Review documents for the Antarctic toothfish stock assessment for the Ross Sea region (Subarea 88.1 and SSRUs 88.2A and B)

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We briefly summarise the key papers that describe the stock assessment used for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region. Appendix A has a list of the papers referenced in the present document. Appendix B provides a more comprehensive list of papers associated with this stock assessment. These papers and the files for the base case model in 2017 are provided in The assessment was published in a peer-reviewed paper by Mormede et al. (2014a) and biennial assessments are presented to CCAMLR, the most recent in 2017. Biennial updates incorporate updated data, any recommendations from CCAMLR Scientific Working Groups and reflect ongoing improvements in stock assessment modelling and methods. The last biennial stock assessment of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region was carried out in 2017.

The 2017 stock assessment is detailed by Mormede (2017a), the model diagnostics are in (Mormede 2017b), the fishery descriptive is in Parker and Mormede (2017a), and the tagging data described in Parker and Mormede (2017b). The assessment rationale and structure are fully described by Mormede et al. (2014a). Information is provided here following the terms of reference for the review:

* Inputs
  + Stock structure: the model has a single domain with three spatially defined fisheries that capture the spatial structure of the toothfish population in the region (Hanchet et al. 2008).
  + Biological parameters: the model contains a sex partition to account for differences in biological parameters by sex and sex ratio observed in the three areas. Most biological parameters, including natural mortality, were derived from area-specific biological data (Hanchet et al. 2015a). All other parameters such as steepness were based on literature review (Mormede et al. 2014a).
  + Observations: a characterisation of the fishery is conducted every time a new stock assessment is carried out, and presented at CCAMLR (Parker & Mormede 2017a).
    - Input data are annual catches by area, and number of fish tagged at length.
    - Observations (with assumed likelihood and error values) are 1) the annual fishery age frequency by sex, 2) the annual number of tagged fish recaptured by length and sex and year of release, 3) the annual shelf survey age frequency by sex, and 4) the annual shelf survey biomass estimate. A catch-per-unit effort index was not included in the models as it does not appear to be indexing abundance (Parker & Mormede 2017a).
  + Tagging parameters: vessel-specific tag detection and tagging mortality indices are calculated using a case-control method (Mormede 2014) and applied to the number of tagged fish released, and the number of fish inspected for a tag in the input observations (Parker & Mormede 2017b). Instantaneous and ongoing tag loss rates were calculated based on the data collected from double tagged fish (Dunn et al. 2011).
* Implementation
  + Model details including likelihoods chosen and data weighting are detailed in Mormede (2017a). Diagnostics are presented in Mormede (2017b).
* Improvements to modelling
  + Step-change analyses and sensitivity runs have been carried out routinely to investigate potential issues and are summarised in Table 1.
  + A research plan to address some of the remaining uncertainties in the assessment are detailed the medium term research plan (Delegations of New Zealand 2014) and in Hanchet et al. (2015a).
* Improvements to data and research
  + Research requirements and, in particular, targeted data collection and data precision requirements are assessed on a regular basis (e.g., Hanchet et al. 2015b, Mormede 2017a, Mormede et al. 2014a).
* Alternative models and structures
  + A fully spatially explicit model of the toothfish population in the Ross Sea region was developed to explore the impact of ignoring the spatial complexity in the stock assessment model (Mormede et al. 2014b). Results showed that the single area stock assessment model currently used for management purposes was likely to be biased low. When the spatial model assumed fish outside of the footprint of the fishery, then the stock assessment model under-estimated the biomass by 30 – 50 %.
  + A calculation of the current biomass in the Ross Sea region using recent tagging data showed that the sum of small area Chapman calculations gave a similar estimate of the current biomass as that from the CASAL model (Parker et al. 2017).

Table 1: Summary of the development of the stock assessment of Antarctic toothfish in the Ross Sea region.

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| **Year** | **Changes from previous assessment** | **Sensitivities** |
| 2005 | First model used for management purposes. Uses proportions at age, CPUE indices, and tagging data from NZ vessels. | No tagging data, tag growth check estimated or ignored, constant or no shift in fisheries selectivities, low mortality value, single fishery, fixed fishing selectivity, 2- and 3- area models |
| 2006 | Revise length-weight and growth parameters, one additional year of data | Tagging data from all vessels, uncertainty added to natural mortality, alternative data weightings |
| 2007 | Remove CPUE indices, one additional year of data | Tagging data from all vessels, tagging data from all vessels in 2006 only, logistic north selectivity |
| 2009 | Tagging data from selected trips from all nations using new data quality method, update maturity curve, two additional years of data | Tagging data from NZ vessels only, 2007 maturity ogive |
| 2011 | Update tag data selection, update tag-loss rates based on the analysis of double-tagging data, two additional years of data | Inclusion of IUU catch, inclusion of various levels of additional mortality, tagging data from all vessels |
| 2013 | New tagging survival and tag detection calculation method using tagging data from all vessels, update maturity curve, change model data weighting to Francis (2011), two additional years of data | Logistic selectivity in the North, retrospective analysis (removing up to 210-2013 observations) |
| 2015 | Add survey age frequencies and biomass estimates and estimate YCS, remove annual selectivity shifts, update tagging survival and tag detection rates, update data weighting, two additional years of data | Logistic selectivity in the North, remove survey data, use tagging data from the last 6 years only, change the catches from quarantined data by +/- 50%, |
| 2017 | Update tagging survival and tag detection rates, update data weighting, two additional years of data | Logistic selectivity in the North, remove survey data, down-weight survey biomass estimates, exclude tag releases from a vessel with a large increase in tagging survival rates |

**Appendix A: References**

Delegations of New Zealand, Norway and the U.K. (2014). Medium-term research plan for the Ross Sea toothfish fishery. Hobart, Australia, CCAMLR. WG-FSA-14/60**:** 27 p.

Dunn, A.; Smith, M.H.; Agnew, D.J.; Mormede, S. (2011). Estimates of the tag loss rates for single and double tagged toothfish (*Dissostichus mawsoni*) fishery in the Ross Sea. Hobart, CCAMLR. WG-SAM-11/18**:** 13 p.

Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences 68*: 1124-1138.

Hanchet, S.M.; Dunn, A.; Parker, S.; Horn, P.; Stevens, D.W.; Mormede, S. (2015a). The Antarctic toothfish (*Dissostichus mawsoni*): biology, ecology, and life history in the Ross Sea region. *Hydrobiologia 761*: 397-414.

Hanchet, S.M.; Parker, S.J.; Mormede, S. (2015b). Draft updated data collection plan for the Ross Sea toothfish fishery. Hobart, Australia, CCAMLR. WG-FSA-15/40**:** 14 p.

Hanchet, S.M.; Rickard, G.J.; Fenaughty, J.M.; Dunn, A.; Williams, M.J. (2008). A hypothetical life cycle for Antarctic toothfish *Dissostichus mawsoni* in the Ross Sea region. *CCAMLR Science 15*: 35-53.

Mormede, S. (2014). Calculating effective releases and recaptures for stock assessments based on tag detection and tagging mortality indices. Hobart, Australia, CCAMLR. WG-SAM-14/30**:** 6 p.

Mormede, S. (2017a). Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region to 2016–17. Hobart, Australia, CCAMLR. WG-FSA-17/37**:** 18 p.

Mormede, S. (2017b). Diagnostic plots of stock assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region to 2016–17. Hobart, Australia, CCAMLR. WG-FSA-17/38**:** 82 p.

Mormede, S.; Dunn, A.; Hanchet, S.M. (2014a). A stock assessment model of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region incorporating multi-year mark-recapture data. *CCAMLR Science 21*: 39-62.

Mormede, S.; Dunn, A.; Hanchet, S.M.; Parker, S. (2014b). Spatially explicit population dynamics operating models for Antarctic toothfish in the Ross Sea region. *CCAMLR Science 21*: 19-37.

Parker, S.J.; Mormede, S. (2017a). A characterisation of the toothfish fishery in the Ross Sea region (Subarea 88.1 and SSRUs 88.2A-B) to 2016-17. Hobart, Australia, CCAMLR. WG-FSA-17/07**:** 22 p.

Parker, S.J.; Mormede, S. (2017b). Mark recapture data inputs to the the 2017 Ross Sea region stock assessment (Subarea 88.1 and SSRUs 88.2A-B). Hobart, Australia, CCAMLR. WG-FSA-17/36**:** 9 p.

Parker, S.J.; Mormede, S.; Dunn, A.; Hanchet, S.M.; Marsh, C. (2017). Developing robust biomass estimates and advice on catch limits in research blocks. Hobart, Australia, CCAMLR. WG-SAM-17/37**:** 9 p.

**Appendix B: supplementary documents**

Abrams, P.A. (2013). How precautionary is the policy governing the Ross Sea Antarctic toothfish (*Dissostichus mawsoni*) fishery? *Antarctic Science* 26(1): 3-14.

Brooks, C.M.; Andrews, A.H.; Ashford, J.R.; Ramanna, N.; Jones, C.D.; Lundstrom, C.C.; Cailliet, G.M. (2011). Age estimation and lead-radium dating of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. *Polar Biology 34*: 329-338. Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H.; Bian, R.; Fu, D. (2012). CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v2.30-2012/03/21. Wellington, NIWA Technical Report 135: 280 p.

CCAMLR (2016). Fishery Report 2016: Exploratory fishery for *Dissostichus* spp. in Subarea 88.1. Hobart, Australia, CCAMLR. 33 p.

Delegations of New Zealand, Norway, and the U.K. (2014). Medium-term research plan for the Ross Sea toothfish fishery. Hobart, Australia, CCAMLR. WG-FSA-14/60: 27 p.

Dunn, A.; Rasmussen, S.; Mormede, S. (2012). Spatial population model user manual, SPM v1.1-2012-09-06 (rev 4806). Hobart, CCAMLR. WG-FSA-12/46: 164 p.

Dunn, A.; Rickard, G.; Hanchet, S.M.; Parker, S. (2012). Models of larval dispersion of Antarctic toothfish (*Dissostichus mawsoni*). Hobart, CCAMLR. WG-FSA-12/48: p.

Francis, R.I.C.C. (2011). Corrigendum: Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 2228.

Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 1124-1138.

Hanchet, S.M.; Mormede, S.; Dunn, A. (2010). Distribution and relative abundance of Antarctic toothfish (Dissostichus mawsoni) on the Ross Sea shelf. *CCAMLR Science* 17: 33-51.

Hanchet, S.M.; Mormede, S.; Parker, S.; Large, K.; Dunn, A.; Sharp, B. (2017b). Monitoring Antarctic toothfish (*D. Mawsoni*) recruitment in the southern Ross Sea. Hobart, Australia, CCAMLR. WG-FSA-17/57: 15 p.

Hanchet, S.M.; Parker, S.J.; Mormede, S. (2015). Draft updated data collection plan for the Ross Sea toothfish fishery. Hobart, Australia, CCAMLR. WG-FSA-15/40: 14 p.

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Hanchet, S.M.; Sainsbury, K.; Butterworth, D.S.; Darby, C.; Bizikov, V.A.; Godø, O.R.; Ichii, T.; Kock, K.-H.; Abellan, L.J.L.; Vacchi, M. (2015). CCAMLR’s precautionary approach to management focusing on Ross Sea toothfish fishery. *Antarctic Science*: 8.

Hanchet, S.M.; Sharp, B.; Parker, S. (2013). Priority research surveys to address uncertainties in the assessment of toothfish in Subareas 88.1 and 88.2. Hobart, Australia, CCAMLR. WG-FSA-13/55: 8 p.

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Mormede, S. (2011). Investigation of the sensitivity of the Ross Sea toothfish assessment to withholding subsets of the available data. Hobart, CCAMLR. WG-SAM-11/17: 8 p.

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Mormede, S.; Dunn, A. (2013). Quantifying vessel performance in the CCAMLR tagging program: spatially and temporally controlled measures of tag detection rates. *CCAMLR Science* 20: 73-80.

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