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Population structure of Patagonian toothfish (*Dissostichus eleginoides*)  
on the Kerguelen Plateau and consequences for the fishery in SIOFA  
Statistical Area 7

*Relates to agenda item: 4*

Working paper  Info paper

Delegation of Australia

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## Abstract

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Patagonian toothfish (*Dissostichus eleginoides*) is a large benthic-pelagic fish species on the Kerguelen Plateau. Almost the entire Kerguelen Plateau is situated within the area managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), with only the William's Ridge on the eastern side of the Plateau extending into SIOFA Statistical Area 7. Most of the suitable Patagonian toothfish habitat on the northern part of the Kerguelen plateau is covered by the Australian Exclusive Economic Zone (EEZ) around Heard Island and McDonald Islands (HIMI) and the adjacent French EEZ around Kerguelen Islands.

Based on available genetic information, catch composition and tag-recapture data from the French and Australian toothfish fisheries, Patagonian toothfish are continuously distributed on the northern part of the Kerguelen Plateau and populations are linked. Population linkages between the French and Australian EEZs are accounted for in the toothfish assessment for the Australian EEZ undertaken by CCAMLR. Based on CCAMLR decision rules, this assessment estimates the catch limit which is fully taken within CCAMLR waters. Any additional fishing mortality of this population, including toothfish catches on William's Ridge, is therefore likely to result in the total fishing mortality exceeding the catch limit set by CCAMLR for this fishery.

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## Recommendations *(working papers only)*

It is recommended that the SERAWG consider the following recommendations to the SC:

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- **Note** that based on genetic information, catch composition and tag-recapture data from the French and Australian toothfish fisheries, Patagonian toothfish on the Kerguelen Plateau are continuously distributed and populations are linked
  - **Note** that five toothfish, released in the Australian or French EEZ and recaptured on William's Ridge in 2018, are consistent with movement patterns of toothfish across the Kerguelen Plateau
  - **Note** that this population structure is accounted in the CCAMLR assessment as well as the estimation of catch limits for toothfish in the Australian EEZ, and the yield is fully taken within CCAMLR waters
  - **Note** that the CCAMLR stock assessments are subject to a rigorous review process
  - **Note** that toothfish catches on William's Ridge are likely to result in catch limits being exceeded for the toothfish population in the Australian EEZ at HIMI, which may undermine the CCAMLR management objectives for the fishery
  - **Recommend** that the SC recommend to the Meeting of the Parties that management measures to regulate toothfish catches from William's Ridge are urgently required to ensure that catches from this population do not exceed the catch limit as determined by CCAMLR.
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# Population structure of Patagonian toothfish (*Dissostichus eleginoides*) on the Kerguelen Plateau and consequences for the fishery in SIOFA Statistical Area 7

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## Abstract

Patagonian toothfish (*Dissostichus eleginoides*) is a large benthic-pelagic fish species on the Kerguelen Plateau. Almost the entire Kerguelen Plateau is situated within the area managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), with only the William's Ridge on the eastern side of the Plateau extending into SIOFA Statistical Area 7. Most of the suitable Patagonian toothfish habitat on the Kerguelen plateau is covered by the Australian Exclusive Economic Zone (EEZ) around Heard Island and McDonald Islands (HIMI) and the adjacent French EEZ around Kerguelen Islands.

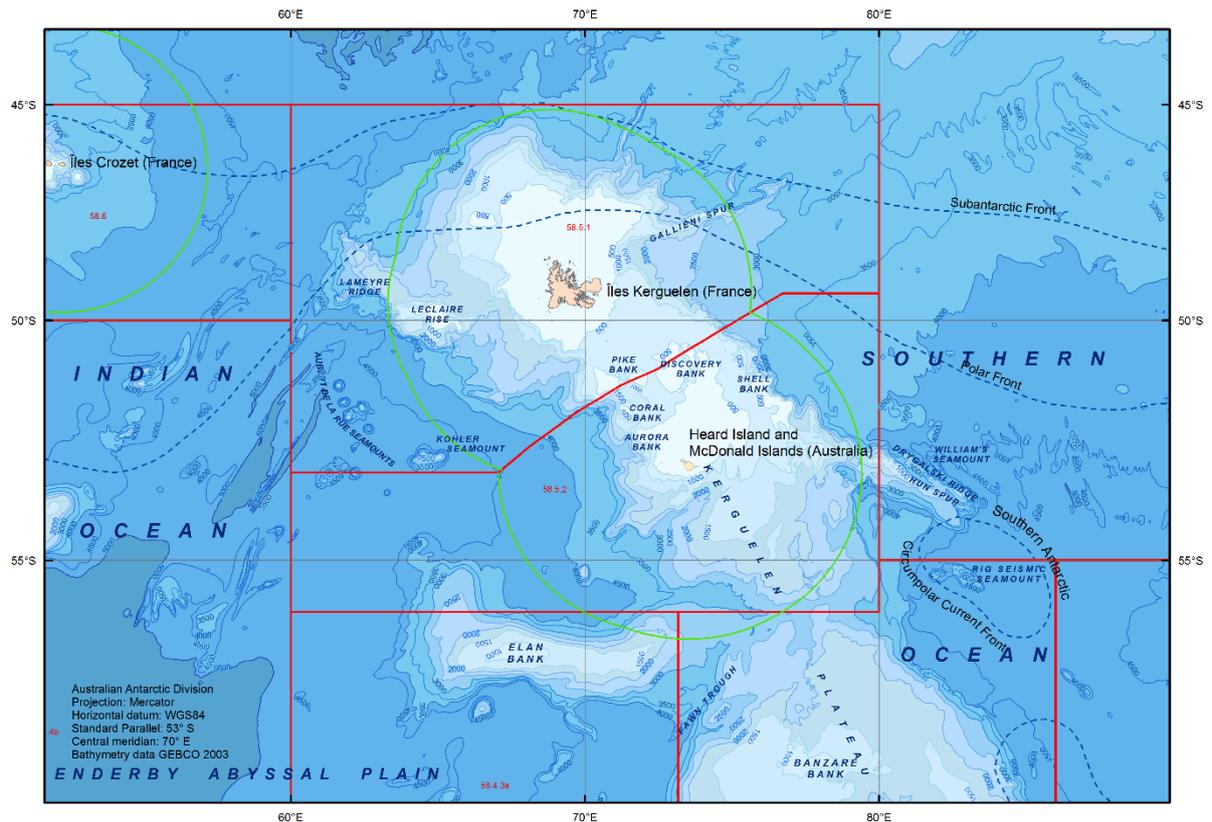
Based on available genetic information, catch composition and tag-recapture data from the French and Australian toothfish fisheries, Patagonian toothfish are continuously distributed on the northern part of the Kerguelen Plateau and populations are linked. Population linkages between the French and Australian EEZs are accounted for in the toothfish assessment for the Australian EEZ undertaken by CCAMLR. Based on CCAMLR decision rules, this assessment estimates the catch limit which is fully taken within CCAMLR waters. Any additional fishing mortality of this population, including toothfish catches on William's Ridge, is therefore likely to result in the total fishing mortality exceeding the catch limit set by CCAMLR for this fishery.

## Introduction

Patagonian toothfish (*Dissostichus eleginoides*) is a large benthic-pelagic fish species with a circumpolar distribution in waters of the Southern Ocean around southern Patagonian and Chilean shelves, and on banks, seamounts and submersed plateaus around islands in the Southern Ocean (Eastman 1993; Gon and Heemstra 1990). The species occurs over a wide depth range from around 10 m to over 2500 m (Duhamel et al. 2005), with an ontogenetic habitat shift towards deeper waters as fish grow (Péron et al. 2016). Similar to other deep-sea fish species, Patagonian toothfish show typical K-selection life-history characteristics including slow growth, large body size (up to 2 m and 100 kg), life expectancy of over 50 years (Ziegler 2017), and late age-at-maturity (Yates et al. 2018).

Targeted fisheries for Patagonian toothfish have been developed in a number of regions, initially in Chile in the 1950s, then later around the Patagonian shelf, South Georgia, the Kerguelen Plateau, Crozet Island, Marion and Prince Edward Islands, Macquarie Island, and a number of isolated banks and seamounts (Collins et al. 2010).

In this paper, we describe the Patagonian toothfish population structure on the Kerguelen Plateau and consequences for the Patagonian toothfish fishery in SIOFA Statistical Area 7. The Kerguelen Plateau is located in the Southern Indian Ocean and stretches from around 45°S to over 60°S (Figure 1). Almost the entire Kerguelen Plateau is situated within the area managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), with only the 'William's Ridge' on the eastern side of the northern part of the Plateau extending into the Southern Indian Ocean Fisheries Agreement (SIOFA) Statistical Area 7. For the purpose of this paper, we denote William's Seamount, Drygalski Ridge, Chun Spur (as defined in e.g. <https://www.ngdc.noaa.gov/gazetteer/>) and all surrounding features as 'William's Ridge' (Figure 1).



**Figure 1:** Map of the northern part of the Kerguelen Plateau with CCAMLR Division 58.5.1 and the French EEZ around Kerguelen Island to the north, and CCAMLR Division 58.5.2 and the Australian EEZ around Heard Island and McDonald Islands (HIMI) to the south. Boundaries of the CCAMLR area and Divisions within are marked by red lines, EEZs by green lines. For the purpose of this paper, we denote William’s Seamount, Drygalski Ridge, Chun Spur and all surrounding features extending into the SIOFA Statistical Area 7 east of 80°E and at around 53°S as ‘William’s Ridge’.

On the northern part of the plateau (north of Fawn Trough or roughly 57°S), two large fisheries for Patagonian toothfish are located in CCAMLR Division 58.5.1 which covers the French Exclusive Economic Zones (EEZ) around Kerguelen Islands, and Division 58.5.2 which covers the Australian EEZ around Heard Island and McDonald Islands (HIMI). On the southern part of the Kerguelen Plateau, Antarctic toothfish (*D. mawsoni*) which is better adapted to the colder waters around the Antarctic continent, is the dominant toothfish species.

France declared an EEZ around Kerguelen Islands in 1978, while Australia declared an Australian Fishing Zone (AFZ) around HIMI in 1979 and an EEZ in 1994 (Welsford et al. 2011b). Currently, there are conservation measures in place for the Patagonian toothfish fishery in Division 58.5.2 specifying fishery access, a catch limit (currently 3525 tonnes), fishing season, observer and data collection requirements (CM 41-08), bycatch limits (CM 33-02) and seabird mitigation measures (CM 25-03). The fishery is restricted to the Australian EEZ while fishing within Division 58.5.2 but outside the EEZ is prohibited (CM 32-02). CM 32-02 was established to stop IUU fishing for toothfish on the high seas and prevent fishing mortality in several Statistical Divisions exceeding the sustainable catch limits set by CCAMLR.

### History of the fishery in CCAMLR Division 58.5.2

In the Australian EEZ around HIMI in CCAMLR Division 58.5.2, commercial trawl fishing started in 1997 and trawl remained the dominant fishing gear for many years (Table 1). The use of longline was initially prohibited due to the risk of seabird bycatch, but following the development of integrated weighted longline (IWL), this gear type was permitted in 2003. The catch taken by longline increased steadily over the years, and longline has become the dominant gear type since 2011. By 2017, almost the entire commercial catch was taken by longline. Concurrently, the number of longliners increased from one to four vessels by 2017, one of which is a dual purpose trawl/longline vessel. Traps were also trialled in 2006 and from 2009-2013 but catches remained too small for traps to be commercially viable.

Illegal, unreported and unregulated (IUU) catches in CCAMLR Division 58.5.2 were potentially large in the late 1990s and early 2000s. IUU catches were estimated based on sightings of IUU vessels, their known fishing capacities, and catch and effort data from the licensed fishery (Table 1). No IUU vessel has been sighted after 2005 and it is likely that no IUU catches have been taken since then.

**Table 1:** Catch limits, reported catch for longline, pot and trawl, estimated IUU catch and total removals in tonnes by fishing season in CCAMLR Division 58.5.2. Data from [CCAMLR Fishery Report for \*D. eleginoides\* in Division 58.5.2 for 2017](#).

Season <sup>a</sup>	Catch limit (tonnes)	Reported catch (tonnes)				Estimated IUU catch (tonnes)	Total removals (tonnes)
		Longline	Pot	Trawl	Total		
1997	3800	0	0	1927	1927	7117	9044
1998	3700	0	0	3765	3765	4150	7915
1999	3690	0	0	3547	3547	427	3974
2000	3585	0	0	3566	3566	1154	4720
2001	2995	0	0	2980	2980	2004	4984
2002	2815	0	0	2756	2756	3489	6245
2003	2879	270	0	2574	2844	1274	4118
2004	2873	567	0	2296	2863	531	3394
2005	2787	621	0	2122	2743	265	3008
2006	2584	659	68	1801	2528	74	2602
2007	2427	601	0	1787	2388	0	2388
2008	2500	835	0	1445	2280	0	2280
2009	2500	1168	10	1286	2464	0	2464
2010	2550	1213	30	1215	2458	0	2458
2011	2550	1383	34	1148	2565	0	2565
2012	2730	1356	0	1361	2717	0	2717
2013	2730	2074	40	563	2677	0	2677
2014	2730	2642	0	108	2750	0	2750
2015	4410	4021	0	205	4226	0	4226
2016	3405	2619	0	156	2775	0	2775
2017	3405	3343	0	24	3367	0	3367

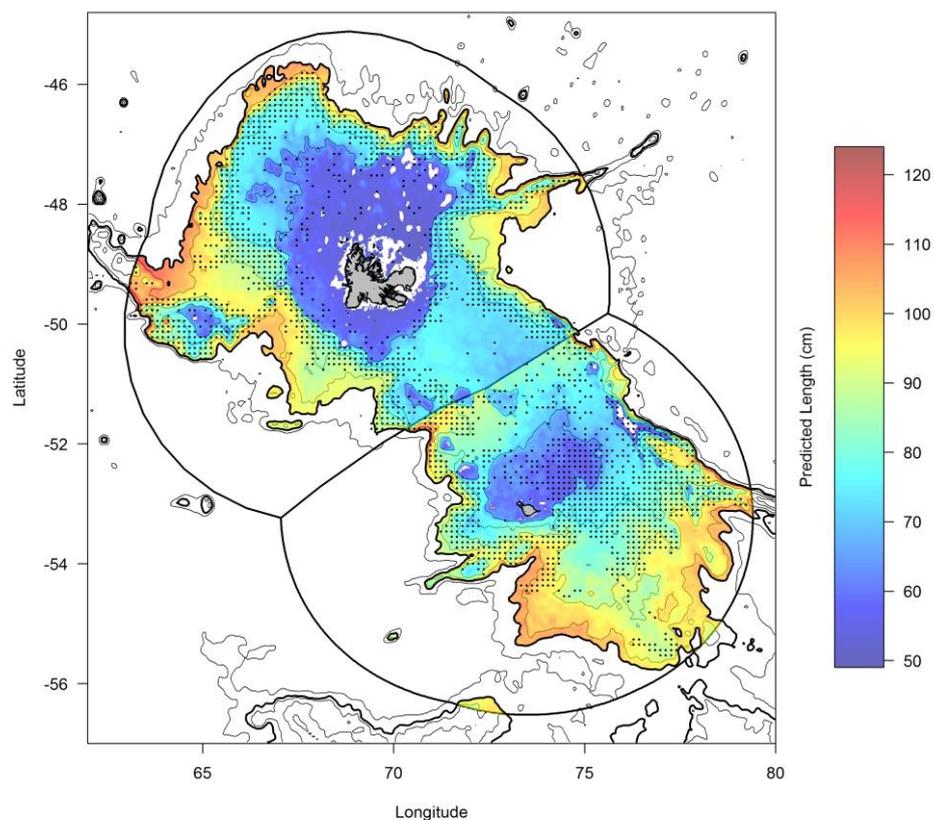
<sup>a</sup> Fishing seasons run from 1 December - 30 November of the following year. 1995/96 is denoted as 1996, 1996/97 as 1997 and so on.

### Population structure of *D. eleginoides* on the Kerguelen Plateau

Based on available genetic information, catch composition and tag-recapture data from survey and the commercial toothfish fishery, Patagonian toothfish are continuously distributed on the northern part of the Kerguelen Plateau and populations are linked.

Linkages between populations of toothfish across large geographic scale, i.e. between the Australian and French EEZs as well as around Crozet Islands, were indicated by a study on genetic differentiation. Using DNA extracts of toothfish otoliths from the three regions, Toomey et al. (2016) investigated the genetic differentiation with four mitochondrial and four nuclear markers. They found genetic homogeneity in nuclear markers between the Australian and French EEZs and Crozet Islands, supporting some level of gene flow attributable to active movement of post-settlement fish across the Kerguelen Plateau. However, the differentiation in mitochondrial markers particularly between HIMI and Crozet Islands indicated that the level of movement was small and potentially dominated by males.

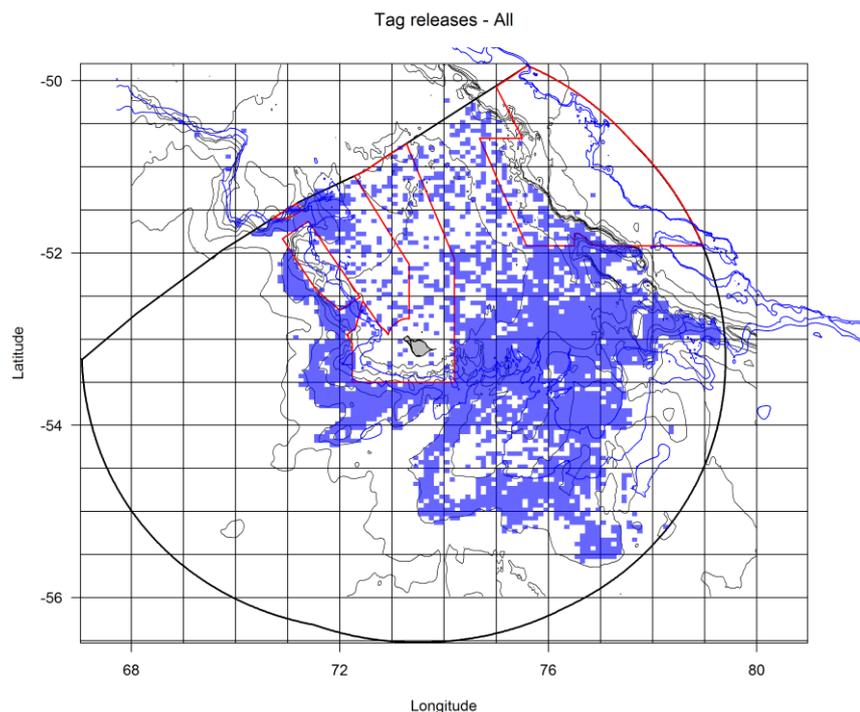
Using fishery-dependent data from the Australian and French EEZs on the Kerguelen Plateau, Péron et al. (2016) developed spatially-explicit statistical models to quantify and predict the spatial distribution of Patagonian toothfish length and sex ratio in longline catches (Figure 2). They found that Patagonian toothfish are continuously distributed in both EEZs on the northern part of the Kerguelen Plateau, with a dominance of small fish in shallow waters and large fish in deeper waters. The distribution models supported an ontogenetic migration from shallow to deep waters as fish grow and the dominance of larger males in the French EEZ and larger females in the Australian EEZ.



**Figure 2:** Prediction map of female Patagonian toothfish median total length caught by commercial longlines in the Australian and French EEZs on the northern part of the Kerguelen Plateau. Bathymetry contours (-400m, -1000m, -2000m and -3000m) are displayed in black. The -2300 m isobath corresponding with the lower limit of the fishing depth is highlighted in bold. Dots correspond to fishing locations. From Péron et al. (2016).

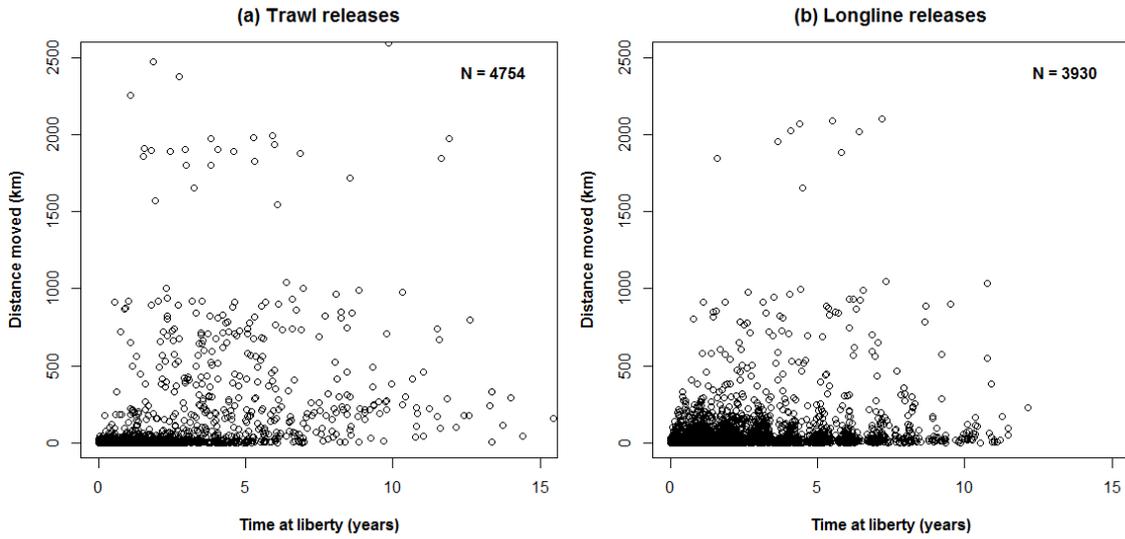
Observed movements from tagged and released toothfish also demonstrated toothfish population connectivity across the entire northern part of the Kerguelen Plateau and even some links to the populations at Crozet and Marion Islands.

Over the last 20 years, more than 100 000 Patagonian toothfish have been tagged and released in the Australian and French EEZs. Tagging of fish with two conventional T-bar tags is conducted by observers and vessel crew during surveys and predominantly commercial fishing. In the Australian EEZ around HIMI, tagged fish were initially released from trawl only and located on a small fishing ground where most of the trawl effort was concentrated. With the start of the longline fishery in 2003 and a subsequent expansion of the fishing effort across large parts of the Australian EEZ, the spatial distribution of tag-releases has increased substantially although it has remained uneven (Figure 3).

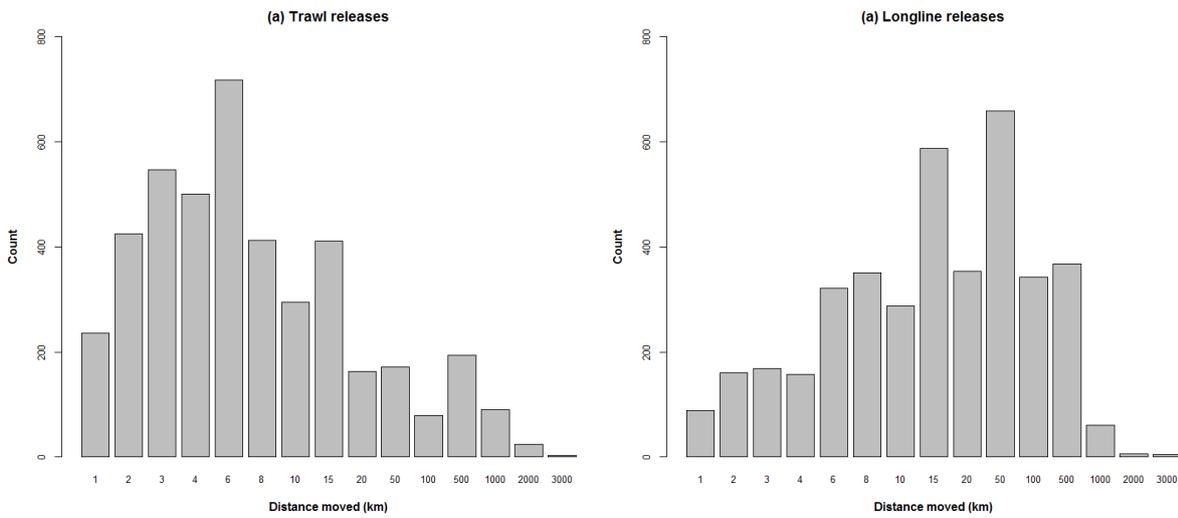


**Figure 3:** Release locations of tagged fish in the Australian EEZ around HIMI between 1997 and 2018.

While some tagged fish have been recaptured soon after release, particularly in the trawl fishery due to repeated trawls and the localised nature of trawl effort on the main trawl ground, many fish have remained at liberty for a number of years and some fish were only recaptured after over 10 years (Figure 4). In their time-at-liberty, most fish of both sexes have been recaptured less than 100 km from their release location, even after over 10 years at liberty (Figures 4 and 5). However, many fish moved long distances over 100 km, and tagged fish have been recaptured around Kerguelen and Crozet Islands and one fish travelled over 2500 km Marion Island (Figure 6). Fish were recaptured in all directions relative to their release locations, but for distances moved over 100 km there was a dominance of movement in north-east and south-west direction. The reasons for these directional preferences could be related to the distribution of available habitat and the higher likelihood of recapture effort in these directions.

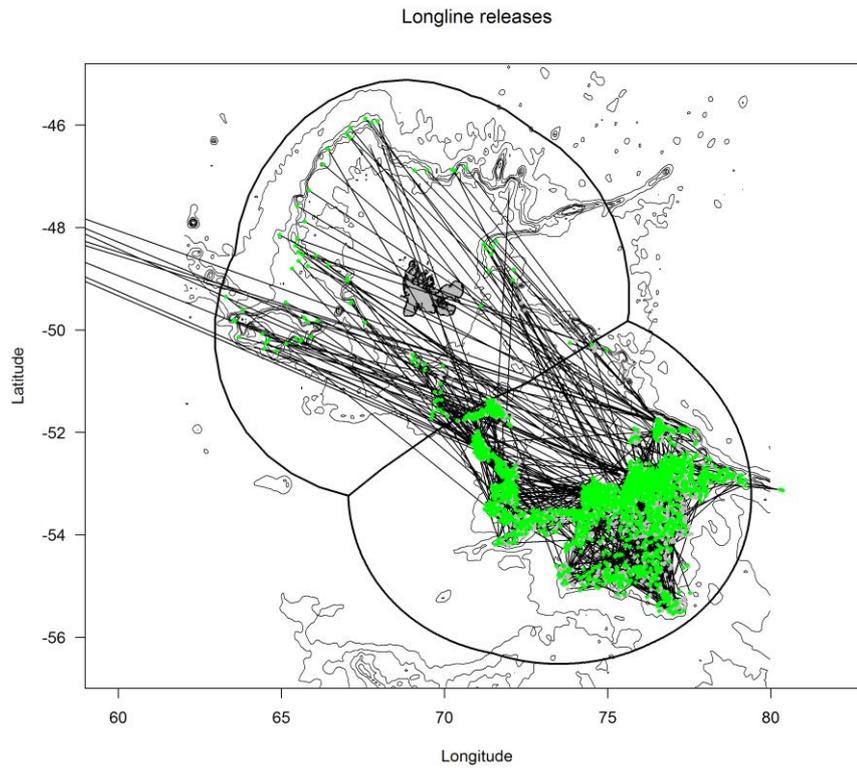


**Figure 4:** Time at liberty (years) versus distance moved (km) for tagged fish in the Australian EEZ around HIMI between 1997 and 2018 that have been released by (a) trawl and (b) longline.

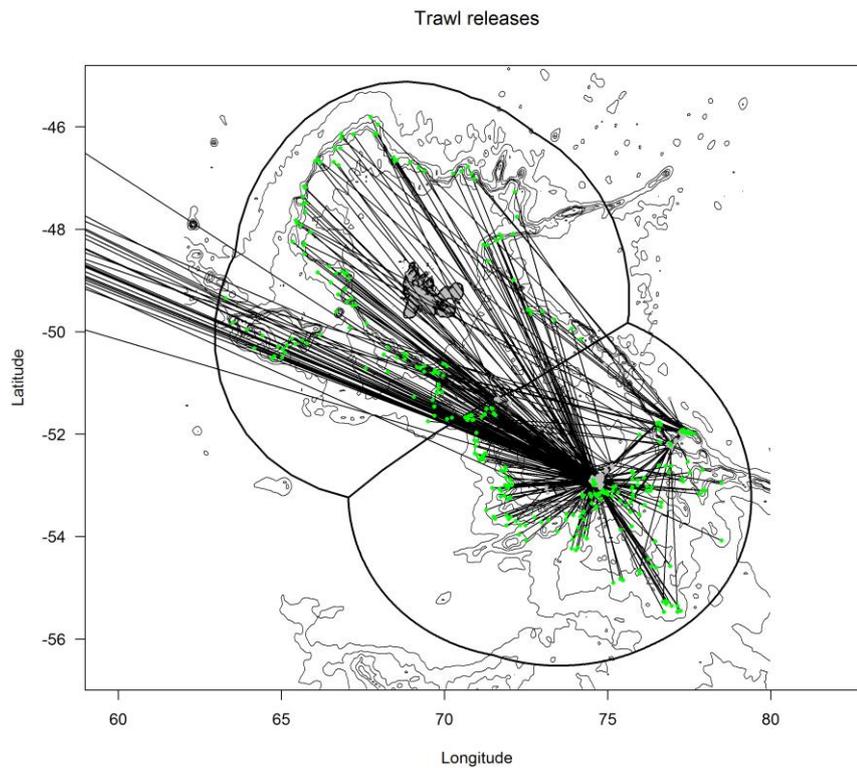


**Figure 5:** Frequency histograms of the minimum distance travelled between release and recapture of toothfish at HIMI between 1997 and 2018 that have been released by (a) trawl and (b) longline. Fish recaptured <10 days after their release were excluded.

(a)

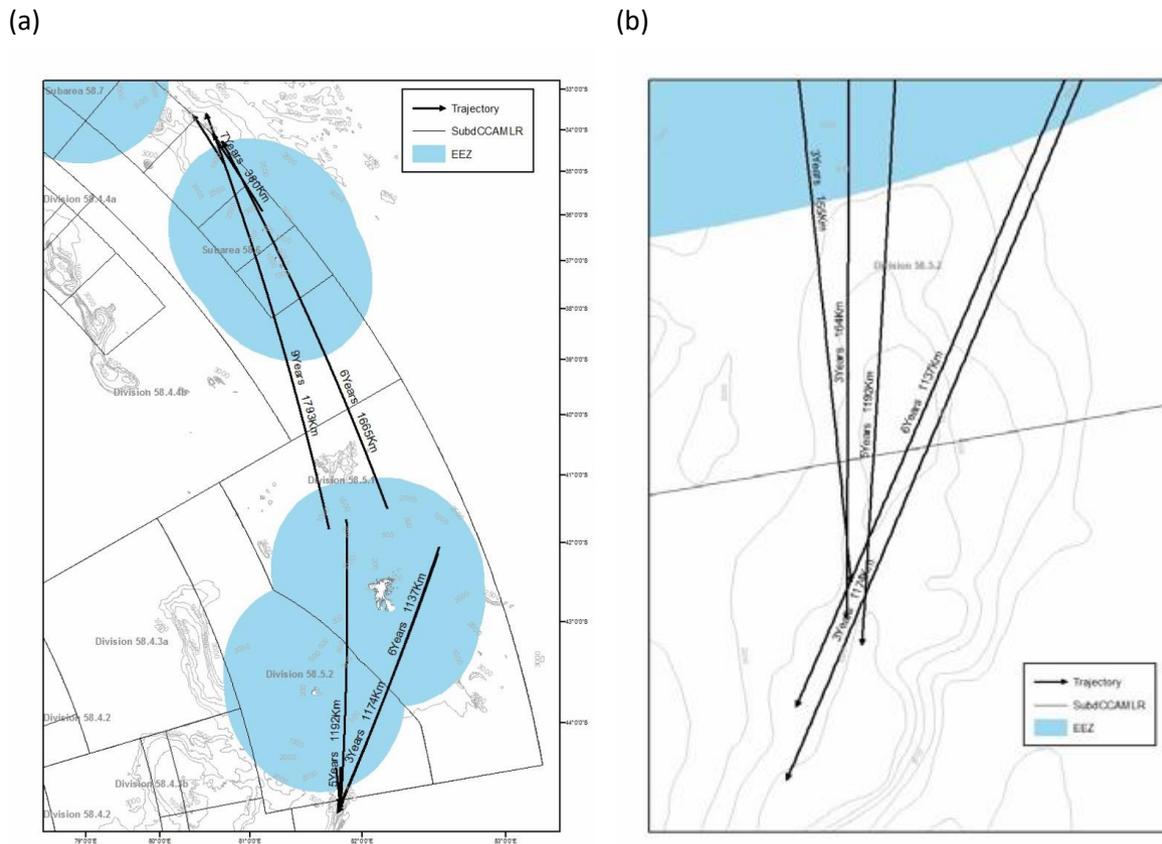


(b)



**Figure 6:** Release (grey) and recapture locations (green) and minimum distances between the two (black lines) for fish released in the Australian EEZ around HIMI by (a) trawl and (b) longline, and caught by longline, between 1997-2018.

These movement patterns are consistent with five toothfish that had been released either in the Australian or French EEZ and recaptured on William’s Ridge in 2018 (Figure 7, Sarralde and Barreiro 2018). Given continuous toothfish habitat and the proximity of William’s Ridge to the Australian EEZ, these observations indicate that toothfish on William’s Ridge belong to the same population as those in the Australian EEZ.

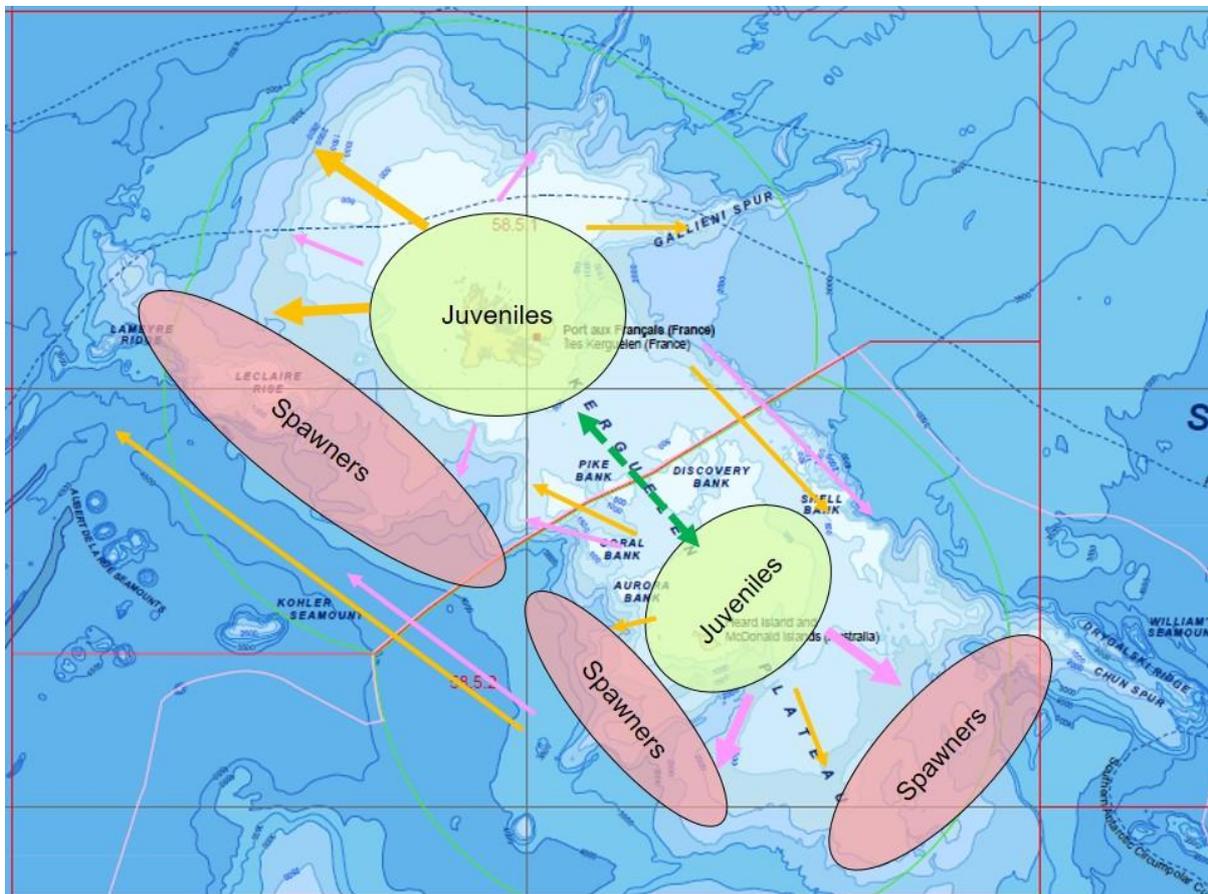


**Figure 7:** (a) Minimum-distance trajectories of toothfish that have been released in the CCAMLR area and recaptured in SIOFA Statistical Areas 3b and 7 in 2017 and 2018, and (b) a close-up of trajectories and recapture locations in SIOFA Statistical Area 7 in 2018 (right). From Sarralde and Barreiro (2018).

Estimation of movement rates, i.e. the proportion of the population that moves between areas which can provide information on the level of fish exchange, is more complex than describing patterns in movement directions and distances, as it requires an estimate of abundance in the areas between which movement is occurring. With abundance estimates available from integrated stock assessments in the Australian ([CCAMLR Fishery Report for Division 58.5.2 2017](#), Ziegler 2017) and French EEZs ([CCAMLR Fishery Report for Division 58.5.1 2017](#)), Burch et al. (2017) estimated annual migration rates of adult toothfish between the two EEZs using longline tag-recapture data and a catch-conditioned modification of a method described by Hilborn (1990). In the analysis, the two EEZs were treated as homogenous populations between which annual migration occurred. Migration was estimated as relatively low, with 1% of adult fish vulnerable to longlines migrating north from the Australian to the French EEZ and 1% migrating south in the reverse direction. Movement rate estimates for juveniles which are less well observed in the fishery, are not available.

Yates et al. (2018) investigated the spatio-temporal dynamics in maturation and spawning around HIMI based on gonads and otoliths collected between 2004-2015. They found that the majority of mature fish were encountered in depths of 1500–2000 m, with the main spawning areas located in waters to the west and south of HIMI. In simulations of egg and larvae transport patterns for velocity fields derived from sea surface altimetry (AVISO) and re-analysis products (SISO), areas to the west of the plateau were considered to be most successful to lead to consistent recruitment success (Mori et al 2016).

Based on these results and given continuous habitat between the French and Australian EEZs and William’s Ridge, it is highly likely that Patagonian toothfish populations on the northern part of the Kerguelen Plateau are linked. Within this area, the populations are likely structured with juveniles settling in shallow waters around the islands and potential exchange between Kerguelen Islands and HIMI (Figure 8). As fish grow larger and older, they move to deeper waters, and major spawning grounds are located on the western and southern side of the plateau.



**Figure 8:** Schematic toothfish population structure on the northern part of the Kerguelen Plateau with Kerguelen Island to the north and Heard Island and McDonald Islands to the south. Juveniles settle in shallow waters on the plateau around the islands with potential exchange between areas (dark green arrows). Males (orange arrows) and females (pink arrows) then move into deeper waters as they grow larger and older, with major spawning grounds on the western and southern side of the plateau. Most adult fish move only short distances, but long-distance movement occur over the entire plateau, with some level of fish exchange between the Australian and French EEZ (green lines). CCAMLR Divisions are marked by red lines.

## HIMI toothfish stock assessment

The latest stock assessment for HIMI toothfish was conducted in 2017 ([CCAMLR Fishery Report for Division 58.5.2 2017](#), Ziegler 2017). The integrated single-area, single-sex, age-structure stock assessment is implemented in CASAL (C++ Algorithmic Stock Assessment Laboratory, Bull et al. 2012) and fits to observations derived from many different sources, mainly biomass indices from survey and tag-recapture data, and catch-at-age composition data from surveys and commercial fishing. Combinations of gear and fishing locations are considered as separate sub-fisheries in the model in order to include some spatial complexity of the region within the single-area model framework.

Burch et al. (2017) used simulations to show that fish emigration can cause a bias in spawning biomass estimates in a tag-based assessment model and that such a bias can be corrected through increasing the tag-shedding parameter by the value of the migration rate. This approach was included in the model as it provided a simple way to correct for the effects of emigration and was considered to be appropriate for situations such as this one where the migration rates were estimated to be low (CCAMLR Independent Stock Assessment Review 2018).

The sustainable yield was calculated based on a MCMC sample of projections for spawning stock biomass following the CCAMLR decision rules:

- Choose a yield  $\gamma_1$ , so that the probability of the spawning biomass dropping below 20% of its median pre-exploitation level over a 35-year harvesting period is 10% (depletion probability).
- Choose a yield  $\gamma_2$ , so that the median escapement of the spawning biomass at the end of a 35-year period is 50% of the median pre-exploitation level.
- Select the lower of  $\gamma_1$  and  $\gamma_2$  as the yield.

The 2017 HIMI assessment model estimated that virgin spawning stock biomass  $SSB_0$  was 77 286 t (95% CI: 71 492-84 210 t), with the  $SSB$  in 2017 at 61% of  $SSB_0$ . The catch limit that satisfies the CCAMLR decision rules was estimated to be 3 525 tonnes. This catch limit is fully taken within the Australian EEZ.

## Conclusions

Based on available genetic information, catch composition and tag-recapture data from the French and Australian toothfish fisheries, Patagonian toothfish are continuously distributed on the northern part of the Kerguelen Plateau and populations are linked. Population linkages between the French and Australian EEZs are accounted for in the toothfish assessment for the Australian EEZ undertaken by CCAMLR. Based on CCAMLR decision rules, this assessment estimates the catch limit which is fully taken within CCAMLR waters. Any additional fishing mortality of this population, including toothfish catches on William's Ridge, is therefore likely to result in the total fishing mortality exceeding the catch limit set by CCAMLR for this fishery.

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