https://doi.org/10.1071/MF21055

Supplementary material

Stakeholder perceptions on actions for marine fisheries adaptation to climate change

Hannah E. Fogarty[A,B], *Christopher Cvitanovic*[B,C], *Alistair J. Hobday*[B,D,E] *and Gretta T. Pecl*[A,B]

[A]Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 49, Hobart, Tas. 7001, Australia.

[B]Centre for Marine Socioecology, University of Tasmania, Private Bag 49, Hobart, Tas. 7001, Australia.

[C]Australian National Centre for the Public Awareness of Science, Australian National University, ACT 0200, Australia.

[D]Commonwealth Scientific and Industrial Research Organisation Oceans and Atmosphere, Castray Esplanade, Hobart, Tas. 7000, Australia.

[E]Corresponding author. Email: alistair.hobday@csiro.au

Case study: Tasmanian commercial wild-catch fisheries

Tasmania has a wild-catch fisheries seascape composed of six main commercial fisheries: abalone, rock lobster, giant crab, scallop, scalefish, and commercial dive (urchins, periwinkles, clams and seaweed), the largest and most valuable of which are the commercial rock lobster and abalone fisheries. Tasmanian commercial wild-catch fisheries hold a total production value of A$194.3 million (US$142 million; 5314 tonnes) in 2017–18, accounting for 18% of Tasmania's seafood gross value production (GVP) – the largest seafood GVP of any Australian state (Steven *et al*. 2020). Tasmanian state fisheries employed 778 people (full-time equivalent) directly, and 564 people indirectly in 2017–18 (Fisheries Research and Development Corporation 2019). Additionally, Tasmania has various recreational and Indigenous fisheries, with 22% of Tasmanian residents (98 000 people) participating in recreational fishing activity at least once per year (Lyle *et al*. 2014). Tasmanian commercial wild-catch fisheries are managed by the Wild Fisheries Management Branch of the Tasmanian Government Department of Primary Industries, Parks, Water and Environment, through overarching legislation (the *Living Marine Resources Management Act* 1995) as well as individual management plans for each fishery set as legislation, and harvest strategies, issued and updated by the Wild Fisheries Management Branch. Tasmanian fisheries management documents currently do not prominently discuss the effects of climate change on the industry or associated environments; however, this may be included in stock assessments for individual fisheries (Fogarty *et al*. 2020). Decisions on important issues around commercial wild-catch fisheries management in Tasmania are issued by the Fisheries Minister (local member of parliament), and may or may not be based on recommendations and advice provided by a Fishery Advisory Committee (FAC), which are the peak advisory groups for each major Tasmanian fishery (Department of Primary Industries, Parks, Water and Environment 2020). The Fisheries Minister must seek consultation over key

arrangements, such as size limits, seasonal closures, gear restrictions, and Total Allowable Catches (TACs). FAC meetings are generally held 2–4 times per year for each fishery, with membership made up of a diverse range of fishery stakeholders (Department of Primary Industries, Parks, Water and Environment 2020). Management methods in place for many of these fisheries include gear restrictions, limited entry, quotas, size limits, spatial closures, temporal closures, and TAC limits (Fisheries Research and Development Corporation 2020).

Of the Tasmanian wild-catch fisheries, the largest and most valuable to the state's economy are the commercial rock lobster fishery and the commercial abalone fishery, in 2017–18 contributing A$97.2 million (US$71 million) and A$86.4 million (US$63.1 million) respectively in GVP to the state (Steven *et al*. 2020). The Tasmanian commercial rock lobster fishery targets the southern rock lobster species (*Jasus edwardsii*) using pots and traps, and has the largest participation size of Tasmanian commercial wild-catch fisheries, with 194 active vessels in the 2017–18 fishing season (Hartmann *et al*. 2019), 383 people directly employed in 2016 (Ogier *et al*. 2018), and 311 licence holders in 2016 (Steven *et al*. 2020). Most exports of commercial southern rock lobster catch are live, fresh product, though markets are also available for frozen rock lobster exports (Hartmann *et al*. 2019). The rock lobster fishery is divided into two fishing 'zones' (east and west regions) and 11 stock assessment areas (Hartmann *et al*. 2019). Management methods in place for the rock lobster fishery include gear restrictions, limited entry, quotas, size limits, spatial closures, temporal closures, and Total Allowable Catch (TAC) limits (Fisheries Research and Development Corporation 2020). The Tasmanian rock lobster fishery has a history of being affected by habitat degradation caused by the long-spined sea urchin (*Centrostephanus rodgersii*; a climate-driven range extender species; Ling and Keane 2018), with management interventions in place aimed at rebuilding the virgin biomass of the stock to 20% by 2023 through implementing an East Coast Stock Rebuilding Zone (SRZ), and adjusting TACs (Hartmann *et al*. 2019). Current fisheries management for southern rock lobster is aimed at ensuring that healthy egg production is maintained at 20% or more of unfished levels (Hartmann *et al*. 2019). Southern rock lobster have a long pelagic larval period of up to 2 years (Fitzgibbon *et al*. 2014), which may lead to variability in stock recruitment from year to year depending on environmental or anthropogenic stressors (Hartmann *et al*. 2019). However, TAC settings are more influential on stock biomass, and are therefore used as an effective management response (Hartmann *et al*. 2019).

Tasmania's commercial abalone fishery is the largest wild abalone fishery in the world (Ogier *et al*. 2018; Tasmanian Seafood Industry Council 2017) and predominantly targets blacklip abalone (*Haliotis rubra*; ~90–95% of catches), with some greenlip abalone (*H. laevigata*; ~5–10% of catch) caught by diving (Mundy and McAllister 2018; Mundy and McAllister 2020). The Tasmanian commercial wild-catch abalone fishery has participation 102 active divers and another 170 people directly employed in 2016, and 121 licence holders in 2017–18 (Ogier *et al*. 2018; Steven *et al*. 2020). The abalone fishery is divided into six fishing 'zones' with smaller-scale block caps within these, which are used in assessing and managing the fishery (Mundy and McAllister 2020). Management methods in place for the abalone fishery include limited entry, quotas, size limits, spatial closures, and TAC limits (Fisheries Research and Development Corporation 2020). The Tasmanian abalone wild-catch fishery is affected by historical overfishing from the 1990s, long-term habitat

degradation caused by *C. rodgersii* and multiple marine heatwaves over the past decade, which together have contributed to reduced abalone stocks, particularly in eastern Tasmania (Mundy and McAllister 2020). Stocks in western Tasmania more recently appeared to be rebuilding, while stocks in northern Tasmania are relatively stable, although some areas still show signs of decline (Mundy and McAllister 2018). To address falling stock levels across much of the fishery, TAC limits for the fishery have been continually reduced since 2011(Mundy and McAllister 2020).

The smaller Tasmanian commercial wild-catch fisheries include the giant crab fishery, scallop fishery, scalefish fishery, and commercial dive fishery. The Tasmanian giant crab fishery primarily the giant crab species *Pseudocarcinus gigas* using pots (or traps), the Tasmanian scallop fishery primarily harvests the commercial scallop species *Pecten fumatus*, but also includes the take of the doughboy scallop and queen scallop (Ogier *et al*. 2018). The Tasmanian scalefish fishery is a multi-gear and multi-species fishery and harvests various scalefish, shark, and cephalopod species using gill-nets, hooks, seine nets (Ogier *et al*. 2018). Finally, the Tasmanian commercial dive fishery collects mainly urchins (*Heliocidaris erythrogramma* and increasingly *Centrostephanus rodgersii*), and periwinkles (*Lunella undulata*), as also allows for harvest of clams and introduced oysters and seaweeds (Ogier *et al*. 2018).

Theoretical saturation of concepts

Interviews were completed with 16 fisheries stakeholders: seven fisheries managers, seven academics, and two industry representatives. These were the available participants who agreed to be part of the study, out of a total of 28 stakeholders that were contacted for interview, including seven industry representatives from various organisations. Theoretical saturation of concepts encountered during interviews was reached after conducting 13 interviews (Fig. S1). Evidence suggests that theoretical saturation often occurs after ~12 interviews (Guest *et al*. 2006; Baker and Edwards 2012).

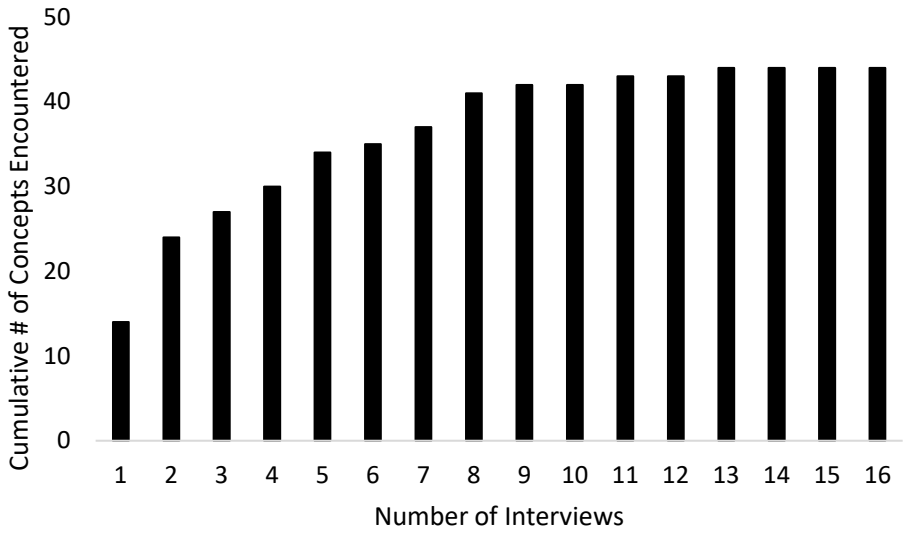

Fig. S1. Cumulative number of concepts encountered with increasing number of interviews, with a plateau after approximately eight interviews, and theoretical saturation of concepts after conducting 13 interviews (following Hagerman *et al*. 2010).

Interview guide

The interview guide was designed to explore the perceptions of participants around how Tasmanian commercial wild-catch fisheries can better prepare for and adapt to long-term environmental changes like climate change. Interview recordings lasted between 20 and 49 min, with an average time of 33 min. Interview guide was structured as follows:

1. What is your role within your organisation? How long have you been in this role?
2. Are you also a member of any (other) councils, committees, or associations related to Tasmanian Commercial state fisheries?
3. What are your personal views on climate change?
    a. Optional prompt: do you agree or disagree that current climate change is human induced?
4. How (if at all) is your organisation or research addressing long-term environmental changes like those associated with climate change, in relation to commercial fisheries?
5. In relation to the state fisheries you deal with, could you please identify some examples of the impacts your fisheries and marine environments have experienced already, as a result of long-term environmental changes?
    a. Optional prompt: Are there any positive changes?
6. How has the Department or industry responded to those changes and impacts?
    a. Optional prompt: Has there been any management changes?
7. How effective have any management changes been to minimise the negative impacts, and maximise the positive outcomes of those long-term environmental changes?
8. How (if at all) does your organisation or research measure or assess the effectiveness of the management changes in relation to long-term environmental changes?
9. What are the costs (financial or otherwise) of implementing management changes in relation to minimising the negative impacts or maximising the positive outcomes of long-term environmental changes? Who is affected by these management changes?
10. What environmental changes and impacts do you expect to affect the commercial state fisheries or marine environment you deal with in the next 10–50 years?
    a. Optional prompt: What about in the next 5 years?
11. Is there anything preventing your state fisheries from responding to the impacts of long-term environmental changes?
12. What do you think is necessary for your agency or industry to minimise the future negative impacts, and maximise future positive outcomes?
    a. Optional Prompts: How might this be improved moving forward? How can fisheries be proactive in responding to climate change?

References

Baker, S. E., and Edwards, R. (2012) How many qualitative interviews is enough? National Centre for Research Methods, Southampton, UK.

Department of Primary Industries, Parks, Water and Environment (2020) Fishery Advisory Committees. Tasmanian Government, Department of Primary Industries, Parks, Water and Environment: Hobart, Tas., Australia.

Fisheries Research and Development Corporation (2019) Australian fisheries and aquaculture industry 2017/18: economic contributions estimates report. FRDC project 2017–210, Fisheries Research and Development Corporation, the Institute for Marine and Antarctic Studies, University of Tasmania, and BDO EconSearch, Australia.

Fisheries Research and Development Corporation (2020) Status of Australian Fish Stocks Reports. (FRDC: Australia)

Fitzgibbon, Q. P., Jeffs, A. G., and Battaglene, S. C. (2014). The Achilles heel for spiny lobsters: the energetics of the non-feeding post-larval stage. *Fish and Fisheries* **15(**2), 312–326. doi:10.1111/faf.12018

Fogarty, H. E., Cvitanovic, C., Hobday, A. J., and Pecl, G. T. (2020). An assessment of how Australian fisheries management plans account for climate change impacts. *Frontiers in Marine Science* **7**, 591642. doi:10.3389/fmars.2020.591642

Guest, G., Bunce, A., and Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods* **18**(1), 59–82. doi:10.1177/1525822X05279903

Hagerman, S., Dowlatabadi, H., Satterfield, T., and McDaniels, T. (2010). Expert views on biodiversity conservation in an era of climate change. *Global Environmental Change* **20**(1), 192–207. doi:10.1016/j.gloenvcha.2009.10.005

Hartmann, K., Gardner, C., León, R., and Rizzari, J. (2019) Fishery Assessment Report: Tasmanian Rock Lobster Fishery 2017/18. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tas., Australia.

Ling, S. D., and Keane, J. P. (2018) Resurvey of the Longspined Sea Urchin (*Centrostephanus rodgersii*) and associated barren reef in Tasmania. Institute for Marine and Antarctic Science, University of Tasmania, Hobart, Tas., Australia.

Lyle, J. M., Stark, K. E., and Tracey, S. R. (2014) 2012–13 Survey of Recreational Fishing in Tasmania. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tas., Australia.

Mundy, C., and McAllister, J. (2018) Tasmanian Abalone Fishery Assessment 2017. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tas., Australia.

Mundy, C., and McAllister, J. (2020) Tasmanian Abalone Fishery Assessment 2019. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tas., Australia.

Ogier, E., Gardner, C., Hartmann, K., Hashino, E., León, R., Lyle, J., and Mundy, C. (2018) Economic and Social Assessment of Tasmanian Fisheries 2016/17. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tas., Australia.

Steven, A. H., Mobsby, D., and Curtotti, R. (2020) Australian fisheries and aquaculture statistics 2018. Fisheries Research and Development Corporation project 2019–093, ABARES, Canberra, ACT, Australia.

Tasmanian Seafood Industry Council (2017) Seafood industry workforce profile: May 2017. Report prepared by Stern and Associates. TSIC, Hobart, Tas., Australia.