

SIGNIFICANT CONSERVATION BENEFITS OBTAINED FROM THE USE OF A NEW FISHING GEAR IN THE CHILEAN PATAGONIAN TOOTHFISH FISHERY

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Abstract

A new fishing technique, adapted from the artisanal trotline fishery for Patagonian toothfish (*Dissostichus eleginoides*) in Chile is described. The modified artisanal system, which includes a net sleeve that is placed on secondary vertical lines, has practically eliminated depredation of fish by killer whales (*Orcinus orca*) and sperm whales (*Physeter macrocephalus*). The performance of this fishing technique with regard to seabird mortality and depredation by sperm and killer whales on fish catch rate was assessed during September–December 2006. The results were then compared with similar data obtained in 2002 in the same fleet in the same fishing grounds prior to the implementation of the modification. The number of seabirds killed in 2002 was 1 542 compared to zero in 2006; there was also a reduction in depredation of the catch from a maximum of 5% in 2002 to a maximum of 0.36% of the total catch in 2006. The fishers who developed the net sleeve modification called it ‘cachalotera’ (from ‘cachalote’ meaning sperm whale in Spanish). The term ‘Chilean longline’ is preferred in this paper because it was developed in 2005 in the Chilean toothfish fishery in the Magellan region.

Résumé

Description d'une nouvelle technique de pêche, adaptée de la pêche artisanale chilienne de type "trotline" visant la légine australe (*Dissostichus eleginoides*). Ce système artisanal modifié, qui comprend une manche en filet placée sur les lignes verticales secondaires, a pratiquement éliminé la déprédation du poisson par les orques (*Orcinus orca*) et les cachalots (*Physeter macrocephalus*). Cette technique de pêche a été évaluée pendant la période de septembre à décembre 2006 pour déterminer son efficacité à pallier la mortalité des oiseaux de mer et les effets des cachalots et des orques sur le taux de capture de poisson. Les résultats ont ensuite été comparés à des données similaires obtenues en 2002 dans les mêmes flottilles et zones de pêche avant la mise en œuvre de la modification. Le nombre d'oiseaux tués en 2002 était de 1 542 par rapport à zéro en 2006 ; on a également noté une réduction de la déprédation qui, de 5% de la capture totale en 2002, est passée à un maximum de 0,36% en 2006. Les pêcheurs ayant mis au point la manche en filet l'ont appelée "cachalotera" (de "cachalote" qui veut dire cachalot en espagnol). Nous préférons toutefois utiliser dans ce document le terme "palangre chilienne" car ce système a été mis au point en 2005 dans la pêche artisanale chilienne de légine de la région de Magellan.

Резюме

В статье описывается новый промысловый метод, основанный на чилийском кустарном промысле патагонского клыкача (*Dissostichus eleginoides*) с использованием трот-ярусов. Эта модифицированная кустарная система, которая включает сетной рукав, помещаемый на вторичные вертикальные поводцы, практически прекратила нападения косаток (*Orcinus orca*) и кашалотов (*Physeter macrocephalus*) на уловы рыбы. Эффективность этого метода промысла в плане смертности морских птиц и влияния нападений кашалотов и касаток на коэффициент вылова рыбы

оценивалась в сентябре–декабре 2006 г. Результаты были затем сопоставлены с аналогичными данными, полученными в 2002 г. по той же флотилии и на тех же промысловых участках до применения этой модификации. В 2002 г. количество погибших морских птиц составило 1542, тогда как в 2006 г. – 0; также сократилось потребление уловов китами с максимум 5% в 2002 г. до максимум 0.36% от общего улова в 2006 г. Рыбаки, разработавшие эту модификацию сетного рукава, назвали его «кашалотера» (от испанского слова «кашалот»). В этом документе отдается предпочтение термину «чилийский ярус», т.к. он был разработан в 2005 г. при чилийском промысле клыкача в районе Магальянес.

Resumen

Se describe una nueva técnica de pesca adaptada del espinel usado por pescadores artesanales de austrorreluzu en Chile. Este sistema artesanal fue modificado para incluir un cono de red que se coloca en las líneas secundarias (barandillos) que prácticamente elimina la depredación de la captura por las ballenas dentadas (*Orcinus orca* y *Physeter macrocephalus*). Se informa el desempeño que esta técnica de pesca tuvo en relación a disminuir el efecto de los cachalotes y orcas en la tasa de captura durante la temporada de pesca de 2006 (setiembre a diciembre) y se comparó con datos similares obtenidos en 2002 por la misma flota y en las mismas zonas de pesca, usando el espinel español clásico. Se encontraron diferencias significativas por uso de la nueva técnica de pesca en términos del número de aves marinas muertas de un promedio de 1542 en el año 2002 v/s cero en 2006. Asimismo, una reducción en la tasa de depredación por ballenas dentadas de 5% en 2002 v/s un máximo de 0.36% de la captura total en 2006. Los pescadores llaman a esta técnica 'cachalotera' (de cachalote que equivale a sperm whale en inglés), pero hemos preferido llamarlo sistema chileno debido a que fue desarrollado por la flota chilena de austrorreluzu en 2005 en la Región de Magallanes (Chile).

Key words: Cooperative research, longline fishing, albatross, petrels, killer and sperm whales, southern Chile, CCAMLR

Introduction

The interaction between killer whales (*Orcinus orca*) and longline vessels is a global problem and occurs in many longline fisheries (Yano and Dahlheim, 1995; Secchi and Vaske, 1998; Hucke-Gaete et al., 2004; Purves et al., 2004; Donaghue et al., 2003; Kock et al., 2006), with depredation levels of almost 100% recorded on some lines (Secchi and Vaske, 1998). Sperm whale (*Physeter macrocephalus*) interactions have been reported from the black cod (*Anoplopoma fimbria*) longline fishery in the Gulf of Alaska (Mitchell et al., 2002), where interactions ranged from entanglement to depredation of catch, or the aggregation of individuals around the vessel with no apparent connection to fishing operations. In the Patagonian toothfish (*Dissostichus eleginoides*) fishery Ashford et al. (1996) and Nolan et al. (2000) reported killer and sperm whales interacting with longline vessels at South Georgia and the Falkland/Malvinas Islands respectively. Ashford et al. (1996) reported high levels of depredation with 'almost the entire catch' lost from some lines. Off Chile, sperm whales have been reported to become entangled with longline fishing gear, have been observed feeding on fish off the lines, and have been reported following vessels for days (Hucke-Gaete et al., 2004). Crespo et al. (1997) also reported killer and sperm whales stealing bait and fish from longlines close to Tierra del Fuego off

South America. On some lines hauled at the Prince Edward Islands, south of South Africa, observers have estimated toothfish losses due to predation by killer whales to be as high as 50% (Tilney and Purves, 1999).

Simultaneously many interactions occur with traditional longlines and seabirds, especially albatrosses and petrels (Ashford et al., 1995; Moreno et al., 1996; Gales, 1998; Cheral et al., 1996). This problem has been solved in part by the use of mitigation measures, such as streamer lines, night setting, line weighting, discharging all offal on the opposite side of the hauling bay of vessels and changes in the fishing season to the time of year in which the birds are absent from the fishing area. CCAMLR has provided developments in this area, engaging an ecosystem approach to fishery management, but without modifying the actual fishing gear to avoid by-catch of seabirds.

There has been little research into finding new operational solutions to both the problem of bird mortality and toothed whale predation on longlines. Robertson et al. (2006, 2007b) have experimented with the sink rates of longline gear in order to improve the autoline system and the traditional

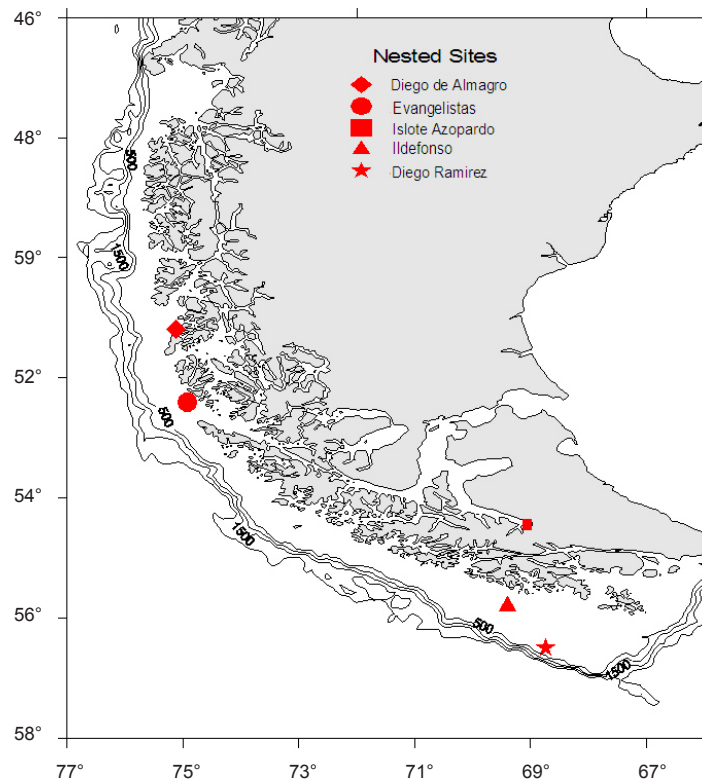


Figure 1: Colony positions of black-browed and grey-headed albatrosses in southern Chile; fishing for *Dissostichus eleginoides* in this region occurs between the 500 and 1 500 m isobaths.

Spanish double-line system by introducing modifications of the gear, like changing the distance between weights or integrating weight in the line.

During the last five years in the Chilean longline fishery for toothfish, strong positive interactions have occurred between the fishers and scientists who developed the National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (NPOA-Seabirds). During the diagnostic period of the NPOA-Seabirds, it was discovered that the Chilean artisanal longline fishery did not kill seabirds and it was therefore excluded from the NPOA. The reason for this exclusion was based on the configuration of the gear used. This gear was based on a modification of the traditional Spanish longline, called the trotline, which is obtained by eliminating the mother line, or hook line, characteristic of the Spanish system, and placing the hooks on secondary branch lines which also carry weights, thus producing fast sink rates of baited hooks in the top 9 m (see Moreno et al., 2006).

This paper describes developments in the Chilean industrial fishery, using the gear configuration from the artisanal fishery, based on the use

of trotline gear plus a net sleeve, and the impact of this on incidental seabird mortality and fish loss to marine mammal depredation. The results of an evaluation, carried out during the 2006 toothfish fishing season, are described together with a discussion of how this technique could easily be expanded to other Spanish longline demersal fisheries with similar seabird and marine mammal issues.

Materials and methods

Study area

The Chilean industrial longline fleet operates south of 47°S in the southeastern Pacific Ocean in the vicinity of Cape Horn (Figure 1). There are three longline fisheries operating in this area targeting *D. eleginoides*, austral hake (*Merluccius australis*) and ling (*Genypterus blacodes*). The last two fisheries set lines at night under normal operations and so have no interactions with albatrosses and limited interactions with white-chinned petrels (*Procellaria aequinoctialis*) (Phillips et al., 2006). They also operate further north in the region so have fewer interactions with toothed whales (Hucke-Gaete et al., 2004).

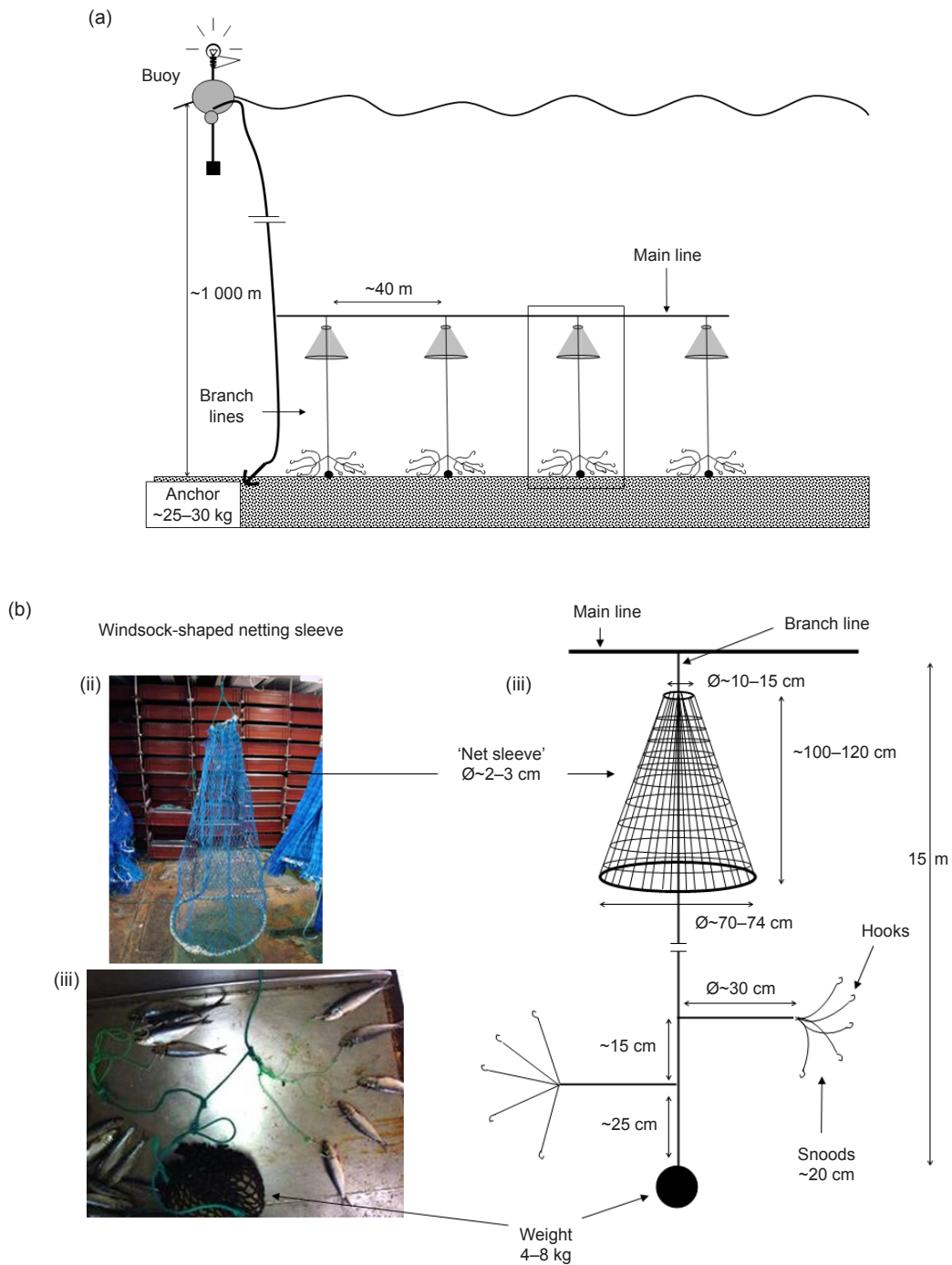


Figure 2: (a) General design of the Chilean longline. The actual 'main line' corresponds to the former 'retenida' of the traditional Spanish system double line. (b) Details of the branch line where (i) is the net sleeve or 'cachalotera'; (ii) provides details of the measurements of the configuration of the branch line with net sleeve, hooks and weight; and (iii) shows the position of the baited hooks at the end of the hook lines with the position of a weight.

Table 1: Fishing effort of the Chilean fishery for *Dissostichus eleginoides* between October and December 2006.

Vessel	Number of sets using the new mix design of the longline	
	Number of sets	≈Effort
1. <i>Isla Camila</i>	101	353 500
2. <i>Isla Santa Clara</i>	113	395 500
3. <i>Isla Sofía</i>	99	346 500
4. <i>Cisne Blanco</i>	107	374 500
5. <i>Magallanes III</i>	120	420 000
6. <i>Polar Pesca</i>	110	385 000
7. <i>Faro de Hercules</i>	114	399 000
8. <i>Puerto Ballena</i>	108	378 000
9. <i>Tierra del Fuego</i>	110	308 000
10. <i>Globalpesca I</i>	109	381 500
11. <i>Globalpesca II</i>	113	395 500
Total		4 137 000

According to Robertson et al. (2007a) this area holds about 123 000 pairs, or about 22% of the world's population, of black-browed albatrosses (*Thalassarche melanophrys*) which breed at the Diego de Almagro Islands (15 594 pairs in 2001/02) (Lawton et al., 2003), the Evangelistas Islets (4 670 pairs in 2002/03) (Arata et al., 2003), the Diego Ramírez Archipelago (55 000 pairs in 2002) (Robertson et al., 2008a) and a small colony of 62 pairs in the Seno Almirantazgo (57°27'20"S 69°01'12"W) (see Robertson et al., 2008a) and finally at the Leonard Islet (594 pairs in 2007, 53°23'S 74°04'W) (Marin and Oehler, 2007). The same area holds approximately 17 000 pairs, 23% of the world's population, of grey-headed albatross (*T. chrysostoma*).

Description of the new gear

This new technique is characterised by three key changes from the traditional Spanish longline. Firstly, elimination of the hook line whilst keeping the thicker main line from which the hook line hangs by a series of branch lines (Figure 2a). Secondly, the hook line and supporting branch lines are replaced with 15–20 m long vertical branch lines placed at 40 m intervals (Figure 2a). Each of the vertical branch lines supports multiple short hook lines and, at its extremity, a bag of weights (Figure 2b). Finally, on each vertical hook line a buoyant net sleeve is attached in such a way that it allows the sleeve to slide up and down the line. During the set, this sleeve remains at the upper end of the branch line, but when the thick main line is hauled, the movement of the vertical branch line through the water causes the sleeve to slide down the line covering the hooks and any captured fish. Chilean

fishers call this sleeve or cone a 'cachalotera' (from 'cachalote' meaning sperm whale in Spanish). The term 'Chilean longline' is preferred in this paper because it was developed in 2005 in the Chilean toothfish fishery in the Magellan region.

The use of net sleeves has a precedent in this fleet. As in 2005, a knotted line was used around hooks to 'camouflage' the hooks and caught fish. This technique was dubbed 'pulpo' (the octopus) by the fishers. However, line movements caused by the currents or the movement of the boat made the pulpo flap, revealing the fish to the whales. Whilst searching for a way to keep line in place, the net sleeve was invented, which gave better results than the pulpo. These first trials took place in 2005 on board a vessel owned by Pesca Suribérica in Chile.

In this gear configuration, hooks were concentrated at the end of the branch line, close to the weight. Individual weights were much heavier than on the artisanal longline, where weights were never more than 0.5 kg per branch line. The weights used in the industrial fishery were the same bags of stones used in the Spanish system (between 4 and 10 kg per branch line). This meant that the sink rate of baited hooks was double that achieved in the artisanal longline (0.47 m s^{-1}), with a mean sink rate of at least 0.8 m s^{-1} , until the branch line was totally extended at a depth of 15 m.

Scientific observation

The fleet of 11 vessels that operated between September and December 2006, were all industrial factory vessels (>45 m in length). The total effort during the period was 4 137 000 hooks (Table 1),

of which 1 508 500 (36.5%) were observed by one of the four scientific observers. Data recorded included: (i) number of seabirds around the vessels and associated mortality; (ii) sightings of sperm and killer whales around the vessels; and (iii) loss of fish from the line to sperm and killer whale depredation.

Observations made on vessels during the study period (September to December 2006) were extrapolated to estimate the total effort during the study period. Data on incidental mortality of seabirds were recorded following the methodology of Moreno and Arata (2006) for comparative studies of seabirds killed in previous years. The depredation rate by toothed whales was evaluated following the modification of Hucke-Gaete et al. (2004) to the relationship of Yano and Dahlheim (1995), where the depredation rate (dr) is:

$$dr = \left(\frac{nd}{nd + nt} \right) * 100$$

where nd is the number of damaged fish, ascertained by the number of heads, trunks or lips, and nt is the total number of fish showing no evidence of damage. This was calculated as a percentage of damaged fish per setting. Depredation rates for the 2006 season were then compared with the data for the 2002 season. Some fish are totally removed from hooks by toothed whales indicating that the depredation rate is usually an underestimation. However, under the assumption that the data of 2002 and 2006 have the same bias, a contrast between the estimates was made using the mean and upper 95% confidence interval (CI) of the depredation rate.

In the 2006 season, when fishers began to use the new system, an experiment to assess the effects on seabird by-catch was carried out on board the FV *Isla Santa Clara* (Suribérica S.A.). This involved comparing randomly sequenced sets with and without streamer lines (30 sets each). The numbers of black-browed albatrosses around the vessel were counted 10 min before each set began. That information, along with the number of birds subsequently caught, was compared with similar previous studies carried out in the *D. eleginoides* fishery in Chile during the diagnosis for the Chilean NPOA-Seabirds in 2002 (Moreno et al., 2003).

Results

Use of the Chilean longline in reducing depredation rate by marine mammals

The results of the application of this gear configuration in 2006 were compared with similar data of depredation rates from 2002 in Hucke-Gaete et al. (2004). This analysis showed a great difference between the traditional Spanish longlines used in 2002 and the new Chilean longline used in 2006. The presence of groups of sperm and killer whales was similar in terms of abundance in both years (sightings of ≈ 500 sperm whales and ≈ 40 killer whales in the season) but the difference in percentage of catch damage was two-fold less with the use of the new system (Figure 3).

One important observation was made by scientific observers when the fleet started using the Chilean longline. After about one week of unsuccessful attempts by sperm whales to obtain fish from the line, the whales disappeared from the fishing grounds. The observers also noted that South American sea lions (*Otaria flavescens*), that normally attempt to take fish from the line, were prevented from doing so.

Incidental mortality of seabirds

With the use of the Chilean longline during the 2006 season, the total number of seabirds killed was zero (Figure 4).

When the fishing season started (September 2006), the Chilean longline was used together with streamer lines. When comparing the incidental mortality with and without streamer lines, using the new Chilean longline the same results were found in both treatments; no birds were killed. The fishers soon realised that the fast sink rate of the Chilean longline ($>0.8 \text{ m s}^{-1}$) did not allow seabirds to see the bait at the surface, (see Robertson et al., 2008b, for further details on sink rates in this system), and were able to remove the streamer lines during sets. In order to show a quantitative comparison of the number of albatrosses and petrels around the vessels, data were obtained from Moreno et al. (2003) of birds-per-unit-effort (BPUE) or birds killed per hook per set) in relation to the number of birds counted around the vessel 10 min before setting the line, with similar data obtained during the 2006 season. Figure 5 shows clearly that the new gear did not kill a single black-browed albatross in spite of their high abundance around vessels that were fishing close to the Diego Ramírez Archipelago. This area also holds very large numbers of grey-headed albatrosses (see description of the study areas under 'Methods') as well as wandering

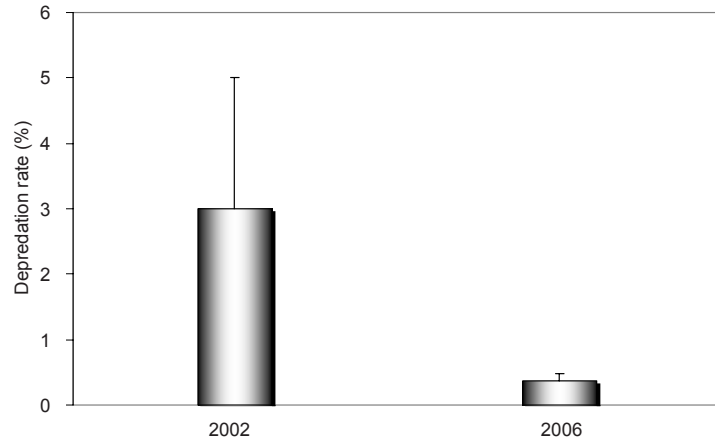


Figure 3: Losses due to depredation from toothed whales during the fishing season in the Cape Horn area; data for 2002 are from Hucke-Gaete et al. (2004).

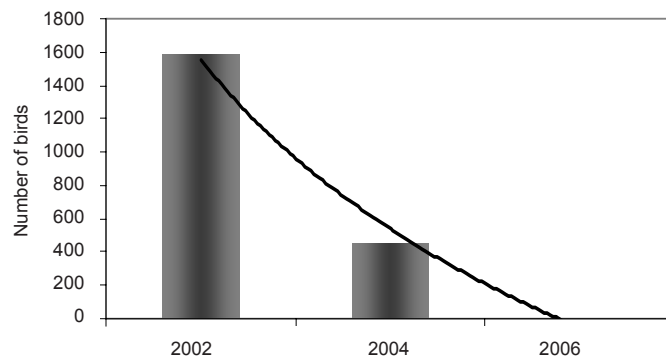


Figure 4: Total incidental mortality of seabirds in the *Dissostichus eleginoides* fishery in 2002, 2004 and 2006 (from Moreno et al., 2003; Moreno and Arata, 2006 and present study respectively).

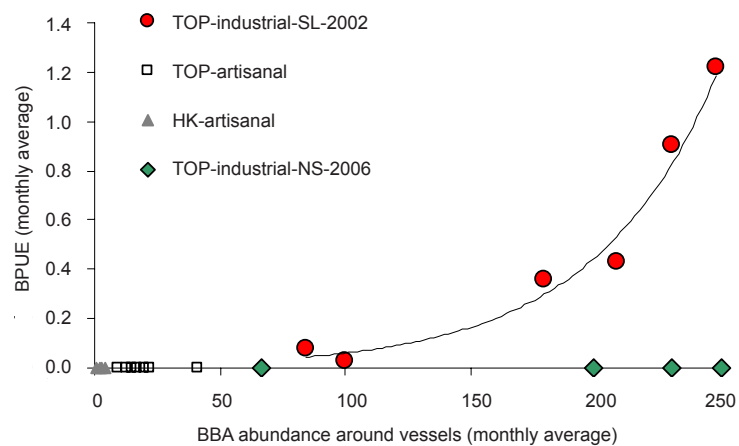


Figure 5: Incidental mortality in relation to the abundance of flying black-browed albatrosses (BBA) counted around the vessel 10 min before setting and birds caught per unit effort (BPUE) in different fisheries, note especially the *Dissostichus eleginoides* (TOP) fishery in 2002 (circles – $y = 0.0081e^{0.02x}$, $R^2 = 0.92$) and 2006 (diamonds).

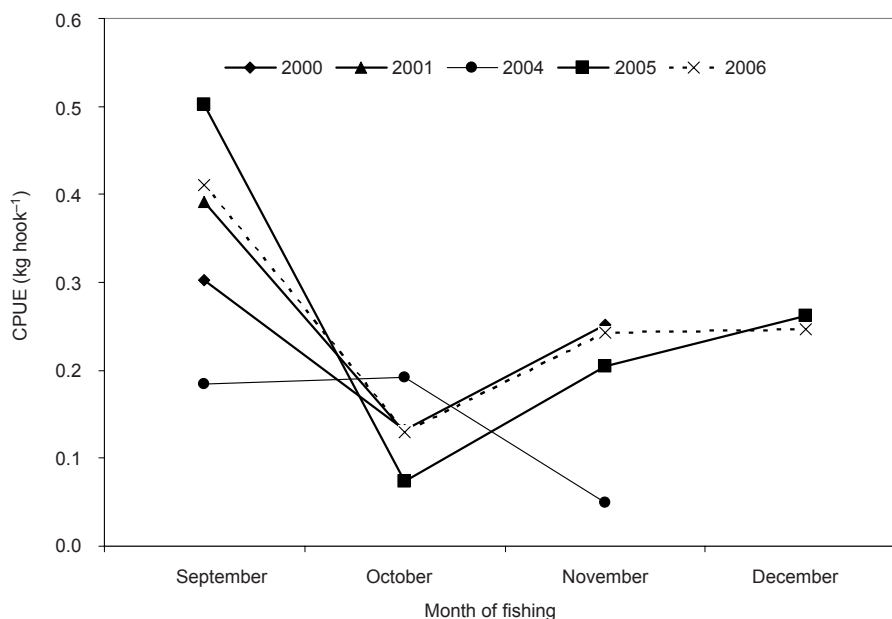


Figure 6: Catch-per-unit-effort (CPUE) obtained during the fishing season for a vessel from the fleet for the last five years, from 2001 to 2005 using the Spanish longline system and in 2006 using the new Chilean longline.

albatrosses (*Diomedea exulans*) from South Georgia and northern royal albatross (*D. sanfordi*) from New Zealand; no incidental mortality of these species was recorded.

Considerations on capture rates

The catch-per-unit-effort (CPUE) data show that in 2006 the CPUE was higher than in at least three of the previous four years (Figure 6), thus clearly indicating that the Chilean longline does not adversely affect fish catch rates.

Cost of the trotline/net system

The new Chilean longline is derived from the traditional Spanish system that was in use in the Chilean fleets in previous years. The modifications reduce the cost of the hook line, because the hooks are attached directly to the branch line. The only additional cost is to build the cachaloterías or net sleeves at an estimated cost of US\$25–30 each. However these net sleeves are durable and can be used for a long time.

The operation of the new system also needs less crew than the traditional Spanish system, which requires 12 people; the Chilean longline requires only eight. During operation of the Chilean longline

it was noted that during setting, the longline had less entanglement as it is relatively easier to set the line.

Discussion

The new Chilean longline, performed excellently in avoiding sperm and killer whales, fish depredation and seabird by-catch during September–December 2006 in the southern Chilean industrial fishery for *D. eleginoides*.

Hucke-Gaete et al. (2004) described a strong correlation between the number of whales and the number of fishing vessels operating in the area within the western mouth of the Magellan Strait and Cape Horn. As a result of such interaction, the predation rate of fish estimated by Hucke-Gaete et al. (2004) ranged between a maximum of 5% to less than 1.5%, with an average of 3%. This is certainly an underestimation of the predation rate because the estimate relies on portions of fish remaining on hooks (indicating that fish were caught), whereas fish are often totally removed, especially by killer whales. However, assuming that the bias in both years (2002 and 2006) is similar, the netting sleeves represent a significant advance in efforts to reduce the number of fish lost to toothed whales as the depredation rate fell to a maximum of 0.36%. The net

¹ J.P. Torres-Florez and P.R. Reyes described in detail the other fish predators that can remove fish from longlines in southern Chile. In: *XII COLACMAR*: 537 pp. (Libro de Resumos, XII Congreso latinoamericano de Ciencias del mar. Florianópolis, Brasil).

sleeves are also effective in reducing depredation by other organisms¹ such as sleeper sharks (*Somniosus pacificus*) and 'marrajo' or porbeagle sharks (*Lamna nasus*).

The use of these net sleeves was the third step in the search for an effective deterrent to the depredation of fish by marine mammals. The first step was when the artisanal fishers divided the extensive longline of 10 000 or 12 000 hooks to four or five short lines. Then, in order to add more hooks, branch or secondary lines (referred to as 'paño' by Moreno et al. (2006)) were lengthened from 0.5 to 9 m to hold more hooks, in most cases between two and four hooks, with a stone weight at the end (Moreno et al., 2006). The second step occurred when industrial fishers enlarged this set-up further by lengthening the branch lines to 15 or 20 m and adding filaments above the hooks to disguise or camouflage the fish. The third step involved the use of a net sleeve which was initially of a size of 1.4 m but, to be more effective against killer whales, was enlarged to 1.8 m.

The rapid sink rates of the Chilean longline appear to make it impossible for seabirds to see the baits or reach them by diving, even with only minimal levels of phytoplankton in the water. The most relevant demonstration of the efficiency of this mitigation measure comes from examining the mean abundance of seabirds around vessels 10 min before setting the line. Previous research has shown that the expected number of albatrosses killed by a longline is higher if seabirds are concentrated around the vessel before the set, as occurs during the second half of the seabird incubation period, from the last week of October to the first three weeks of November (Arata, 2004). In the current study, the mean number of black-browed albatrosses around vessels exceeded 200 birds (that number was exceeded if other species, such as giant petrels and other albatross species, were included). The results for 2006 were absolute; no birds were killed from an effort of almost 4 million hooks during October–December despite a 100% overlap between the fishing season and the reproductive period of the seabirds in the area.

In 2002, a large number of black-browed albatrosses were killed by the Chilean *D. eleginoides* fleets in the fishing zone. According to Moreno and Arata (2006), the annual mean mortality was 1 588 seabirds, including 1 555 black-browed albatrosses, 6 grey-headed albatrosses, 2 Cape petrels (*Daption capense*) and 25 white-chinned petrels. This mortality was the reason why the Chilean fishery authorities began to implement the NPOA-Seabirds. Two years after the application of the

mandatory use of streamer lines, and many other measures included in the Chilean NPOA, the mean number of seabirds killed was only 448 (including 440 black-browed albatrosses and 8 grey-headed albatrosses). No petrel deaths were recorded in that year (2004) in the Chilean toothfish fishery. The Chilean longline described here was added as an appendix to the NPOA-Seabirds in Chile (Supreme Decree No. 136 of 17 April 2007) as a measure that replaced the use of streamer lines. However, if the fleet return to using the traditional Spanish longline, it is essential that it also reverts back to using the complete suite of mitigation devices included in the Chilean NPOA.

Future research

The fish by-catch was not quantified during these trials in the Chilean toothfish fishery. Although few rays and grenadiers were taken as by-catch in the main fishing ground around Cape Horn and Diego Ramírez Archipelago this matter is one that needs further study to consider this aspect of the Chilean longline.

Conclusion

Without doubt there has been a breakthrough in solving the problem of interactions between Spanish longline fishing activities and various vertebrates, from birds to mammals, making for a friendlier relationship between the fishers and the ecosystem. This is a lesson that has been learnt through fishers being motivated to solve problems with whale interactions and scientists motivated to reduce seabird interactions. Preventing seabird by-catch and reducing bait loss from longlines provides some motivation to address the problem of seabird by-catch. However, nothing must be harder to watch than recovering only the head of a large fish that has been taken by a whale. Here both motivations have found an effective solution without affecting the catch rate.

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