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**No boundaries for whales interacting with fishing activities targeting Patagonian toothfish (*Dissostichus eleginoides*)**

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N. Gasco, P. Tixier, F. Massiot-Granier, C. Péron and R. Sarralde



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# No boundaries for whales interacting with fishing activities targeting Patagonian toothfish (*Dissostichus eleginoides*).

Gasco N<sup>1</sup>, Tixier P<sup>2</sup>, Massiot-Granier F<sup>1</sup>, Péron C.<sup>1</sup>, Sarralde R<sup>3</sup>.

<sup>1</sup> Laboratoire de Biologie des Organismes et des Ecosystèmes Aquatiques (BOREA) – Muséum national d’Histoire naturelle, 43 rue Cuvier 75005 Paris, France.

<sup>2</sup> School of Life and Environmental Sciences (Burwood campus), Deakin University, Geelong, Victoria, Australia.

<sup>3</sup> Instituto Espanol de Oceanografia (IEO) – Centro Oceanographico de Canarias, Calle Farola del mare 22, 38180 Santa Cruz de Tenerife, Spain.

## Abstract

With the development of longlines targeting Patagonian toothfish (*Dissostichus eleginoides*), killer and sperm whale have adapted their preying behaviour by feeding on fish caught on the gear. Estimating depredation rates allows to correct catches and model the real impact of fishing activities on Patagonian toothfish stocks. Depredation has been documented as a severe issue in the fishery of Crozet EEZ since the late 90’s. The recent development of fishing activities in waters adjacent to the CCAMLR convention area such as in the Del Cano rise (Southern Indian Ocean Fisheries Agreement, SIOFA) might enhance the risk of spreading this feeding behavior to new pods.

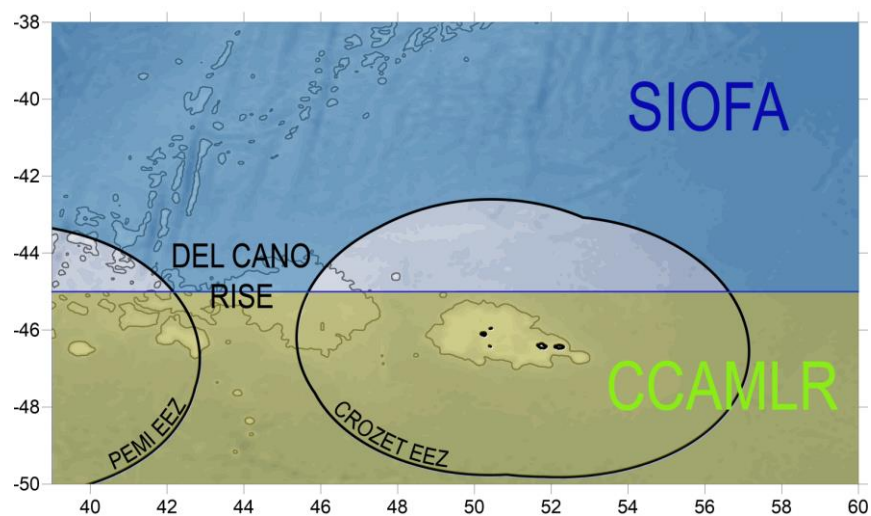
Photo-identification technique revealed movements of sperm whales and killer whales individuals across boundaries. Over the 2009 – 2019 period, depredation rates were estimated to be around 8% in the Del Cano – SIOFA area based on the available data from France and Spain.

## Introduction

Killer whale and sperm whale depredation interactions with toothfish longlines have been documented as a severe issue in the Crozet EEZ since the late 90’s (Tixier et al. 2010). These interactions have been extensively monitored and studied through long-term observation and photo-identification consistently collected by fishery observers during fishing operations involving depredation events since the late 90’s.

Estimating interaction and depredation rates is of primary importance as it allows to correct catches to account for the mortality due to depredation and therefore modelling the real impact (catches+depredation) of fishing activities on Patagonian toothfish stock. Indeed, as killer whale and in a lesser extent sperm whale benefit of an access to a resource they mostly do not have access to naturally, depredation represents an extra source of mortality which is not fully accounted for by the natural mortality parameter. Depredation rate estimations by the CPUE method (Gasco et al. 2015) have already been applied to the stock assessment of Patagonian toothfish in Kerguelen EEZ and Crozet EEZ stock assessment (Sinègre et al., 2017a, Sinègre et al., 2017b).

The Del Cano Rise is a submarine feature covering ~600 km in longitude and 200 km in latitude. This region, adjacent to CCAMLR waters, is located between two Economic Exclusive Zones (EEZ): the Crozet EEZ (France) to the East and the Marion and Prince Edward EEZ (South Africa) to the West (Figure 1). It has the particularity to be managed by two international organizations: the Southern Indian Ocean Fisheries Agreement (SIOFA) north of 45°S and CCAMLR south of 45°S. Fishing for Patagonian toothfish is authorized by SIOFA in Del Cano rise area and fishing has occurred with variable catch levels in the last 10 years. Del Cano rise also extends within the Crozet EEZ where French fishing vessels target Patagonian toothfish.



**Figure 1** Map of the study area showing the EEZ boundaries of Prince Edward & Marion Islands (PEMI) and Crozet, the Del Cano Rise area the two RFMO (SIOFA and CCAMLR separated by the 45°South latitude). The grey line represents the 2000 meters bathom.

Data on whale interactions with longline fishing vessels are collected in CCAMLR waters (outside EEZs) through the Scheme of International Scientific Observation (SISO). When fishing in SIOFA area, French observers apply the same protocol as in the French EEZs (Gasco et al. 2013). Despite the lack of protocol enforcement in the SIOFA area, observers onboard Spanish vessels in SIOFA area documented depredation sporadically with different levels of

effort. During two fishing trips, depredation data were reported in the same way as in the CCAMLR scheme (SISO) and during one fishing trip only presence was reported (and absence was not). Photo-identification was opportunistic and most of the time pictures were not suitable for identification.

The aim of this paper was to synthesize available information on whale interactions with fisheries in the Del Cano rise area and their potential links to adjacent regions. More specifically, this study:

- examined whether the killer whales involved in depredation interactions in the Crozet EEZ were also depredating in the Del Cano – SIOFA region;
- assessed the frequency at which depredation interactions occurred (interaction rate) and the proportion of the catches removed by whales during these interactions (depredation rate).

### Killer whale movements between Del Cano - SIOFA and Crozet EEZ

We used photographs taken by fishery observers onboard French and Spanish vessels targeting Patagonian toothfish to identify the depredating killer whale individuals and to examine their movements between Del Cano-SIOFA and Crozet EEZ. Within the French EEZs and in the adjacent Del Cano–SIOFA area, French observers consistently take photographs of whales during depredation interactions following a standardized photo-identification protocol implemented since 2003 using DSLR cameras and telelenses (described in Gasco et al. 2013)

Observers on Spanish vessels operating in the Del Cano-SIOFA area in the last 3 years did not follow a protocol since documenting depredation is not mandatory in this RFMO. However, observers took photographs opportunistically using their own cameras or cell phones.

In total 432 pictures were collected in the Del Cano–SIOFA region over the 2003-2018 period, including 423 pictures taken from French vessels and 9 pictures taken from Spanish vessels. These pictures were analyzed and compared to existing killer whale photo-identification catalogues developed by the Centre d'Etudes Biologiques de Chizé (CNRS) in France (Tixier 2014a, 2014b) and the Marine Research Institute in South Africa (Reisinger 2014).

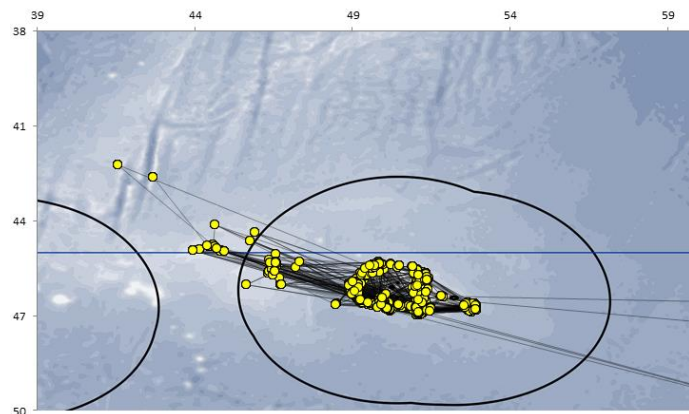
The 9 pictures taken from Spanish vessels were taken between 2018 and 2019 and provided the following information:

- 6 pictures taken with a compact camera showed 3 distinct individuals but the quality was too low to allow any matching with certainty or naming of new individuals. One individual photographed in 2019 is likely to be “C023” from the Crozet killer whales but this is yet to be confirmed at this stage.

- 3 pictures taken with an SLR camera showed 1 individual with a quality high enough to confirm that this was a new individual, and no match was found with previously known individuals.

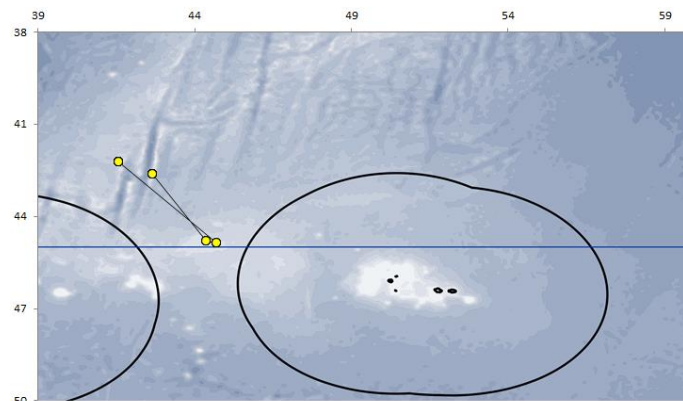
As further pictures are required to assign an identification code to these 4 individuals and add them to catalogues, in this paper they were referred to as “NO ID”.

From the photographs taken by French observers, 33 distinct individuals were observed, including 26 individuals that had been previously identified within the Crozet EEZ (Tixier et al. 2014a, 2014b). These individuals were observed in the Crozet EEZ regularly and several times in the Del Cano-SIOFA area (Figure 2). Among these 26 individuals, 3 have also been sighted within the Kerguelen EEZ.



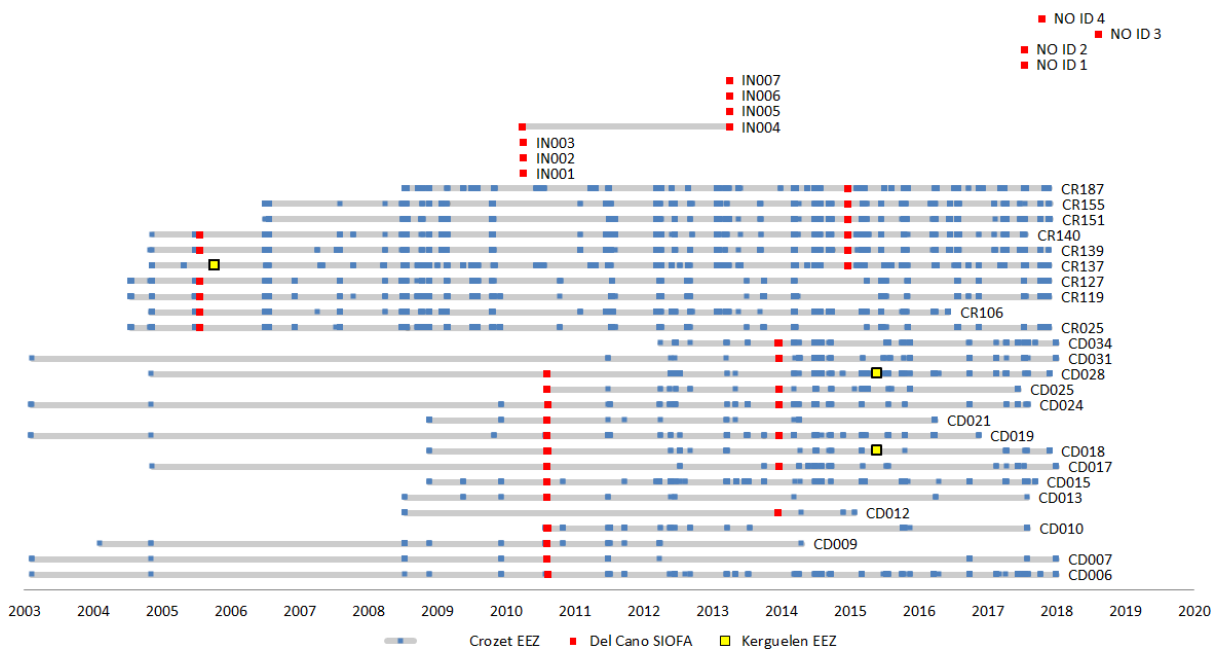
**Figure 2 Locations of 26 killer whale individuals observed in the Del Cano rise outside and also within Crozet EEZ, dark lines represents movements between observations.**

In 2010 and 2013, 7 individuals were photographed at Del Cano - SIOFA but were not, to date, observed in Crozet or Kerguelen EEZ (Figure 3).



**Figure 3 Locations of 7 killer whale individuals observed only in the Del Cano - SIOFA area.**

Figure 4 shows the chronology of killer whale interactions in the region. The first documented interactions occurred in 2005 on French fishing vessels and others documented interactions occurred in 2010, 2013, 2014, 2015 on French fishing vessels and 2017, 2018 on Spanish vessels. All individuals observed in the Crozet EEZ were first observed in this area and then in the Del Cano - SIOFA area outside EEZ, 21 of them were observed one time in the Del Cano-SIOFA area and 6 of them were observed two times in the Del Cano-SIOFA area. Three individuals regularly observed in the Crozet EEZ were observed in the Kerguelen EEZ, one in 2006 and two in 2015.



**Figure 4 Identification of killer whales through photo-identification over time. Horizontal lines correspond to each individual, names are given on the left of their last observation. Individuals at the top left corner starting with "NO ID" correspond to photos provided from Spanish vessel where individuals could not be matched to known individuals.**

The number of individuals observed in Del Cano - SIOFA area is not marginal compared to the number of individuals observed in Crozet, it reaches 15% in 2011 (average: 7.4%) despite a much lower photo-identification effort.

### Sperm whale movements between Del Cano-SIOFA and Crozet EEZ

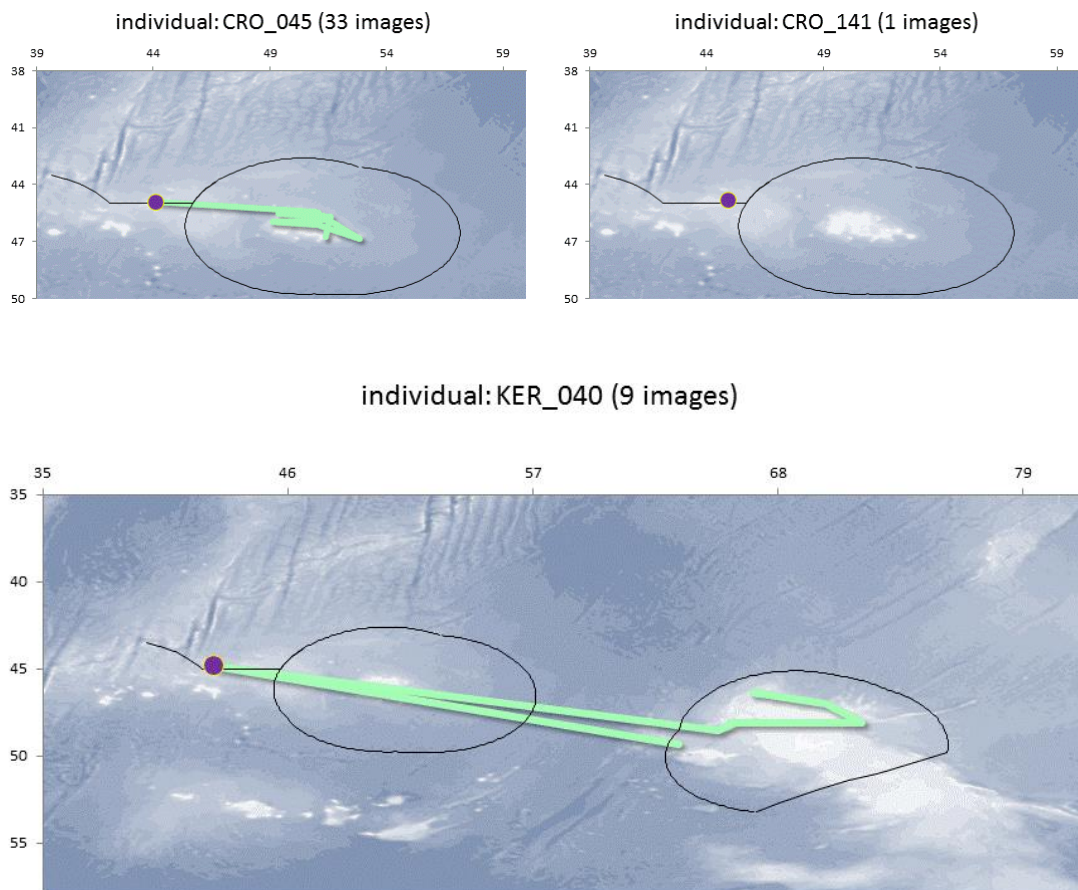
French observers collected data and photographs of sperm whales following a photo-identification protocol adjusted to this species (photographs of tail flukes). These images were matched with the photo-ID catalog of sperm whales developed by Centre d'Etudes

Biologiques de Chizé (CNRS) in France (Tixier 2015) and movements were reconstructed from the fishing locations where pictures were taken.

Additional images of sperm whales were collected opportunistically from Spanish vessels and were also analyzed. Unfortunately, the low quality of those pictures did not allow either to match them with known individuals or to find new individuals.

Given the difficulty of photographing sperm whale tail flukes, only three individuals were identified from the pictures collected in the Del Cano-SIOFA area (Figure 5):

- "CRO\_045" was also observed within French EEZ of Crozet,
- "CRO\_141" was only observed in the Del Cano - SIOFA area and
- "KER\_040" was also observed regularly in Kerguelen EEZ from 2008 to 2012 then in Del Cano - SIOFA area in 2013 and back to Kerguelen in 2016.



**Figure 5. Sperm whale individuals observed in the Del Cano - SIOFA area. Green lines represent movements between observations and purple dots represent observations in the Del Cano - SIOFA area. Number of images used to produce each map is shown in brackets.**

### Estimation of whale interaction rates at Del Cano - SIOFA

We estimated interaction rates for killer whales and sperm whales separately (see Annex 1 for a brief method description). When fishing in Del Cano-SIOFA, French observers apply the same data collection scheme than in the French EEZ. Depredation was reported systematically for each haul. We used these data from 2009/2010 to 2018/2019 (n=754 hauls) to estimate interaction rate per year.

Interaction rates greatly varied between years for both killer whales and sperm whales (Table 1), with no clear temporal trend. The interaction rate of sperm whales was generally higher than that of killer whales. In recent years, killer whales interaction rate ranged from 0% to 4% and sperm whales from 14% to 44%.

**Table 1. Number of longlines set and interaction rates for killer whales and sperm whales by season in the Del Cano - SIOFA area.**

	Longlines set:		interaction rates:	
	french	spanish	Killer whale	Spermwhale
2009_2010	14		0,0%	0,0%
2010_2011	107		28,0%	23,4%
2011_2012	88		9,1%	7,5%
2012_2013	105		0,0%	42,5%
2013_2014	244		13,6%	19,0%
2014_2015	137		10,2%	16,5%
2015_2016				
2016_2017	32		0,0%	43,8%
2017_2018		260	2,7%	14,7%
2018_2019	27	47	4,3%	14,9%
total	754	307		

### Estimation of depredation rates at Del Cano - SIOFA

Depredation rates were estimated using the CPUE method (Gasco 2015, see Annex 2 for a brief method description) for the three cases of marine mammals retrieving fish hooked on longlines:

- Killer whales observed alone
- Sperm whales observed alone
- Both species observed together

This method was applied on the entire dataset because we did not have enough presence-absence data to run this analysis on an annual basis.

The estimated depredation rate (fraction of fish caught on the line but not landed on board) was higher for sperm whales (3.2%) than killer whales (1.7%) and intermediate when both species were interacting (2.6%). Overall by summing the three cases, the total amount of toothfish retrieved from the lines by those two marine mammals reaches almost 8% of the fish caught on the line.



## Discussion

This paper provided evidence that depredation occurs in waters adjacent to the CCAMLR Convention area where longline toothfish vessels operate.

### **Killer whales**

At least 33 killer whale individuals interacted with fishing vessels in the Del Cano - SIOFA area and 26 of them were also observed within Crozet EEZ. Whether the resident populations of Crozet explored this area in response to the fishing vessels presence or because it is part of their home range is unknown. Nevertheless, this result indicated that a large proportion of individuals of the 80 to 90 killer whales interacting with fishing activities at Crozet Is. (Tixier et al 2017) can broaden their home-range up to Del Cano - SIOFA.

Killer whale interaction rates varied and could reach high values (28%) in some years at Del Cano-SIOFA, but it was overall lower than in the Crozet EEZ (average 40% Tixier et al 2019.).

The proportion of killer whale individuals from Crozet EEZ visiting Del Cano-SIOFA in a given year was variable but it could reach 15% in some years (2011). This percentage is high given the much lower fishing effort in Del Cano-SIOFA compared to Crozet EEZ on a given year.

None of the individuals observed in the Del Cano–SIOFA area were matched with the individuals from the Prince Edward and Marion islands, the reason might be the low photo-identification effort deployed from fishing boats in this area.

Despite the important effort of photo-identification in Crozet EEZ, at least 8 individuals observed in the Del Cano-SIOFA area were never observed in the Crozet EEZ and may have been 'naïve' to depredation. Fishing activities may have modified their behavior. As a consequence of poor photo-identification effort, we were unable to assess whether the 3 individuals photographed from Spanish vessels (with no identification) were already known as interacting with toothfish fishery in others areas or if they were "naïve" to depredation. This highlights the importance of systematic reporting and photos.

To avoid the generalization of depredation behavior in CCAMLR areas, strict mitigations measures are being enforced in the Kerguelen EEZ, where killer whales interaction rate is lower than in Crozet and a proportion of the population is still considered 'naïve' to depredation.

### **Sperm whales**

The interaction rate of sperm whales was highly variable. Highest values (40%) was overall lower than in the Crozet EEZ (60%) (Tixier et al 2019). Only 3 individuals could be

identified, but the number of interacting individuals is probably larger given the high value of the interaction rate.

## Conclusion

Our results showed that :

- depredation by marine mammals (both killer whales and sperm whales) occur in longline toothfish fisheries adjacent to the CCAMLR Convention area.
- Interaction and depredation rates are uncertain because of the lack of systematic documentation in these area.
- While most killer whales individuals were known as interacting at Crozet, 8 individuals had never been seen at Crozet and 3 could not be matched because of poor photoID. This means that potentially 11 individuals have been less exposed to toothfish fisheries and may be less prone to depredation.

Together, these results highlight the importance of a consistent data collection scheme across areas such as CCAMLR and SIOFA because marine mammal populations do not have boundaries. Depredation in waters adjacent to the CCAMLR Convention area can have an impact on the toothfish fisheries through the generalization of the depredation behavior to naïve pods or through additional fishing mortality for toothfish populations located in different jurisdictions.

Collecting data on depredation in water adjacent to CCAMLR areas is thus essential to :

- Better understand killer whales and sperm whales population dynamic and the effect of depredation on it.
- Better understand how the depredation behavior can be passed onto naïve populations.
- Track the proportion of marine mammals involved in depredation and assess the risk of seeing a generalization of this behavior in others areas, not yet impacted by this phenomenon.

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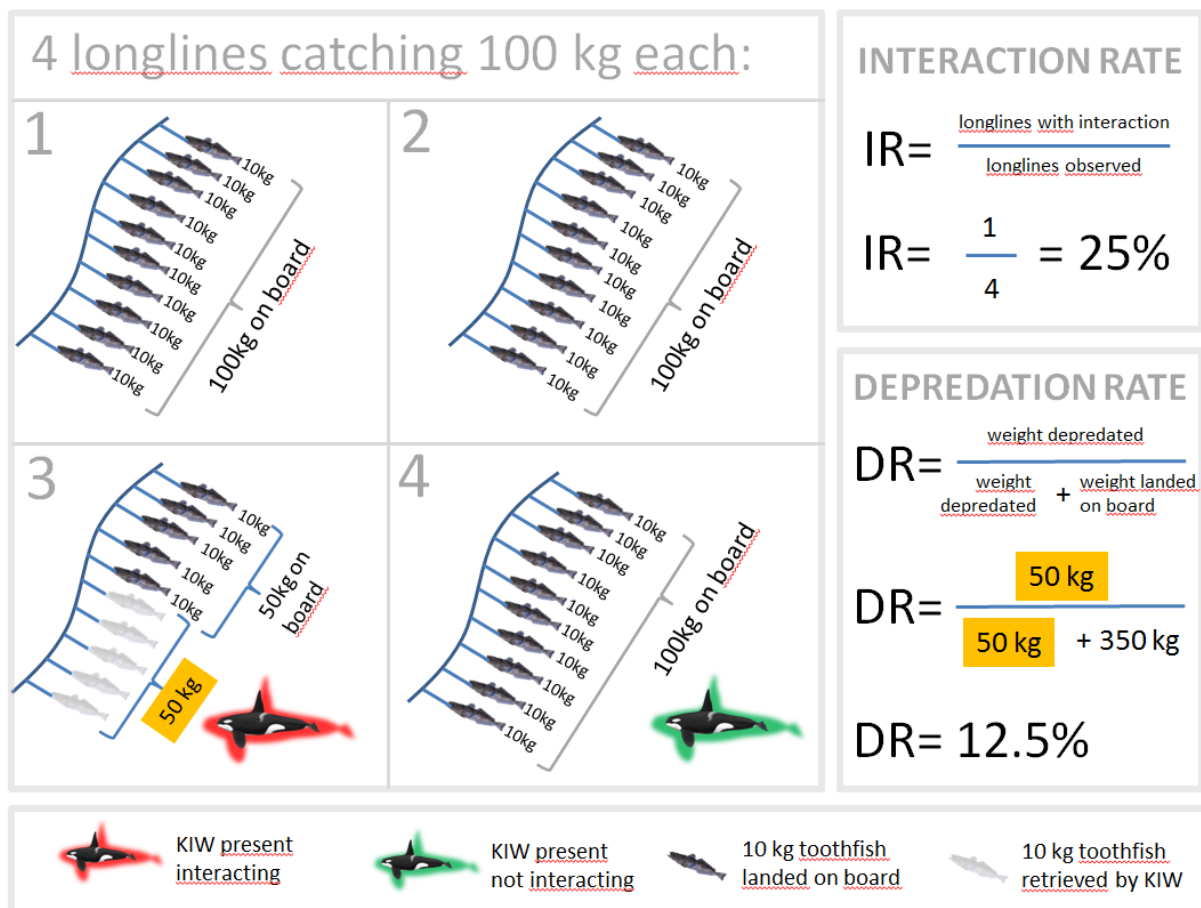
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# ANNEXES

## Annexe 1 : Interaction and depredation rates.

The interaction rate (for one species of marine mammal) corresponds, for an area, to the number of longlines hauled in presence of this species reported as interacting with fishing operations by retrieving part of the catch, divided by the total number of longlines hauled and observed for marine mammals in this area.

The depredation rate corresponds to the estimated weight of fish lost due to marine mammals divided by the total weight caught on the fishing gear (estimated loss + weight landed on board). Only lines observed for marine mammals interactions are considered in the calculation of depredation rate.



**Figure 6 Four simplified longlines with 10 kg toothfish caught on each hook to illustrate definition of terms.**

Annexe 2 : The CPUE method

This method uses the difference between the average CPUE in absence and the average CPUE in presence within each spatial cell of a grid over the area multiplied by the number of hooks hauled in presence in each cell, example for one cell is shown in **Erreur ! Source du renvoi introuvable..**

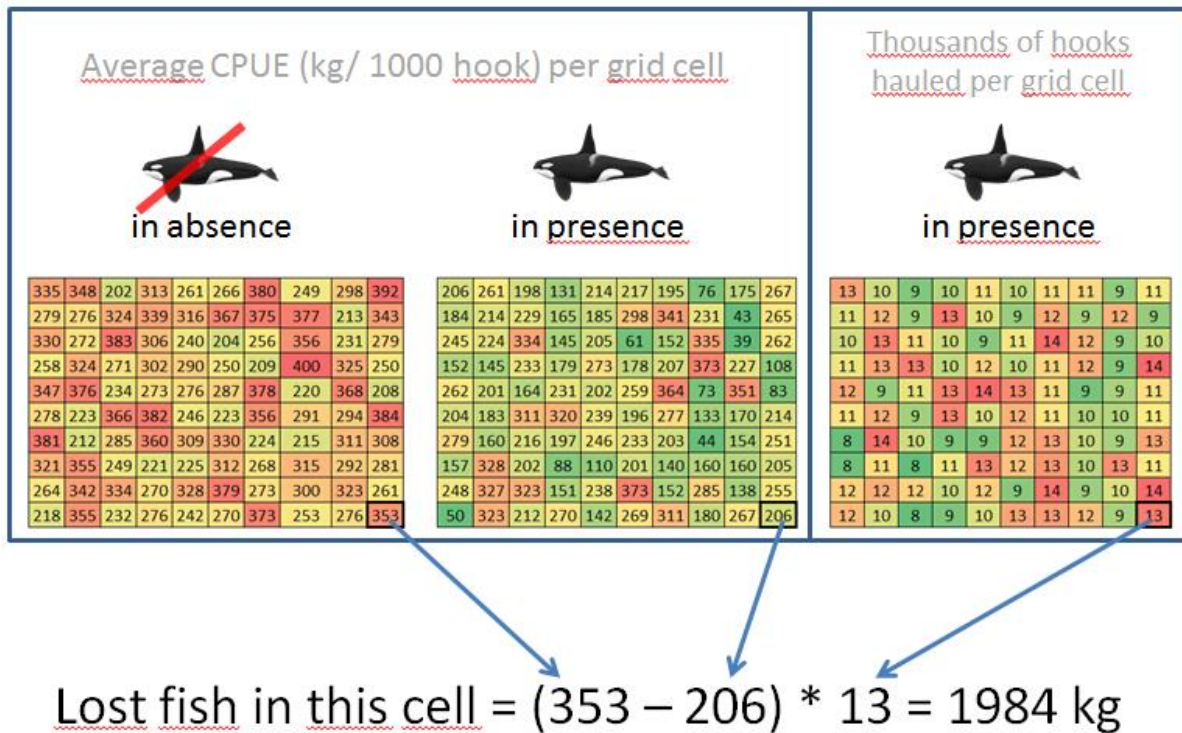


Figure 7 Simplified example of the principal of the “CPUE” method.