fishery zones are not being exceeded.

The specific trigger points for when an assessment would be undertaken the next season are:

- a) In line with the recommended target reference point (B TARG = B60) and taking into account the conservative approach preferred by industry, if the biomass of coral trout is less than B_{60} (B TARG) then an integrated stock assessment will be conducted. To determine the biomass level, this trigger will use CPUE data as a proxy for biomass. It was agreed that the average CPUE from 2012 until 2017 (inclusive) would be used as an indicative reference point of the CPUE at B_{80} (average = 120.8 kg per vessel per day) from which the CPUE at B_{60} can be calculated and used as the trigger reference point. Given the ratio of 80:60 is equal to 0.75 then the trigger reference point which would activate the rule that an assessment must be undertaken is: *if the standardised CPUE falls below 90.6 kg per (primary) vessel per day* (computed as 0.75*120.8 = 90.6).
- b) If the combined yearly total catch of the four coral trout species from both commercial sectors is greater than 90 tonnes. Ninety tonnes was agreed because this 2/3 of the current constant RBC of 134.9 tonnes.

If either (a) or (b) above occurs, the stock assessment must be repeated the following year in order to monitor the condition of the stock.

Outstanding

FFRAG to provide advice on likely data needs to support monitoring stock performance under the Strategy over time.

The FFRAG advice should also take into account the possible scenario where assessments are able to be funded in accordance with the recommended cycle and/or the additional data recommended to support a further stock assessment are not readily available.

FFRAG to provide advice on procedures for interpreting the stock assessment outcomes under HS and how decision rules are to be applied based on these outcomes. While a stock assessment may be triggered through analysis of CPUE data in intervening years between assessment FFRAG advice is sought on what the process should be following this trigger being met and what decision rules should be applied based on the outcomes of this stock assessment i.e. whether the TAC should be changed to reflect this suggested change in biomass.

Torres Strait Finfish Fishery: Management Strategy Evaluation of Spanish mackerel for the Torres Strait Finfish Fishery

A Harvest Strategy for the Torres Strait Spanish Mackerel Fishery (TSSMF) is required to guide future decisions on sustainable commercial catch limits and potential expansion of the fishery using indicators of stock status. The strategy will help the fishery achieve its ecological, economic and cultural management objectives consistent with the Torres Strait Fisheries Act 1984, Torres Strait Finfish Fishery Management Plan 2013 and the Commonwealth Fisheries Harvest Strategy Policy and Guidelines.

A Harvest Strategy for the Spanish mackerel fishery will also guide future investment on finfish research, assessment, data collection and monitoring to make sure the interests of Torres Strait Traditional Owners are considered in developing biologically, culturally, and economically sustainable fishing opportunities.

An AFMA-funded project, led by CSIRO, titled: Harvest Strategies for the Torres Strait Finfish Fishery was funded in 2017/18 and 2018/19. Under this project guiding principles and key fishery attributes for developing a harvest strategy for Spanish mackerel were identified, together with operational objectives, an interim target reference point, an aspirational future target reference point and limit reference point.

The identified project work along with FFRAG/ Working Group recommendations to date can be accessed in Table 6 of the FFRAG 10 (18-19 November 2021) meeting papers. These components were developed in collaboration with broader industry members that participated in several harvest strategy workshops.

In conjunction with a yearly stock assessment, the identified guiding principles have been applied by the Finfish Fishery Resource Assessment Group (FFRAG) in formulating a yearly Recommended Biological Catch.

The FFRAG has recommended that a Management Strategy Evaluation now be undertaken to test these proposed harvest strategy rules and finalise a harvest strategy for Spanish mackerel that meets Traditional Owner objectives and is robust to uncertainties. The components of this candidate harvest strategy will be further refined at a joint FFRAG/FFWG workshop attended by stakeholders in March 2023, before this contract would be due to commence work in July 2023.

Desired outcomes:

In consultation with AFMA and the FFRAG, the project team should use Management Strategy Evaluation to quantitatively evaluate the performance of the candidate Harvest Control Rules, as recommended from the previous project (Harvest Strategies for the Torres Strait Finfish Fishery) and FFRAG advice.

The identified components of the candidate harvest strategy will be provided to the successful applicant.

Applicants wishing to submit a proposal can contact AFMA for further information that may support you developing your proposal.

Contacts:

Chris Boon Senior Management Officer Torres Strait Fisheries 07 4069 1990 Chris.Boon@afma.gov.au Lisa Cocking
Executive Officer
Torres Strait Scientific Advisory Committee
02 6225 5451
torresstraitresearch@afma.gov.au

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
MANAGEMENT Management of the Take of Shark	Agenda Item 4.2 For DISCUSSION & ADVICE

RECOMMENDATIONS

- 1. That the Resource Assessment Group (RAG):
 - a) **DISCUSS** the current management arrangements for the take of sharks in the Torres Strait Finfish Fishery.
 - b) **PROVIDE ADVICE** on whether the current arrangements align with Commonwealth best practice.
 - c) **DISCUSS AND PROVIDE ADVICE** on necessary shark bycatch management measures.

Key Issues

- 1. Condition 6 of the Finfish Fishery Wildlife Trade Operation approval 6 stipulates that the *Torres Strait Protected Zone Joint Authority must review the current measures applied to the management of the take of sharks in the Torres Strait Finfish Fishery to ensure that they are in line with Commonwealth best practice.* This process will need to be formally reviewed within the current WTO approval (by 1 November 2023).
- 2. The current commonwealth best-practice management measures applied to the take of shark in AFMA fisheries and that with the Torres Strait Fishery include:
 - A ban on finning at sea (Currently, the processing of a shark by removing the fins from the shark and discarding the remainder of the shark into the sea by a person in the Torres Strait Finfish Fishery (TSFF) is prohibited).
 - A ban on wire traces (not addressed in management instruments or licence conditions for the TSFF). AFMA understands that wire traces are used in the Spanish mackerel fishery. However, it is noted that the wire trace ban was implemented in Australia's pelagic longline fisheries to allow sharks the opportunity to be freed from the line before hauling. The Spanish mackerel fishery is an operationally different fishery, in that catch are immediately hauled upon capture, allowing the live release of sharks.
 - A ban on the take of certain species of shark (The TSFF currently has no-take prohibitions on hammerhead shark (*Sphyrna lewini*), grey nurse shark, (*Carcharias taurus*) and tiger shark (*Galeocerdo cuvier*)).
 - VMS/Electronic Monitoring (TSFF sunset sector vessels currently required to have VMS devices installed on primary vessels).
 - Education supported by shark handling/identification/best practice guides. These can be found here: https://www.afma.gov.au/sustainability-environment/bycatch-discarding/bycatch-reports-publications-id-guides

See **Attachment 4.2a** for an extract from AFMA's *Handling Practices Guide for Commonly Caught Bycatch Species*

- Bycatch work plan with identified risks and responses to risk to sharks, developed through an ecological risk assessment (ERA). (The development of an ERA is also a WTO condition for the TSFF).
- 3. Further information on the current commonwealth shark management measures relating to shark finning can be reviewed in **Attachment 4.2b**.
- 4. Noting arrangements in the Torres Strait Finfish Fishery are mostly consistent with Commonwealth best practice, AFMA proposes for the RAG and Working Group (WG) to review and provide advice on necessary shark bycatch management measures.

Sharks

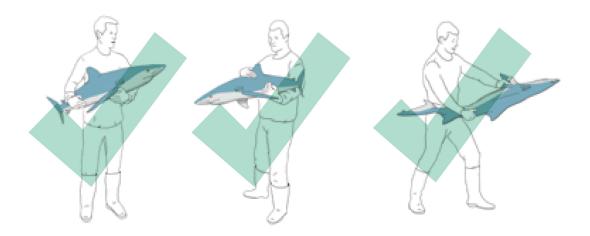
CORRECT HANDLING

If possible, release the shark without bringing it onto the deck.

If the shark has to be brought on board:

Holding and lifting of sharks

- Generally, small sharks are fragile and need to be handled very carefully.
 It is best to handle and release them with both hands. Methods of holding include:
 - both hands supporting the body
 - one hand grabbing the pectoral fin and the other the tail
 - holding the dorsal fin and supporting the body and tail.



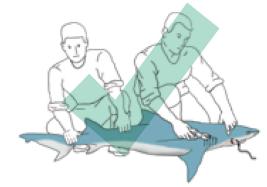
Holding large sharks

 Two people may be required with one person holding the dorsal fin and pectoral fin, while the other person holds the tail.



Treating sharks on deck

- Always attempt to keep the shark in a horizontal position to reduce the risk of internal organ damage
- Hold the shark firmly behind the head and around the tail using gloves and/ or a wet towel, and then try to remove the hook
- If the hook cannot be removed easily the line should be cut as close to the mouth as possible



- To calm a shark down turn it over onto its back or place a wet towel over its eyes
- To prevent bites place a dead fish or stick in its jaws
- If release needs to be delayed place a deck hose in the shark's mouth so that water flows through the shark's gills.

Returning sharks to the water

1. Lower the shark gently into the water head first and release it.

Do not throw it

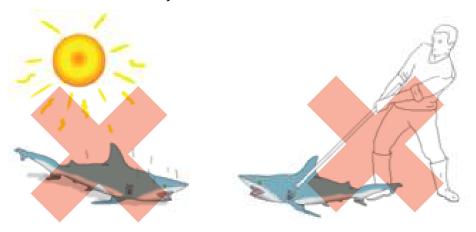
- 2. It may be necessary to face the shark into the current and swim it for a few minutes to aid in recovery before it swims away
- Small sharks can be released by one person
- **4.** Large sharks may require two people to lift and hold the shark
- 5. Very large sharks may need to be lifted with the use of wide slings. Do not use thin wires or cables.



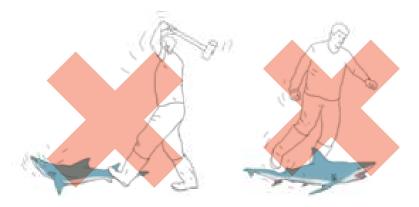


INCORRECT HANDLING

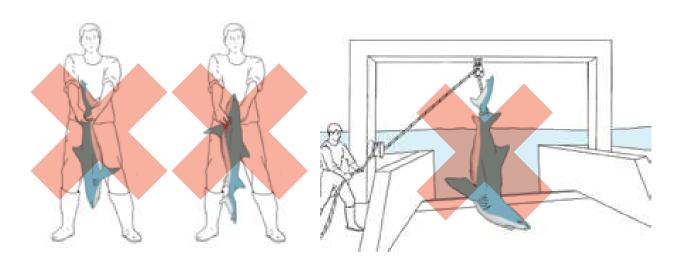
 Do not use gaffs or sharp objects in direct contact with the shark. A gaff should be used only to control the line



- Do not leave the shark exposed to sunlight for extended periods of time
- Do not kick, hit, throw or push the shark harshly, or expose it to other physical trauma



Do not pick up the shark by the tail, head or the gill slits.



Shark finning – frequently asked questions

You are here: 🖟 / Resources / Educational

What is shark finning?

Shark finning is simply the practice of removing a shark's fins from the body for separate sale. The term is sometimes used to describe the practice when a shark's fins are removed to sell and the rest of the body is discarded at sea.

Why do people take the fins? What are the fins used for?

Shark fin is used in predominantly Chinese cooking, e.g. shark fin soup. It is considered a delicacy and some people believe it has medicinal value. It is a high priced commodity, especially as shark finning at-sea has now been banned by a lot of countries.

What happens to the shark when its fins are taken?

The body of the shark is either returned to the water without its fins or the fins and the body are sold separately. On rare occasions the shark is sometimes alive when returned to the water but will soon die.

In Australian fisheries it is illegal to possess shark fins on board a commercial fishing vessel without having the whole shark on the vessel. This helps ensure that shark finning is not occurring at sea. Not allowing finning at-sea allows for more effective monitoring of the catch and promotes optimum utilisation as the fins can then be used along with the rest of the shark. Once landed the whole shark must be offloaded to a licensed fish receiver. From that point on the shark can be processed with various body parts going to different markets, including the fins.

Does AFMA allow shark finning in Commonwealth fisheries?

Shark finning at-sea is illegal in Commonwealth fisheries. This means that the removal of shark fins at sea and the dumping of the carcass are prohibited. To prevent this occurring, all fisheries are subject to Fisheries Management Regulation 9ZO that makes it an offence for the caudal lobe, caudal fin, pectoral fin and dorsal fin to be removed from the shark at sea before it is in the possession of a fish receiver.

Is illegal shark finning at-sea a problem in Commonwealth fisheries?

Between 2008-09 and 2011-12 reports of and evidence for illegal shark finning became less common in Commonwealth fisheries.

AFMA takes this issue very seriously and has done extensive analysis of catch landings and export data, investigated allegations of shark finning and has conducted strategic intelligence assessments on market demand and potential black market implications. Evidence available to AFMA suggests that illegal shark finning at-sea is a low risk however, compliance officers remain on the lookout for evidence of illegal shark finning when they are out in the field.

How does AFMA stop shark finning at-sea in Commonwealth fisheries? Rules and regulations

In parts of Australia where the Commonwealth has jurisdiction over fishing, AFMA has imposed a range of measures to prevent shark finning at-sea. These include limits on the number of sharks which can be carried on board vessels and restrictions on processing sharks at sea and the form in which fish receivers are permitted to receive shark.

No wire traces

In addition, AFMA has banned the use of wire traces in Australia's pelagic longline fisheries. Elsewhere in the world, wire is used to connect the hook to the main fishing line. The increased strength of wire prevents sharks from biting through the line and escaping. Scientific research has shown banning wire traces allow many sharks to escape longlines by biting through the monofilament that connects the hook to the mainline.

Inspections

AFMA also undertakes regular targeted inspections of Commonwealth fishing vessels and fish receiver premises. These inspections check compliance levels against all Commonwealth fisheries management arrangements, including the landing and receipt of sharks.

Vessel Monitoring Systems

AFMA also ensures strong compliance measures are in place on fishing vessels, including the use of electronic vessel monitoring systems for all boats so their movements can be tracked. This allows fisheries officers to better target their inspections because they know when fishing vessels are coming into port.

E-monitoring

AFMA has also installed electronic monitoring systems on some vessels operating in fisheries that target or otherwise catch significant numbers of shark. These systems monitor vessel location through GPS and video record 100% of fishing activities. AFMA then analyses the footage for data verification and compliance purposes.

What is AFMA doing about shark finning risks in our region?

Australia has taken a leading role at Regional Fisheries Management Organisations (agreements between countries to manage shared fish stocks) to implement stronger shark management measures. Australia has regularly called for the international banning of the use of wire traces and the shark finning at sea.

Which fisheries catch shark?

AFMA manages one fishery that actively targets shark. This fishery predominantly targets gummy shark. Gummy shark is not caught for its fins but to sell as 'flake' which is often used in fish and chips. The fishery is subject to high levels of monitoring and assessment to ensure catches are sustainable and within scientifically-based limits. Catch limits are actively enforced by AFMA Compliance Officers and through catch documentation requirements. School shark, which can be caught with gummy shark, was historically subject to high levels of fishing pressure and the stocks are now being closely managed to ensure recovery.

Some sharks are taken as incidental catch in the Eastern and Western Tuna and Billfish Fisheries. The main species caught are shortfin make sharks and blue sharks.

Is there legal shark fin?

Yes. Where sharks have been harvested and landed in accordance with the regulations, fins removed from these sharks can be sold legally.

What can I do to help?

If you suspect illegal fishing, including shark finning at-sea or shark catches beyond sustainable limits, please report it via our hotline CRIMFISH on 1800 274 634 or via our <u>CRIMFISH online form</u>.

EDUCATIONAL

Shark finning - frequently asked questions

▼ EXPLORE THE SITE ▼





We acknowledge the Aboriginal and Torres Strait Islander Peoples as the Traditional Owners and Custodians of this Country. We recognise their connection to land, sea and community. We pay our respect to them, their cultures, and their Elders, past, present and emerging.

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
MANAGEMENT Review of Barramundi Cod Management	Agenda Item 4.3 For DISCUSSION

RECOMMENDATION

- That RAG members **DISCUSS** the recent catch trends of Barramundi Cod in the Torres Strait Finfish Fishery.
- 2. **PROVIDE ADVICE** on the risks to sustainability of Barramundi Cod in the Torres Strait Finfish Fishery. This advice may be required to guide future management decision for the species.

KEY POINTS

- 4. At FFRAG 11 meeting the RAG had a preliminary discussion about the capture of barramundi cod in the finfish fishery.
- 5. AMFA agreed to gather a summary of the current biological and management aspects for this species. AFMA also agreed to investigate logbook data and review with scientific members. This information will be provided to the RAG in-session.
- 6. The RAG will be asked to review the relative ratio of barramundi cod vs coral trout catch over time, as this available information can guide the RAG in providing advice on the risk to sustainability.
- 7. The RAG noted that a possible management option is to monitor catches and set a catch amount 'trigger' which would prompt a further review. The specific trigger amount will need to be formulated after the historical logbook data is assessed.
- 8. The RAG noted that the high value live fish trade is currently unviable in the Torres Straits, so the risk of intense fishing pressure remains low.
- 9. Considering recent CDR data, the RAG in its preliminary advice did not consider the current amount of take to be a risk to sustainability.

BACKGROUND

- 10. Barramundi Cod, *Cromileptes altivelis*, otherwise known as Humphead Grouper are currently listed as "Data Deficient" under the IUCN Red List meaning there is insufficient data to quantify its population status throughout its natural range. This status was published in 2018, after first being listed as "Vulnerable" in 2007.
- 11. Barramundi cod are a no-take species in the commercial Queensland East Coast Reef Line Fishery, and a no-take species for recreational anglers throughout all Queensland waters. This reflects a perceived vulnerability to over-fishing, and its status as an 'Iconic Species' in the Great Barrier Reef Marine Park.
- 12. Since the Fisher Receiver System was introduced in December 2017, landed catch weights of all finfish species including Barramundi Cod have been reported via Catch Disposal Records. There are now four complete seasons worth of verified data for this species. See **Table 1** for catch data since the 2018/19 season.

- 13. This newly available data serves as a timely reminder to review the sustainability of this activity.
- 14. The objective of this preliminary discussion is to review the current knowledge of this species, and identify gaps which require further research. The RAG may wish to review the current literature Out of Session, with the intention of conducting an in-depth discussion at FFRAG 12.
- 15. Once a review of the current risk to sustainability is completed, the RAG will be asked to discuss management actions which may be required in relation to the targeted capture of this species.

Table 1: Summary of reported Barramundi Cod catches in the TSFF

Season	Sun	TIB	Total (kgs)
2018/19	654	425.7	1079.71
2019/20	1306.6	197.6	1504.26
2020/21	532	248.4	780.4
2021/22	1251.7	392	1643.72

- 16. The scientific research paper "Age-based demography of humpback grouper *Cromileptes altivelis*: implications for fisheries management and conservation" (Williams et al.) was published in 2009. See Attachment 3.1a of the FFRAG 11 papers)
- 17. This paper provided the first estimates of age-based population parameters for *C. altivelis*, using samples from the Great Barrier Reef and the Torres Strait. The project team also considered a "combination of management strategies including size limits, effort controls and no-take areas that are likely to be most effective in minimising the conservation risk for *C. altivelis* populations and provide sustainable yields across the species' range."
- 18. The FFRAG may wish to refer to this paper as the basis for discussions into the current stock status and vulnerability of Barramundi cod.

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
RESEARCH Environmental Risk Assessments	Agenda Item 5.1 For NOTING & ADVICE

RECOMMENDATIONS

- 1. That the Resource Assessment Group (the RAG):
 - a. **NOTE** a presentation from Dr Miriana Sporcic on the two DRAFT Environmental Risk Assessment (ERA) reports have been completed by CSIRO for the Torres Strait Spanish Mackerel and Reef Line fisheries.
 - b. **DISCUS and PROVIDE ADVICE** on these draft ERA reports.
 - c. **NOTE** that it is a WTO condition to develop an associated risk management strategy to address any risks identified in these assessments.

BACKGROUND

- 2. The ERA framework was initially developed in 2007 by CSIRO in collaboration with AFMA to help AFMA meet its ecologically sustainable development (ESD) objective¹ by managing the impacts of commercial fisheries on commercial species, by-product species, bycatch species, protected species, and habitats and communities. The framework also addresses the need to assist in evaluating impacts of fishing for strategic assessments under the Environment Protection and Biodiversity Conservation Act 1999.
- 3. Since its development, the framework has been successfully applied to several fisheries in Australia and internationally. The framework has been reviewed and refined since its implementation to ensure that it is credible, cost effective and adaptable enough to consider new information, species, reference points, methods/tools or adaptation to new standards and policy developments.
- 4. The framework consists of a set of risk assessment methodologies that are used to assess the impact of fishing across five ecological components of the marine environment (commercial species, by-product species, bycatch species, protected species, and habitats and communities). The methodologies start off as qualitative and becomes more quantitative as the fishery progresses through the different assessment levels.
- 5. CSIRO are undertaking ERAs for both the Torres Strait Finfish (Reef Line) Fishery and Torres Strait Spanish Mackerel Fisheries to address a RAG priority and Wildlife Trade Operation (WTO) export approval condition for the fishery, which requires an ERA to be completed by 30 June 2023².
- 6. Stakeholder consultation is an important feature of the ERA especially in the Scoping and Level 1 phases to improve the assessment, increase the chance of uptake of results and to identify suitable management responses.

.

¹ Under the Fisheries Management Act 1991

² Torres Strait Finfish Fishery WTO Condition 5: By 30 June 2023 the Torres Strait Protected Zone Joint Authority must complete an ecological risk assessment of the Torres Strait Finfish Fishery and develop an associated risk management strategy to address any risks identified in this assessment.

- 7. For both the Finfish (Reef Line) Fishery and Spanish Mackerel Fisheries, all 'ecological components' and 'fishing hazards' were eliminated at the level 1 phase.
- 8. The full draft ERA documents were circulated to the RAG in the FFRAG 11 papers. Executive summaries of these reports can be referred to at **Attachment 5.1a & 5.1b.**
- 9. More information on the ERA and ERM process is available on the <u>AFMA website</u> and the <u>Guide to AFMA's Ecological Risk Management</u>.

Executive Summary

The "Ecological Risk Assessment for Effect of Fishing" ERAEF was developed jointly by CSIRO Oceans and Atmosphere and the Australian Fisheries Management Authority (Hobday et al., 2007, 2011a). This assessment of the ecological impacts of the Torres Strait Finfish (Reef Line) Fishery was undertaken using the ERAEF method version 9.2, with some additional modifications currently in final stages of development with AFMA. This revised ERAEF provides a hierarchical framework for a comprehensive assessment of the ecological risks arising from fishing, with impacts assessed against five revised ecological components –key commercial and secondary commercial species; byproduct and bycatch species; protected species; habitats; and (ecological) communities (see ERM Guide, AFMA, 2017).

The ERAEF proceeds through four stages of analysis: scoping; an expert judgement-based Level 1 analysis (SICA – Scale Intensity Consequence Analysis); an empirically based Level 2 analysis (including PSA – Productivity Susceptibility Analysis and SAFE – Sustainability Assessment for Fishing Effects); and a model-based Level 3 analysis. This hierarchical approach provides a cost-efficient way of screening hazards, with increasing time and attention paid only to those hazards that are not eliminated at lower levels in the analysis. Risk management responses may be identified at any level in the analysis.

Application of the ERAEF methods to a fishery represents a set of screening or prioritization steps that work towards a full quantitative ecological risk assessment. At the start of the process, all components are assumed to be at risk. Each step, or Level, potentially screens out issues that are of low concern. The Scoping stage screens out activities that do not occur in the specific fishery. Level 1 screens out activities that are judged to have low impact, and potentially screens out components with all low impact scores. Level 2 is a screening or prioritization process for individual species, habitats and communities at risk from direct impacts of fishing, using either PSA or b-SAFE. The Level 2 methods do not provide absolute measures of risk. Instead they combine information on productivity and exposure to fishing to assess potential risk – the term used at Level 2 is risk. Because of the precautionary approach to uncertainty, there will be more false positives than false negatives at Level 2, and the list of high risk species or habitats should not be interpreted as all being at high risk from fishing. Level 2 is a screening process to identify species or habitats that require further investigation. Some of these may require only a little further investigation to identify them as a false positive; for some of them managers and industry may decide to implement a management response; others will require further analysis using Level 3 methods, which do assess absolute levels of risk.

This Torres Strait Finfish (Reef Line) ERAEF assessment is the first assessment, based on analyses of data (from 2017 to 2021) conducted in 2022. This 2017-2021 assessment of the Torres Strait Finfish (Reef Line) Fishery consists of the following:

- Scoping
- Level 1 results for the (i) Key/Secondary/Commercial Bait species, (ii) byproduct/bycatch species, (iii) Habitats and (iv) Communities components

Fishery Description

Gear Line fishing

Area Torres Strait region

Depth range less than 30 m

Fleet size 24 active Traditional Licence Holders (TIB) and 2 Sunset Licence Holders in 2020/21 fishing season

Effort 184-229 operation days (TIB sector) and 92-205 operation days (Sunset sector)

Landings 17.3 - 27.3 t p.a. of Coral Trout

Discard rate fishery wide estimate unavailable

Key commercial species Common Coral Trout (*Plectropomus leopardus*), Barcheek Coral Trout (*P. maculatus*), Bluespotted Coral Trout (*P. laevis*) and Passionfruit Coral Trout (*P. areolatus*)

Management Input and output controls

Observer program An Observer Program does not currently exist for this fishery

Ecological Units Assessed

A total of 184 species across all ecological components were assessed in this ERAEF (Table 0.1).

Table 0.1: Ecological units assessed in 2022 (data from 2017 to 2021).

Ecological units assessed	2022
Key/secondary commercial species	4
Commercial species/Bait	2
Byproduct species	178
Bycatch species	0
Protected species	0
Benthic habitats	12
Pelagic habitats	2
Demersal communities	8
Pelagic communities	2

There are four key commercial species, expanded from higher order taxonomic group codes. Similarly, the 178 byproduct species assessed were mostly expanded from higher taxonomic group codes. There are currently no bycatch or protected species reported.

Level 1 Results and Summary

All ecological components were eliminated at Level 1 (i.e. no components with risk scores of 3 – moderate – or above) (Table 0.2). Fishing for Coral Trout is selective as they are harvested by handlines. Very little byproduct and no bycatch species are reported for this fishery. The 178 byproduct species assessed were mostly expanded from higher taxonomic group codes. Also, no protected species are reported for this fishery. As a result, this ecological component was not assessed.

All hazards (fishing activities and external) were considered as 'low risk' and eliminated at Level 1 (i.e. no components with risk scores of 3 – moderate – or above). The highest risk scores (2 (minor); with high confidence level) were The highest risk scores (2 (minor); with high confidence level) were reported as a result of addition/movement of biological material from chemical pollution for key commercial and byproduct species. All of the assessed direct and indirect impacts to this fishery were either low or negligible based on scale and nature of the fishery as well as available survey data.

Coral Trout are assessed as a basket of four species: Common Coral Trout (*Plectropomus leopardus*), Barcheek Coral Trout (*P. maculatus*), Bluespotted Coral Trout (*P. laevis*) and Passionfruit Coral Trout (*P. areolatus*). The 2019 preliminary stock assessment for these species estimated that the mean spawning biomass was ~80% of unfished levels (see Table 0.3 and reference within). Given there are no additional key commercial species in this fishery that are not assessed, a Level 1 analysis was not required for this hazard, i.e., fishing by capture.

The direct ecological impact on habitats from harvesting key commercial and byproduct species was low. In particular, fishing for Coral Trout represented a 'low risk' (minor; risk score = 2) to benthic habitats largely due to the small footprint of gear used in the fishery (handlines with hook and sinker) and effort along the forereef zones (Northeast and GBR Biome: assemblages 5, followed by 7, 6 and 4), consisting of fungiid corals, soft corals and sponges; and the deep reef habitats (Northeast and GBR Biome: assemblages 5, followed by 7, 6 and 4), consisting of gorgonians, whip corals and sponges. This fishing activity may affect species directly and also break or damage benthic communities and coral reef structures.

Although still considered a 'low risk' external hazard, coastal development was the highest scored risk (risk score = 2) to key commercial and byproduct species, habitats and communities because of localised pollution in some Islands and sediment runoff from coastal developments along the Fly river (PNG). Sediments can smother sessile species like corals and increased turbidity and reduction in light penetration can negatively affect species that depend on light, such as corals, algae and seagrasses. Confidence is low because impacts

from Fly river are still poorly understood and there is a lack of data on water quality issues and recovery times of species and habitats. All of the assessed direct and indirect impacts to the this fishery were either low or negligible based on scale and nature of the fishery as well as on available survey data. Similarly, the external hazard, coastal development was assessed as a minor risk (risk score = 2) to key commercial and byproduct species.

Hazards assessed as minimally affected from external impacts consisted of other fisheries in the region also capturing the same key/secondary commercial or byproduct species. The Habitats and Communities ecological components were also assessed to be minimally impacted by other fisheries.

Table 0.2: Outcomes of assessments for ecological components conducted in 2022. *: there are no reported protected species in this fishery. ^: includes Commercial Bait species.

Ecological Component	2022
Key/secondary commercial species^	Level 1
Byproduct and bycatch species	Level 1
Protected species	Not assessed*
Habitats	Level 1
Communities	Level 1

Table 0.3: Stock assessments including status detail (where available) of key commercial species in the Torres Strait Finfish (Reef Line) fishery. NOF: not overfished, NSTOF: not subject to overfishing, ABARES: Australian Bureau of Agricultural and Resource Economics and Sciences, ^: Based on ABARES classification. MSE: Managament Strategy Evaluation.

Common Name	Species Name	ERA Clas- sification	Biomass^ / Fishing Mortal- ity^	References	Year Last Assessed
Coral Trout (man- aged as a basket of four species)	Barcheek Coral Trout (Plectropomus maculatus), Bluespotted Coral Trout (P. laevis), Common Coral Trout (P. leopardus), Passionfruit Coral Trout (P. areolatus)	Key Com- mercial	NOF / NSTOF	Preliminary stock assessment for Coral Trout: estimated spawning biomass ~80% of unfished levels (Holden & Leigh, 2019); An earlier MSE was conducted (Williams et al., 2007; 2011). ABARES: Bromhead et al. (2021)	2007; pre- liminary assess- ment conducted in 2019

Level 2 Results and Summary

For this report, a Level 2 assessment was not conducted.

Executive Summary

The "Ecological Risk Assessment for Effect of Fishing" ERAEF was developed jointly by CSIRO Oceans and Atmosphere and the Australian Fisheries Management Authority (Hobday et al., 2007, 2011a). This assessment of the ecological impacts of the Torres Strait Spanish Mackerel Fishery was undertaken using the ERAEF method version 9.2, with some additional modifications currently in final stages of development with AFMA. This revised ERAEF provides a hierarchical framework for a comprehensive assessment of the ecological risks arising from fishing, with impacts assessed against five revised ecological components –key commercial and secondary commercial species; byproduct and bycatch species; protected species; habitats; and (ecological) communities (see ERM Guide, AFMA, 2017).

The ERAEF proceeds through four stages of analysis: scoping; an expert judgement-based Level 1 analysis (SICA – Scale Intensity Consequence Analysis); an empirically based Level 2 analysis (including PSA – Productivity Susceptibility Analysis and SAFE – Sustainability Assessment for Fishing Effects); and a model-based Level 3 analysis. This hierarchical approach provides a cost-efficient way of screening hazards, with increasing time and attention paid only to those hazards that are not eliminated at lower levels in the analysis. Risk management responses may be identified at any level in the analysis.

Application of the ERAEF methods to a fishery represents a set of screening or prioritization steps that work towards a full quantitative ecological risk assessment. At the start of the process, all components are assumed to be at risk. Each step, or Level, potentially screens out issues that are of low concern. The Scoping stage screens out activities that do not occur in the specific fishery. Level 1 screens out activities that are judged to have low impact, and potentially screens out components with all low impact scores. Level 2 is a screening or prioritization process for individual species, habitats and communities at risk from direct impacts of fishing, using either PSA or b-SAFE. The Level 2 methods do not provide absolute measures of risk. Instead they combine information on productivity and exposure to fishing to assess potential risk – the term used at Level 2 is risk. Because of the precautionary approach to uncertainty, there will be more false positives than false negatives at Level 2, and the list of high risk species or habitats should not be interpreted as all being at high risk from fishing. Level 2 is a screening process to identify species or habitats that require further investigation. Some of these may require only a little further investigation to identify them as a false positive; for some of them managers and industry may decide to implement a management response; others will require further analysis using Level 3 methods, which do assess absolute levels of risk.

This Torres Strait Finfish Reef Line Fishery ERAEF assessment is based on analyses of data (from 2017 to 2021) conducted in 2022. It is the first ERAEF assessment conducted for this fishery. This 2017-2021 assessment of the Torres Strait Spanish Mackerel Fishery consists of the following:

- Scoping
- Level 1 results for the (i) Key/Secondary/Commercial Bait species, (ii) byproduct/bycatch species, (iii) Habitats and (iv) Communities components

Fishery Description

Gear Trolling

Area Tidal waters within Torres Strait Protected Zone (TSPZ) and area 'outside but near' the TSPZ for commercial (finfish) fishing

Depth range less than 30 m below the surface

Fleet size 16-23 active Traditional Inhabitant licence holders; 3-7 Sunset licence holders

Effort 71-120 operation days annually (TIB sector; over three years only); 80-373 operation days annually (Sunset sector)

Landings 318.5 t of Spanish Mackerel within assessment period; 2.1 t of other Mackerel species

Discard rate fishery wide estimate unavailable

Key commercial species Spanish Mackerel (*Scomberomorus commerson*)

Management Input and output controls

Observer program No Observer program in this fishery

Ecological Units Assessed

A total of 12 species across all ecological components were assessed in this ERAEF (Table 0.1). The following components were not assessed in this report: secondary commercial species, bycatch species, protected species.

Table 0.1: Ecological units assessed in 2022 (data from 2017 to 2021).

Ecological units assessed	2022
Key/secondary commercial species	1
Commercial species/Bait	8
Byproduct species	3
Bycatch species	0
Protected species	0
Benthic habitats	12
Pelagic habitats	2
Demersal communities	8
Pelagic communities	2

One key commercial species, eight commercial bait species and three byproduct species were assessed. There are currently no bycatch or protected species reported.

Level 1 Results and Summary

All ecological components were eliminated at Level 1 (i.e. no components with risk scores of 3 – moderate – or above). Fishing for Spanish Mackerel is very selective as they are harvested by trolling mostly during spawning aggregations. Currently, no byproducts are reported at the species level in Commonwealth logbooks. There are no reported discarded species. Also, no interaction with any protected species have been reported. As a result, the 'Protected species' ecological components was not assessed.

All hazards (fishing activities) were considered as 'low risk' and eliminated at Level 1 (i.e. no components with risk scores of 3 – moderate – or above). The highest risk scores (2 (minor); with high confidence level) were reported as a result of addition/movement of biological material from chemical pollution for key/secondary and byproduct species. All of the assessed direct and indirect impacts to this fishery were either low or negligible based on scale and nature of the fishery as well as available survey data.

As a result of direct capture, the most vulnerable key commercial species was the Spanish Mackerel (*Scomberomorus commerson*) as it is the mostly caught species (AFMA catch disposal record; Commonwealth logbooks). The assessment is based on a group code and therefore consists of four mackerel species. As such, no further action was required for this activity (fishing).

The direct ecological impact on the benthos from harvesting key commercial and byproduct species was low (minor; risk score = 2). In particular, fishing for Spanish Mackerel represented a minor risk to benthic habitats largely due to the effort along the reef flats (Northeast and GBR Biome: assemblages 7, 6, 5, 4 and 3), consisting of seagrasses, soft corals, sponges and algae; and the forereef habitats (Northeast and GBR Biome: assemblages 7, 6, 5, 4 and 3), consisting of gorgonians, whip corals, fungiid corals, soft corals, sponges and algae. This fishing activity may affect species directly and also break or damage benthic communities and coral reef structures.

Although still considered a 'low risk' external hazard, coastal development was the highest scored risk (risk score = 2) to key commercial and byproduct species, byproduct, habitats and communities because of localised pollution in some Islands and sediment runoff from coastal developments along the Fly river (PNG). Sediments can smother sessile species like corals and increased turbidity and reduction in light penetration can negatively affect species that depend on light, such as corals, algae and seagrasses. Confidence is low because impacts from Fly river are still poorly understood and there is a lack of data on water quality issues

and recovery times of species and habitats.

Table 0.2: Outcomes of assessments for ecological components conducted in 2022. *: there are no reported protected species in this fishery. ^: includes Commercial Bait species

Ecological Component	2022
Key/secondary commercial species^	Level 1
Byproduct and bycatch species	Level 1
Protected species	Not assessed*
Habitats	Level 1
Communities	Level 1

Table 0.3: Stock assessments including status detail (where available) of key commercial species in the Torres Strait Spanish Mackerel fishery. NOF: not overfished, NSTOF: not subject to overfishing, ABARES: Australian Bureau of Agricultural and Resource Economics and Sciences, ABARES: A: Based on ABARES classification

Common Name	Species Name		Biomass^/Fishing Mortality^	References	Year Last Assessed
Coral Trout	Scomberomorus commerson	Key Com- mercial	NOF/NSTOF	O'Neill et al. (2021)	2021

Level 2 Results and Summary

For this report, a Level 2 assessment was not conducted.

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
RESEARCH Project update – Spanish mackerel and coral trout biological sampling	Agenda Item 5.2 For NOTING

RECOMMENDATIONS

1. That the RAG **NOTE** the update provided via video conference at the meeting by Joanne Langstreth and Andrew Trappett, Queensland Department of Agriculture and Fisheries (QDAF), on the biological sampling project.

BACKGROUND

- 1. Age data is an important input into the Spanish mackerel stock assessment, helping to understand: changes in abundance, the impact of fishing and fishing selectivity, as well as recruitment variability. In line with recommendations from the FFRAG, the collection of age and length data for Spanish mackerel resumed in the 2019-20 fishing season (most recent ageing data before this was from 2005).
- 2. QDAF, led by Jo Langstreth, was funded by AFMA and TSRA to undertake the sampling (AFMA Project number: 2019/0832, project title: *Enhancing biological data inputs to Torres Strait Spanish mackerel stock assessment*).
- 3. A subsequent project was funded to continue sampling in the 2020-21 fishing season. Under the project, for the first time, samples were collected from coral trout (AFMA project number: 190851, project title: *Torres Strait Finfish Fishery: Coral trout and Spanish mackerel biological sampling*).
- 4. The project was funded again for another three fishing seasons 2021-22, 2022-23, 2023-24 (contract formed 28 Aug 2021) (AFMA project number 2020/0814, project title: *Torres Strait Finfish Fishery Coral Trout and Biological Sampling 2021-2024*). On 14 September 2021, the project team wrote to Torres Strait Finfish Fishery stakeholders advising them of the continuation, objectives and intended outcomes of the project.
- 5. Research has continued for the current fishing season with Spanish mackerel samples being collected and processed (length, sex and otoliths taken for ageing later in the season) at the Cairns based laboratories.
- 6. For the 2021/22 season, the following samples were collected:

Spanish mackerel

- 1074 Spanish mackerel sampled in the lab with measurements and otoliths taken.
- 424 aged.
- 1530 Spanish mackerel from 50 catches measured on length sheets by commercial fishers.

Coral trout

- 91 coral trout sampled in the lab with measurements and otoliths taken .
- 206 coral trout from 3 catches measured on length sheets by commercial fishers.

- 7. As part of the project for the 2022/23, the project team planned community visits for:
 - 12-15 September 2022 on Mer & Erub
 - 24-27 September Oct on Mer and Erub
- 8. Jo Langstreth and Andrew Trappett will be attending the FFRAG meeting to provide a project update. Members are asked to consider the update and if relevant, provide any advice on any additional initiatives to ensure industry support and participation in the sampling.

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
RESEARCH Designing a close-kin mark-recapture study for Torres Strait Spanish mackerel	Agenda Item 5.3 For NOTING & ADVICE

RECOMMENDATIONS

1. That the RAG:

- a) **NOTE** the video presentation provided by Dr Ashley Williams on the status of the project *Designing a Close-Kin Mark-Recapture study for Torres Strait Spanish mackerel* (project number 200817).
- b) **PROVIDE ADVICE** to the project investigator on the DRAFT final report for the project. This advice will be considered when finalising the report for submission.

BACKGROUND

- 2. This study was funded to design a full-scale close-kin mark-recapture (CKMR) study to estimate the current level and trend in spawner biomass of Spanish mackerel in Torres Strait. The project will evaluate alternative sampling designs and their associated costs and resource requirements for their implementation in a full-scale CKMR monitoring program for Spanish mackerel.
- 3. The main objectives of this project are to:
 - a) Examine genetic population structure between the Torres Strait population of Spanish mackerel and surrounding populations on the Queensland east coast, Gulf of Carpentaria and the Gulf of Papua; and
 - b) Using information on population structure from objective (a), and rough abundance estimates from existing stock assessments, design a full-scale CKMR study to estimate the current level and trend in spawner biomass of Spanish mackerel in the Torres Strait, including an evaluation of alternative sampling designs and their associated costs and resource requirements for their implementation in a full-scale CKMR monitoring program for Spanish mackerel.
- 4. A copy of the DRAFT final project report can be found at **Attachment 5.3a**.
- 5. The research was initially identified and discussed by FFRAG 5 (31 Oct 1 Nov 2019) and FFRAG 6 (27-28 November 2019) as a need to develop an alternative index of abundance for Spanish mackerel other than the relative abundance provided from fishery dependent logbook catch rate data noting the relatively data-poor state of the fishery with few vessels providing data to build a signal of stock trends.
- 6. AFMA and the RAG technical members discussed out of session that progressing a close-kin mark-recapture study could be feasible and would likely address abundance and reliance on the stock assessment as well as address genetic connectivity and hyper-stability issues in the longer term.

7. FFRAG 7 (8 October 2020) recommended that a scoping study for CKMR could report on whether the method would work biologically the number of samples that would be required over time (based on the population model) and how the technique might provide other insights such as connectivity with adjacent stocks. This research was supported as essential, and ranked as number for in the priority for research funding in the 2020-21 TSSAC funding round.

Attachment 5.3a



Box 7051, Canberra Business Centre, ACT 2610 / Ph (02) 6225 5555 / Fax (02) 6225 5500 / AFMA Direct 1300 723 621 afma.gov.au

This document can be cited as:

Williams, A.J., Feutry, P., Mayne, B., Tremblay-Boyer, L., Gunasekera, R., Bravington, M., Thomson, R., Trappett, A., Buckworth, R., Baylis, S. 2022. Designing a close-kin mark-recapture study for Torres Strait Spanish mackerel. Draft Final Report, AFMA Project No. 2020/0817. 55 pages.

AFMA Project No. 2020/0817: Designing a close-kin mark-recapture study for Torres Strait Spanish mackerel

Project Principal Investigator: Ashley Williams (Ashley.williams@csiro.au)

Users who require any information in a different format to facilitate equal accessibility consistent with Australia's Disability Discrimination Act may contact;

Ashley.williams@csiro.au or CSIRO Enquiries.

Copyright and disclaimer

© Australian Fisheries Management Authority 2022

This work is copyright. Except as permitted under the Copyright Act 1968 (Cth), no part of this publication may be reproduced by any process, electronic or otherwise, without the specific written permission of the copyright owners. Information may not be stored electronically in any form whatsoever without such permission.

Disclaimer

The authors do not warrant that the information in this document is free from errors or omissions. The authors do not accept any form of liability, be it contractual, tortious, or otherwise, for the contents of this document or for any consequences arising from its use or any reliance placed upon it. The information, opinions and advice contained in this document may not relate, or be relevant, to a reader's particular circumstances. Opinions expressed by the authors are the individual opinions expressed by those persons and are not necessarily those of the publisher, research provider or the AFMA.

Cover page: Photo courtesy of Dr Jeff Kinch

Contents

Contents							
Figures							
Tabl	Tables						
Executive summary							
Acknowledgements							
1	Bad	kgro	und	. 11			
2	Pilo	ot tiss	sue sampling program for Torres Strait Spanish mackerel close-kin mark-recapture	. 13			
2.	1	Intro	oduction	. 13			
2.	2	Met	hods	. 13			
2.	3	Resi	ults	. 15			
2.	4	Con	clusions	. 17			
2.	5	Rec	ommendations	. 18			
3	Ge	netic	connectivity between Torres Strait Spanish mackerel and surrounding populations	. 19			
3.	1	Intro	oduction	. 19			
3.	2	Met	hods	. 19			
3.	3	Resi	ults	. 21			
3.	4	Con	clusions	. 24			
3.	5	Rec	ommendations	. 25			
4	Eva	luati	on of epigenetic ageing for Torres Strait Spanish mackerel	. 26			
4.	1	Intro	oduction	. 26			
4.	2	Met	hods	. 27			
4.	3	Resi	ults	. 28			
4.	4	Con	clusions	. 31			
4.	5	Rec	ommendations	. 32			
5	De	signir	ng close-kin mark-recapture for Spanish mackerel	. 33			
5.	1	Intro	oduction	. 33			
5.	2	Clos	e-kin mark-recapture overview	. 34			
5.	3	Met	hods	. 36			
	5.3	.1	Population model	.36			
	5.3	.2	Sampling scenarios	.39			
	5.3	.3	Estimation of CVs for population metrics	.41			

5	.3.4 Ageing error matrix	42
5.4	Results	43
5.5	Conclusions	51
5.6	Recommendations	52
Refere	nces	53
F	igures	
Figure 1.	Gene tagging handle (left) with inserted single-use tip (right) used to take tissue samples fro Spanish mackerel.	
Figure 2.	Locations and associated sample sizes of Spanish mackerel sampled in Torres Strait	15
Figure 3.	Length frequency distribution for Spanish mackerel sampled for muscle tissue from Torres Strait in 2021. Fork length refers to individuals for which fork length was measure directly. Converted jaw length refers to the estimated fork length derived from jaw length measurements.	16
Figure 4.	Predicted age distribution for Spanish mackerel derived from applying an average (2020-2022) age-length key to the length of fish sampled for muscle tissue from Torres Strait in 2021.	17
Figure 5.	Locations and associated sample sizes of Spanish mackerel sampled in Torres Strait for analysis of population structure. A = Northern Territory (NT), B = Gulf of Carpentaria (GoC), = Torres Strait, D = Queensland East Coast (EC), and E = Papua New Guinea (PNG)	
Figure 6.	Genome-wide mean observed heterozygosity of Spanish mackerel samples from Queensland East Coast (ec), Torres Strait (ts), Gulf of Carpentaria (goc), Northern Territory (nt), Papua New Guinea (png), and pooled across all regions (OVERALL). Dashed horizontal lines indicate the average and 95% confidence limits of heterozygosity for each dataset. The size of each data point relates to the proportion of missing data in the SNP markers for each individual.	e
Figure 7.	Probabilities of membership of each individual fish (bars) from Northern Territory (NT), Gulf of Carpentaria (GoC), Torres Strait (TS), Queensland East Coast (EC), and Papua New Guines (PNG) to one of five genetic groups (clusters)	3
Figure 8.	Percentage success in reassigning individual fish to the location they were sampled from (PNG, EC, TS, GoC or NT).	23
Figure 9.	Correlation between the otolith age and the predicted age in the A. training data set and B. testing data set. Both data sets show a high and consistent correlation (Pearson correlation 0.93, p-value $< 2.20 \times 10^{-16}$). Each dot represents and individual fish (Blue = Male, Pink = Female, Black = Unknown Sex).	
Figure 10). Boxplots showing the absolute error rate in both the training and testing data sets. No statistical difference was found between the error rates in the data sets (p-value = 0.89, t-test, two-tailed).	29
Figure 11	. Time series of catches of Torres Strait Spanish mackerel from 2000 to 2020 (data sourced from [3])	37

Figure 12	2. Annual recruitment deviation computed from 2021 assessment model prediction for age-0 individuals and used in the simplified CKMR population model. Recruitment deviates for the projection period are shown in red
Figure 13	3. Distribution of samples over time (left column) and age (right column) for different sampling scenarios. To ease comparison, the dotted line in the right column panels show the agedistribution for the other catch-at-age scenario
Figure 14	I. Predicted annual abundance (numbers across all ages) for the 2021 assessment model (circles) compared to the simplified CKMR population model (line). The grey rectangle delineates the projection period
Figure 15	5. Proportion catch-at-age from the 2021 assessment (blue line) compared to predicted proportion catch-at-age from the simplified CKMR population model (shaded area). The period 2021 to 2025 is based on assumed future catch levels
Figure 16	6. Number of parent-offspring pairs (POPs; left panel) and half-sibling pairs (HSPs; right panel) detected when varying the length of the sampling program and the intensity of annual sampling (coloured bars)
Figure 17	7. Number of parent-offspring pairs (POPs; top panel) and half-sibling pairs (HSPs; bottom panel) detected when varying the intensity of annual sampling for a five years program (coloured bars) and the time- or age- distribution of samples (vertical panels)
Figure 18	3. Predicted precision (coefficient of variation, CV) in spawning biomass of 3 -year-old fish under three different program length (coloured lines) and annual samples of 750 to 1500 individuals (panels). The brown horizontal line highlights a benchmark CV of 15%47
Figure 19	D. Predicted precision (coefficient of variation, CV) in spawning biomass of 3 -year-old fish and total fecundity under three different sampling strategies. The brown horizontal line highlights a benchmark CV of 15%
Figure 20). Predicted precision (coefficient of variation, CV) in total population fecundity under three different program length (coloured lines) and annual samples of 750 to 1500 individuals (panels). The brown horizontal line highlights a benchmark CV of 15%
Figure 21	. Predicted precision (coefficient of variation, CV) of estimated natural mortality (<i>M</i>) under three different sampling strategies with different levels of annual and total samples
Figure 22	2. Ageing error matrix for Spanish mackerel. Top panel indicates the count of each age in the CKMR sample under the "Equal number of samples (all years)" sampling scenario with 5000 total samples. The proportion of each age class in the sample is shown in white for each bar when it exceeds 0.05. Bottom panel shows the distribution of true ages given the observed ('measured') age under a CV of 15%. The cells coloured in red show higher probabilities, and the numbers in black denote the actual probability of an individual being of a given true age given its observed age

Tables

Table 1. Number of tissue samples collected from Spanish mackerel in Torres Strait listed by catch location and fishing sector.	15
Table 2. Total number of samples collected including number of samples retained or discarded from the analysis due to contamination.	
Table 3. Population differentiation pairwise FST (lower diagonal) and associated p-values (upper diagonal)	23
Table 4. Performance of the Spanish mackerel epigenetic clock across age classes in the testing data sets (note: there were no 7-year-old fish in the sample).	
Table 5. Approximate current (2022) costs (\$/individual) for the ageing of Spanish mackerel using whole otoliths or epigenetic ageing.	30

Executive summary

Spanish mackerel supports the largest finfish fishery in Torres Strait where it is an important resource for both Traditional Inhabitants and non-Traditional Inhabitants. Stock assessments have indicated that the Torres Strait Spanish mackerel stock has declined over the past decade and reached levels close to being overfished in 2018. In an effort to reverse the declining trend in stock status, total allowable catches for the fishery have been reduced in each year since 2016, and there are some indications that the stock may be starting to rebuild.

Catch per unit effort (CPUE) data from the non-Traditional Inhabitant sector of the Spanish mackerel fishery is the main source of information used in the stock assessments to estimate current stock size. The Torres Strait Finfish Resource Assessment Group (FFRAG) identified several uncertainties in the stock assessments, including uncertainties in the standardised CPUE series, which can have an impact on the estimated levels of abundance. Therefore, the FFRAG prioritised research that can provide alternative, fisheries-independent, estimates of abundance to compare with those derived from the assessments.

Close-kin mark-recapture (CKMR) is a new, but proven, technique that uses modern genetics to identify closely related pairs from samples of fish, enabling estimation of key population parameters, such as absolute spawning biomass and natural mortality, without needing fisheries-dependent CPUE data. In 2020, the FFRAG supported the development of a project to evaluate the feasibility of CKMR for providing an estimate of abundance for Torres Strait Spanish mackerel.

The overall aim of this project was to complete the preparatory work and develop a sampling design for the successful implementation of CKMR for Torres Strait Spanish mackerel. To achieve this, there were four primary objectives to this project:

- 1. Implement a pilot sampling program to evaluate the potential for industry to collect sufficient tissue samples from Spanish mackerel with minimal cross-contamination.
- 2. Examine genetic population structure between the Torres Strait population of Spanish mackerel and surrounding populations in Queensland, Gulf of Carpentaria, Northern Territory and Papua New Guinea.
- 3. Evaluate the utility of epigenetic ageing to provide accurate estimates of age for Spanish mackerel.
- Design a CKMR study to estimate the current level and trend in spawner biomass of Spanish mackerel in Torres Strait, including an evaluation of alternative sampling designs.

The pilot sampling program was successful in collecting 981 tissue samples from Spanish mackerel in Torres Strait in 2021, indicating that an ongoing tissue sampling program to support a CKMR study is achievable. Key recommendations from this objective are:

 The collection of muscle tissue sampling from Torres Strait Spanish mackerel should continue in 2022 and subsequent years to support the compilation of a tissue bank for future CKMR work.

- 2. The CSIRO-designed gene tagging tool, or other similar technique, should be used when collecting muscle tissue to minimise contamination of DNA between samples.
- 3. Ongoing sampling of muscle tissue should ensure that sufficient tissue is collected to support concurrent application of epigenetic ageing, genetic sex determination, and CKMR.

The examination of genetic population structure revealed four distinct genetic populations of Spanish mackerel in Torres Strait, PNG, Queensland east coast and a combined Northern Territory and Gulf of Carpentaria population. This pattern of population structure is consistent with previous work and reinforces the existing paradigm that genetic boundaries for Spanish mackerel occur between Torres Strait and the Queensland east coast and Gulf of Carpentaria, and that significant connectivity exists between the Gulf of Carpentaria and the Northern Territory. Key recommendations from this objective are:

- 1. It is appropriate to assume that the Spanish mackerel population in Torres Strait is genetically separate from the Gulf of Carpentaria and the Queensland east coast.
- 2. Additional Spanish mackerel samples should be collected from the Gulf of Papua to confirm the level of connectivity between Torres Strait and the Gulf of Papua.
- 3. Future application of CKMR should be implemented simultaneously in Torres Strait and Queensland to provide a direct measure of the level of connectivity and potential boundary between these two regions.

Epigenetics provides a useful, precise and unbiased alternative method to estimate age of Spanish mackerel. Epigenetic ageing is currently slightly more expensive than estimating age from whole otoliths, but is likely to become cheaper in the near future as technology improves. The low bias and relatively high level of precision of epigenetic ageing for Spanish mackerel means it will be a valuable method in the application of CKMR. Key recommendations from this objective are:

- 1. Additional tissue samples should be collected from older Spanish mackerel (>8 years) to enable the extension of the age range of the epigenetics ageing model, which would support a more complete application of the model for CKMR. These samples would not necessarily need to be collected from Torres Strait, as the model is not stock specific.
- 2. The epigenetics model for Spanish mackerel provides sufficiently precise and unbiased estimates of age for CKMR, but current costs indicate that it would be cheaper to use otoliths to estimate age. Epigenetic age estimation should be considered in future CKMR studies or other applications for the species, when otoliths are not available, are logistically difficult to collect, or when the costs of epigenetic ageing become cheaper than otoliths.

The evaluation of alternative CKMR sampling scenarios revealed that a sufficient number of kin pairs would be detected (i.e. >100) with the collection of 1,000 individuals per year over a 5-year period (i.e. 5,000 samples). From these samples, spawning biomass could be estimated with a precision of 11% and mortality with a precision of around 27%. Increasing the sample size in each year increases the precision of these population metrics. Key recommendations from this objective are:

- Continue the collection of approximately 1,000 tissue samples from Torres Strait Spanish mackerel in 2022 and subsequent years for a total program length of at least 5 years to provide the required total sample size (~5,000) for the full application of CKMR.
- 2. Genotype the full collection of tissue samples, when available, to enable the detection of kin pairs for input into the CKMR model and estimation of key parameters such as spawning abundance and mortality.
- 3. Expand the CKMR model to account for uncertain age. This will be particularly important when using age estimates from less precise methods such as epigenetic ageing.
- 4. Evaluate the possibilities for collaboration with Queensland Fisheries who have recently commenced an FRDC-funded CKMR design study for the Queensland east coast population of Spanish mackerel. Analysing samples from Torres Strait and the Queensland east coast within the same CKMR analysis will enable a direct evaluation of connectivity between the two populations, further strengthening our understanding of population structure for Spanish mackerel in this region.

Acknowledgements

CSIRO acknowledges the Traditional Owners of the land, sea and waters, of the area that we live and work on across Australia. We acknowledge their continuing connection to their culture, and we pay our respects to their Elders past and present. We thank Torres Strait Islander fishers and Mr Egon Stewart for providing valuable Spanish mackerel samples for this research, which was funded through AFMA project R2020/0814. We are grateful to Dr Jeff Kinch from Papua New Guinea National Fisheries Authority for providing samples from Kavieng. We thank Michael O'Neill for the provision of important stock assessment outputs, Jo Langstreth and staff from Queensland Fisheries for substantial support in acquiring and processing samples, and Russ Bradford for training in the use of the gene tagging tool. Thank you to all TSFF RAG members and observers for constructive comments and feedback on all aspects of this research. We gratefully acknowledge funding support for project R2020/0817 from AFMA and CSIRO.

1 Background

Spanish mackerel (*Scomberomorus commerson*) is an important commercial and recreational species in the tropical and subtropical coastal waters of Australia, from Geraldton in Western Australia to Port Macquarie in New South Wales [1]. In Torres Strait, Spanish mackerel support the third largest fishery, and the largest finfish fishery. Traditional Inhabitants have exclusive access to fishing entitlements for Spanish mackerel in Torres Strait, which can be leased to Non-Traditional Inhabitant fishers. Fishing operates almost exclusively in the eastern Torres Strait, with most of the catch taken by Non-Traditional Inhabitant fishers during the spawning season (September to November) within the small area of Bramble Cay. Annual catches of Spanish mackerel in Torres Strait peaked at over 300 t in 2005 but have declined rapidly to average less than 100 t in recent years [2].

Recent stock assessments have estimated that the spawning biomass of Torres Strait Spanish mackerel has declined to levels close to the Commonwealth Fisheries Harvest Strategy limit reference point of 20% of unfished biomass [3]. In 2018, the Torres Strait Spanish mackerel stock was estimated to be at approximately 23% of unfished biomass [4], but recovered to approximately 30% of unfished biomass in 2019 [3] and 2020 [5]. The total allowable catch (TAC) for the fishery has been reduced each year since 2016 in response to the declining estimates of biomass, but standardised catch per unit effort (CPUE), which is the primary index of abundance for the stock assessments, has remained relatively low.

The Torres Strait Finfish Resource Assessment Group (FFRAG) has identified several uncertainties in the stock assessments, including uncertainties in the standardised CPUE series, which can have an impact on the estimated levels of abundance. Hyperstability is considered to be one of the main uncertainties with the standardised CPUE and occurs when CPUE remains relatively high despite a decline in the overall abundance. Spanish mackerel in Torres Strait are likely to exhibit hyperstability due to the large spawning aggregations that form around Bramble Cay, where the majority of the annual catch is taken. There has also been a large reduction in the number of commercial vessels operating in the fishery, which reduces the amount of data available to inform the analysis of the standardised CPUE. Therefore, uncertainty remains in the actual relationship between standardised CPUE and the underlying population abundance, and the FFRAG has prioritised research that can provide alternative, fisheries-independent, estimates of abundance.

Close-kin mark-recapture (CKMR) is a new, but proven, technique that uses modern genetics to identify closely related pairs from samples of fish, enabling estimation of key population parameters, such as absolute spawning biomass and natural mortality, without needing fisheries-dependent CPUE data [6]. CKMR has been successfully applied since 2013 to southern bluefin tuna, transforming the stock assessment for this species and forming an ongoing key index of abundance [7-9]. CKMR has also been applied successfully to Australian shark species [10, 11] and to several commercial fish stocks in other countries [12-14]. In 2020, the FFRAG supported the development of a project to

evaluate the feasibility of CKMR for providing an estimate of abundance for Torres Strait Spanish mackerel.

The successful application of CKMR to Torres Strait Spanish mackerel would provide much needed fishery-independent estimates of spawning biomass, natural mortality, age-specific fecundity, and connectivity. However, CKMR studies can fail altogether unless properly designed. This project aimed to complete the design work necessary to ensure the successful implementation of CKMR for Torres Strait Spanish mackerel. To assist with the design work, it was important to have a better understanding of the likely stock structure of Spanish mackerel in the region to inform the spatial domain of the design model. It was also important to assess the feasibility of collecting the number of samples required for CKMR to provide precise estimates of abundance, and to a have a robust method for estimating the age of these samples so that cohorts could be identified. To address these needs, four primary objectives were defined for this project:

- Implement a pilot sampling program to evaluate the potential for industry to collect sufficient tissue samples from Spanish mackerel with minimal crosscontamination
- 2. Examine genetic population structure between the Torres Strait population of Spanish mackerel and surrounding populations in Queensland, Gulf of Carpentaria, Northern Territory and Papua New Guinea
- 3. Evaluate the utility of epigenetic ageing to provide accurate estimates of age for Spanish mackerel.
- Design a CKMR study to estimate the current level and trend in spawner biomass of Spanish mackerel in Torres Strait, including an evaluation of alternative sampling designs.

2 Pilot tissue sampling program for Torres Strait Spanish mackerel close-kin mark-recapture

2.1 Introduction

The application of CKMR requires the collection of tissue samples from individuals in a population and the identification, through genetics, of close kin in the individuals sampled. The number of close kin pairs then becomes an input to a population model estimating population size. The number of genotyped individuals required for a precise estimate of abundance is proportional to the population size. The success of CKMR is, therefore, highly dependent on obtaining a sufficient number of tissue samples to robustly estimate abundance and other important parameters. The minimum required sample size required to meet a specified level precision can be determined through a formal design study (see Chapter 5).

An established biological sampling program has been operating for the Torres Strait Spanish mackerel fishery since 2019, and has been collecting length measurements and otoliths from a subset of measured fish [15]. The samples and data collected from this program have provided valuable size and age composition data for the Spanish mackerel stock assessments. Length measurements have been collected from nearly 4,000 fish since 2019, indicating that there is a potential opportunity to access a large number of fish for sampling muscle tissue for CKMR.

Preliminary analyses, using a range of simplifying assumptions, estimated that somewhere in the range of 3,000 to 5,000 samples may be required to obtain a reliable estimate of absolute spawning biomass for Torres Strait Spanish mackerel using CKMR. Fortunately, it is not necessary to collect all samples in a single year, as a strength of CKMR is that samples collected over multiple years provide cumulative information. Therefore, if 3,000 to 5,000 samples from Spanish mackerel were required for a robust estimate of spawning biomass, these samples could be collected over a few years, rather than in a single year.

The aim of this chapter was to establish a pilot sampling program to evaluate the feasibility of collecting tissue samples from the Torres Strait Spanish mackerel fishery. The initial target was set at 1,000 samples over a 12-month period, which the preliminary analyses indicated would be sufficient for CKMR if a similar sample size could be collected in each year over several years.

2.2 Methods

The initial pilot sampling program that was proposed involved non-Traditional Inhabitant commercial fishers taking samples of muscle tissue from Spanish mackerel on board the vessel during normal fishing operations. After further discussions with commercial fishers and the biological sampling project team of AFMA project R2020/0814, it was agreed that a better option would be for the non-Traditional Inhabitant commercial fishers to retain Spanish mackerel frames and/or heads, and ship these to Queensland Fisheries in Cairns for the tissue samples to be collected in the laboratory. Non-Traditional Inhabitant

commercial fishers provided strong support for this sampling program, and confirmed that it was easily achievable to retain, freeze and ship the target number (~1,000) of fish frames and heads to Queensland Fisheries.

To supplement the samples from non-Traditional Inhabitant commercial fishers, additional sampling from commercial and subsistence Traditional Inhabitant fishers was conducted by the biological sampling project team at Torres Strait Fish Receiver premises during visits to conduct workshops in communities [16]. A small number of samples were also collected from recreational fishers on Thursday Island.

Samples of muscle tissue from each individual fish were collected using a gene tagging tool (Figure 1) specially designed to minimise DNA contamination between samples. Tissue samples were taken from the fleshy portion at the dorso-posterior of the fish's head, placed in in a 2 ml vial filled with 98% ethanol, labelled with a unique sample number, and stored in the laboratory freezer. Samples were later sent to CSIRO in Hobart for archiving and future processing.



Figure 1. Gene tagging handle (left) with inserted single-use tip (right) used to take tissue samples from Spanish mackerel.

2.3 Results

During the 2021 fishing season, the project collected tissue samples from a total of 981 Spanish mackerel. Of these, 943 were from non-Traditional Inhabitant commercial fishers, 28 from non-Traditional Inhabitant commercial fishers, 6 from subsistence Traditional Inhabitant fishers, and 4 from recreational fishers (Table 1, Figure 2). Most of these samples were collected from fish caught around Bramble Cay.

Table 1. Number of tissue samples collected from Spanish mackerel in Torres Strait listed by catch location and fishing sector.

Catch location	non-Traditional Inhabitant commercial	Traditional Inhabitant commercial	Traditional Inhabitant subsistence	Recreational
Bramble Cay	943	-	-	-
Masig Island	-	28	-	-
Mer Island	-	-	6	-
Thursday Island	-	-	-	4

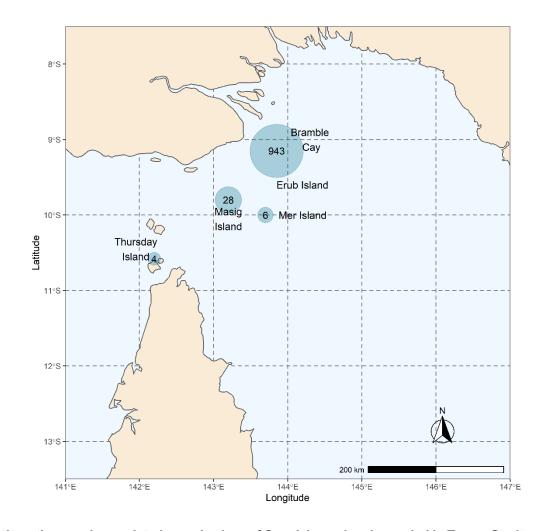


Figure 2. Locations and associated sample sizes of Spanish mackerel sampled in Torres Strait

Most of the tissue samples (883) were taken from fish heads provided by non-Traditional Inhabitant commercial fishers, while the remaining 98 samples were taken from fish frames. As a result, information on the fork length and sex of individuals is only available for 98 fish. Conversion factors developed by [15] were used to convert jaw length measurements to estimates of fork length.

The length of sampled Spanish mackerel ranged from 58-136.5 cm FL, with most fish (75%) between 86-105 cm FL, and a median length of 95 cm FL (Figure 3). This length distribution is very similar to other sampling of the Torres Strait Spanish mackerel fishery [15, 16], except for the single very small individual (58 cm FL) which may represent an error in the measured or recorded jaw length.

The age-length key used in the stock assessments to convert sample lengths to age was applied to the length distribution to produce a predicted age distribution of the samples collected. This predicted age distribution is very similar to the age distribution derived from annual age and length data from the fishery, with a most (>80%) of fish between two and four years of age.

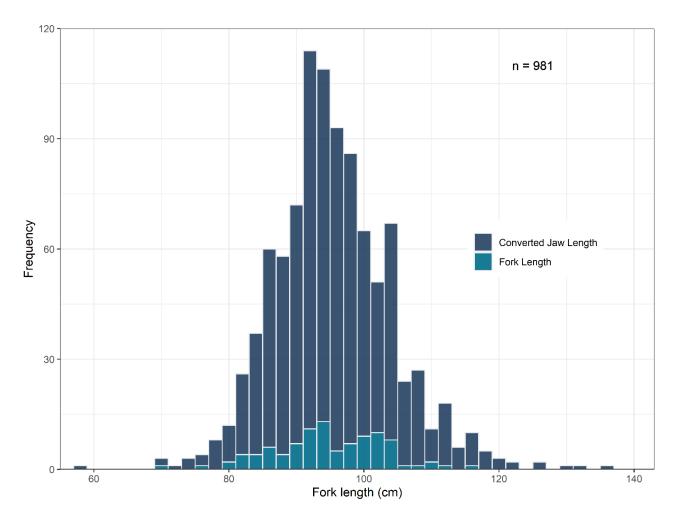


Figure 3. Length frequency distribution for Spanish mackerel sampled for muscle tissue from Torres Strait in 2021. Fork length refers to individuals for which fork length was measure directly. Converted jaw length refers to the estimated fork length derived from jaw length measurements.

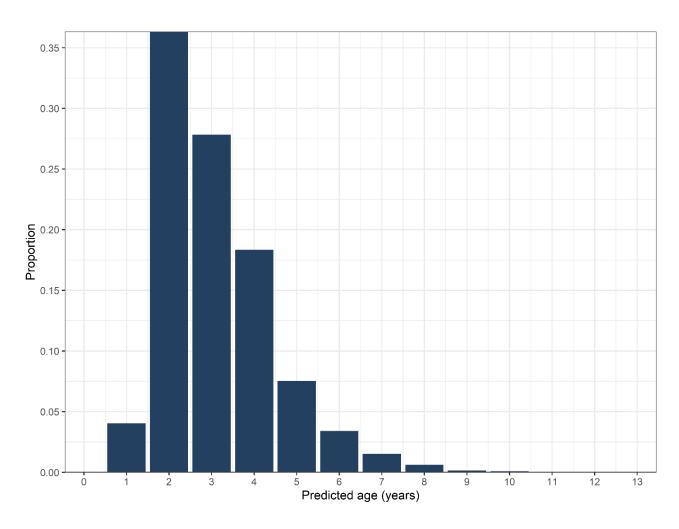


Figure 4. Predicted age distribution for Spanish mackerel derived from applying an average (2020-2022) age-length key to the length of fish sampled for muscle tissue from Torres Strait in 2021.

2.4 Conclusions

The pilot sampling program was successful in collecting 981 tissue samples from Spanish mackerel in Torres Strait in a single year, indicating that an ongoing tissue sampling program to support a CKMR study is achievable, assuming this level of sampling provides the required precision in estimates of abundance (see Chapter 5). Furthermore, all samples collected from the non-Traditional Inhabitant commercial sector were provided by a single vessel, indicating that more samples could be collected each year if additional vessels participated in the sampling. Additional sampling is also possible from the Traditional Inhabitant sectors. Maintaining relationships with key fishery stakeholders, regular community engagement and feedback will be essential to build effective working relationships to support ongoing sampling in the fishery.

The estimated size and age distributions of the samples collected were similar to those from previous sampling programs for the fishery [15, 16]. As such, future similar sampling programs are likely to be able to obtain samples from fish across the entire age range (1-13 years) and in similar proportions in each age class. In fact, age distributions have been relatively consistent over many years of sampling in Torres Strait [3]. Therefore, it is reasonable to assume a similar sampled age distribution for the modelling work when determining the best sampling strategy for CKMR (see Chapter 5).

To facilitate the implementation of CKMR, it will be important to continue tissue sampling from Torres Strait Spanish mackerel in 2022 and subsequent years to build on the samples collected in 2021. CKMR works by comparing individuals from different birth years to identify parent-offspring and half-sibling pairs. Analysing samples from consecutive years increases the probability of finding these close-kin pairs. This becomes particularly important for Torres Strait Spanish mackerel because approximately 80% of the samples are typically in ages classes 2 to 5 years. Therefore, cohorts will pass quickly through the sampled population and years with missing samples will reduce the probability of finding kin-pairs.

Recent advances in epigenetic ageing (reported in Chapter 4) indicate significant potential to estimate age for Spanish mackerel from DNA extracted from tissue samples. If epigenetic ageing was the chosen method for estimating age of fish in a CKMR study, additional muscle tissue may need to be collected from each fish to enable sufficient DNA to be extracted to support both epigenetic ageing and kin-finding for CKMR. Furthermore, the identification of genetic sex markers from tissue samples would enable the accurate assignment of sex to those fish for which sex could not be determined from gonads (i.e. those fish for which only heads were available to be sampled). Therefore, ongoing sampling of Torres Strait Spanish mackerel should ensure sufficient tissue sample is collected for concurrent application of epigenetic ageing, genetic sex determination, and CKMR, which might be achieved by taking a larger sample or multiple muscle tissue samples from each fish.

2.5 Recommendations

- The collection of muscle tissue sampling from Torres Strait Spanish mackerel should continue in 2022 and subsequent years to support the compilation of a tissue bank for future CKMR work.
- 2. The CSIRO-designed gene tagging tool, or other similar technique, should be used when collecting muscle tissue to minimise contamination of DNA between samples.
- 3. Ongoing sampling of muscle tissue should ensure that sufficient tissue is collected to support concurrent application of epigenetic ageing, genetic sex determination, and CKMR.

3 Genetic connectivity between Torres Strait Spanish mackerel and surrounding populations

3.1 Introduction

Developing a CKMR population model requires consideration of the spatial structure of the population. An implicit assumption of CKMR is that all individuals (parents and offspring) have an equal probability of being sampled [6]. However, this assumption can be violated if spatial structure exists within a sampled population and sampling is strongly spatially biased, resulting in negatively biased estimates of abundance [17]. The design of the sampling, therefore, is key to minimising potential biases in CKMR estimates resulting from spatial population structure. A poorly designed sampling scheme would be unable to deliver reliable estimates regardless of modelling efforts and would not provide the information required to determine whether a spatially explicit population model is necessary. Ultimately, with a well-designed sampling scheme, CKMR itself can provide direct information on spatial population structure because observations of closely-related pairs provide a direct measure of population connectivity [18].

The population structure of Spanish mackerel across northern and western Australia was examined in detail most recently by [19]. Using a suite of methods, including isotope ratios in otoliths, parasite abundances, and genetic analyses (allozyme, mitochondrial DNA, and microsatellite DNA), [19] concluded that Spanish mackerel populations across northern and western Australia should be regarded as metapopulations. More specifically, three broad genetically distinct populations were identified: northern/western Australia, Torres Strait, and the Queensland east coast. These results underpin the current management of Spanish mackerel in Australia which is presently applied at the jurisdictional level. However, there have been significant advances in genetic approaches since, such as the use of thousands of single nucleotide polymorphisms (SNPs) spread across the entire genome, for grouping individuals into discrete populations. These advances allow for greater resolution than the allozyme, mitochondrial, and microsatellite approaches used previously for Spanish mackerel, and greatly improve the power to detect population structure by significantly reducing the risk of failing to identify barriers to geneflow due to a lack of adequate genetic resolution [20].

Here, we use SNPs to examine the contemporary genetic population structure in northern Australia. Specifically, we examine the evidence for connectivity between populations of Spanish mackerel between the Torres Strait, Queensland east coast, Gulf of Carpentaria, Northern Territory and Papua New Guinea. The results from this analysis will directly inform the required design of a CKMR population model for Spanish mackerel and the appropriate distribution of sampling to achieve robust estimates from CKMR.

3.2 Methods

Tissue samples from Spanish mackerel were collected from commercial, recreational, traditional commercial and non-commercial fishers in Torres Strat (TS) and commercial

fishers from the Queensland east coast (EC) and Gulf of Carpentaria (GoC) (Figure 5). Additional samples from a previous project [21] which were collected from the EC and Northern Territory (NT) were also used to increase the sample size and spatial coverage for the analysis. Efforts to collect samples from the Gulf of Papua in PNG were unsuccessful. However, 50 samples were sourced from Kavieng in PNG for comparison with other locations (Figure 5). To evaluate the evidence for connectivity of Spanish mackerel among regions, the five sampling regions (NT, GoC, TS, EC and PNG) were used in the analyses.

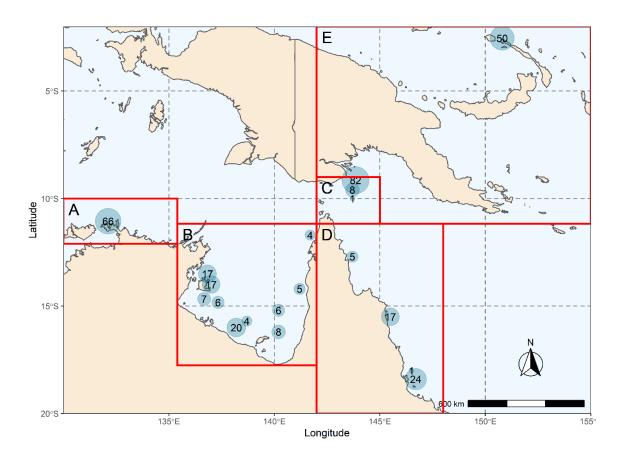


Figure 5. Locations and associated sample sizes of Spanish mackerel sampled in Torres Strait for analysis of population structure. A = Northern Territory (NT), B = Gulf of Carpentaria (GoC), C = Torres Strait, D = Queensland East Coast (EC), and E = Papua New Guinea (PNG)

Initial processing of the first batch of samples collected indicated a potentially significant level of contamination (i.e. the presence of DNA from more than one fish in the same sample). To minimise the risk of contamination in subsequent sampling, a training workshop was held between CSIRO scientists and Fisheries Queensland staff in September 2021 to ensure that the correct procedure was followed when collecting tissue samples in future.

Genomic DNA was extracted using Qiagen DNeasy Blood and Tissue kits following standard protocol and sent to Diversity Arrays Technology for DArTseq genotyping as described elsewhere [20].

Individual samples and DNA marker quality was assessed using the R package *Radiator* [22]. Briefly, markers were screened based on reproducibility, missingness, minimum and maximum coverage, minor allele frequency and Hardy-Weinberg equilibrium. Also, only one marker per RAD contig (short genomic regions sequenced during the DArTseq approach) was kept in order to avoid linkage disequilibrium issues. Individuals with low DNA quality, based on missingness, and samples with abnormally high heterozygosity, likely due to DNA contamination, were removed. Finally, we screened the DNA markers for putative sex markers using the function sexy_markers as implemented in the R package *Radiator* [22].

The presence of population structure was investigated using a Discriminant Analysis of Principal Components (DAPC) as implemented in Adegenet [23, 24], using the sampling regions as putative populations (K=5) and K-1 principal components in order to capture maximal among-population variation while still avoiding over-fitting [25]. We then performed an assignment analysis to evaluate how accurately the true population of origin could be retrieved from the genetic data alone. We also calculated population differentiation pairwise F_{ST} values using the R package StAMPP [26] and p-values were estimated through 1,000 bootstraps.

3.3 Results

The DArTseq approach yielded 57,916 SNPs across 337 samples (including 26 technical replicates added for quality control purposes). A total of 14,651 SNPs and 150 unique individuals passed QC. Most of the samples discarded had high heterozygosity, which is an indication of DNA contamination. Overall heterozygosity was high for samples collected from Torres Strait, Gulf of Carpentaria, and Northern Territory, and low for the Queensland east coast and Papua New Guinea (Figure 6).

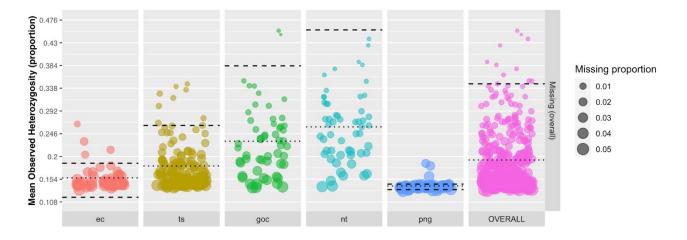


Figure 6. Genome-wide mean observed heterozygosity of Spanish mackerel samples from Queensland East Coast (ec), Torres Strait (ts), Gulf of Carpentaria (goc), Northern Territory (nt), Papua New Guinea (png), and pooled across all regions (OVERALL). Dashed horizontal lines indicate the average and 95% confidence limits of heterozygosity for each dataset. The size of each data point relates to the proportion of missing data in the SNP markers for each individual.

A total of 128 samples (out of a total of 278) were considered to contain sufficient contamination to be discarded from the analysis (Table 2). The largest proportion of contaminated samples were collected from Torres Strait, the Gulf of Carpentaria and the Northern Territory. For the 91 samples from Torres Strait, a much higher proportion of contaminated samples were found prior to the training (67%) compared with after the training (25%).

Table 2. Total number of samples collected including number of samples retained or discarded from the analysis due to contamination.

Location	Retained	Discarded	Total
Northern Territory	6	41	47
Gulf of Carpentaria	9	38	47
Torres Strait	51	40	91
East coast	39	7	46
Papua New Guinea	45	2	47
Total	150	128	278

No sex markers were identified, and we were able to proceed to clustering analysis with all 14,651 markers. The DAPC revealed four distinct genetic groups, one per sampling location except for the Northern Territory and Gulf of Carpentaria which presented very similar genetic signatures (Figure 7).

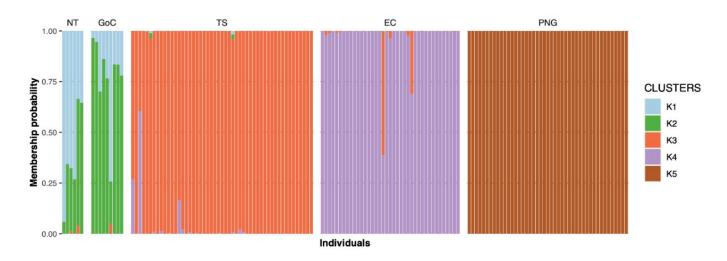


Figure 7. Probabilities of membership of each individual fish (bars) from Northern Territory (NT), Gulf of Carpentaria (GoC), Torres Strait (TS), Queensland East Coast (EC), and Papua New Guinea (PNG) to one of five genetic groups (clusters).

Assignment success was over 97% for Torres Strait, Queensland east coast and Papua New Guinea, but only 89% and 17% for the Gulf of Carpentaria and Northern Territory respectively (Figure 8). Pairwise population differentiation F_{ST} values ranged from 0.0014 (NT vs GoC) to 0.0743 (GoC vs PNG) with F_{ST} values an order of magnitude higher between PNG and other locations than between locations on the Australian coastline. All F_{ST} values were statistically significant except for the northern Territory vs Gulf of Carpentaria (Table 3).

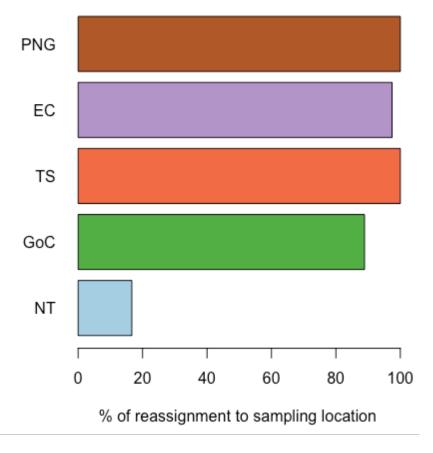


Figure 8. Percentage success in reassigning individual fish to the location they were sampled from (PNG, EC, TS, GoC or NT).

Table 3. Population differentiation pairwise FST (lower diagonal) and associated p-values (upper diagonal).

Location	NT	GoC	TS	EC	PNG
Northern Territory	-	0.145	<0.001	<0.001	<0.001
Gulf of Carpentaria	0.0014	-	<0.001	<0.001	<0.001
Torres Strait	0.0054	0.0054	-	<0.001	<0.001
East coast	0.0071	0.0076	0.0034	_	<0.001
Papua New Guinea	0.0737	0.0743	0.0589	0.0692	-

3.4 Conclusions

The analysis of SNPs revealed strong evidence of genetic population structure of Spanish mackerel across Northern Australia and PNG. Within the area sampled, four distinct genetic populations of Spanish mackerel were identified which included Torres Strait, PNG, Queensland east coast and a combined Northern Territory and Gulf of Carpentaria population. The strength of the differentiation of these populations provides a very clear example of the power of the SNP markers to identify population structure.

The pattern of population structure is consistent with previous work by [19], and reinforces the existing paradigm that genetic boundaries for Spanish mackerel occur between Torres Strait and the Queensland east coast and Gulf of Carpentaria, and that significant connectivity exists between the Gulf of Carpentaria and the Northern Territory. While we observed a distinct genetic separation between Torres Strait and Kavieng in PNG, we were not able to collect samples from the Gulf of Papua, which is in closer proximity to Torres Strait, so we cannot rule out the possibility of connectivity between Torres Strait and the Gulf of Papua.

Current management arrangements for Spanish mackerel in Australia assume separate stocks in Western Australia, Northern Territory, Queensland Gulf of Carpentaria, Torres Strait, and the Queensland/New South Wales east coast. Our results support the assumption of separate stocks in Torres Strait and the Queensland east coast, but the lack of genetic differentiation between fish sampled in the Gulf of Carpentaria and Northern Territory suggest that Spanish mackerel is likely to be a shared stock across these areas. The absence of samples from the Gulf of Papua limits our ability to determine whether Spanish mackerel is a shared stock between Torres Strait and the Gulf of Papua in PNG.

Although there is strong evidence that Spanish mackerel are a single genetic stock in Torres Strait, there was some indication of a low level of genetic mixing between the Torres Strait and the Queensland east coast in a very small number of individuals. These individuals from the Queensland east coast were all captured north of Cooktown, where a low level of connectivity with Torres Strait, perhaps via larval exchange, might be expected. Evaluating the level of connectivity in this region is unlikely to be resolved much further by analysing SNPs from additional samples. However, the simultaneous implementation of CKMR in Torres Strait and Queensland would provide a direct measure of the level of connectivity and potential boundary between these two regions on a demographic time scale that is most relevant to management [18].

The strong evidence of a separate genetic stock of Spanish mackerel in Torres Strait supports the development of a CKMR population model specifically for this region. The potential for connectivity between Torres Strait and the Gulf of Papua (which could not be evaluated in this study) will not affect CKMR as long as all fish (of a given size, age, sex etc.) in the population have an equal probability of being sampled [17]. If Spanish mackerel are well-mixed between Torres Strait and the Gulf of Papua, then CKMR can provide a robust estimate of the size of the population across both regions when sampling only in Torres Strait. However, if Spanish mackerel are not well-mixed between Torres Strait and the Gulf of Papua, but form a single genetic stock, and sampling for CKMR occurs only in Torres Strait, then CKMR may produce a biased estimate of abundance [17]. Collection of

Spanish mackerel samples from the Gulf of Papua to confirm the level of connectivity between Torres Strait and the Gulf of Papua is recommended. This could be achieved through analysis of SNP data from a relatively small sample size (~50), or through the implementation of CKMR which would require substantially more samples.

3.5 Recommendations

- 1. It is appropriate to assume that the Spanish mackerel population in Torres Strait is genetically separate from the Gulf of Carpentaria and the Queensland east coast.
- 2. Additional Spanish mackerel samples should be collected from the Gulf of Papua to confirm the level of connectivity between Torres Strait and the Gulf of Papua.
- 3. Future application of CKMR should be implemented simultaneously in Torres Strait and Queensland to provide a direct measure of the level of connectivity and potential boundary between these two regions.

4 Evaluation of epigenetic ageing for Torres Strait Spanish mackerel

4.1 Introduction

The application of CKMR requires an estimate of age for the individuals that are sampled in order to derive birth year and age-specific parameters for the calculation of kinship probabilities [6]. For example, the probability that an individual is the parent of a juvenile is only greater than zero if the individual was alive and mature at the time that the juvenile was born. This can be determined with knowledge of the birth years of both the putative parent and juvenile, and the age-specific maturity and mortality schedules for the species. Therefore, information on age is important for the successful application of CKMR.

Age can be estimated from a range of methods including length measurements or other morphometrics, but the most common and robust method for estimating the age of fish is by counting growth increments in otoliths [27]. For Spanish mackerel, counts of annual increments in whole otoliths have been validated through marginal increment analysis [28] and is the most commonly used method to estimate age. For Torres Strait Spanish mackerel, an established biological sampling program has been collecting otoliths since 2019 for the purpose of estimating age of individuals and deriving age frequency distributions for stock assessments [16]. During this sampling program, approximately 300 otoliths have been collected and processed each year for age estimation.

CKMR is likely to require age estimates from substantially more than 300 individuals per year, with the potential for more than 1000 samples to be required annually. To increase the current otolith sampling and processing to provide the number of age estimates required for CKMR would be logistically difficult and potentially costly. Finding an alternative ageing method that is more logistically feasible, cost effective, and with an acceptable level of precision, is therefore a priority for the application of CKMR.

Recent advances in epigenetic ageing using DNA methylation are demonstrating encouraging results across a range of species [29-32]. In vertebrates, the most common form of DNA methylation is the addition of a methyl group to cytosine residues within cytosine-phosphate-guanine (CpG) sites [33]. In zebrafish (*Danio rerio*), the methylome (DNA methylation genome-wide) has been fully characterised [30]. This has enabled the identification of CpG sites that are age-associated, which makes it possible to identify age-associated and conserved sites in other species. For example, the CpG sites known to be age-associated in zebrafish have been used to develop epigenetic clocks in Murray cod (*Maccullochella peelii*) and the evolutionary distant Australian lungfish (*Neoceratodus forsteri*) [29]. Therefore, if a reference genome and an adequate training data set of known ages are available, it is possible to transfer epigenetic clocks between fish species [34].

Here, we evaluate the utility of epigenetic ageing to provide precise estimates of age for Spanish mackerel. The Torres Strait Spanish mackerel biological sampling program provides an excellent source of samples for this evaluation given that otoliths have already been collected and aged for several hundred individuals, and tissue samples are available

for many of these. We also evaluate the relative cost in estimating age from otoliths or from epigenetics based on potential sample sizes required for CKMR.

4.2 Methods

Otoliths and tissue samples from Spanish mackerel were collected from 200 fish provided by commercial, recreational, and traditional non-commercial fishers in Torres Strait. Methods for extracting, processing and reading otoliths, including quality control procedures are outlined in [16], but briefly described here.

Age estimates for each fish were derived from counting the number of opaque increments between the primordium (nucleus) and the distal (outside) edge of whole otoliths. The edge of each otolith was classified as new, intermediate, or wide. Estimates of age in months for each fish were then obtained using information on the month of capture, the number of annual increments, the otolith edge type category, and a presumed birth date of November 1.

Genomic DNA was extracted from tissue samples using the DNeasy Blood and Tissue Kit (QIAGEN) as instructed by the manufacturer's protocol. DNA was bisulfite treated using a modified version of a previous protocol [35].

To develop an epigenetic clock for Spanish Mackerel, we used the same approach that we have used previously on other fish [29]. Using a genome pairwise alignment method we identified age associated CpG sites conserved between zebrafish and Spanish mackerel. The reference genomes were pairwise aligned using LASTZ with the following options: --notransition --step=20 -nogapped. CpG sites that were both known to be age associated in zebrafish and conserved between both species were targeted for primer design in the multiplex PCR assay.

Multiplex PCR was designed for one pool of primers with age associated CpG sites in zebrafish using PrimerSuite [36]. Each amplicon was tested in singleplex with GoTaq® Flexi DNA Polymerase (Promega) using the manufacture's recommended protocol. The annealing temperature was tested between 55-60°C. Primer pairs that produced multiple or no bands were excluded from the multiplex PCR reaction. Barcoding was carried out using the Fluidigm 384 set of barcodes (Cat. 100-4876). Multiplex PCR and barcoding reaction were clean-up using the Solid Phase Reversible Immobilization (SPRI) Methodology (Bio-strategy, Cat. GEHE65152105050250) as previously described [37]. Barcode reactions after clean-up were pooled together in equal volumes and were sequenced using an Illumina MiSeq Reagent Kit v2 (300 cycle; PN MS-102-2002) was used for 150bp paired-end sequencing.

Sequencing reads were hard clipped by 15bp at both 5' and 3' ends by SeqKit v1.2 to remove any trailing adaptor sequences [38]. Reads were aligned to the targeted amplicon sequences using Bismark v0.20.0 with the following parameters: --bowtie2 -N 1 -L 15 - bam -p 2 -score L, -0.6, -0.6 -non_directional [39]. DNA methylation was called using the default parameters in the bismark methylation extractor function [39].

To generate the model to predict age from DNA methylation, samples were randomly assigned to either a training or testing data set with a 70/30 split respectively. Age in years was log transformed to fit a linear model using an elastic net regression model [40]. The glmnet function in the glmnet R package was used to apply the elastic net regression model [40]. The glment function was set to a 10-fold cross validation and the α -parameter was set to 0.5 similar to other studies [30, 41-43]. By setting the α -parameter to 0.5 allowed the model to identify the minimum number of sites required to predict age with the amplicon sequence. This allowed other CpG sites that were captured during the amplicon sequencing to be part of the model. The testing data set was used as a validation of the model. The performance of the model was measured using Pearson correlations, median absolute errors, and the age-specific coefficient of variation.

4.3 Results

Genome pairwise alignment identified 5,287 CpG sites conserved between species. Of the 1,311 CpG sites found to be age associated in zebrafish, 138 were found to be conserved. Since 138 amplicons is too many for one multiplex PCR, the CpG sites were ranked by Pearson correlation. 17 amplicons were successful for one multiplex PCR assay.

On average, per sample, 44,203 reads aligned to the reduced representative reference genome with an alignment rate of 97.3%. A high correlation was found in the training data set between the otolith and predicted age (Figure 9A, Pearson correlation = 0.93, p-value < 2.20×10^{-16}). The high correlation was also maintained in the testing data set (Figure 9B, Pearson correlation = 0.93, p-value < 2.20×10^{-16}). This suggests a lack of overfitting as the training and testing data set had similar performance. This was further demonstrated with no statistical difference found between the absolute error rates between the training (median = 4.6 months) and the testing (median = 4.9 months) data sets (Figure 10, p-value = 0.89, t-test, two-tailed).

The performance of the model was also analysed with increasing annual age (Table 4). The model decreased in performance as measured by median absolute error, but when scaled to the age of individuals, the performance was relatively consistent across ages in terms of standard deviation (SD) and coefficient of variation (CV), with a CV range of 0.1 to 0.2. This suggests the model is relatively precise in estimating age of individuals across the age classes included in the testing data (1-8 years). Furthermore, most estimates of age derived from epigenetics were within 1 year of those derived from otoliths (Figure 10).

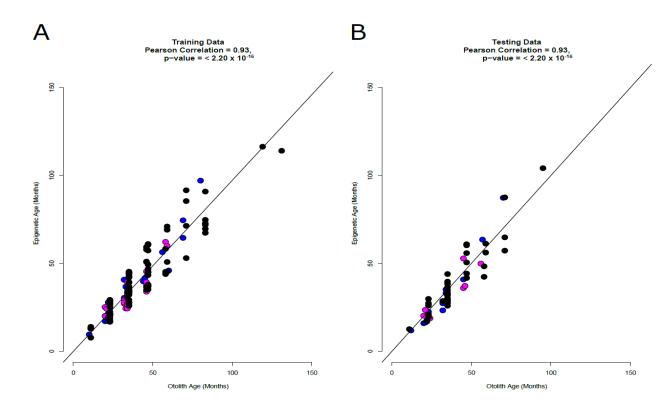


Figure 9. Correlation between the otolith age and the predicted age in the A. training data set and B. testing data set. Both data sets show a high and consistent correlation (Pearson correlation = 0.93, p-value < 2.20×10^{-16}). Each dot represents and individual fish (Blue = Male, Pink = Female, Black = Unknown Sex).

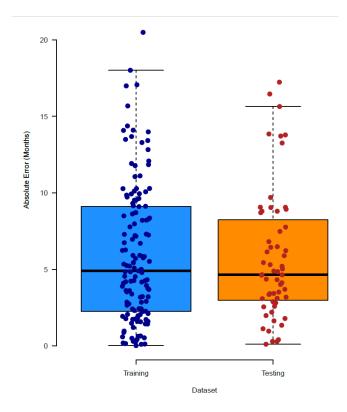


Figure 10. Boxplots showing the absolute error rate in both the training and testing data sets. No statistical difference was found between the error rates in the data sets (p-value = 0.89, t-test, two-tailed).

Table 4. Performance of the Spanish mackerel epigenetic clock across age classes in the testing data sets (note: there were no 7-year-old fish in the sample).

Age (Years)	Median Absolute error (Years)	Standard deviation (SD)	Coefficient of Variation (CV)
1	0.17	0.14	0.14
2	0.27	0.32	0.16
3	0.42	0.49	0.16
4	0.75	0.79	0.20
5	0.56	0.73	0.15
6	1.28	1.20	0.20
7	-	-	-
8	0.76	0.76	0.10

In addition to the precision in age estimates, it is also important to compare the relative costs of the different ageing methods to evaluate which ageing method would be more appropriate for the application of CKMR. Table 5 outlines the current costs (\$/individual) of ageing Spanish mackerel using whole otoliths (by Queensland Fisheries) or epigenetics (by CSIRO) based on a sample size of 1,000 fish. To provide a total cost for each ageing method, the table includes the cost of fish sampling (purchasing and shipping of fish samples from the fishery), even though this is required for both ageing methods. DNA extraction costs are not included in the epigenetic ageing, as DNA extraction would be completed and costed as part of the CKMR sample preparation. The total costs indicate that epigenetic ageing is \$6.15 per sample more expensive than estimating age from whole otoliths. The difference is mostly due to the costs associated with laboratory consumables and DNA sequencing.

Table 5. Approximate current (2022) costs (\$/individual) for the ageing of Spanish mackerel using whole otoliths or epigenetic ageing.

Item	Otolith ageing	Epigenetic ageing
Sampling (purchasing, shipping, extraction)	\$19.10	\$19.10
Sample processing and analysis (labour)	\$20.90	\$14.00
Laboratory consumables (incl. DNA sequencing)	\$0.80	\$13.85
Total	\$40.80	\$46.95

4.4 Conclusions

The epigenetics model developed to predict age for Spanish mackerel from DNA methylation provides a useful, precise and unbiased alternative method for age estimation of the species. Furthermore, the strong correlation between age estimated from otoliths and epigenetic ageing indicates that epigenetic age can produce more reliable estimates of age than other metrics such as fork length or jaw length, which poorly estimate the age of Spanish mackerel, particularly at ages >2 years, due to the large variability in length at age and an asymptotic growth curve (e.g.[15]). The low bias and relatively high level of precision of epigenetic ageing for Spanish mackerel means it will be a valuable method in the application of CKMR where age estimates are used to assign birth years (not age in months) and the models can account for errors in age estimates.

The epigenetics model developed here for Spanish mackerel was limited to an age range of 1-8 years. For a more complete application of the model for CKMR, it will be necessary to extend the age range in the model to approximately 13 years, which is the oldest fish sampled to date from Torres Strait [15]. The extension of the age range for the model would not be a costly exercise, as only 5-10 samples from five or so age classes would be required (i.e. approximately 50 samples). However, it would require the collection of tissue samples from the oldest fish sampled from the fishery, which may take some time to accumulate given these older fish are relatively rare in the catch. Samples collected from other regions where older fish are more common, such as the Queensland east coast, could be used to extend the age range of the epigenetics model, as the model is not stock specific.

The application of epigenetic ageing to Torres Strait Spanish mackerel will be dependent on the relative costs compared to estimating age from otoliths. This study showed that the cost of epigenetic ageing is currently around \$6.15 per sample more expensive than estimating age from whole otoliths, with the difference mostly due to the costs associated with laboratory consumables and DNA sequencing. It is likely that these costs will decline in the near future as technology improves and efficiencies in the processing are made, particularly when larger samples sizes are processed during a routine ageing process [44]. The current costing method is based on completing the laboratory task by hand. Further development is currently being undertaken to use more commercially available reagents and to automate the process with high throughput robotics. This will further decrease the laboratory consumables and labour costing. DNA sequencing cost is also expected to decrease when the platform is transferred to a larger operation with an Illumina NovaSeq where a larger number of samples (>1,500) can be run at a similar current cost to the current 384 samples, resulting in a reduction in cost of approximately \$4 per sample.

However, until the costs are more comparable, it will be more cost effective, and accurate, to age Spanish mackerel from whole otoliths. In the meantime, epigenetic ageing will be a valuable alternative method for estimating the age of fish when otoliths are not available, but tissue samples have been collected, or in cases where it is logistically difficult to collect large numbers of otoliths, but easy to collect a tissue sample. The identification of sex markers for Spanish mackerel would also enable these tissue samples to be used to determine the sex of individuals when gonads are not available. When epigenic ageing

becomes cheaper than estimating age from otoliths, it would be worthwhile revisiting the potential to use epigenetics for estimating age of Spanish mackerel.

4.5 Recommendations

- Additional tissue samples should be collected from older Spanish mackerel (>8
 years) to enable the extension of the age range of the epigenetics ageing model,
 which would support a more complete application of the model for CKMR. These
 samples would not necessarily need to be collected from Torres Strait, as the model
 is not stock specific.
- 2. The epigenetics model for Spanish mackerel provides sufficiently precise and unbiased estimates of age for CKMR, but current costs indicate that it would be cheaper to use otoliths to estimate age. Epigenetic age estimation should be considered in future CKMR studies or other applications for the species, when otoliths are not available, are logistically difficult to collect, or when the costs of epigenetic ageing become cheaper than otoliths.

5 Designing close-kin mark-recapture for Spanish mackerel

5.1 Introduction

Annual catches of Spanish mackerel in Torres Strait averaged around 200 t in the 1980-2005 period, peaking at over 300 t in 2005 [2]. However, catches have declined rapidly since then to average less than 100 t in recent years [2]. Recent stock assessments have estimated that the spawning biomass of Torres Strait Spanish mackerel has declined to levels close to the Commonwealth Fisheries Harvest Strategy limit reference point of 20% of unfished biomass [3]. In 2018, the Torres Strait Spanish mackerel stock was estimated to be at approximately 23% of unfished biomass [4], but recovered to approximately 30% of unfished biomass in 2019 [3] and 2020 [5]. The declining status of the stock resulted in reductions in the TAC for the fishery in each year since 2016.

Torres Strait Spanish mackerel stock assessments use standardised catch per unit effort (CPUE) as the primary index of abundance. However, the Torres Strait Finfish Resource Assessment Group (FFRAG) has identified several uncertainties in the standardised CPUE series, which can have an impact on the estimated levels of abundance. Hyperstability is considered to be one of the main uncertainties with the standardised CPUE and occurs when CPUE remains relatively high despite a decline in the overall abundance. Spanish mackerel in Torres Strait are likely to exhibit hyperstability due to the large spawning aggregations that form around Bramble Cay, where the majority of the annual catch is taken. There has also been a large decline in the number of commercial vessels operating in the fishery, which reduces the amount of data available to inform the analysis of the standardised CPUE. Therefore, uncertainty remains in the actual relationship between standardised CPUE and the underlying population abundance, and the FFRAG has highlighted the need for research that can provide alternative, fisheries-independent, estimates of abundance.

Close-kin mark-recapture (CKMR) is a new, but proven, technique that uses modern genetics to identify closely related pairs from samples of fish, enabling estimation of key population parameters, such as absolute spawning biomass and natural mortality, without needing fisheries-dependent CPUE data [6]. CKMR has been successfully applied since 2013 to southern bluefin tuna, transforming the stock assessment for this species and forming an ongoing key index of abundance [7-9]. CKMR has also been applied successfully to Australian shark species [10, 11] and to several commercial fish stocks overseas [12-14]. In 2020, the FFRAG supported the development of a project to evaluate the feasibility of CKMR for providing an estimate of abundance for Torres Strait Spanish mackerel.

CKMR design studies simulate the process of conducting a CKMR analysis for a given species. They are used to predict the coefficient of variation (CV) of estimates of population or management metrics of interest that would result from a CKMR analysis including a given number of genotyped individuals. A target CV of 15% for key management metrics (e.g. spawning biomass) is often used as a benchmark for an

acceptable level of parameter uncertainty. Given the costs of CKMR, the design phase is an important step to undertake prior to implementation in order to assess the number of genotyped samples required to achieve the target CV. Alternative sampling strategies can also be explored to see, for instance, whether the number of years of sampling, the age distribution of the samples, or the distribution of samples through time can improve precision.

Apart from information on the biology of the species, the design phase requires assumptions about the true population size, which can be taken from a recent stock assessment if available. If the true population size is lower than the assumed size, then CKMR will provide abundance estimates with a precision that is greater than the required precision. If the true population size is larger than assumed, then the CKMR estimate of abundance will be less precise, but the finding that the stock is larger than previously thought is also useful to management.

Here, we use parameters and abundance estimates from the most recent Torres Strait Spanish mackerel stock assessment [5] to evaluate alternative sampling designs for the application of CKMR. Sampling designs explored the effect of varying the number of total samples over three- to five-years sampling program, evenly spreading of the samples per year vs. having greater emphasis on the first year of sampling, and sampling different proportions of the catch-at-age. The performance of alternative sampling designs was measured in terms of the expected precision of the resulting estimates of spawning biomass, total stock fecundity and natural mortality. The precision of estimated ages in the collected samples (i.e. ageing error) was also considered.

5.2 Close-kin mark-recapture overview

CKMR uses modern genetics to identify closely related pairs of fish ('kins', such as parent-offsprings and siblings). The number of kin-pairs identified, and how they are distributed in space and time, are used to estimate key population parameters, such as absolute spawning biomass, total mortality, and connectivity [6]. CKMR is different to other types of mark-recapture approaches in that offspring 'tag' their parents via their DNA, and half-siblings 'tag' each other and their parents via their shared DNA. CKMR requires collection of tissue samples for DNA extraction and genotyping, but these can be sampled from dead fish (i.e., fishery catches). In contrast to other mark-recapture approaches, there is no requirement to consider tag shedding, tag-induced mortality, mixing rates of tagged fish, or reporting rates of recaptured fish.

The concept of CKMR is based on the fact that every individual has exactly two parents [6]. For a given sample from a population, we would then expect to find more parent-offspring pairs (POPs) in a smaller population than we would from a larger population. The probability that any random comparison between a juvenile and adult in the population is a parent-offspring pair can be expressed as:

$$\Pr\left(POP\right) = \frac{2}{N_{parents}}$$

where N_{adults} is the total number of adults in the population and the 2 represents the two parents of each offspring. The expected number of observed POPs, k, for a sample from the population can then be determined by summing the probabilities across all possible adult-juvenile comparisons from the sample, such that:

$$k=rac{2(m_{parents} imes m_{offspring}}{N_{parents}},$$
 or $N_{parents}=rac{2(m_{parents} imes m_{offspring}}{k}$

where $m_{parents}$ and $m_{juveniles}$ are the number of adults and juveniles sampled from the population, respectively. Another type of useful kin probability is the probability that any two individuals share a parent (i.e., they are half-siblings). Both types of kin probability depend on population dynamics for the stock, and so can be used to derive estimates of population parameters.

Parent-offspring pairs and half-sibling pairs provide different information in CKMR population models. Parent-offspring pairs primarily inform estimates of relative reproductive output, while half-sibling pairs allow us to estimate total mortality. We can then partition estimates of total mortality (Z) into natural mortality (M) and fishing mortality (F) if data on catch-at-age/size are available. The application of CKMR across several years also allows us to estimate relative reproductive output by size/age and connectivity across the sampled areas.

The explanation above is an oversimplification of the CKMR approach. Other factors that are considered in a real application include adult mortality in the interval between birth and sampling, relative fecundity of fish by age or sizes, non-random sampling, and uncertainties with genotyping individuals (Bravington et al. 2016).

In summary, the application of CKMR involves at least five main elements:

- 1. A design phase (this chapter) to determine the sampling design that will yield a sufficient number of kin pairs to achieve the required level of precision in parameter estimates from CKMR.
- 2. Collection of tissue samples from a stratified sample of the population, where a design study evaluates the likely precision in CKMR estimates from alternative spatial locations and size/age/sex structures of the samples.
- 3. Genotyping of the samples using a sufficient number of genetic markers that enable the detection of closely related individuals.
- 4. Kin-finding to accurately identify closely-related pairs. Parent-offspring pairs (POPs), and half-sibling pairs (HSPs) have proved feasible and sufficient in applications to date. Full-sibling pairs are not as useful for most teleost CKMR applications.
- 5. A population model to find the parameters that achieve the best fit between the observed and expected number of closely-related pairs, given the sampling design and the demographic co-variates (e.g. length, age, sex) from the population. The population model is very similar to a standard age-structured stock assessment model.

5.3 Methods

A CKMR analysis was simulated to estimate the expected precision in key population metrics under different sampling regimes. The steps are summarised here briefly and described in further details below:

- A simplified version of the most recent stock assessment for Torres Strait Spanish mackerel [3] was produced to generate estimates of population size (in numbers) by age;
- A 5-year CKMR sampling program was defined outlining the number of annual samples, their distribution across years, and the distribution of samples by ageclass;
- The population was projected into the future for the number of years covered by the sampling program;
- The projected population was sampled and age estimated according to the sampling scenario;
- The precision of key population metrics under the sampling scenario was estimated from the probability of observing POPs and HSPs given the projected population abundance and the sampling regime;
- Different sampling scenarios were explored to identify sampling designs resulting in higher precision of key population metrics.

Precision for natural mortality (M), total reproductive output and total reproductive output in equivalent three-year-old is estimated for each sampling scenario.

Total reproductive output is converted to the number of 'equivalent' three-year-old fish needed to produce this output given fecundity at age. This allows us to convert reproductive output in a more concrete population metric (similar to spawning biomass). Any age could be used; we chose 3 years because most of the reproductive output for Spanish mackerel over the sampling period is provided by 2- and 3-year-olds, and about 75% of individuals are mature at 3 years old.

5.3.1 Population model

The two main quantities required to estimate the expected number of POPs and HSPs given a sampling regime are the total population fecundity and the distribution of numbers-by-age. A simplified version of the age-structured model used in the most recent stock assessment for Torres Strait Spanish mackerel [3] was used to predict these quantities and project them over a sampling program of a 5 years.

The 2021 stock assessment explored multiple scenarios spanning different assumptions about *M* and the shape of the fishing selectivity curve. "Analysis 5" from the 2021 assessment was used as a baseline for the CKMR population model as it assumes the median natural mortality, uses a logistic selectivity curve which has a straightforward interpretation, and the prediction of median depletion was closest to the overall median depletion across all scenarios.

Simplifications to the 2021 stock assessment model included fixing selectivity parameters to those estimated in the stock assessment, assuming a random walk for recruitment whereby annual recruitment deviates are derived from the stock assessment predictions of

numbers at age 0, and fitting the age-structured model to annual catch data (Figure 11) instead of catch-at-age data. Fishing mortality by age was estimated from annual catches using the Baranov catch equation.

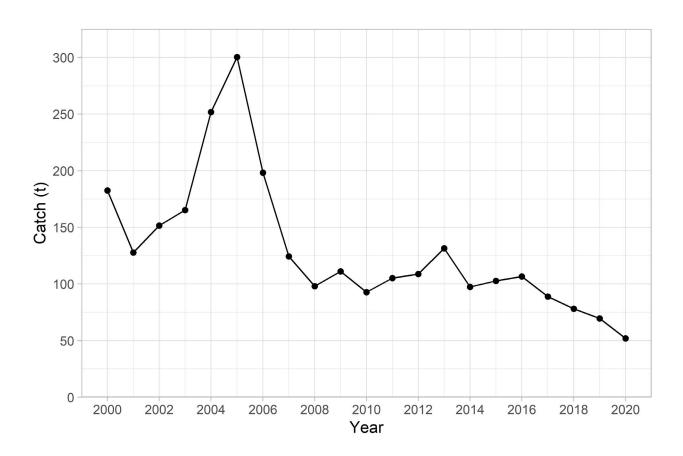


Figure 11. Time series of catches of Torres Strait Spanish mackerel from 2000 to 2020 (data sourced from [3])

The CKMR population model was defined over the period 2000 to 2020, the last year of the stock assessment, with an additional projection period of 5 years to span a future sampling program. Of note, the CKMR model timeframe does not necessarily need to match that of the stock assessment (which starts in 1940). Instead, it only needs to span a period long enough that we can assume that all individuals sampled as part of the sampling program were born during the timeframe of the model. This is because individuals born outside of the model timeframe cannot be used for CKMR estimation. As such, a start year of 2000 was chosen as a conservative value to ensure all individuals sampled as part of the CKMR program (assumed to start in 2021) have been spawned, given very few individuals survive beyond age 12 years.

An age plus-group was defined to include individuals aged 13 years and above. This threshold was high enough to ensure that their contribution to total reproductive output (TRO) at the level of the population was low enough that it could be ignored.

Model parameters are included in Table 6. Fishing mortality at the start of the model was tuned to reproduce total abundance (in numbers) for the year 2000 in the 2021 stock assessment model. To project the population in the future, catches were assumed to stay constant at 2020 levels and recruitment deviates were sampled with replacement from the most recent five annual recruitment deviates (Figure 12).

Table 6. Parameters used in the CKMR population model

Parameter	Description	Value
Ls∞	Sex-specific L_{∞} for von Bertalanffy growth model	F = 160.32 cm TL
		M = 159.95 cm TL
Ks	Sex-specific k for von Bertalanffy growth model	F = 0.13
		M = 0.08
ts0	Sex-specific t_0 for von Bertalanffy growth model	F = -5.78 y
		M = -9.93 y
ms50	Sex-specific age at 50% maturity (assumed equal for each sex)	1.59 y
ms95	Sex-specific age at 95% maturity (assumed equal for each sex)	5.42 y
as	Sex-specific parameter for weight-at-age exponential curve	F = 2.96e-6
		M = 4.224e-6
bs	Sex-specific b parameter for weight-at-age exponential curve	F = 3.148
		M = 3.068
s50	Age at 50% selectivity	1.72 y
s95	Age at 95% selectivity	2.34 y
М	Natural mortality	0.35 y ⁻¹
aplus	Age of plus-group	13 y
amat	Age at first maturity	1 y
F ₁	Equilibrium fishing mortality in first model year (2000)	0.368 y ⁻¹
R_0	Mean annual recruitment in first model year (2000)	84,070
Design code		
nsamp_y	Number of annual CKMR samples	750, 1000, 1250,
		1500
Pr_HSP_detection	proportion of true HSPs that are detected during kin finding	0.75
nci f	power parameter for female fecundity-at-age relationship	1.01
psi_f	, , ,	
psi_m	power parameter for male fecundity-at-age relationship	2000
first_dy	First year in population dynamics model	
last_dy	Last year in population dynamics model	2025
first_sy	First year in which CKMR sampling occurs	2021
last_sy	Last year in which CKMR sampling occurs	2025
Catch_y	Constant catches over the projection period	65 t

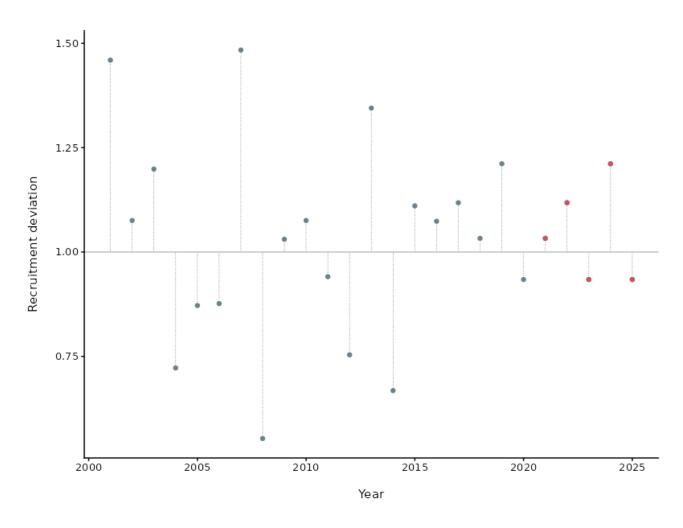


Figure 12. Annual recruitment deviation computed from 2021 assessment model prediction for age-0 individuals and used in the simplified CKMR population model. Recruitment deviates for the projection period are shown in red.

5.3.2 Sampling scenarios

Different sampling scenarios were chosen to span plausible sampling options for Spanish mackerel in Torres Strait, starting in 2021. The default sampling scenario sampled 1,000 individuals annually over 5 years (i.e. 2021 to 2025; Figure 13). From this, we varied the annual number of samples, their distribution over time, and the length of the sampling program:

- 1. Equal sampling levels over the sampling period, with 750, 1,000, 1,250 and 1,500 individuals sampled annually, corresponding to 3,750, 5,000, 6,250 and 7,500 total samples.
- 2. The same number of total samples overall but with greater emphasis in the first year, such that the first-year samples are 50% higher than samples for subsequent years (e.g., for 5,000 total samples, this results in about 1,360 samples in the first year and 900 samples in the remaining four years).
- 3. The same number of annual samples (750, 1,000, 1,250 and 1,500) but a shorter program length of 3 or 4 years.

For these scenarios, samples are drawn proportionally to the predicted catch-at-age over the sampling period.

A fourth sampling scenario was trialled to explore the distribution of annual samples by age:

4. Samples drawn proportionally to the predicted catch-at-age over the sampling period but with slightly greater emphasis on sampling larger individuals (ages 4 to 6), as their cumulative reproductive output at the time of capture would have been higher.

For this scenario, samples were evenly distributed over five years.

The three types of sampling scenarios for a five-year program are illustrated in Figure 13. Catch-at-age is projected given assumed future catches from 2021 to 2025 (Table 6), and annual samples by age are distributed across ages according to the proportion of catch-at-age for each projected year. Samples are distributed evenly across both sexes.

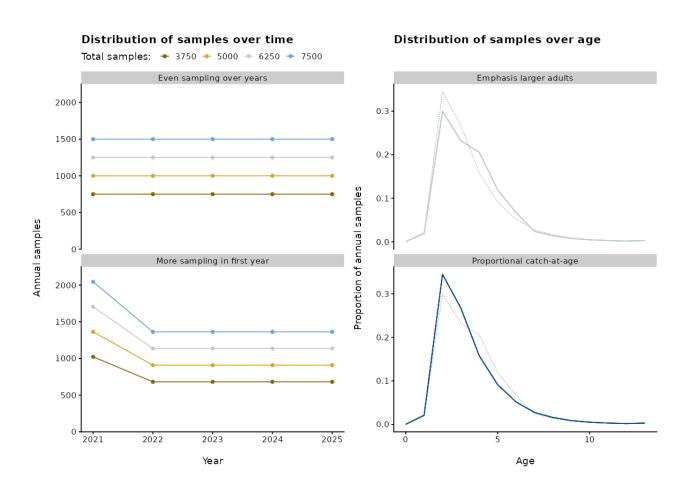


Figure 13. Distribution of samples over time (left column) and age (right column) for different sampling scenarios. To ease comparison, the dotted line in the right column panels show the age-distribution for the other catch-at-age scenario.

5.3.3 Estimation of CVs for population metrics

Coefficients of variation (CVs) for key population metrics were first estimated under the assumption that the age of sampled individuals is known exactly. The approach is currently being expanded to account for age uncertainty when computing the probability of observing a POP or an HSP (see below).

The estimation of CVs for quantities computed within a CKMR population modelling framework consisted of three main steps:

Step 1:

Population dynamics for Torres Strait Spanish mackerel was estimated from 2000 to 2025 as detailed in the previous section. For close-kin computations, three resulting quantities are especially important: numbers at age ($N_{t,a,s}$ is individual abundance at time t, age a and sex s), survival at age (from natural and fishing mortality), and Total Reproductive Output (TRO) for the stock at time t:

$$TRO_{t,s} = \sum_{a=0}^{A} N_{t,a,s} \varphi_{a,s}$$

where $\varphi_{a,s}$ is fecundity at age a and sex s, defined by a power relationship between weight-at-age and individual reproductive output, scaled by maturity-at-age.

Step 2:

Given population dynamics estimated in the first step, compute the probability of observing a POP or a HSP for each pairwise combination of individual samples, as a function of the year they were sampled, their age at sampling and, for POPs only, the sex of the parent, for a given number of samples.

The following assumptions are made:

- Population dynamics (selectivity, maturity, fecundity, length) vary across age only, with no variability in individual length-at-age;
- Samples taken from the plus group are ignored (i.e., they do not contribute to improving the precision of population metrics of interest). The plus-group contributes to less than 1% of the TRO for Torres Strait Spanish mackerel over the years of the sampling program, so this should have minimal impact;
- POPs and HSPs are computed but grandparent-grand offspring pairs (GGPs) are not explicitly modelled (see below).

The probability that an individual of age a_i captured in year t_i is the parent of an individual born in year c_i is defined as:

$$\mathbb{P}(POP | \{i, j\}) = \mathbb{I}(c_j < t_i < c_j + a_i) \frac{\varphi_{a_i - (t_i - c_j), s_i}}{TRO_{c_j, s_i}}$$

which is the ratio of the fecundity of a possible parent of that age in the year that the juvenile was born to the total reproductive output of the population in that year. This probability only gets computed if the possible offspring was born before the possible parent was captured (given lethal sampling), and if the possible offspring was born after the possible parent was born. Otherwise, it is set to zero.

The probability that an individual i born in year c_i is the half-sibling of an individual i' born in year $c_{i'}$ is the probability that an unobserved individual of unknown age would have been the parent of offspring born in two different cohorts separated by the difference in birth years between the cohorts ($\delta_i = c_{i'} - c_i$):

$$\mathbb{P}\left(HSP \mid \{i, i'\}\right) = \sum_{s} \sum_{a} \left(\frac{N_{c_{i}, a, s} \varphi_{a, s}}{TRO_{c_{i}, s}} \times \left[\frac{\eta_{a + \delta_{i}, s} N_{c_{i'}, a + \delta_{i}, s}}{N_{c_{i}, a, s}}\right] \times \frac{\varphi_{a + \delta_{i}, s}}{TRO_{c_{i'}, s}}\right)$$

The first term computes the probability that the unobserved parent was the parent of the older juvenile, the second term computes the probability that the unobserved parent survived from the birth year of the older juvenile to the birth year of the younger juvenile (given natural and fishing mortality), and the third term computes the probability that the unobserved parent was in fact the parent of the younger juvenile given its reproductive output in that birth year.

The final probability integrates this number over all possible parent ages and sex, as we do not know the actual age or sex of the unobserved parent.

For HSPs, same cohort comparisons (i.e. individuals born in the same year) are not performed to avoid possible bias from 'good years' that could result in an excess of HSPs. In addition, cross-cohort comparisons are only allowed for cohorts separated by one or two years. This is to prevent the inclusion of HSPs that are actually grand-offspring-grand-parent pairs (GGPs), as current genetic approaches cannot differentiate between those and half-sibling pairs. As some Spanish mackerel individuals start maturing at 1 year of age, there is some chance that they would have grand-offspring two years after their birth year. A threshold of two years should thus prevent the inclusion of most GGPs in the comparisons.

Step 3:

Once the probabilities of observing a POP and observing a HSP for each combination of individuals has been estimated, the expected covariance matrix of the parameter vector is computed and used to approximate the variance for computed quantities of interest. This process is equivalent to simulating a large number of input datasets, fitting the CKMR model to each one, and calculating the variance in the resulting estimated quantities.

Steps 2 and 3 are updated for each different sampling scenario. The precision for the natural mortality and total reproductive output is then estimated.

5.3.4 Ageing error matrix

An ageing error matrix was derived based on the results of the epigenetic ageing study (Chapter 4) in order to assess the likely impacts of expanding the CKMR model to account for uncertain age. Ages 2 and 3 are the most prevalent in the predicted catch-at-age

distribution in the simplified CKMR model. We thus assumed a CV of 15% to derive the probability of true age given observed age, based on the CVs estimated for the lower age classes of Torres Strait Spanish mackerel (Chapter 4, Table 4). For each observed age \bar{a} from 0 to 13 years, the probability of true age a was derived by assuming a normal distribution of true ages around the observed age (with SD = 0.15 \bar{a}), and normalising to sum to 1.

5.4 Results

The simplified population model was able to reproduce total abundance from "Analysis 5" in the 2021 stock assessment (Figure 14), as well as catch-at-age (Figure 15).

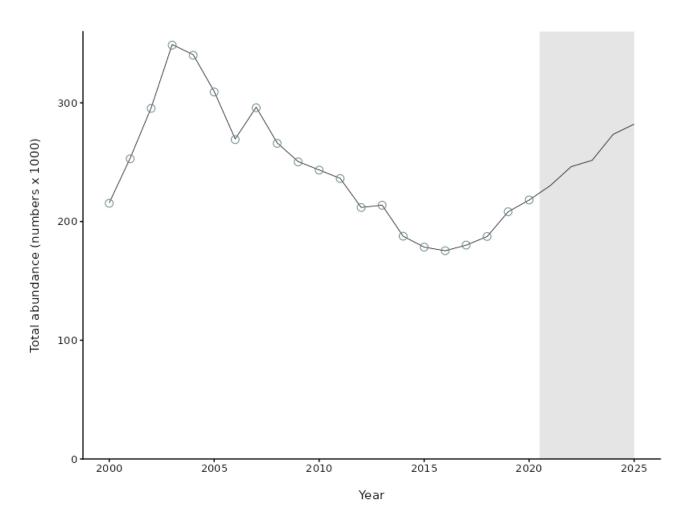


Figure 14. Predicted annual abundance (numbers across all ages) for the 2021 assessment model (circles) compared to the simplified CKMR population model (line). The grey rectangle delineates the projection period.

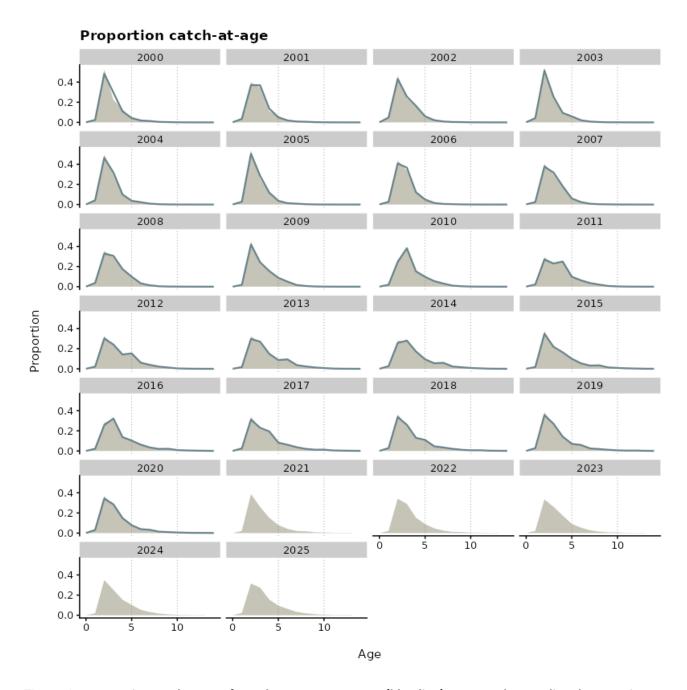


Figure 15. Proportion catch-at-age from the 2021 assessment (blue line) compared to predicted proportion catch-at-age from the simplified CKMR population model (shaded area). The period 2021 to 2025 is based on assumed future catch levels.

Given this population model, we estimated the number of POPs and HSPs that would be detected under each of the CKMR sampling strategies explored, as detection of POPs and HSPs is required for the tuning of CKMR models (Figure 16 and Figure 17). Increasing the length of the sampling program from 3 to 5 years led to a doubling of the number of POPs and HSPs detected over the length of the program (Figure 16).

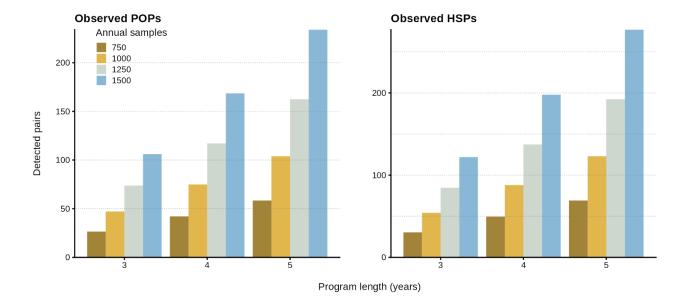


Figure 16. Number of parent-offspring pairs (POPs; left panel) and half-sibling pairs (HSPs; right panel) detected when varying the length of the sampling program and the intensity of annual sampling (coloured bars).

Of the remaining sampling strategies (varying annual sample sizes, extra samples in the first year, emphasis on older individuals), vary annual sample sizes had the most impact (Figure 16 and Figure 17), while the other strategies had minimal impact on kin detection (for the same total sample size). With 1,000 annual samples (5,000 total), the design model predicts that about 100 POPs and 125 HSPs would be detected over the course of the sampling program.

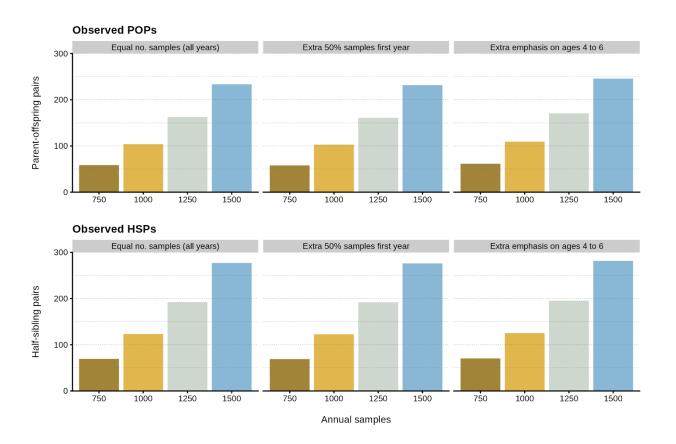


Figure 17. Number of parent-offspring pairs (POPs; top panel) and half-sibling pairs (HSPs; bottom panel) detected when varying the intensity of annual sampling for a five years program (coloured bars) and the time- or age- distribution of samples (vertical panels).

The expected precision in key population metrics resulting from the different CKMR sampling strategies was estimated. The population metrics surveyed were natural mortality, total fecundity and spawning biomass (in 3-year-old equivalent). Precision was highest for spawning biomass (in 3-year-old equivalent), followed by total fecundity and natural mortality. A five-year sampling program was able to achieve CVs of 15% or less for the spawning biomass of 3-year-old fish with annual samples of 1,000 or more, while a 3-year sampling program needed at least 1,500 annual samples (Figure 18). With an annual sample size of 1,000 and a 5-year sampling program, a CV of about 11% for the spawning biomass of 3-year-old fish was achieved between 2019 and 2021 (Figure 18 and Figure 19).

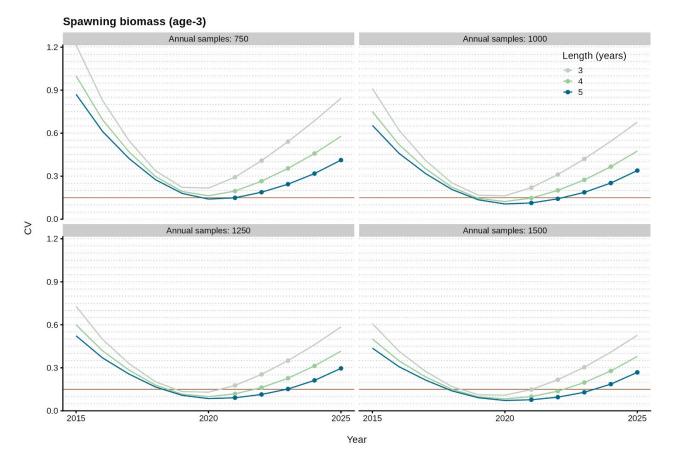


Figure 18. Predicted precision (coefficient of variation, CV) in spawning biomass of 3 -year-old fish under three different program length (coloured lines) and annual samples of 750 to 1500 individuals (panels). The brown horizontal line highlights a benchmark CV of 15%.

Precision for total fecundity was less, with CVs of about 30% with 1,000 annual samples over 5 years (Figure 19 and Figure 20). For all sampling strategies, precision decreased in years further from the start of the sampling programme (Figures 18 to 21). The precision achieved for natural mortality was slightly better, with a CV of 27.6% for 1,000 annual samples over 5 years (Figure 21).

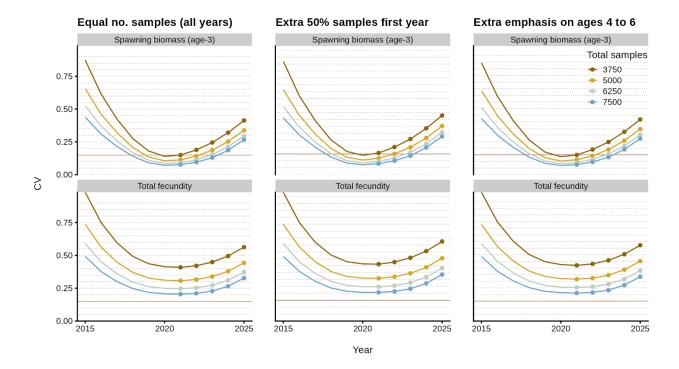


Figure 19. Predicted precision (coefficient of variation, CV) in spawning biomass of 3 -year-old fish and total fecundity under three different sampling strategies. The brown horizontal line highlights a benchmark CV of 15%.

While higher sample sizes are expected to improve CVs, the most gain in precision (across all population metrics) was obtained by increasing annual sample size from 750 to 1,000 and increasing program length (Figures 18 to 21). In contrast, there was little discernible effect on CVs of changing the distribution of samples over time to increase first year numbers, or of having extra emphasis on sampling older individuals of age 4 to 6 years (Figure 19 and Figure 21).

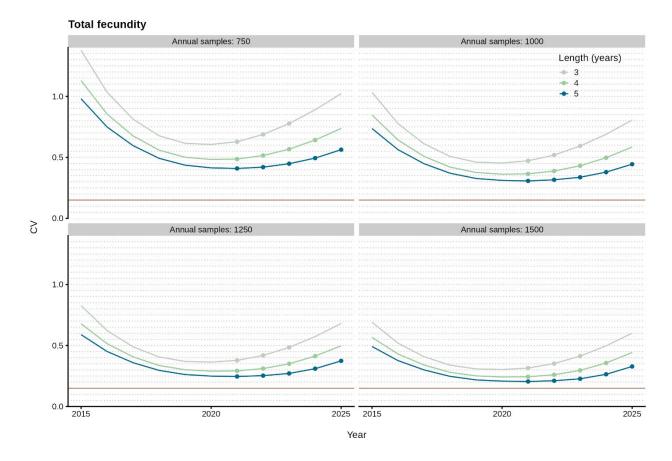


Figure 20. Predicted precision (coefficient of variation, CV) in total population fecundity under three different program length (coloured lines) and annual samples of 750 to 1500 individuals (panels). The brown horizontal line highlights a benchmark CV of 15%.

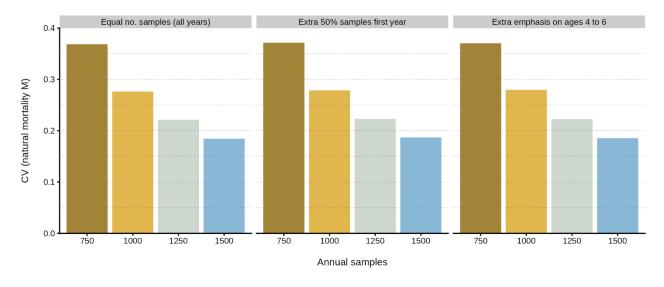


Figure 21. Predicted precision (coefficient of variation, CV) of estimated natural mortality (*M*) under three different sampling strategies with different levels of annual and total samples.

The ageing error matrix compared to the expected sampling distribution (assuming the same age distribution as in the catch) showed that for ages 2 and 3 years, the percentage of individuals assigned to an incorrect age is expected to be 1% and 14%, respectively (Figure 22). These two ages are expected to comprise about 60% of all individuals sampled.

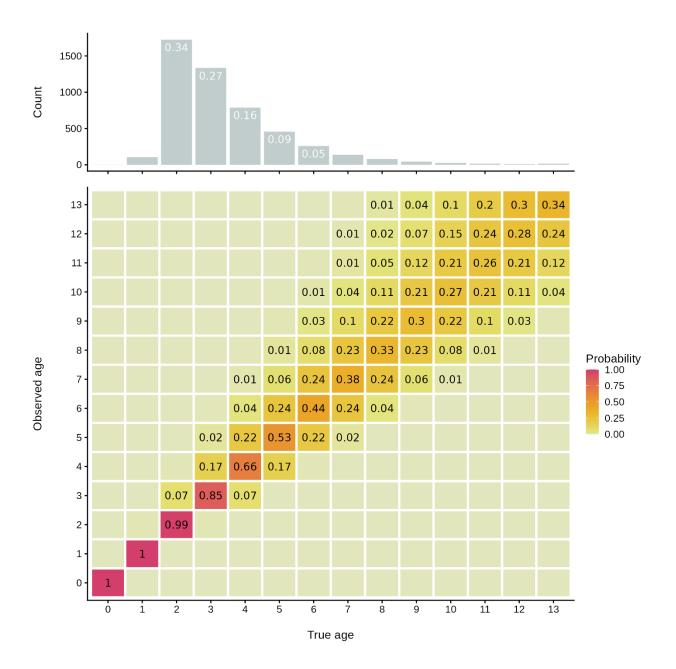


Figure 22. Ageing error matrix for Spanish mackerel. Top panel indicates the count of each age in the CKMR sample under the "Equal number of samples (all years)" sampling scenario with 5000 total samples. The proportion of each age class in the sample is shown in white for each bar when it exceeds 0.05. Bottom panel shows the distribution of true ages given the observed ('measured') age under a CV of 15%. The cells coloured in red show higher probabilities, and the numbers in black denote the actual probability of an individual being of a given true age given its observed age.

5.5 Conclusions

CKMR models inform estimates of population abundance by comparing the expected number of kin pairs (given population size) to that observed during sampling. A general rule with CKMR studies is that at least 50-100 kin pairs (spread across POPs and HSPs) are required to gain useful insights on population metrics. This CKMR design study allowed us to predict the number of kin pairs that would be detected for different sampling scenarios for Torres Strait Spanish mackerel, as well as the resulting CVs in estimated model parameters using the CKMR detections as input.

The sampling strategies with the most impact on the predicted CVs of population metrics were varying program length and increasing the total number of samples. Changing the temporal or age distribution of samples had little effect on expected CVs. While a total of both 3,750 and 5,000 samples evenly spread over 5 years resulted in at least 100 kin pair detections (across POPs and HSPs), CVs below 15% for spawning biomass (in 3-year-old equivalent) were only achieved for three or more years under the scenario of 5,000 total samples. CVs below 15% for spawning biomass (in 3-years-old equivalent) could not be achieved with 3 years of 1,000 samples, but extending the sampling for 4 or 5 years or increasing the sample size to 1,250 (for 4 years) or 1,500 (for 3 years) resulted in annual spawning biomass estimates meeting this target CV.

Across all scenarios, the lowest CVs were achieved between 2019 and 2021, corresponding to the years where the CKMR model has the most information to tune population dynamics (based on the birth year of the detected POPs and HSPs). Therefore, continued sampling beyond the simulated sampling period would reduce the CVs in subsequent years (i.e. 2022 onwards) to similar levels achieved for 2019 to 2021.

As noted above, the sampling scenario giving higher emphasis on older ages (4 to 6 years) yielded little improvement in expected precision. However, this scenario was quite conservative in the additional emphasis given to those ages, as we wanted to ensure the sampling was realistic given the difficulty in sampling a greater proportion of older fish from the fishery. It might be worth exploring this scenario further if, following consultation, it is deemed that a higher number of those older individuals could be sampled.

The results included here assume individual age is known exactly, however some ageing error is expected for samples using both otolith and epigenetic approaches. Expanding the CKMR approach to account for age uncertainty is not trivial as we must account for both uncertain age of the possible parent and its offspring (for POPs), and uncertain age of both half-siblings (for HSPs). An ongoing area of CKMR model development is thus to account for ageing uncertainty in the kin probability. While this development is expected to inflate the CVs in population metrics for the sampling scenarios used here, we note that ageing error is expected to be minimal for most of the individuals sampled, given the prevalence of 2- and 3-year-old fish in the samples of Spanish mackerel from Torres Strait.

In addition, we made two conservative assumptions in the current application, which will likely compensate for the CV inflation from age uncertainty. First, we excluded Grand-parent-grand-offspring comparisons, but these would be included in the final CKMR model and would improve precision in all estimated parameters. Second, we assumed that only 75% of half-siblings could be detected, however ongoing development in kin detection are

likely to increase this rate in the short term. As such, while accounting for age uncertainty remains a priority, we do not expect an important change in the CVs obtained once age uncertainty is accounted for in the final CKMR population model.

5.6 Recommendations

- 1. Continue the collection of approximately 1,000 tissue samples from Torres Strait Spanish mackerel in 2022 and subsequent years for a total program length of at least 5 years to provide the required total sample size (~5,000) for the full application of CKMR.
- 2. Genotype the full collection of tissue samples, when available, to enable the detection of kin pairs for input into the CKMR model and estimation of key parameters such as spawning abundance and mortality.
- 3. Expand the CKMR model to account for uncertain age. This will be particularly important when using age estimates from less precise methods such as epigenetic ageing.
- 4. Evaluate the possibilities for collaboration with Queensland Fisheries who have recently commenced an FRDC-funded CKMR design study for the Queensland east coast population of Spanish mackerel. Analysing samples from Torres Strait and the Queensland east coast within the same CKMR analysis will enable a direct evaluation of connectivity between the two populations, further strengthening our understanding of population structure for Spanish mackerel in this region.

References

- 1. Roelofs, A., Langstreth, J., Lewis, P., Butler, I., Stewart, J., Grubert, M., *Spanish Mackerel (2020)*, in *Status of Australian Fish Stocks Reports 2021*. 2021.
- 2. Bromhead, D., Blake, S., Steven, A.H., *Torres Strait Finfish Fishery: Chapter 16: Torres Strait Finfish Fishery.* 2021.
- 3. O'Neill, M.F., Buckworth, R.C., Trappett, A.G., Langstreth, J.C., *Stock assessment of Torres Strait Spanish mackerel, with appraisal of environmental drivers.* 2021. p. 74
- 4. O'Neill, M.F., Buckworth, R.C., Trappett, A.G., *Torres Strait Spanish mackerel: Stock assessment 2019*. 2020.
- 5. Anon, 10th meeting of the PZJA Torres Strait finfish fishery resource assessment group (FFRAG 10). 2021: Thursday Isand, Torres Strait.
- 6. Bravington, M.V., H.J. Skaug, and E.C. Anderson, *Close-kin mark-recapture*. Statistical Science, 2016. **31**(2): p. 259-274.
- 7. Bravington, M.V., P.M. Grewe, and C.R. Davies, *Absolute abundance of southern bluefin tuna estimated by close-kin mark-recapture.* Nature Communications, 2016. **7**(1): p. 13162.
- 8. Hillary, R., Preece, A., Davies, C., Summary of updated CKMR data and model performance in the Cape Town Procedure, in Paper CCSBT-ESC/2008/BGD 07 2020.
- 9. Davies, C.R., Bravington, M.V., Eveson, J.P., Lansdell, M., Aulich, J., Grewe, P.M., Next-generation Close-kin Mark Recapture: Using SNPs to identify half-sibling pairs in Southern Bluefin Tuna and estimate abundance, mortality and selectivity, in FRDC Project No 2016-044. 2020.
- 10. Hillary, R.M., et al., Genetic relatedness reveals total population size of white sharks in eastern Australia and New Zealand. Scientific Reports, 2018. **8**(1).
- 11. Thomson, R., Bravington, M., Feutry, P., Gunasekera, R., Grewe, P., Close Kin Mark Recapture for School Shark in the SESSF, in FRDC 2014/024, Final report to the FRDC. 2020.
- 12. Rawding, D.J., C.S. Sharpe, and S.M. Blankenship, *Genetic-Based Estimates of Adult Chinook Salmon Spawner Abundance from Carcass Surveys and Juvenile Out-Migrant Traps.* Transactions of the American Fisheries Society, 2014. **143**(1): p. 55-67.
- 13. Ruzzante, D.E., et al., *Validation of close-kin mark–recapture (CKMR) methods for estimating population abundance*. Methods in Ecology and Evolution, 2019. **10**(9): p. 1445-1453.
- 14. Trenkel, V.M., et al., Close-kin mark–recapture abundance estimation: practical insights and lessons learned. ICES Journal of Marine Science, 2022. **79**(2): p. 413-422.
- 15. Langstreth, J.C. and M.F. O'Neill, *Enhancing biological data inputs to Torres Strait Spanish mackerel stock assessment*, in *Torres Strait AFMA Project RR2019/0832*. 2020, Queensland Government: Fisheries Queensland, Department of Agriculture and Fisheries.
- 16. Trappett, A.G., J.C. Langstreth, and M.F. O'Neill, *Torres Strait Finfish Fishery: Coral Trout and Spanish Mackerel Biological Sampling*, in *Torres Strait AFMA Project* 190851. 2021, Queensland Government: Department of Agriculture and Fisheries.
- 17. Conn, P.B., et al., Robustness of close-kin mark–recapture estimators to dispersal limitation and spatially varying sampling probabilities. Ecology and Evolution, 2020. **10**(12): p. 5558-5569.
- 18. Feutry, P., et al., *Inferring contemporary and historical genetic connectivity from juveniles*. Molecular Ecology, 2017. **26**(2): p. 444-456.

- 19. Buckworth, R.C., Newman, S. J., Ovenden, J. R., Lester, R. J. G., and McPherson, G. R., *The Stock Structure of Northern and Western Australian Spanish Mackerel*. 2007. p. 225.
- 20. Grewe, P.M., et al., Evidence of discrete yellowfin tuna (Thunnus albacares) populations demands rethink of management for this globally important resource. Scientific Reports, 2015. **5**(1): p. 16916.
- 21. Davies, C.R., Marsac, F., Murua, H., Fraile, I., Fahmi, Z., Farley, J., Grewe, P., Proctor, C., Clear, N., Eveson, P., Lansdell, M., Aulich, J., Feutry, P., Cooper, S., Foster, S., Rodríguez-Ezpeleta, N., Artetxe-Arrate, I., Krug, I., Mendibil, I., Agostino, L., Labonne, M., Nikolic, N., Darnaude, A., Arnaud-Haond, S., Devloo-Delva, F., Rougeux, C., Parker, D., Diaz-Arce, N., Wudianto, Ruchimat, T., Satria, F., Lestari, P., Taufik, M., Priatna, A., Zamroni, A., Study of population structure of IOTC species and sharks of interest in the Indian Ocean using genetics and microchemistry: 2020 Final Report to IOTC. 2020. p. 249 pp.
- 22. Gosselin, T., Lamothe, M., Devloo-Delva, F., Grewe, P., *radiator: RADseq Data Exploration, Manipulation and Visualization using R.* 2020.
- 23. Jombart, T. and I. Ahmed, adegenet 1.3-1: new tools for the analysis of genomewide SNP data. Bioinformatics, 2011. **27**(21): p. 3070-3071.
- 24. Jombart, T., S. Devillard, and F. Balloux, *Discriminant analysis of principal components: a new method for the analysis of genetically structured populations.* BMC Genetics, 2010. **11**(1): p. 94.
- 25. Thia, J.A., Guidelines for standardizing the application of discriminant analysis of principal components to genotype data. Molecular Ecology Resources, 2022.
- 26. Pembleton, L.W., N.O.I. Cogan, and J.W. Forster, *StAMPP: an R package for calculation of genetic differentiation and structure of mixed-ploidy level populations.* Molecular Ecology Resources, 2013. **13**(5): p. 946-952.
- 27. Campana, S.E., Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology, 2001. **59**(2): p. 197-242.
- 28. McPherson, G.R., *Age and Growth of the Narrow-barred Spanish Mackerel* (Scomberomorus commerson Lacépède, 1800) in North-eastern Queensland Waters. Australian Journal of Marine and Freshwater Research, 1992. **43**: p. 1269-1282.
- 29. Mayne, B., et al., Nonlethal age estimation of three threatened fish species using DNA methylation: Australian lungfish, Murray cod and Mary River cod. Molecular Ecology Resources, 2021. **21**(7): p. 2324-2332.
- 30. Mayne, B., et al., *A DNA methylation age predictor for zebrafish.* Aging, 2020. **12**(24): p. 24817-24835.
- 31. Mayne, B., et al., *Age prediction of green turtles with an epigenetic clock.* Molecular Ecology Resources, 2022.
- 32. Anastasiadi, D. and F. Piferrer, *A clockwork fish: Age prediction using DNA methylation-based biomarkers in the European seabass.* Molecular Ecology Resources, 2020. **20**(2): p. 387-397.
- 33. Bird, A.P., *Functions for DNA Methylation in Vertebrates.* Cold Spring Harbor Symposia on Quantitative Biology, 1993. **58**(0): p. 281-285.
- 34. Mayne, B., O. Berry, and S. Jarman, *Optimal sample size for calibrating DNA methylation age estimators*. Molecular Ecology Resources, 2021. **21**(7): p. 2316-2323.
- 35. Clark, S.J., et al., *DNA methylation: Bisulphite modification and analysis.* Nature Protocols, 2006. **1**(5): p. 2353-2364.
- 36. Lu, J., et al., *PrimerSuite: A High-Throughput Web-Based Primer Design Program for Multiplex Bisulfite PCR*. Scientific Reports, 2017. **7**(1): p. 41328.

- 37. Deangelis, M.M., D.G. Wang, and T.L. Hawkins, *Solid-phase reversible immobilization for the isolation of PCR products.* Nucleic Acids Research, 1995. **23**(22): p. 4742-4743.
- 38. Shen, W., et al., SeqKit: A Cross-Platform and Ultrafast Toolkit for FASTA/Q File Manipulation. PLOS ONE, 2016. **11**(10): p. e0163962.
- 39. Krueger, F. and S.R. Andrews, *Bismark: a flexible aligner and methylation caller for Bisulfite-Seq applications*. Bioinformatics, 2011. **27**(11): p. 1571-1572.
- 40. Friedman, J., T. Hastie, and R. Tibshirani, *Regularization Paths for Generalized Linear Models via Coordinate Descent.* J Stat Softw, 2010. **33**(1): p. 1-22.
- 41. Thompson, M.J., et al., *An epigenetic aging clock for dogs and wolves.* Aging, 2017. **9**(3): p. 1055-1068.
- 42. Horvath, S., *DNA methylation age of human tissues and cell types.* Genome Biology, 2013. **14**(10): p. R115.
- 43. Stubbs, T.M., et al., *Multi-tissue DNA methylation age predictor in mouse.* Genome Biology, 2017. **18**(1).
- 44. Li, H., et al., Cost-reduction strategies in massive genomics experiments. Marine Life Science & Difference & Differen

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
Finfish Fishery Research Priorities	Agenda Item 5.4 For DISCUSSION and ADVICE

RECOMMENDATIONS

- 1. That the Resource Assessment Group (the RAG):
 - a. **NOTE** that details of the outcomes of the 2022-23 funding round, and changes to the Torres Strait Scientific Advisory Committee (TSSAC) research cycle timeline were circulated to RAG members out of session on 25 August 2022.
 - b. **NOTE** that AFMA sought advice from RAG and Finfish Fishery Working Group (FFWG) members out of session on a proposal for the 2023-24 limited research budget funding cycle with approximately \$110,000 available to fund new research in the 2023-24 financial year.
 - i. In September 2022, the TSSAC released a direct call for research for a project relating to *Management Strategy Evaluation of Spanish mackerel for the Torres Strait Finfish Fishery.*
 - c. **NOTE** and **PROVIDE ADVICE** on the status of identified research priorities and needs for the Torres Strait Finfish Fishery as previously advised by the FFRAG in 2021 (**Table 1**).
- Having regard to Table 1, DISCUSS and PROVIDE ADVICE on research priorities for the rolling fiveyear research plan for the Finfish Fishery (Attachment 5.4a) (to be updated following advice from FFRAG 12 and FFWG). This will include advice on the feasibility, timing and indicative costing of essential, unfunded research project(s) to inform the TSSAC annual call for research funding proposals in 2024-25.

KEY ISSUES

Research priorities for the Finfish Fishery

- 3. The FFRAG last discussed research priorities at FFRAG 11 meeting (12 October 2022) in preparation for the 2024-25 TSSAC research funding round. The advice from the meeting is summarised in **Table 1.** Based on this advice and further discussion at FFRAG 12, the rolling five-year research plan for the Finfish Fishery will be updated.
- 4. The current research priorities for the Finfish fishery in order of priority) are:
 - i. Biological Sampling Program (length freq, sexing, ageing). Currently funded through to 2023/24.
 - ii. Spanish Mackerel Stock Assessment. Currently funded through to 2023/24.
 - **iii. Torres Strait Finfish Fishery Coral Trout Catch Per Unit Effort Standardisation.** Currently funded in 2022/23.
 - iv. Management Strategy Evaluation (MSE) of Spanish Mackerel for the Torres Strait Finfish Fishery. Scheduled to be released a limited call for research for funding in 2023/24.

- v. Development of a Harvest Strategy for The Torres Strait Finfish Fishery. Remains an essential priority, however it is intended that the MSE project will finalise a harvest strategy for the fishery based on candidate Harvest Control Rules.
- vi. Ecological Risk Assessment (ERA). The priority was able to be progressed by AFMA under AFMA's broader ERA contract with CSIRO. Draft reports due to be reviewed at FFRAG 12.
- vii. Developing an Alternative Index of Abundance for Spanish Mackerel. Scoping study currently being completed draft report to be revied at FFRAG 12.
- viii. Estimating Catches Outside the Commercial Fishery. Likely to be addressed through the PZJA's broader need to develop an approach for measuring non-commercial catch across Torres Strait Fisheries. A non-commercial catch project has recently been approved for funding by FRDC.
- ix. Development of a Coral Trout Stock Assessment. The RAG recommends that this research need should be considered a desirable priority. However it will only be considered for funding once the identified data priorities have been addressed (an updated standardised CPUE timeseries will guide the RAG on the timing of a future stock assessment).
- **x.** Understanding the Stock structure of Spanish Mackerel Being addressed under the funded CKMR project, in which a specific objective is to assess the stock structure of the Spanish mackerel fishery.
- **xi. Shark Depredation.** The RAG recommends that this priority be reassessed as relevant research is completed in other fisheries (jurisdictions).
- 5. No proposal was submitted for the MSE project for the 2022/23 funding cycle. TSSAC are currently awaiting a response to a direct call for research for an MSE project for the 2023/24 funding cycle.

Table 1. Research priorities for the Torres Strait Finfish Fishery as updated at FFRAG 11 meeting on 12 October 2022.

Research need	Objectives and component tasks	Priority as at 2022-23 (essential/desirable)	Status (as of September 2021)	FFRAG 11 advice
Biological sampling (Spanish mackerel and coral trout)	Project funded for age, sex and length data for Spanish mackerel to support stock assessment.	Essential	Multiyear project funded for 2021/22 – 2023/24 (project number 2020/0814).	Due to end in 2023/24. Biological sampling in a similar form is a required input into an ongoing stock assessment. The RAG will need to further consider the possibility of collecting biological samples through either a CKMR project or new biological sampling project. The length at age key is a key input into the stock assessment.
Spanish mackerel stock assessment	Need for ongoing assessment of key commercial species.	Essential	Multiyear project funded for 2021/22 – 2023/24 (project number 200815).	As per previous RAG advice, it has been recommended to retain a yearly stock assessment as the highest priority until the stock has been assessment to reach 40% of virgin biomass. Future assessments will more streamlined and cost effective should stock synthesis be applied.
Harvest strategy development	Strategy with harvest control rules and agreed reference points required to support management. It is a condition of the FF WTO that by 30 June 2023 a HS must be developed for the fishery. As per FFRAG 9 advice it was noted that the optimum ratio of B _{MSY} (maximum sustainable yield) to B _{MEY} (maximum economic yield) will need to be taken into account as part of the harvest strategy process. FFRAG supported a desktop study (e.g. applying Pascoe et al. work to the Torres Strait Spanish mackerel stock c.f. QDAF east coast work) to determine the optimum ratio between B	Essential	Previous scope and components were not funded. New scope to be developed as needed and requires an indicative cost estimate.	The FFRAG will be asked to identify outstanding refinements to the current draft harvest strategy / harvest controls rules. These refinements are to be address at a harvest strategy workshop in March 2023.

Research need	Objectives and component tasks	Priority as at 2022-23 (essential/desirable)	Status (as of September 2021)	FFRAG 11 advice
	MSY and B MEY and the appropriate proxy economic target for the fishery.			
Management Strategy Evaluation (MSE) of draft harvest strategy	Requirements of Cwth HS Policy and Guidelines to undertake MSE prior to implementation.	Essential	Not currently funded. Detailed scope to be developed as needed.	Currently advertised in a direct call for research. FFRAG due to review research proposal at FFRAG 12.
Ecological Risk Assessment (ERA)	It is a condition of the FF WTO that by 30 June 2023 an ERA must be undertaken for the TS Finfish Fishery	Actioned	Not currently funded. Estimated cost \$20,000	Draft reports completed. FFRAG to review at FFRAG 12.
Alternative index of abundance for Spanish mackerel – scoping study	Develop an alternative to CPUE data to provide stock status/abundance	Essential	Scoping study due for completion in November 202	CKMR scoping study draft final report to be presented at FFRAG 12. RAG to provide further advice after this presentation in relation to a full-scale study
Coral trout stock assessment development	RAG has noted work required to further develop the preliminary stock assessment and address the range of uncertainties identified. The additional data priorities are: analysing the identified 1994-95 CSIRO survey data examining improved TIB catch and effort data incorporating underwater visual survey data if conducted. Undertake further habitat mapping work discounting independent data	Desirable	Not currently funded. Identified data priorities to be addressed prior to scoping.	This research priority to be assessed after an updated standardised CPUE timeseries is completed. The RAG notes that the status of the fishery is at risk of becoming 'uncertain' in the absence of a formal stock assessment.
Coral trout catch- per-unit-effort standardisation	Catch Per Unit Effort is an important input into the assessment and may be used to monitor the performance of the Fishery in years without a full assessment being undertaken. Having an agreed CPUE standardization is the first necessary step towards using CPUE to inform management decisions.	Essential	Previous application not funded. Previous proposal sought funding of around 12k.	Project approved for funding in 2022/23, however yet to be contracted. The FFRAG are to note an update on the status of the project at FFRAG 12 meeting.

Research need	Objectives and component tasks	Priority as at 2022-23 (essential/desirable)	Status (as of September 2021)	FFRAG 11 advice
	A small project is required to further refine the current CPUE standardisation methods and to update the CPUE time series with new catch and effort data. The CPUE series is to be based on:			
	• any recommended refinements of the CPUE standardisation methodology developed through the AFMA funded project: Harvest Strategy of the Torres Strait Finfish Fishery (project number: 2016/0824); and •all available catch and effort data.			
Spanish mackerel stock structure	Define the spatial scale of management and connectivity of Torres Strait populations of SM with adjacent areas (Gulf, Qld, Coral Sea, PNG) potentially through collection of samples for genetic relatedness.	Desirable	Multiyear project currently funded for 2021/22 – 2023/24 (project number 200817).	CKMR scoping study due to be presented at FFRAG 12. RAG to provide further advice after this presentation in relation to a full-scale study. The RAG note that questions relating to stock structure have been partially addressed through the current CKMR scoping study.
Estimating catches outside the commercial fishery	Acquiring data of catch taken from non-commercial fishers.	Essential	Relevant research project funded and completed (project number 190827). Project recommendations are under consideration.	RAG noted a non-commercial catch project has been funded.
Shark depredation	Study to investigate increased shark interaction with fishery operations and depredation impacts on Finfish Fishery catch rates (how to capture and track over time or investigate potential mitigation options).	Desirable	Not funded or scoped.	The RAG advised that this is not a priority research need at this time. The RAG recommended that this priority be reassessed as relevant research is completed in other fisheries (jurisdictions). The RAG noted that a current FRDC project on depredation is being conducted in Queensland.
Otolith morphology	Developing an index of mackerel ages based on the shapes and sizes of otoliths recorded	Desirable	Not funded or scoped.	The RAG advised this not priority research need at this time and can be removed from the research plan. This is because an alternative ageing technique (epigenetic

Research need	Objectives and component tasks	Priority as at 2022-23 (essential/desirable)	Status (as of September 2021)	FFRAG 11 advice
				ageing) is instead being assessed by project number 200817 (CKMR).
Coral Trout Harvest Strategy		Essential		The FFRAG notes that a harvest strategy for coral trout is an essential priority. The RAG recommends that this item requires further discussion to identify the most efficient method for developing a harvest strategy.













Rolling Five Year Research Plan 2022/23 - 2026/27

Torres Strait Finfish Fishery



Compiled by AFMA with FFRAG advice November 2021

ABOUT THIS PLAN

The Torres Strait Scientific Advisory Committee (TSSAC) seeks input from each fishery advisory body (Resource Assessment Group (RAG), Management Advisory Committee (MAC) or Working Group (WG)) to identify research priorities over five year periods from 2022/23 to 2026/27. This template is to be used by the relevant advisory body to complete their five-year plan. The plans are to be developed in conjunction with the TSSAC Five-year Strategic Research Plan (SRP) with a focus on the three research themes and associated strategies within the SRP.

All fishery five-year plans will be assessed by the TSSAC using a set ofcriteria, and used to produce an Annual Research Statement for all Torres Strait fisheries.

The TSSAC then develop scopes for the highest ranking projects in order to publish its annual call for research proposals. There are likely tobe more scopes that funding will provide for so TSSAC can consider a number of proposals before deciding where to commit funding.

The fishery five-year plans are to be reviewed and updated annually by the Torres Strait forums to add an additional year onto the end to ensurethe plans maintain a five year projection for priority research. Priorities may also change during the review if needed.

RESEARCH PRIORITIES

Table 1. Five-year Torres Strait Finfish Fishery research plan for 2022/23 to 2026/27.

			Year project	to be carried	dout and ind	icative cost*			Evaluation	
Proposed Project	Objectives and component tasks	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	Priority essential / desirable	Priority ranking 1-5 (1 = highest)	Theme
Biological sampling program (length freq, sexing, ageing)	Project funded for age, sex and length data for Spanish mackerel to support stock assessment.	\$122,000 (currently funded)	\$128,000 (currently funded)	\$135,000 (currently funded)	0	0	0	Essential	1	1a
	Need for ongoing assessment of key commercial species.	\$57,000 (currently funded)	\$59,000 (currently funded)	\$61,000 (currently funded)	0	0	0	Essential	2	1a
Fishery Coral Trout Catch Per Unit Effort Standardisation	A small project is required to further refine the current CPUE standardisation methods and to update the CPUE time series with new catch and effort data. The CPUE series is to be based on: any recommended refinements of the CPUE standardisation methodology developed through the AFMA funded project: Harvest Strategy of the Torres Strait Finfish Fishery (project number: 2016/0824); and all available catch and effort data.	0	Not currently funded, requires an indicative cost estimate. Previous proposal sought funding of around \$12,000.	0	0	0	0	Essential	3	1a
Fishery: Management Strategy Evaluation of Spanish mackerel for the Torres Strait Finfish Fishery	The project team will use Management Strategy Evaluation to quantitatively evaluate the performance of candidate Harvest Control Rules (HCR) to complete the elements of a fisheries harvest strategy. This includes using current HS objectives as guidance (developed during project Harvest Strategies for the Torres Strait Finfish Fishery, and engaging with the FFRAG to refine the form of the HCRs. Requirement of Cwth HS Policy and Guidelines to undertake MSE prior to implementation.	0	Not currently funded, requires an indicative cost estimate.	0	0	0	0	Essential	4	1a
Harvest strategy	It is a condition of the FF WTO that by 30 June 2023 a HS must be developed for the fishery.	0	0	0	0	0	0	Essential	5	1a

	Component projects to progress Harvest Strategy development for the TSFF are being addressed though research priorities 3 & 4. (TSFF CT CPUE Standardisation & MSE for Spanish Mackerel). The RAG advised that the future work to develop the harvest strategies should examine the optimum ratio of BMSY (maximum sustainable yield) to BMEY (maximum economic yield).				
Ecological Risk Assessment (ERA)	It is a condition of the FF WTO that by 30 June 2023 an ERA must be undertaken for the TS Finfish Fishery	The RAG advised that this research need remains an essential priority. To be progressed by AFMA under AFMA's broader ERA contract with CSIRO.	Essential	4	1a
Alternative index of stock abundance	Develop an alternative to CPUE data to provide stock status/abundance.	Close-Kin Mark-Recapture (CKMR) project funded in 2021/22 (\$93,000).	Essential	4	1a
Estimating catches outside the commercial fishery.	Acquiring data of catch taken from non- commercial fishers.	Outcomes of scoping project (funded in 2019/20) will inform likely future work if a program is to be implemented. This research need may continue to be addressed through the PZJA's broader need to develop an approach for measuring non-commercial catch across Torres Strait Fisheries. The RAG recommends that this priority be reassessed as relevant research is completed.		4	1a, 3b
Coral trout stock assessment	Need for ongoing assessment of key commercial species.	The RAG clarified that this research need should only be considered for funding once the identified data priorities have been addressed. The RAG also noted that future stock assessment needs for the fishery would be guided by the harvest strategy.	Desirable	5	1a
Management Strategy Evaluation (MSE) of draft harvest strategy	Requirements of Cwth HS Policy and Guidelines to undertake MSE prior to implementation.	MSE work requires funding and HS development to be completed first	Desirable	5	1a
Stock structure of Spanish mackerel.	Define the spatial scale of management and connectivity of Torres Strait populations of SM with adjacent areas (Gulf, Qld, Coral Sea, PNG) potentially through collection of samples for genetic relatedness.	Not funded, genetic samples banked for future studies. Not designed or costed. Torres Strait otoliths collected under sampling project will be stored to facilitate future genetic sampling. Being addressed under the funded CKMR project, in which a specific objective is to assess the stock structure of the Spanish mackerel fishery.	Desirable	5	1a, 1b
Shark depredation	Study to investigate increased shark interaction with fishery operations and depredation impacts on Finfish Fishery catch rates (how to capture and track over time or investigate potential mitigation options).	Not designed or costed. The RAG recommended that this priority be reassessed as relevant research is completed in other fisheries (jurisdictions).	Desirable	5	1a

Torres Strait Finfish Resource Assessment Group	Meeting 12 3-4 November 2022
FFRAG PRIORITIES AND DATE FOR THE NEXT MEETING	Agenda Item 6 For Discussion & Advice

RECOMMENDATIONS

- 1. That the Resource Assessment Group:
 - a) **NOTE** the management priorities for 2022 for the fishery supported by the Finfish Working Group at their meeting on 25 November 2021.
 - b) **DISCUSS** and **PROVIDE ADVICE** on priorities for the RAG together with a work plan for addressing recommended priorities;
 - c) **REVIEW** the proposed dates for future meetings.

KEY ISSUES

- 2. The FFRAG last reviewed their management priorities at FFRAG 10 (18-19 November 2021). The RAG agreed that the immediate priorities for the RAG were to:
 - a) provide advice as necessary on the Western Line Closure including any future fishing that may occur;
 - b) further develop harvest strategies for the Spanish mackerel and coral trout;
 - c) review shark management measures; and
 - d) undertake annual fishery assessments and provide RBC advice.
- 3. Finfish Fishery Working Group (FFWG) also considered management priorities at its meeting on 25 November 2021.
- 4. A summary of these priorities and their current progress can be found in **Table 1.** This table forms a workplan for the FFRAG to address its management priorities.
- 5. The RAG are invited to review this workplan and provide advice on the current priorities of the FFRAG.

BACKGROUND

- 6. The RAG have a standing item at its meetings to discuss assessment, data collection and research needs for the Torres Strait Finfish Fishery. This may be informed by the RAG's meeting discussions, advice from individual members of the RAG and/or advice from the Finfish Working Group (FFWG).
- 7. At its meeting on 18-19 November 2021, the RAG noted the proposed management and research priorities for 2022 and made recommendations on how to progress some of those priorities.

- 8. Where possible, the RAG aims to prioritise and set a timeline for any identified items, having regard for resourcing.
- 9. In considering its priorities, the RAG may also wish to note the summary of management priorities supported by the FFWG provided in **Table 1** (some of which align with the RAG's priorities) and their progress to date.
- 10. Having regard for the outcomes of this meeting (including the assessment and management requirements stipulated in the WTO conditions), the RAG may wish to amend the list of priorities.

Date and venue for future meetings

- 11. In developing its work plan, the RAG may consider the summary of key due dates for the finfish fishery outlined in Table 2.
- 12. The next RAG meetings are currently proposed for March, September, and November 2023.

Table 1. Comments relating to any progress against each management priority considered by the FFRAG on 4-5 November 2020 and FFWG on 26 November 2020. These priorities were again reviewed by the FFRAG on 18-19 November 2021 and FFWG on 25 November 2021. Priorities are listed chronologically and not in order of importance.

Pr	iority	FFRAG 4-5 Nov 2020 FFWG 26 Nov 2020 comments		Progress to date and comments	
1	Progress the development of a harvest strategy	Subject to funding this will require additional workshops with members and broader industry stakeholders including the FFRAG.	Supported as a priority and noted that clear guidance from AFMA to prospective funding applicants on expected deliverables is needed. It was noted that the RAG and Working Group have been developing a harvest strategy approach for Spanish mackerel over the last four years and arguably there are no immediate risks for coral trout given the low fishing effort.	In progress. FFRAG 9 noted an update from QDAF on the development of the East Coast Spanish Mackerel Fishery harvest strategy, and the current QLD Reef Line Fishery harvest strategy: 2020-2025.	
			However, the Working Group recognised that it is best practice to develop agreed harvest strategies to provide certainty to stakeholders on the information requirements and decision rules for setting TACs in the fishery. This certainty enables more informed business decisions and importantly supports industry and community leaders in building broader stakeholder support for improving data for the Fishery. To ensure a clear return on investment, members agreed that it was essential that a future project build on work already completed to develop a harvest strategy for the fishery. In this regard all potential applicants were encouraged to contact AFMA to discuss proposals prior to submission.	FFRAG 10: Developed a scope for an MSE project to finalise a harvest strategy for the Spanish mackerel fishery.	
				FFWG Dec 2021: Remains a high priority	
				FFRAG 12: RAG to identify outstanding refinements to be progressed at a harvest strategy workshop in March 2023. RAG are also to note the East Coast Spanish Mackerel Harvest Strategy.	
2	Supporting possible changes to the Western Line Closure	The RAG noted a number of risks and considerations with lifting the northern part of the closure and supported a suggestion that a targeted round of consultation occurs in Gudumalulgal to discuss the three options to support	Supported as a priority noting that as a long-standing issue, but that good progress has been made more recently to understand the views of Torres Strait Islanders throughout the region and to develop risk-based management options. It was noted that advice needed to be made clear on allowable fishing methods.	Progressed: Based on a final round of advice from the FFRAG and FFWG in 2021, and community consultation, the PZJA decided in March 2022 to amend the boundary of the Western Line Closure. This decision came into effect on May 1 2022.	

Pr	iority	FFRAG 4-5 Nov 2020	FFWG 26 Nov 2020	Progress to date and comments
			comments	
		opening the reef line fishery in this area: 1. Opening with data collection and monitoring 2. Survey before opening 3. Adaptive management		As per FFRAG advice, catch records will be monitored carefully to assess the level of effort.
3	Update the daily fishing logbook (TSF01) in line with recommendations from the FFRAG.	The RAG supported the logbook changes recommended by AFMA to various aspects of the TSF01 logbook to IMPROVE Sunset sector catch and effort data and support spatial reporting by the TIB sector.	The WG noted the importance of "data priorities for the fishery and information needed to support the development of a more accurate stock assessment that could be relied upon to adjust the TAC and therefore have greater confidence around the future harvest levels." These priorities which were noted included "improvements to the accuracy of logbook reporting (effort, species 'split')."	Ongoing. AFMA to progress an updated TSF01 logbook for the 2023/24 season in line with an update to the logbook Gazette and Instrument in 2023.
4	Supporting the PZJA's consideration of quota unit allocation options	N/A	The Working Group noted the PZJA decision and rationale. That being to consider quota unit allocation options for the Finfish Fishery alongside the review it must undertake for the Traditional Inhabitant quota unit allocation in Tropical Rock Lobster Fishery. The AFMA member advised that having clearly defined catch entitlements (i.e. quota units) will be important to support the transfer of the sunset leasing arrangements from TSRA to nongovernment entity/ies. Members noted that the PZJA has not yet allocated quota in the Finfish Fishery despite there being a plan of management in place to do so. The AFMA member advised that, following Australian Government buyout of licences held by non-traditional inhabitants in 2008 and therefore potential effort, the PZJA agreed that it was no longer a priority to introduce quota management. Some Traditional Inhabitant members raised strong concerns that a quota allocation process could start to divide their people and cause in-	Ongoing. Not reviewed in 2021.

Pri	ority	FFRAG 4-5 Nov 2020	FFWG 26 Nov 2020	Progress to date and comments
			comments	
			fighting. In their view it should be a matter for the new Zenadth Kes Fishing Company (the entity) to consider whether to pursue such an option. The Working Group noted the sensitivities around allocation and whilst there was support to involve the new entity as a means of involving stakeholders, members noted AFMA member advice that the nature and extent of any involvement would be subject to the role of the entity. Details on this are to be released by TSRA once the entity is established	
5	Formalising total allowable catches for the Finfish fishery	N/A	Supported as a priority noting the Working Group's previous consideration and support for ensuring the TAC is binding on all sectors. The Working Group noted that, in the absence of having quota management under the management plan, current arrangements do not limit catches by the Traditional Inhabitant sector. Having an enforceable TAC was noted as a necessary part of carefully managing catches in the fishery.	FFWG 2021: Remains a medium priority
7	Potential application of VMS on tenders	FFRAG provided advice on the potential scientific benefits from using VMS data to address data needs in the fishery at meeting 6 (27-28 November 2019). AFMA will continue to prepare information, including implementation costs across all licence holders to support further consideration of this initiative.	The Working Group did not consider this a high priority at this time, however, supported further information being tabled on the pros and cons on having VMS on tenders (boats that work in conjunction with a primary boat). Some Traditional Inhabitant members did not support having VMS on TIB boats but supported the measure applying to the sunset sector noting concerns with sunset boats breaching the 10nm closures around eastern communities. The AFMA member noted that the FFRAG had previously considered the use of VMS as an option for addressing the spatial data needs. The AFMA member further advised that whilst VMS is generally considered to be a cost-effective compliance tool, there was still much analysis to be done by AFMA on matters such as implementation costs across all licence holders to support further consideration of this initiative. AFMA maintains this as a lower priority, subject to resourcing.	FFWG 2021: Remains a low priority.

		FFRAG 18-19 Nov 2021	FFWG 25 Nov 2021	Progress to date and comments
N	Review Shark Management 'Best Practice'	The RAG agreed that it is an immediate priority to review current measures applied to the management of the take of sharks.	The FFWG considered it to be a high priority to review current measures applied to the management of the take of sharks in the Fishery to ensure that they are in line with Commonwealth best practice (condition 6 of the Wildlife Trade Approval for the fishery). AFMA is aiming for an Ecological Risk Assessment to be undertaken for the Fishery in 2022 which may also inform management needs as it relates to the take of sharks.	FFRAG 10: The RAG noted this condition and background documents in the meeting papers in anticipation of review in 2022. FFRAG 12: The RAG scheduled to review and provide advice on the current measures applied to the management of the take of sharks. FFWG 2021: Remains a high priority.

Table 2. Key dates for the Finfish Fishery for 2022 and 2023.

Key date	Activity
December 2022	 Finfish Working Group meeting Spanish Mackerel Total Allowable Catch Advice for the 2022-23 Season Coral Trout Total Allowable Catch Advice for the 2022-23 Season Review shark management best practice (WTO condition) Progress harvest strategy Torres Strait Finfish Fishery management priorities
Jan/Feb 2023	 PZJA meeting to decide TAC for Spanish mackerel and coral trout for 2023/34 season.
March 2023	Joint FFRAG/FFWG harvest strategy with industry stakeholders • Refine the objectives of a harvest strategy for Spanish mackerel
September 2023	 FFRAG13 – Stock assessment 'data' meeting Review the data for the Spanish mackerel stock assessment. Non-commercial catch estimate. Research priorities
November 2023	 FFRAG14 – RBC meeting Review updated Spanish mackerel stock assessment. Spanish mackerel - Recommended Biological Catch for 2022-23 Season. Coral trout - Recommended Biological Catch for 2022-23 Season. Priorities for the RAG
01 November 2023	Annual WTO final report due to the Department of Agriculture, Water and the Environment
November 2023	 Finfish Working Group meeting Spanish Mackerel Total Allowable Catch Advice for the 2024-25 Season Coral Trout Total Allowable Catch Advice for the 2024-25 Season Torres Strait Finfish Fishery management priorities

Torres Strait Finfish Fishery Resource Assessment Group	Meeting 12 3-4 November 2022
OTHER BUSINESS	Agenda Item 7 For Discussion

RECOMMENDATION

1. That RAG members **NOMINATE** and **DISCUSS** any additional items of business for the meeting.

TORRES STRAIT FINFISH FISHERY RESOURCE ASSESSMENT GROUP	Meeting 12 3-4 November 2022
Clearance of FFRAG Advice	Agenda Item 8 For DISCUSSION and ADVICE

RECOMMENDATION

1. That RAG members **DISCUSS** a summary of FFRAG advice compiled during this meeting and provide **ADVICE** on an approved communique. This written communique will contain the key advice/outcomes from the current meeting.