CCAMLR

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Commission pour la conservation de la faune et la flore marines de l'Antarctique
Комиссия по сохранению морских живых ресурсов Антарктики
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Patagonian toothfish in the South Indian Ocean outside CCAMLR waters: a preliminary analysis of the SIOFA Patagonian toothfish population

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Introduction

The first evidence of Patagonian toothfish (D*issostichus eleginoides*) caught in the southern parts of the Southern Indian Ocean Fisheries Agreeement (SIOFA) Area, which was a Spanish experimental fishing survey, took place from 28 June to 27 July 2003, in the Del Cano Rise. Results of this experience were presented in a CCAMLR Science document (López-Abellán, 2005). Since then some minor fishing activities have been made by other fishing countries as well.

From 2017 onwards, two Spanish vessels have been fishing on the Del Cano Rise (FAO area 51.7) and Williams Ridge (FAO area 57.4) (Figure 1), where an increase of the Spanish fishery targeting Patagonian toothfish (TOP) is observed (Figure 2).

Observers on board, trained by the Spanish Institute of Oceanography (IEO), have collected fishing information, biological samples and biological data following the CCAMLR Scheme of International Scientific Observation protocols (SISO). Although the SIOFA agreement was not in place during the initial fishing activities, those have been reported to CCAMLR in 2005. Once SIOFA entered into force in 2012, reports to both SIOFA and CCAMLR bodies have been made.

An ongoing work with the Secretariats of SIOFA and SPRFMO to update the respective MOUs (www.ccamlr.org/node/74517) is being made, including data-sharing protocols, cooperation on tagging programs and toothfish catch reporting. FSA-WG in 2018 welcomed this active cooperation between the respective Secretariats, noting that there was a need to increase integration of toothfish research and stock assessment taking account of movement of toothfish across the Convention Area’s northern boundary.

A preliminary analysis of the Patagonian toothfish population using data collected from observers onboard two Spanish fishing vessels, obtained between 2017 and May 2019, in international waters of the South Indian Ocean within the FAO areas 51.7 and 57.4 managed by SIOFA, adjacent to the Commission for the Conservation of Antarctic Marine Resources (CCAMLR) convention area is provided in this paper.

A metapopulation of *D. eleginoides* with genetic homogeneity in the Indian Ocean sector of the Southern Ocean is suggested (Appleyard et al., 2002 and 2004; Williams et al., 2002; Welsford et al., 2011; Sarralde and Barreiro, 2018), although the rate of exchange between the different areas/divisions has not been determined until recently within the Kerguelen plateau (Burch et al., 2017). Population of Del Cano Rise in the FAO area 51.7 could be the outer edge of the main TOP population ground (López-Abellán, 2005) and it may be the fished area in FAO area 57.4 would be the outer edge for the TOP population in the Kerguelen Plateau.

In this paper, different approaches have been made to define the TOP population features taking into account the depth, latitude, sex and geographic zone. Some differences between the two study areas have been found but differences in temporary distribution of the three surveys could have influenced the results.

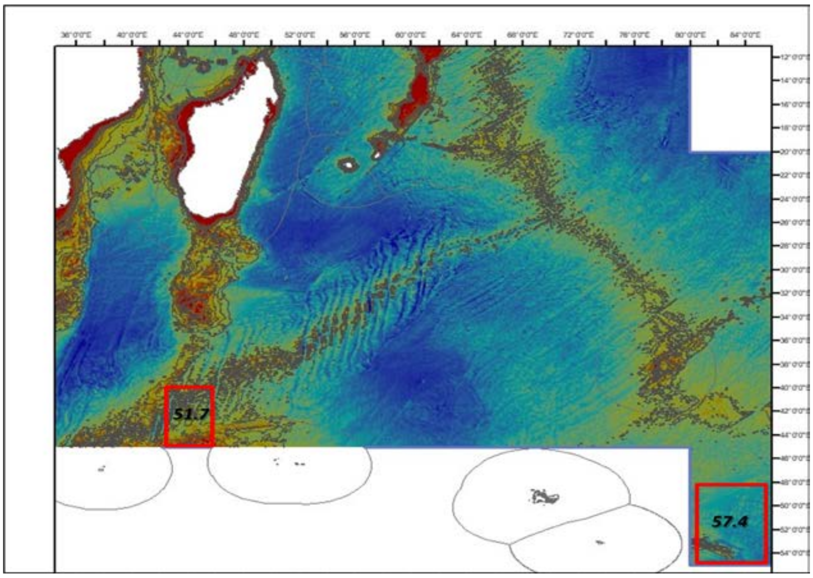

Figure 1: SIOFA convention area. Fished areas in red.

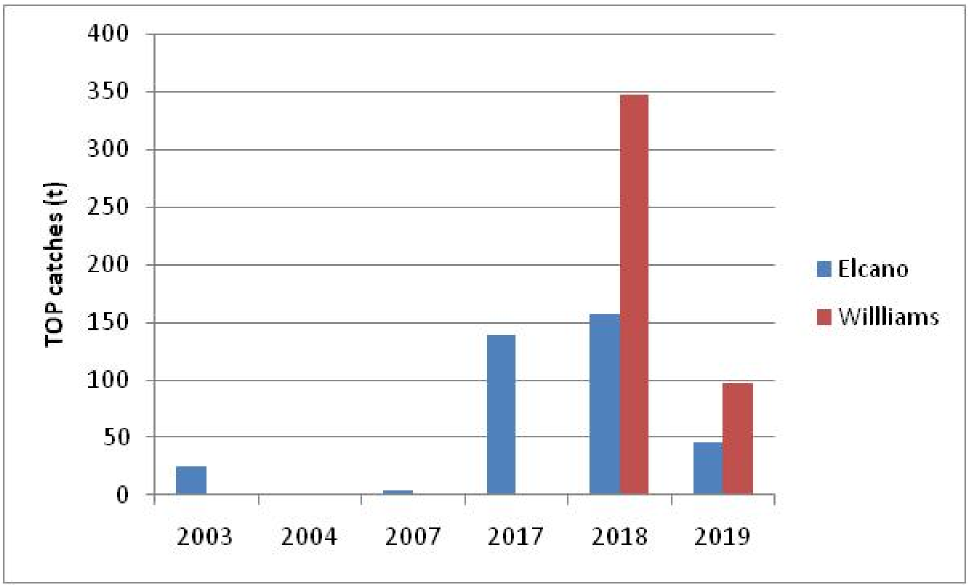

Figure 2.- Catches of Patagonian toothfish (t) between 2003 and 2019 in the SIOFA Area.

Methods

Data was used from 2017 onwards, when further activity took place in the Del Cano Rise and a new fishing ground was explored near the Kerguelen Plateau (Fig. 1) targeting *D. eleginoides* in the SIOFA Area (Williams Ridge), from three Spanish fishing surveys with observers onboard two vessels, the F/V IBSA QUINTO fishing with autoline with integrated weighting line and F/V TRONIO with a Spanish system longline.

Scientific observations were conducted by Spanish observers and monitored by the IEO (Spanish Institute of Oceanography).

A chronogram of the period of the study is presented in Figure 3. Both vessels have fished in the two areas however there was not temporary overlap.

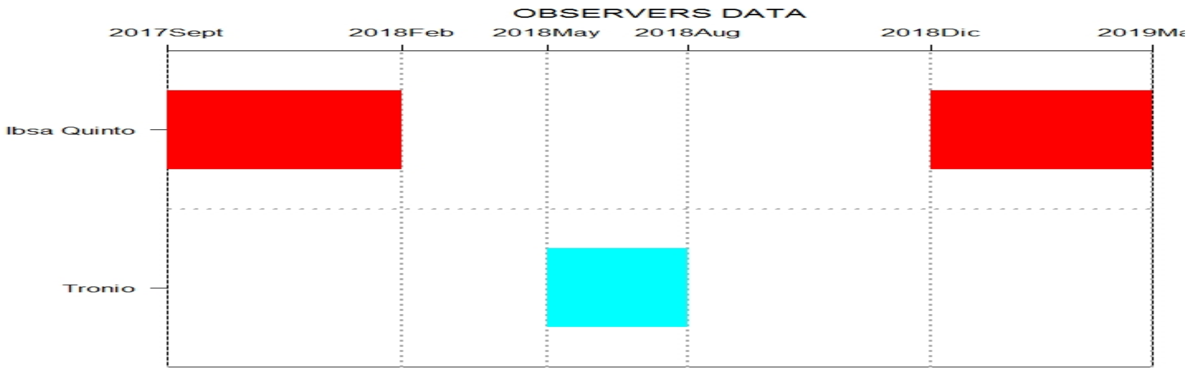

Figure 3: Chronogram of the fishing activities (up to May 2019)

Catch and effort data from the vessel and biological data sampled by scientific observers have been used. Biological data collection includes representative samples of length, weight, sex and maturity stage, as well as collection of otoliths for age determination.

In order to analyze the data taking into account the depth distribution, three depth strata have been adopted considering the initial depth of the setting:

- ✓ *strata 1* betwen 600 and 1000m
- ✓ *strata2* between 1000 and 1500m
- ✓ *strata 3* between 1500 and2000m.

To classify the maturity stages of the TOPs, the observers have used the same macroscopic key for gonads as the International Scheme of Scientific Observation (SISO) of CCAMLR:

Stage	***Female***	***Male***
1	Immature	Immature
2	Maturing virgin or resting	Developing or resting
3	Developing	Developed
4	Gravid	Ripe
5	Spent	Spent

Results

Catches by depth and latitude

Fishing occurred between 635 m and 2000 m, with a mean value of 1370 m (Table 1). The depth stratum 2 (1000-1500 m) has been the most sampled stratum in both areas, around 61% of the total sets.

Table 1: Number of sets by depth strata, vessel and area.

	Area				
	51.7		57.4		
Depth strata	IBSA QUINTO	TRONIO	IBSA QUINTO	TRONIO	***Total***
stratum 1	6	3	5	21	35
stratum 2	156	39	49	40	284
stratum 3	81	19	18	32	150

The deepest set (2000 m) has been performed in the area 51.7 and the shallowest (635 m) in area 57.4. (Figure 4).

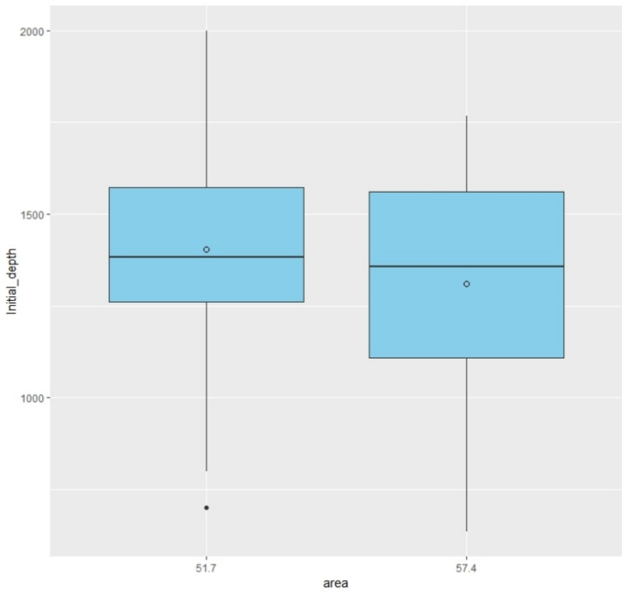

Figure 4: Fishing depth sampled by area. The circle on the boxplot is the mean depth value.

The mean CPUE in the area 57.4 has been 292 kg/1000 hooks, much higher than the 98 kg/1000 hooks obtained from area 51.7.

Descriptive results of non standardised CPUE analysis show that the CPUE from the vessel using the Spanish system is significantly lower in area 51.7 that the CPUE of the vessel using autoline, while in area 57.4 is the opposite (Figure 5).

When comparing the CPUE between depth strata we notice that the CPUE of the 3rd depth strata (>1500m) is higher that the CPUE in the two more superficial strata in the area 57.4, with an ascending trend as the activities go deeper. In area 51.7 the trend is similar for the F/V IBSA QUINTO unlike the pattern in the F/V TRONIO where a steady decrease on the CPUE is observed as the vessel activities go deeper.

Looking to the soaktime between both gears (Figure 6) we see that the autoline vessel is much higher than the spanish system vessel.

Up to now, only few data from both vessels overlapping the fishing area are available. Approaches to consolidate effort between different gear types for CPUE standardisation will be made as soon as more data are incorporated into the study.

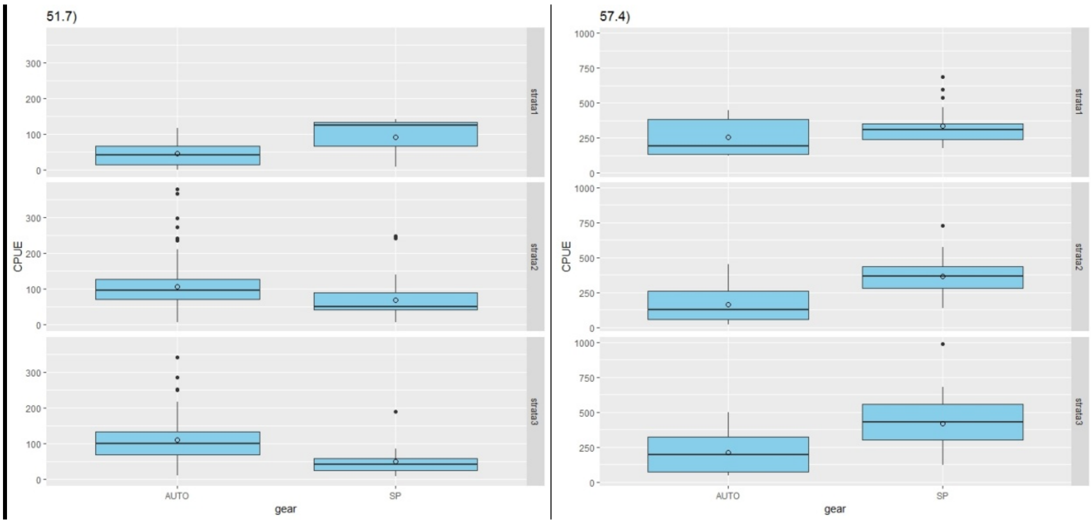

Figure 5: CPUE (kg/1000hooks) by gear, depth strata and area. The circle on the boxplot is the mean CPUE value

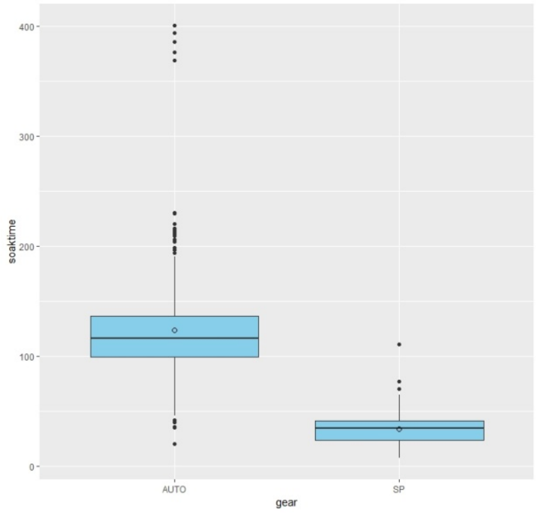

Figure 6: Soaktime (hours) by gear. The circle on the boxplot is the mean soaktime value

Length frequencies

Different approaches have been made to analyze the length frequency data, firstly by sex and area, secondly by sex and depth strata and finally by sex and latitude of the catch.

Length distributions show that the female sizes in the catch is longer in the area 57.4, with a mean of 93 cm TL compared to 82 cm TL in the area 51.7 (Figure 7). Mean length distribution of males in 57.4 is also longer (85 cm) than the mean TL in area 51.7 (80 cm).

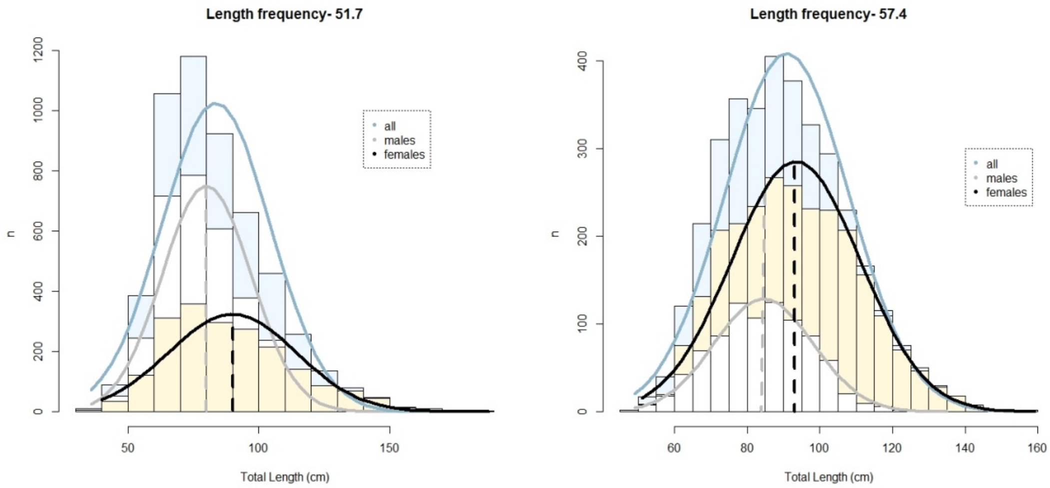

Figure 7. Length frequency distributions of TOP by sex and area. Black line: females; grey line: males;blue line: both sexes combined.

The length of females and males sampled along the three depth strata in area 57.4 are similar (Figure 8), as well as the male length distribution in area 51.7, without depth distribution pattern, whereas sampled females in the area 51.7 are slightly bigger on the deepest strata.

D. eleginoides has an ontogenetic habitat shift toward deeper waters as fish grow older (Near et al., 2003; Welsford, 2011), so that older and larger fish are caught at deeper depths, eg. deeper than 1000m. This trend could also be observed in the area 51.7 but not in the area 57.4.

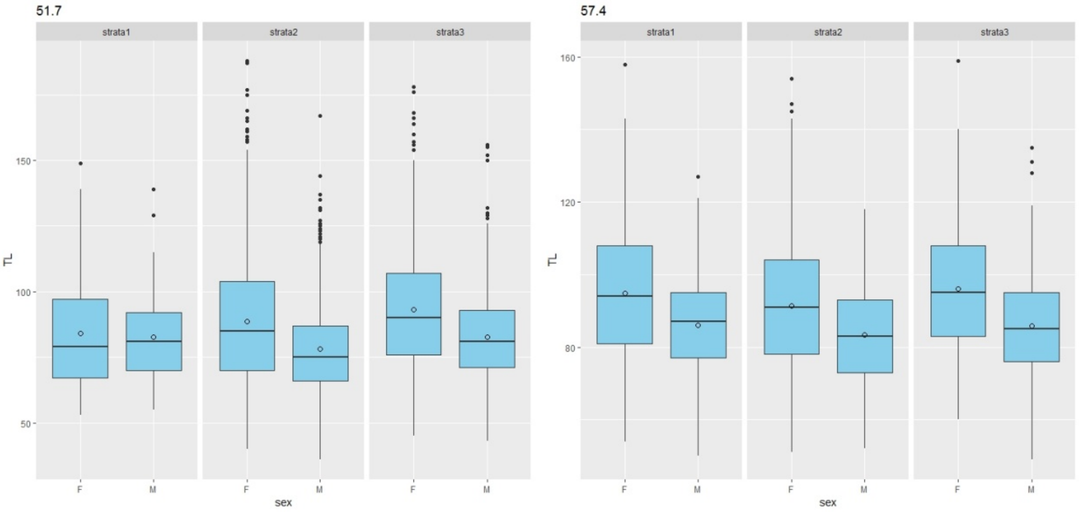

Figure 8: TOP total length (cm) by depth strata and sex. On the left side females and males on the right side. The circle on the boxplot is the mean value

When comparing the length composition in relation to the latitude (Figure 9) results show differences between both areas. In area 57.4 there is a decreasing trend for both sexes in the length composition with decreasing latitude, while the trend is not so clear in the area 51.7, although is also in the Southernmost sector of this area where the smaller fishes were found.

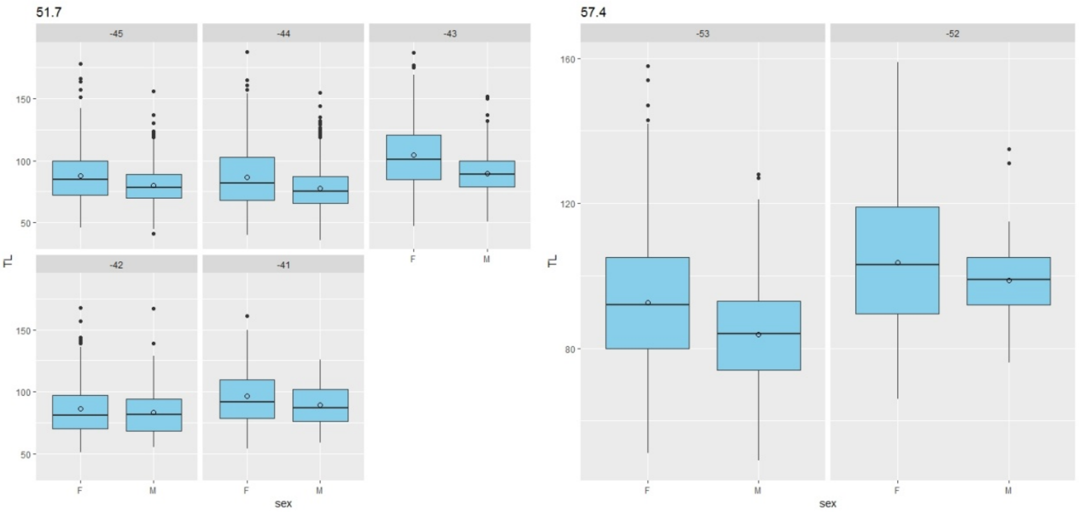

Figure 9: TOP total length (cm) by latitude and sex. The circle on the boxplot is the mean value

Length-weight relationship.

The length-weight relationship obtained from a total of 4531 females and 4121 males, is similar for both areas (Figure 10). The weight of *D. eleginoides* caught was modeled in relation to the length as a non-linear function and predicted for both sexes and areas combined by the following relationship:

$Weight = 2*10^{-6} Length^{3.3384}$. Being $R^2 = 0.9802$.

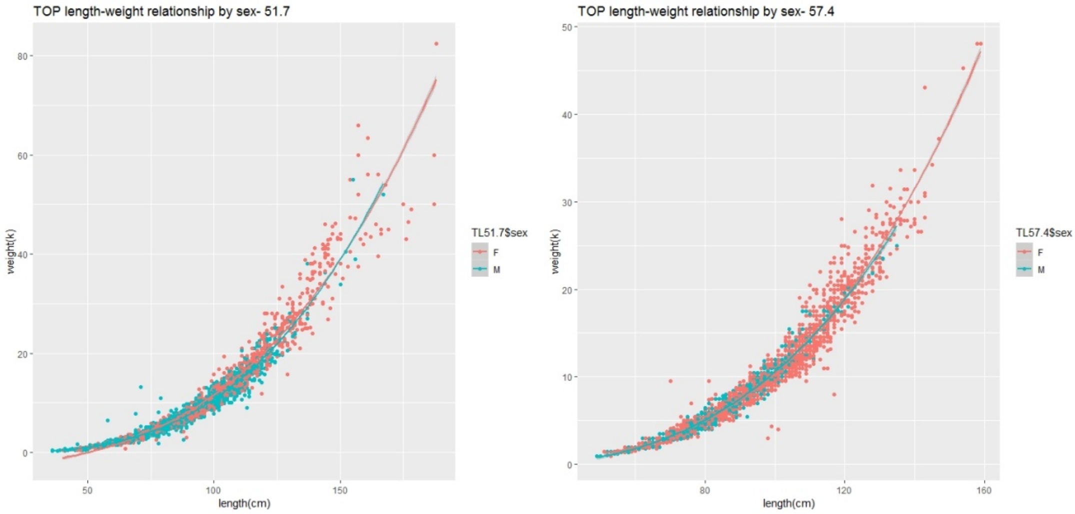

Figure 10. Length-weight relationship of *D. eleginoides*. Green and red lines are the non-linear regression of length-weight relationship by sex.

Sex ratio and maturity

8603 individuals have been sampled for sex, and differences in sex ratio were found between areas. 62% of the sampled individuals in the area 51.7 were males and those were predominant at small sizes. The ratio 1:1 is reached at the 110-120 cm TL interval when the female proportion increases steadily (Figure 11). In area 57.4 the ratio of females is much bigger than males, 74% of caught fish were females, and predominant at all sizes. The size at which males reached sexual maturity could be related to the abrupt shift (male:female) in the sex ratio (López-Abellán and González Jiménez, 1999). This hypothesis could explain the sex ratio in the area 51.7 but the larger presence of females at all sizes in area 57.4 needs further research to understand this high sexual segregation found. It is common in many fish species on spawning grounds, with males typically arriving earlier and remaining for longer periods resulting in a higher proportion of males on spawning grounds (Péron et al., 2016), but in this particular case the length distribution and maturity stage would suggest that these areas are inhabited primarily by subadult fish with a low proportion of large mature individuals.

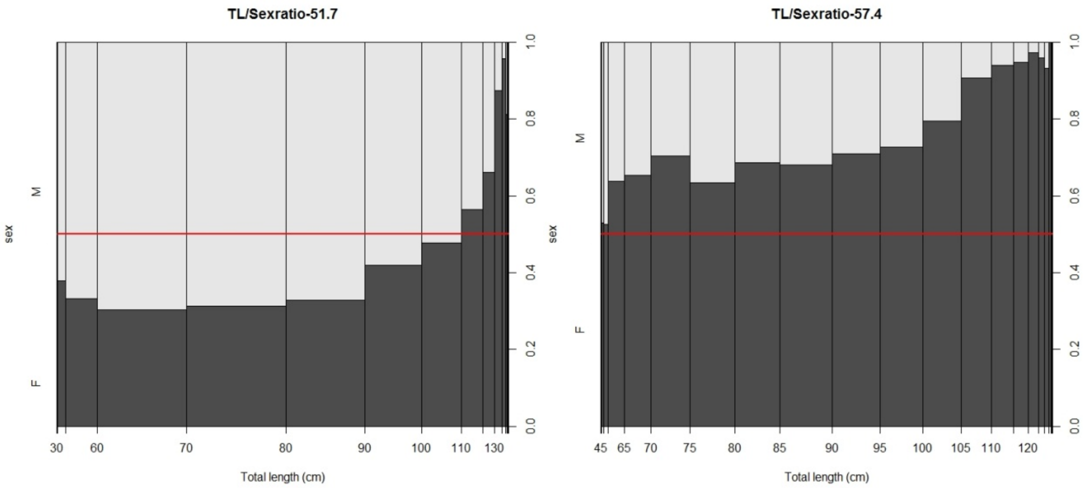

Figure 11. Sex ratio of *Dissostichus eleginoides* by size. The red line shows the 1:1 proportion.

In the area 51.7, most of the females were immature with gonad stages 1 or 2 (80%), and also most of males were immature (71%). Only 5.6% of all sampled females were in stage 4 (spawning) and 0.4% of males (ripe).

In the area 57.4 immature females contributed 78% of the total caught females and immature males contributed 84% of all caught males.

The spatial variation in maturity stage and sex composition is also likely to be influenced by the months in which sampling took place. López-Abellán in 2005 found that 50% of the TOP sampled for maturity were in stage 4 (gravid or ripe) or 5 (spent), in the area 51.7, but sampled in a different time period than the study period (June-July 2003).

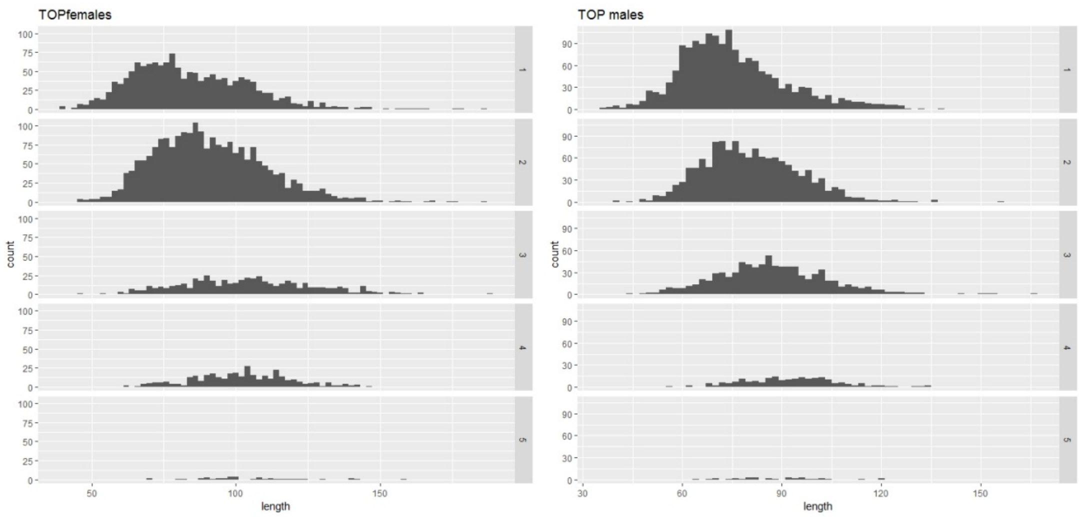

Figure 12. Total Length by sex and maturity stage of *Dissostichus eleginoides.* left: females and right: males

As only a low proportion of fishes were mature, a latitudinal pattern of maturity could not be observed with the current data.

Onboard the F/V TRONIO, 3016 gonads have been weighted. In Figure 13 is showed the length-gonad weight relationship. In the area 57.4 only few females and males were found matures. The mean gonad weight for spawning females is 2.87k and 0.42 for ripe males. The maximum gonad weight of a spawning female is 8.3k in area 51.7.

In Figure 13 is shown a Gonadosomatic index (GSI) for females by length and area. The number of females sampled in area 51.7 is 568 and 1397 in the area 57.4.

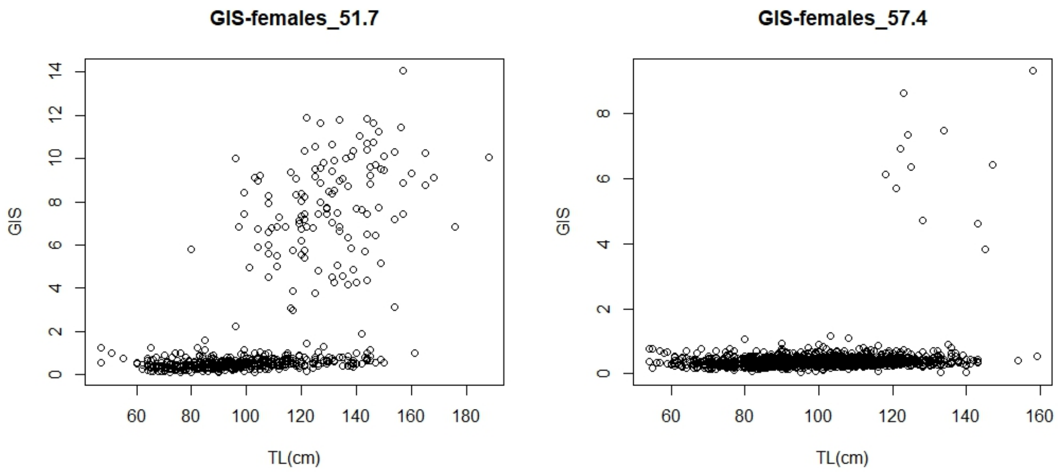

Figure 13: GIS by length and area.

In Figure 14, a histogram of frequencies of maturity stages by sex and area is shown.

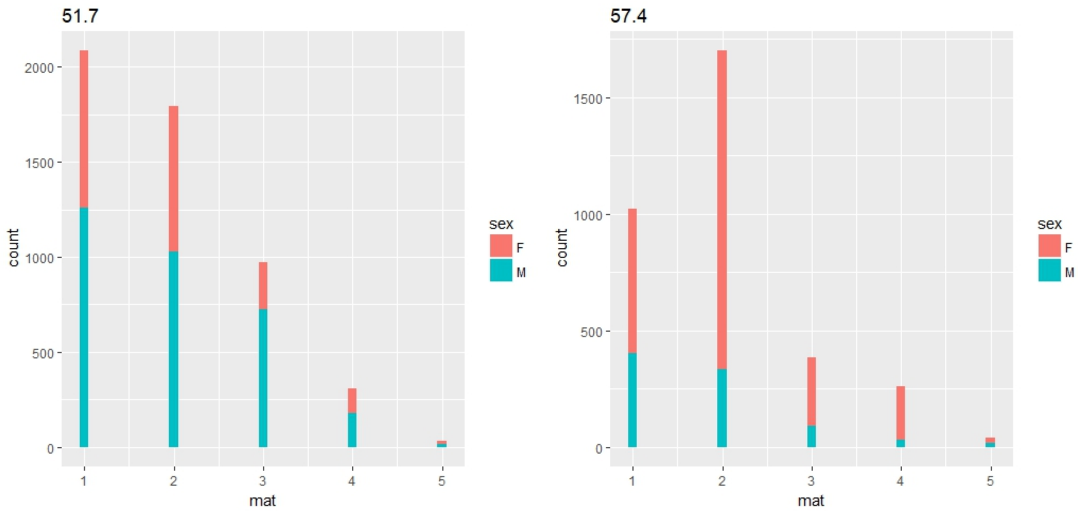

Figure 14: Maturity stage by sex and area**.**

Recaptures of tagged TOP within the SIOFA area

Up to May 2019, sixteen tagged *D. eleginoides* released in the CCAMLR convention area have been recaptured, within the SIOFA management area, by these two Spanish vessels. Biological and location information have been reported at the SIOFA and CCAMLR Secretariat. These tagged fish were released in the CCAMLR convention area in Divisions 58.5.2 and 58.5. 1 and Subarea 58.6. The years at liberty were between 3 and 10 years and 6 out of 15 fish travelled a very long distance exceeding 1 000 km (Figure 15). All fish were subadults at release (between 75-93 cm) being the maximum increment in weight 7 kg and 33 cm in length.

A previous report has been presented in the WG-FSA-2018 (Sarralde and Barreiro, 2018) and the WG noted that most of the fish that travelled long distances were subadults, which was similar to findings from Area 48.3 (Soeffker et al., 2014) and that movement frequency, directions and distances were consistent with previous movement studies conducted in Areas 48.3 and 58.6 and Divisions 58.5.1 and 58.5.2.

Table 2.- Information about TOP released in CCAMLR and recaptured in SIOFA.

	RELEASE				***RECAPTURE***				***PARAMETERS***			
ID	CCAMLR SSRU	sp	length	Weigth	vessel	Area	length (cm)	weigth (k)	Days at liberty	Distance (km)	Δ weigth	Δ length
TR_01	58.2	TOP	76.5	4.42	TRONIO	FAO 57-SIOFA SUBAREA 7	81.4	5.2	1112	155	0.78	4.9
TR_02	58.2	TOP	79.2	4.96	TRONIO	FAO 57-SIOFA SUBAREA 7	80.2	5.2	1145	164	0.24	1
TR_03	58.5.1	TOP	61.4	2.07	TRONIO	FAO 57-SIOFA SUBAREA 7	72.4	3.3	2373	1137	1.23	11
TR_04	58.5.1	TOP	73.4	3.86	TRONIO	FAO 57-SIOFA SUBAREA 7	74.8	3.8	1292	1174	-0.06	1.4
TR_05	58.5.1	TOP	80.5	5.35	TRONIO	FAO 57-SIOFA SUBAREA 7	87.8	5.55	2035	1192	0.2	7.3
IB_01	58.5.1	TOP	61	2.12	IBSA V	FAO 51-SIOFA SUBAREA 3b	87	7.19	3353	1793	5.07	26
IB_02	58.6	TOP	70.9	3.57	IBSA V	FAO 51-SIOFA SUBAREA 3b	87	5.91	2694	380	2.34	16.1
IB_03	58.6	TOP	66.8	2.7	IBSA V	FAO 51-SIOFA SUBAREA 3b	75	4.02	1947	249	1.32	8.2
IB_04	58.5.1*	TOP	-	-	IBSA V	FAO 51-SIOFA SUBAREA 3b	93	8.36	-	-	-	-
IB_05	58.5.1	TOP	66.5	2.6	IBSA V	FAO 51-SIOFA SUBAREA 3b	82	5.01	2252	1665	2.41	15.5
IB_06	58.6	TOP	-	-	IBSA V	FAO 51-SIOFA SUBAREA 3b	68	2.76	3623	6	-	-
IB_07	58.5.2	TOP	61.7	2.45	IBSA V	FAO 57-SIOFA SUBAREA 7	61.7	2.45	2634	185	7.05	33.3
IB_08	58.5.2	TOP	76.7	4.29	IBSA V	FAO 57-SIOFA SUBAREA 7	76.7	4.29	792	350	0.71	4.3
IB_09	58.5.3	TOP	68.2	3.66	IBSA V	FAO 57-SIOFA SUBAREA 7	68.2	3.66	113	397		0.8
IB_10	58.6	TOP	70.6	3.68	IBSA V	FAO 51-SIOFA SUBAREA 3b	70.6	3.68	219	105		1.4
IB_11	58.5.2	TOP	80.3	5.4	IBSA V	FAO 51-SIOFA SUBAREA 3b	80.3	5.4	1247	2694	1.6	8.7

*Estimated, there is not release information available.

As not tagging of *D.eleginoides* is made in the SIOFA area, it is difficult to know the residence time in these areas and the migration pattern from the SIOFA waters towards other grounds, likely within CCAMLR convention area.

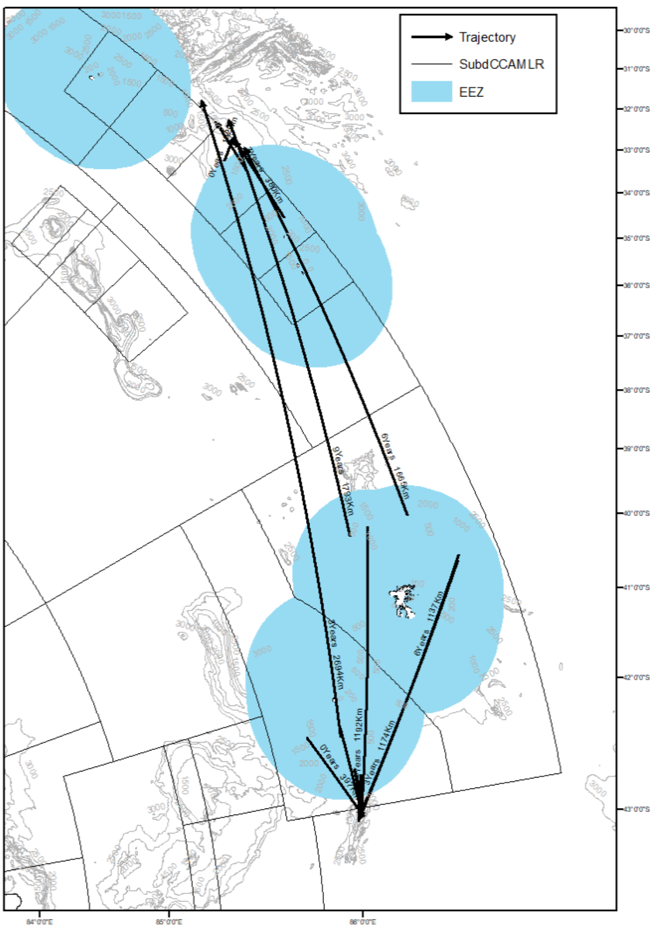

Figure 15. Trajectory showing the years at liberty and distance traveled (km).

Discussion

Dissostichus eleginoides are widespread around the Subantarctic islands of the Indian ocean sector and are known to move long distances associated with the different stages of the life cycle. On maturation they migrate to spawning locations in deep water around sub-Antarctic islands.

From the recaptures obtained in these two areas, it seems that the SIOFA TOP fisheries are located towards the outer edge of the main TOP grounds, but further research is needed to understand the ontogenetic movements of the TOP population, as well as the movements associated with water masses that would affect the distribution area of *D.eleginoides*.

On the other hand, the presence of two marine mammals, sperm whales (*Physeter macrocephalus*) and killer whale (*Orcinus orca*) that feed on TOP catches add incertitude to the total catch estimates (Gasco et al, WG-FSA-19/***).

Marine mammals impact into the vessel´s catch in Crozet and Kerguelen area have been preliminary estimated based in the presence or absence of odontocetes during the hauling of the catch (Gasco et al 2016), however a large series of data are needed to do these estimations. During the three Spanish surveys, more than 50 interactions with sperm whales, the most frequent mammal species, and 12 with killer whales (**KIW**) have been registered in the area 51.7 and none from the area 57.4. Marine mammal impact is likely lower in SIOFA waters than in the neighboring Crozet area due to the higher proportion of fishing vessels operating in this later area, although estimates from recent years in delCano area shows that killer whales interaction rate ranged from 0% to 4% and sperm whales from 14% to 44% (Gasco et al, 2019).

The regions from where data *on D. eleginoides* were collected in the SIOFA Area are adjacent to CCAMLR 58.6 (Crozet) and Divisions 58.5.2 (Heard and McDonald) and 58.5.1 (Kerguelen), all of them are established toothfish fisheries within the CCAMLR convention area, where the assessment models include tag recapture information. The emigration of tagged fish out of the assessed area results in initial and current spawning biomass, so stock status being over-estimated (Burch et al., 2017). A mutually supportive cooperation between SIOFA and CCAMLR especially around a stock that is likely shared between the two bodies is needed.

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