Minimising whale depredation on longline fishing

Australian Toothfish fisheries

A report for

NUFFIELD AUSTRALIA FARMING SCHOLARS

by Rhys Arangio

2012 Nuffield Scholar

October 2012

Nuffield Australia Project No 1201

Sponsored by the Fisheries Research & Development Corporation and Woolworths:

Australian Government

Fisheries Research and Development Corporation

Woolworths
the fresh food people

Scholar Contact Details
Rhys Arangio
Austral Fisheries
Level 4, 50 Oxford Close
West Leederville, WA, 6007
Australia

Phone: +61 402 883 195
Email: rarangio@australfisheries.com.au

In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

Nuffield Australia Contact Details

Nuffield Australia
Telephone: (03) 54800755
Facsimile: (03) 54800233
Mobile: 0412696076
Email: enquiries@nuffield.com.au
586 Moama NSW 2731

Foreword

In Australian toothfishing waters, whale depredation (whales eating fish that are hooked on a fishing line) is not yet a significant issue, though in 2011 the first instances of Sperm whale depredation were seen. From our knowledge, this has only occurred on the one occasion, and once the gear was hauled and the vessel moved from the area, the whales did not follow. Though not currently a significant problem, with an increasing portion of longline caught fish in the fishery, we would like to be prepared in case the whales develop this skill further and begin to have a significant impact on toothfish caught in Australian waters.

On the other hand, whale depredation in toothfish fisheries not far from the Australian fishery has reduced catches by up to 75% at times (Roche, *et al*., 2007); this comes from the likes of Sperm whales as well as Killer whales. This is a significant portion of catch, which largely affects profits for the fisherman.

There is also the fact that with depredation there an increased risk of injury to the animal due to close proximity to the vessel, which has resulted in death to at least 20 individuals in other fisheries around the world (Hamer, Childerhouse & Giles, 2012). This learned skill alters their natural foraging behaviour and diet, and also becomes an issue in fish stock assessment where scientists may not be able to accurately account for how much fish catch has been taken by whales, and therefore may lead to over or underestimating fish escapement in stock assessments.

By looking at mitigation methods around the world, I am aiming to give Australian toothfish operators an insight into what is available and whether they are suitable for current operations. This report looks at alternate methods to the current auto-line system used in Australia's toothfish fisheries as well as technology that may confuse, track or deter whales from the vessel.

This project has been funded through the generous sponsorship of the Fisheries Research and Development Corporation and Woolworths.

Acknowledgements

I would firstly like to thank Nuffield Australia for making this all possible. For a person relatively new to the seafood industry I feel privileged and humbled to be amongst all that is Nuffield. The people who are involved in this organisation are leaders in their respective industries and some of the most inspirational people I have come across. It is an honour to call myself a Nuffield Scholar.

To my sponsors, the Fisheries Research Development Corporation and Woolworths, I thank you kindly for the generous contribution that has allowed me to undertake this study and it is heartening to see the role both organisations play in the seafood industry.

To my employer, Austral Fisheries, who have not only allowed me the time to undertake this experience, but have shown great faith in me over the past few years - I hope I can repay this faith in the years to come. A special thank you to David Carter, Peter Stevens and Martin Exel for your guidance and support along the way.

A huge thank you to all my extremely generous hosts in Chile, Norway, Belgium, France, Canada and the USA, who helped me throughout my study tour. You all went above and beyond the call of duty and without your help this trip would not have been possible.

To Bryan, Ryan, Ray, Dave, Murph, Crosby, Nat and the multitude of hosts during the February-March 2012 Global Focus Tour – it was a pleasure spending seven weeks with you looking at agriculture around the world. Thank you for making it such an unforgettable trip with many fond memories to look back on, and also for taking the time to explain things in a little less detail for the lone fisherman.

Glossary

ADD	Acoustic Deterrent Device
AHD	Acoustic Harassment Device
Cachalotera	A meshed net sleeve which is attached to a manual longline that protects fish from whale depredation
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CPUE	Catch per Unit Effort
Depredation	In a fishing context, the removal of fish from fishing gear by animals such as marine mammals or sharks
FRDC	Fisheries Research & Development Corporation
GDP	Gross Domestic Product
HIMI	Heard Island & McDonald Islands
Hydrophone	A listening device that is able to record sounds in the water
IWL	Integrated Weighted Line
OrcaSaver	An acoustic device hung in the water, producing sonar pulses, aimed at deterring Killer whales from fishing vessels
SEASWAP	South East Alaska Sperm Whale Avoidance Project
Snood	In longline fishing, a thin line by which a fishing hook is attached to the longline
TAAF	Territory of the French Southern and Antarctic Lands
TAC	Total Allowable Catch
WG-FSA	Working Group on Fish Stock Assessment

Contents

Executive Summary

Background

The Australian toothfish industry began in 1994 when commercial quantities of Patagonian toothfish were found by Austral Fisheries off Macquarie Island in Australia's sub-Antarctic waters. Today, there is also a commercial stock at Heard Island & McDonald Islands (HIMI) and both these toothfish fisheries are independently certified as sustainable and well managed by the Marine Stewardship Council. These fisheries contribute approximately $50 million per annum to Australia's Gross Domestic Product and account for around 14% of the world's Patagonian and Antarctic toothfish tonnage. There are two companies that own the rights to fish for toothfish in Australian waters, Austral Fisheries (who hold around 74% of quota) and Australian Longline (who hold around 26%).

Austral Fisheries operate two toothfish vessels, a longline/trap vessel and a trawler. The company's aim is to replace the trawler with an additional longliner in 2013 to increase the amount of longline caught fish taken from the fishery. Longline and trap caught fish are of a premium quality over trawl caught fish, while reducing the impact on the fish stock[1] and reducing the potential impact on the seabed.

With an increased portion of longline caught fish there is also an increased risk of being affected by marine mammal depredation. In our case, this is most likely to occur from Sperm whales and potentially Killer whales. In other toothfish fisheries such as the French Crozet Islands fishery, these whales take up to 75% of the fish from the line when they are present (Roche, *et al*., 2007), which has a serious detrimental effect to the fisherman's profits.

Aims

This report is targeted at the Australian toothfish industry, but is also applicable to any form of demersal longlining that experiences whale depredation. The aim of this study is to see if any whale depredation mitigation techniques currently used around the world will be both effective and efficient in Australia's toothfish fisheries.

[1] Trawling generally catches smaller sized toothfish than longline and traps. Therefore you must remove a larger number of trawl caught fish than longline/trap caught fish from the fishery in order to catch the allocated tonnage. This, in turn, means that a lower TAC must be set by scientists to ensure sustainable fishing levels.

Methods

I used Austral Fisheries' contacts within the industry as well as searching numerous published reports to find experts that have dealt with the major aspects of my topic – whales, depredation and fishing. Along the journey I met with fishermen, gear suppliers and scientists to gain their perspectives on the topic and their thoughts on the question: how do we ensure our fish don't get taken from the line by whales?

Results

There are many potential mitigation options for whale depredation, but results vary depending on the depredating species, the fishery involved and the fishing gear that is being used. Fisheries affected by Sperm whales generally lose between 3% and 5% of their total catch to depredation, though this figure is usually much higher for Killer whales.

Potential mitigation options

- Trap fishing is a certain solution against depredation; however commercial catch rates for toothfish (1-2t/day) are far below that of longlines (5-6t/day), so while this method has potential, until either depredation rates or trapping catch rates increase dramatically, trapping is a costly operation to continue working with.
- Passive acoustic listening through hydrophones will map where and when whales frequent the fishery.
- Active decoys – A 'fake' longline attached with a hydrophone and an acoustic playback device emitting propeller cavitation sounds that will attract whales to a decoy location.
- Cachalotera – a manual longline method with fish protection through a 'net sleeve'. This requires a change in gear and vessel setup. It also means less hooks can be used per day.
- Acoustic deterrents – OrcaSaver will only work against Killer whales and results are not conclusive. There is potential scope in navy sonar.
- In development:
    - "SAGO" – a combined longline and trap gear.
    - Poly bead on each snood emitting the same 'ping' as sablefish to a whale's sonar; decreasing the perceived depredation success rate and potentially dissuading the whales because of this.
    - Jamming frequencies and water bubbles to confuse whales.

Things in favour of Australian toothfish fisheries

- Depredation onset has only just begun; compared to decades of depredation in some fisheries where the skill is instilled in the whale's psyche.
- HIMI depredation being caused by Sperm whales and not Killer whales. Fisheries affected by Killer whales are generally worse off.
- Australian vessels do not dispose of offal overboard, which reduces the attraction of whales. This is not the case in other fisheries.
- Currently only 2 longline vessels work at HIMI between April and October. In other fisheries, several longline vessels work 10 months of the year (in some fisheries up to 250 vessels). This becomes a constant food supply source for the whales. It is also thought that the major cue in attracting whales is the cavitation noise of vessels' propellers.

Recommendations

Initial steps:

- Develop a whale depredation best practice handbook for Australian toothfish vessels;
- Develop a HIMI whale sighting catalogue and compare with nearby French fisheries;
- When whales may be in the area, decrease longline length and depth fished; and increase hauling speed without risking breakage of line;
- Buoy off gear and steam at least 40 nautical miles away when whales sighted. Do not give whales a chance to develop depredation skill further;
- Continue to develop toothfish trap fishery.

Next steps:

- Closely watch current SEASWAP project in active decoys, poly beads, bubblers and jamming frequencies in Alaska.
- Enquire into passive acoustic listening devices with Australian suppliers in order to map the whereabouts of Sperm whales at different times of year at HIMI.

Introduction

I have a Marine Science background and have been working for Austral Fisheries since 2009. Within my first two years with the company I gained almost a year's worth of sea time on our vessels – prawn trawling in the Gulf of Carpentaria; longlining and trapping for Patagonian toothfish in both Australian and French waters; and trawling in the southern Indian Ocean. This was a valuable experience in understanding the way we fish and the rules we must abide by in these highly regulated fisheries. Importantly, I also got to meet and interact with our crew, whom I have a great appreciation for the hard work and the sacrifices they make when choosing the life of a deep sea fisherman.

My role with the company now lies with the operational aspects and the science and policy side of our Southern Ocean fleet. We have two vessels in this fleet, the Southern Champion and the Austral Leader II, whose major target species is Patagonian toothfish, which is caught around two of Australia's sub-Antarctic territories, HIMI (annual Total Allowable Catch (TAC) of 2,730t) and Macquarie Island (annual TAC of 455t).

Figure 1: A 91kg, 1.9m Patagonian toothfish caught via trap in the French Crozet fishery.

Patagonian toothfish (*Dissostichus eleginoides*) (Figure 1) is a deep sea species found throughout large areas of the sub-Antarctic oceans. In other markets it is also known as Chilean Sea Bass (USA), Bacalao de Profundidad (Chile), Mero (Japan), Legine Australe (France) and Merluza Negra (Argentina).

Patagonian toothfish are bottom dwelling opportunistic predators, found in depths between 300 and 3,000 metres. Their fishing grounds are concentrated on continental shelves around sub-Antarctic islands and off the coast of southern South America. The fish can reach a maximum age of around 50 years, a maximum length of 2.2 metres and about

120kg in weight. Its adult diet is mainly based on squid, fish and crustaceans.

The Antarctic toothfish (*Dissostichus mawsoni*), a close relative, is generally found south of 60°S and has very similar biological characteristics, but is thought to grow slower than Patagonian toothfish, and has a smaller maximum length (estimated at around 1.8 metres) and maximum age of 35 years.

Austral Fisheries began longlining for toothfish in 2008. At HIMI, operators can only use longlines between the dates of 1 May and 14 September[2] due to increased seabird abundance during the summer months[3], whereas vessels can trawl and trap all year round as there is less risk of seabird interaction with these methods. This was the reason for designing the longline vessel with the ability to trap (for use in the longline off-season); however, to date traps have not been commercially successful for the company. There have been two commercial trap trips to HIMI (2008, 2011), with a third planned for the end of 2012, and one joint venture with the French toothfish industry to the French Crozet region (2010), where they experience significant whale depredation on longline fishing. These trips have proven that trapping can potentially work with toothfish; however, profitable catches have not been sustained throughout the entirety of a trip.

During the French joint venture trip, numerous different pots and baits were tested to see which may be the best match for toothfish. Results found a type of trap that catches approximately 17% better than the Canadian sablefish trap Austral Fisheries was initially using (Figure 2).

Demersal longline gear is comprised of a long weighted mainline that sits on the seafloor, with numerous baited hooks attached via a snood. The longline is anchored at both ends, with downlines attached to floats that reach the water's surface (Figure 3). To help with the sink rate of these lines in the water (and also helping to achieve effectively zero seabird mortality), Integrated Weighted Line (IWL) is used, which has a weighted core threaded through the

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[2] Season extensions are possible. If CCAMLR Conservation Measures regarding seabird interactions are met, the season may be extended to 15 April - 31 October.

[3] Resident seabirds use the summer months to rear their chicks on sub-Antarctic islands. The increase in seabird abundance in the area therefore increases the potential risk of interaction with the longline gear. In saying this, seabird mortality rates in the HIMI fishery are negligible, averaging 0.0003 deaths per 1000 hooks since longline operations began in 2005 (Australian Fisheries Management Authority, 2012).

mainline. This achieves a fast sink rate, where the line disappears below the surface before seabirds get a chance to dive for the baited hooks.

Figure 2: In the foreground, collapsible French traps. In the background, Canadian sablefish traps.

Austral's longline system is also automated, which means instead of manually baiting every hook, there is an automatic baiting machine that cuts the bait to size and automatically baits each hook as it is propelled into the water. Some toothfish fisheries use auto-longlines, and some use manual longlines.

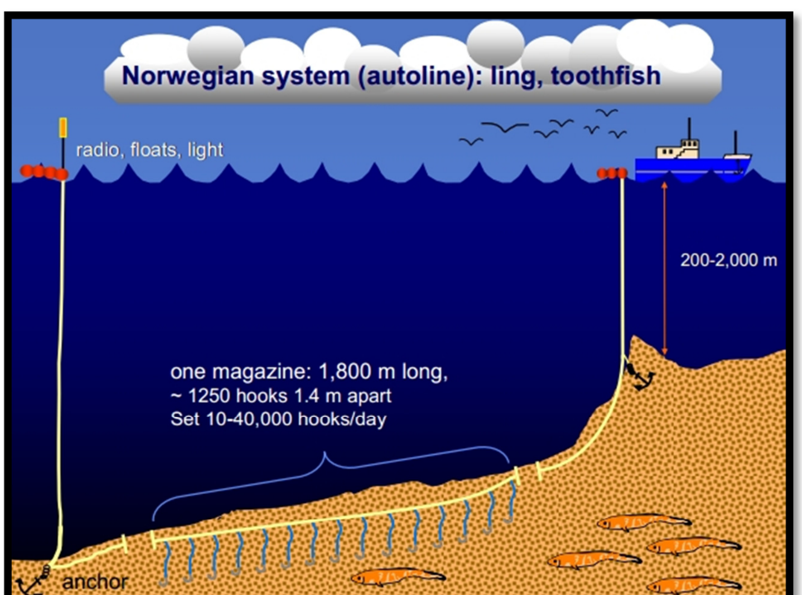

Figure 3: Image depicting a typical demersal automated longline magazine setup in Australian toothfish fisheries.

The same mainline concept is used with trapping – though using a neutrally buoyant mainline, with up to 200 traps attached at 20m or 40m intervals that sit on the seabed (Figure 4).

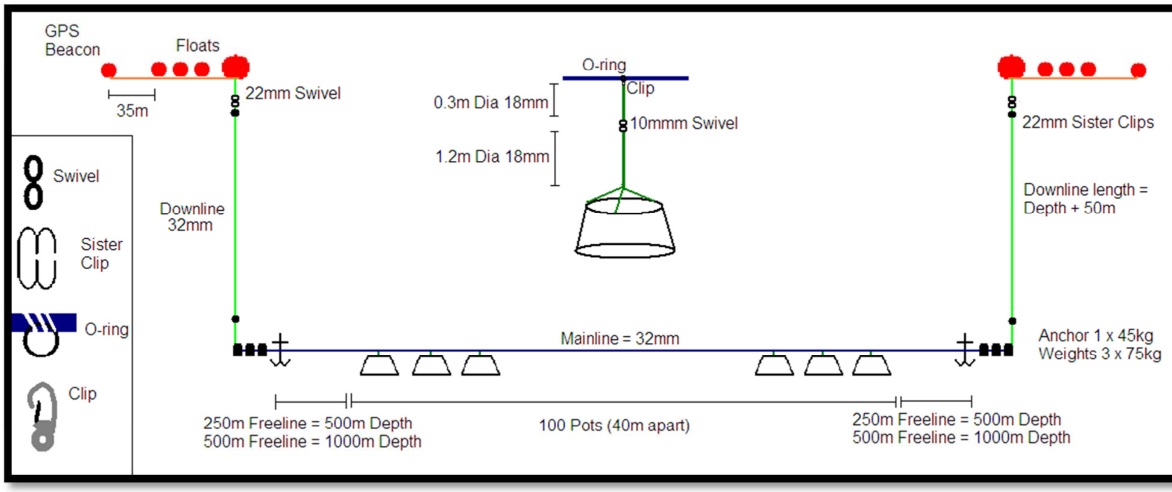

Figure 4: Image depicting a typical demersal trap line setup in Australian toothfish fisheries.

In the 2010/11 season Austral caught 60% of toothfish via trawl, 38% via longline and 2% via traps. Within the next 12 months we would like to be catching 10% trawl, 80% longline and 10% trap. This increase in longline and trap catch, along with the whale depredation currently taking place in nearby French toothfish fisheries, is the basis behind my Nuffield study.

Study Tour

My Nuffield study tour took me to Chile, Norway, Belgium, France, Alaska, British Columbia and California to speak with scientists, fishing gear suppliers and fishermen. Since the study tour I have also spoken with experts in Australia, Italy, South Africa, South Georgia and Falkland Islands to gain an insight into what is happening in the places I was unable to visit.

Depredation

Depredation is defined as the removal of fish from fishing gear by animals such as marine mammals or sharks (Donoghue *et al.*, 2003). There has been very little video evidence of Sperm whale or Killer whale depredation but Figure 5 shows it taking place in both sablefish and toothfish fisheries.

Figure 5: On the left, Sperm whale depredation in the Gulf of Alaska sablefish fishery, and on the right, Killer whale depredation at the Crozet Islands toothfish fishery.

When whale depredation occurs, sometimes the entire fish will be removed (which makes it harder to calculate the depredation rate), or there will be damage to the hooks or remaining fish, such as lacerations on the body, or only the heads or lips will be left remaining on the hook (Goetz, *et al.*, 2011). The first evidence of depredation dates back to 1904 (Santos, *et al.*, 1999) and as recently as the 1980s some fishermen were still using guns, dynamite and explosives to *legally* deter whales. Data suggests that depredation by marine mammals on commercial longlines is currently increasing and now occurs throughout all oceans and many fisheries. This increase coincides with the cessation of commercial whaling in 1986, along with the increasing proportion of longline caught fish worldwide taking preference over other methods. (Rabearisoa, *et al.*, 2009; Roche, *et al.*, 2007).

Schakner (2011) describes depredation as a 'cultural arms race' between whales and fishers, where one keeps outdoing the other. The social transmission of this behaviour can be fitted with a diffusion curve (Figure 6) that shows the number of individuals that develop a behaviour over time. These curves are often seen in technology, for example, not many people used Facebook at its infancy; then over time it spread virally; and now the uptake has slowed because so much of the population is already using it.

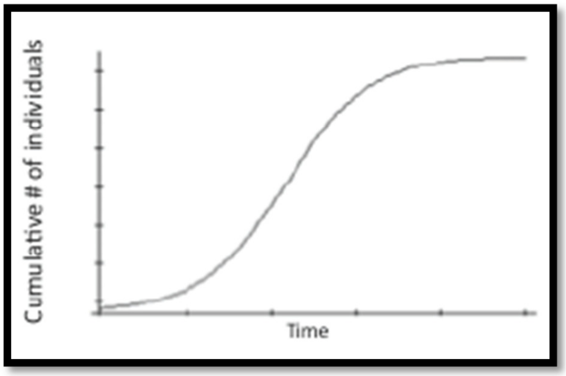

Figure 6: The social transmission of behaviour as described by Schakner (2011).

This is similarly seen with depredation. At the early stages of depredation in a fishery, there may only be 1 or 2 individuals that have developed this skill, but then over time this ability spreads, whether through teaching or observation, but once a large enough portion of a population has developed this skill, depredation rates will plateau as there becomes less individuals who are new to this skill.

Associated whales

Sperm whales (*Physeter macrocephalus)* and Killer whales (*Orcinus orca*), both of which are toothed whales, are the two major culprits in regards to demersal longline depredation (Figure 7). Table 1[4] shows selected demersal longline fisheries throughout the world that are affected by Sperm and Killer whale depredation.

Figure 7: On the left, a Sperm whale, and the right, a Killer whale approaching a fishing vessel in a French toothfish fishery.

Results of studies that were originally based on stomach contents of commercially taken Sperm whales, or more recently on stranded specimens, indicate a diet based largely on deep sea cephalopods with a smaller portion of fish.

[4] See explanations of figures from Table 1 in fishery descriptions on pages 17-21.

Table 1: Depredation rates and CPUE (Catch per unit effort) reduction across selected demersal longline fisheries. CPUE figures are averages when marine mammals are present. Depredation rates are annual averages unless otherwise stated.
Key - SW: Sperm Whale; KW: Killer Whale; SEA: Antarctic fur seal; ↓: decrease; NS: Not significant; - : Not calculated

Fishery	Depredating species	Depredation rates
South Georgia toothfish	KW, SW	SW: ≤ 20% CPUE ↓ KW: 50% CPUE ↓ Depredation rate: 3.6%
Falkland Islands toothfish	NS: KW, SW	- ; minimal
Prince Edward & Marion Islands toothfish	KW, SW	Depredation rate: ≤ 67% when present[5]
Crozet Islands toothfish	KW, SW	SW: 9% CPUE ↓ KW: 27% CPUE ↓ KW+SW: 37% CPUE ↓ Depredation rate: 17.7%
Kerguelen Islands toothfish	SW NS: KW	SW: 12% CPUE ↓ KW: < 1% CPUE ↓ SW+SEA: 21% CPUE ↓ Depredation rate: 3.2%
Heard Island toothfish	NS: SW	- ; minimal
Chilean toothfish	KW, SW	SW: 18% CPUE ↓ (Spanish Longlines) Depredation rate: 5% (Spanish Longlines) Depredation rate: 0.36% (Chilean Longlines)
Greenland halibut	SW	-
Gulf of Alaska sablefish	SW NS: KW	SW: 3-5% CPUE ↓ Depredation rate: 5%
Canadian sablefish	NS: KW, SW	- ; minimal

[5] This figure is not associated with any scientific data, only visual observation.

There are also several studies (Abe & Iwami, 1989; Clarke, 1980) that have reported the presence of Patagonian toothfish in the diet of Sperm whales in the Southern Ocean. Sperm whales are capable of a much greater diving depth (around 3,000 metres) than Killer whales (around 265 metres), and thus the availability of certain demersal fish species that may be available to Sperm whales, such as toothfish, are not naturally available to Killer whales, but are an opportunistic inclusion to their diet when there is the prospect of available fish surfacing on a longline (Moir-Clark & Agnew, 2010). In most high latitude fisheries only 'bachelor groups' or lone male Sperm whales are present, though family groups are sighted around South America (Berzin, 1971). Killer whales are generally found in pods (Baird, 2000).

Depredation in toothfish fisheries

Depredation (Figure 8) was first publically recorded in a commercial toothfish fishery in South Georgia in 1994 (Moir-Clark & Agnew, 2010) and in the French Crozet fishery soon after (C. Guinet, pers. comm. 28 May 2012). Since this time there have also been published events from the Falkland Islands (Nolan, *et al.*, 2000), Prince Edward & Marion Islands (Tilney & Purves, 1999), Kerguelen Islands (Roche, *et al.*, 2007), as well as off the coast of Chile (Hucke-Gaete et al., 2004). Apart from the Ross Sea Antarctic toothfish fishery, Australia's toothfish fisheries seem to be the only toothfish fisheries without the depredation issue.

Figure 8: The impact of Sperm whale depredation off South Georgia (left, taken from Kock, *et al*., 2006) and Chile (right, courtesy of C.A Moreno).

South Georgia

Moir-Clark & Agnew (2010) state that in the South Georgia toothfish fishery, when Killer whales or Sperm whales are present, they suppress CPUE by up to 50% and 20% respectively. Between 2003 and 2009 it is estimated that total catches have been reduced by 1% to 8% each year, with a mean of 3.6% per year. Overall, 4% of lines were affected by Killer whales and 18% by Sperm whales. The presence of Killer whales has been steady over time, whereas Sperm whale interactions have been steadily increasing. It is suggested that Sperm whales are still obtaining most of their diet from natural foraging activities rather than depredation.

Crozet Islands

Tixier (2010) estimates that on average between 2003 and 2008 at the Crozet Islands fishery, around 18% of the total toothfish catch was taken from the line, with Killer whales being responsible for over 75% of this and the majority being taken by only 35 of 97 Killer whale individuals present at Crozet; showing that these 35 individuals have learned to be highly skilled at depredation. The mean CPUE loss is 27% when Killer whales are present; 9% for Sperm whales and 31% when both species are present.

Kerguelen Islands

Roche, *et al*. (2007) state that between 2003 and 2005 at the Kerguelen Islands fishery, Killer Whale depredation was negligible though Sperm whales reduced CPUE by 12% and when Sperm whales and Antarctic fur seals were present simultaneously, it resulted in a 21% reduction. Over this period it was estimated 3.2% of total catch was taken by depredation, or about 116 tonnes per year. Most of the Sperm whales sighted at Kerguelen are not the same ones sighted at Crozet, but at both fisheries they are lone adult males.

Prince Edward & Marion Islands

At the Prince Edward & Marion Islands toothfish fishery, there is no scientific data publicly available but observers and fishermen have suggested that the depredation rate can reach up to 67% when whales are present (Moir-Clark & Agnew, 2010), and this figure has been included in Brandao & Butterworth's (2009) proposed management procedure for this fishery. The Convention for the Conservation of Antarctic Marine Living Resources' (CCAMLR) Working Group on Fish Stock Assessment (WG-FSA) noted that this level of depredation is much greater than suspected for other toothfish fisheries, and encouraged the deployment of a scientific observer to gather further data on this (CCAMLR, 2011).

Chile

In the toothfish fishery off the Chilean coast they have moved from Spanish longlines to the 'cachalotera' system (also known as the Chilean longline system) (Figure 9). Moreno, *et al*. (2008) found that when they compared traditional Spanish longline data from 2002 with 2006 'cachalotera' data, depredation rates dropped from 5% down to 0.36%. It was noted that with the use of cachaloteras, after unsuccessful attempts by Sperm whales, they began to disappear from fishing grounds. An earlier study by Hucke-Gaete, *et al.* (2004) indicates with Spanish longlines, the median CPUE in the presence of Sperm whales dropped by around 18%.

Figure 9: The cachalotera in action.

Falkland Islands

In the Falkland Islands toothfish fishery, they have traditionally used the Spanish longline system, but in 2008, Brown, *et al*. (2010) compared it with the Chilean system. It was found that even though depredation was occurring, CPUE generally increased with the presence of Sperm whales, as it is believed that Sperm whales are attracted to areas of high toothfish abundance. When comparing CPUE using the Chilean system in the presence of Sperm whales it was found there was around a 30% increase in median CPUE when compared to Spanish system, and a 300% increase when comparing the two in the absence of Sperm whales. On the other hand, in another experiment in the Falklands by Yates & Brickle (2007), no significant difference was found between catches when Sperm whales were present or absent.

Heard Island

Austral Fisheries saw its first instance of Sperm whale depredation at the Heard Island fishery in May 2011. The first clear signs of depredation appeared with two toothfish heads being hauled up on the line. This depredation event caused an immediate movement of fishing grounds approximately 42 miles away, but a few days later a Sperm whale had once again found the vessel, resulting in the move of grounds again to the other side of the fishery. When the vessel returned back to the original location 5 days later, the whales had moved on (C. Rowsell, personal communication, 19 May 2011). As this is the first and only depredation event at Heard Island there has not been any study on depredation rates.

Ross Sea

Although there is a strong presence of Killer whales in the Ross Sea, there have been no reports of Killer whale depredation in this Antarctic toothfish fishery. Likely reasons behind this is the short period of the year the vessels are active (December to March) and no overboard discharge of offal. There have been some incidents of toothfish being damaged by colossal squid, though this type of event is insignificant (Akroyd, *et al.,* 2010).

Depredation in sablefish fisheries

Sablefish (*Anoplopoma fimbria*) are a demersal species that inhabit the North Eastern Pacific Ocean from northern Mexico to the Gulf of Alaska, westward to the Aleutian Islands, and into the Bering Sea. Adult sablefish occur along the continental slope and in deep fjords, generally at depths greater than 200m. Their reported maximum age is 94 years in Alaskan waters and 55 years in Canadian waters. They reach a maximum size of around 1m in length and 20kg in weight.

Sablefish form two populations: a northern population that inhabits Alaska and northern British Columbian waters and a southern population that inhabits southern British Columbia down to California, with mixing of the two populations occurring off southwest Vancouver Island and northwest Washington (Hanselman, *et al*., 2008).

Gulf of Alaska fishery

In 1992 the South East Alaska Sperm Whale Avoidance Project (SEASWAP) was launched, including fishermen and scientists investigating the interactions between Sperm whales and longline fishers in the Gulf of Alaska. The first record of depredation in this fishery dates back to 1978 and there were likely instances before that. Since this time Sperm whale depredation has increased dramatically, probably due to the extended time frame that vessels are fishing throughout the year due to changes from an Olympic style fishery (where all operators catch the total fishery quota as quickly as possible) to that of individual quotas (Straley, *et al.*, 2005). The only known video recording of Sperm whale depredation in the world was taken by the SEASWAP team in this fishery (Figure 5).

In this fishery, 89 male Sperm whales have been photographically identified, and models predict that there are 123 individuals present here (Thode, *et al.*, 2007a). On average, Sperm whales are present during hauling 33% of the time, and during this time there is a 78% chance the fisherman will be affected by depredation. It is estimated that this depredation results in a 3-5% decrease in CPUE (Straley, *et al.*, 2005).

Bering Sea fishery

Killer whale depredation is prominent in the Bering Sea. The SEASWAP team have recently been awarded new project funding to investigate four mitigation options here and in the Aleutian Islands: active decoys, echolocation jammers, passive reflectors and deep-water bubbles (North Pacific Research Board, 2012). Since 2004, trap gear has accounted for over half of the Bering Sea catch and up to 34% in the Aleutian Islands. No depredation estimates have been undertaken for this fishery (Hanselman, *et al.*, 2008).

Canadian sablefish and halibut fisheries

Depredation in British Columbia's longline fisheries are not considered a significant issue; although Sperm and Killer whales are still present. Depredation is occurring in the sablefish and halibut longline fisheries in northern British Columbia and also seen in recreational angling in southern British Columbia. It is believed that depredation is mostly occurring from resident Killer whales whose natural diet is comprised of 98% Salmon (72% being Chinook salmon). Depredation events tend to increase when the Chinook salmon are not available to the whales due to seasonal variations (C. Birdsall, pers. comm., 28 June 2012). Sablefish trapping vessels regularly encounter Sperm whales although this gear type does not allow depredation to occur. It is believed an additional Sperm whale attractant is the processed offal that is discharged overboard. (M. Derry, pers. comm., 29 June 2012).

Greenland halibut fishery

The Greenland halibut fishery is fished by Norwegians. Sperm whale depredation was first seen in this fishery in 1995 and since that time depredation has increased. In 1995, there were eight longliners and four trawlers operating in the fishery. Now there is just one longliner remaining due to the reduced catches caused by Sperm whale depredation (Dyb, 2006a; J. Kennedy, pers. comm., 15 May 2012).

Mitigation

There are a number of whale depredation mitigation methods that are being utilised around the world. Below are those that are currently in use as well as some that are currently in development.

Fishing technique

Many fisheries that are experience whale depredation have realised that there may not be a 'silver bullet' that totally removes the depredation issue but have found that changes in fishing technique may decrease the effects. Moreno, *et al*. (2005) suggest that using shorter longlines (hauled in less time than longer lines) gives Sperm whales less time to detect them, thus less chance of arriving in time in order to depredate. However, when the vessel is detected by whale, it should stop hauling, buoy off the line, and move to another area (either to shoot new gear or haul another line) so the whales do not get the chance to depredate.

Tixier, *et al*. (2010) also subscribe to the theory of shorter lines, specifying less than 5,000m. It was said that once Killer whales find the vessel, it should cease hauling and buoy off the line immediately and steam at least 40 nautical miles away in order to have the most success in not encountering the same pod again. If relocation is less than 40 nautical miles away, this significantly increases the likelihood that the same pod will find the vessel again. It also seems likely that Killer whales are able to detect the bearing taken by a fishing vessel leaving an area, and use that information to find it again over longer distances. Therefore it is also recommended to set off in an alternate direction to deceive the whales. It was suggested by P. Tixier and C. Guinet (pers. comm., 28 May 2012) that increasing the hauling speed to around 50 hooks per minute will also reduce the ability of the whales to successfully steal the fish off the line.

Chilean Longlines (Cachalotera)

In 2004, the Chilean longline, or cachalotera system (Figure 10 & 11), evolved from the trotline, which in turn progressed from the Spanish longline system. All three of these systems are classed as manual longlines, as the hooks are hand-baited, and all have been used in various Patagonian toothfish fisheries[6]. Currently, toothfish fisheries in Chile, Argentina,

[6] The automatic longline system also evolved from the manual longline system and now accounts for a large portion of toothfish tonnage around the world.

South Georgia, Falkland Islands and the Prince Edward Islands use the Chilean longline system.

The Chilean longline has a long mainline with numerous branch lines that are about 15m long and spaced approximately 40m apart. These branch lines each have 6-12 hooks attached, with a weight at its end (Figure 11). What distinguishes the Chilean system is the buoyant 'net sleeve' or 'cachalotera' that is attached in such a way that allows it to remain floating above and out of the way of the hooks during the set, though during hauling, the force of the line being dragged up through the water column pulls the sleeve down over the hooks and captured toothfish (Figure 10) (Moreno, *et al*., 2008).

In 2006, cachaloteras were trialled and showed a similar catch rate to the Spanish system, with the advantage of a highly reduced depredation rate (Moreno, *et al*., 2008). Cachaloteras continue to be highly efficient against Sperm whales, dropping their depredation rates to negligible levels. Unpublished data shows that fishermen are currently catching at higher CPUEs than they were with the Spanish system (C.A. Moreno, pers. comm., 4 April 2012).

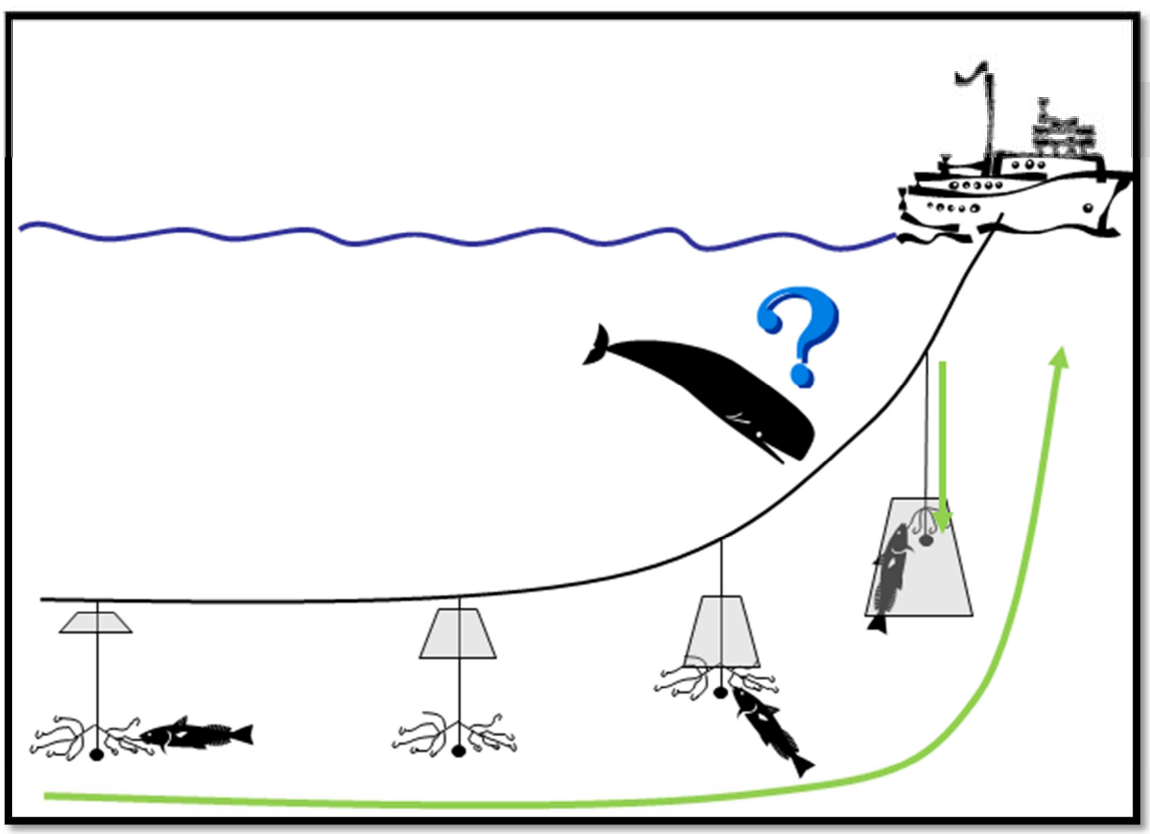

Figure 10: Cachalotera movement during the hauling process. As the line is hauled, the cachalotera slides down to protect the fish from the depredating whale (adapted from Moreno, *et al*., 2007).

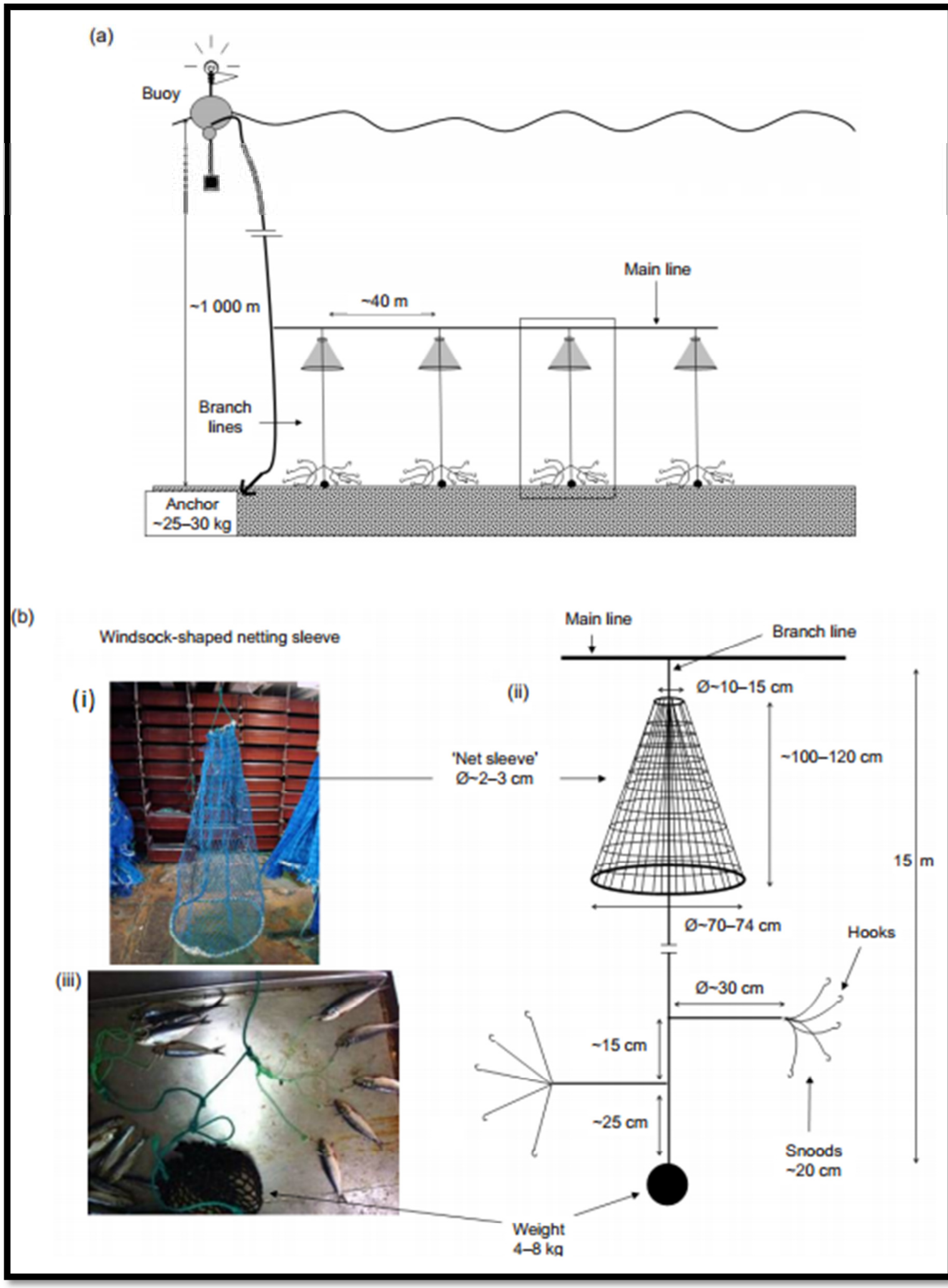

Figure 11: (a) General design of the Chilean longline. (b) Details of the branch line where (i) is the net sleeve or 'cachalotera'; (ii) provides details of the measurements of the configuration of the branch line with net sleeve, hooks and weight; and (iii) shows the baited hooks at the end of the hook lines with the weight attached (taken from Moreno, *et al*., 2008).

Some toothfish are, however, still taken by Killer whales that have learnt how to depredate against the Chilean system. There is currently a project running with an evolved cachalotera design which aims to prevent Killer whale depredation by completely encapsulating the toothfish from top and bottom (C.A. Moreno, pers. comm., 4 April 2012).

Acoustic Devices

Whales have highly developed hearing capabilities dependant on species, which influences the effectiveness of different types of acoustic devices (Kraus, 1999). These can fall into two main categories – Acoustic Deterrent Devices (ADDs) and Acoustic Harassment Devices (AHDs). ADDs reflect or produce sound to make marine mammals aware of them, whereas AHDs produce a more powerful signal, utilising intensity and frequency to deter marine mammals by causing pain or discomfort to the approaching animal (Reeves, *et al.*, 1996). Highlighted below are the numerous examples of acoustic devices that are being used or trialled in toothfish and sablefish fisheries.

OrcaSaver

OrcaSaver is an AHD launched in 2008 by SaveWave (a Dutch company producing acoustic and lighting devices for fishermen) in conjunction with Mustad (Norwegian automatic longline gear supplier). The 140kg device is hung 10m below the vessel (Figure 12) and aims to reduce Killer whale depredation by producing random high frequency sonar pulses during the hauling phase of fishing. These pulses are specified to emit within the hearing range of Killer whales and thus do not interfere with other species (therefore it does not work against Sperm whales). The pulses are said not to be harmful, but are highly annoying and even interfere with their echolocation capabilities (A. Tennoy, pers. comm., 16 May 2012). OrcaSaver was used in the Crozet toothfish fishery and was thought to be working, however the French government department for the Territory of the French Southern and Antarctic Lands (TAAF), believed it may have been damaging to the whales so a project was run in July 2012 to test this theory. OrcaSaver testing has also been taking place in Chile (C. Guinet, pers. comm., 28 May 2012).

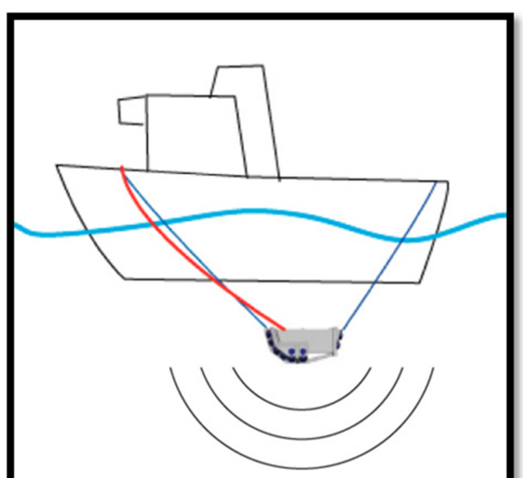

Figure 12: Diagram depicting the OrcaSaver setup.

OrcaSaver is specified to last between 500 and 750 hours with a range of 1,000m and produces sound at 195dB (Bates, 2012; Mustad Longline, 2012). The device is said to have increased catch rates by 30% in some fisheries, although other reports say that after a short period of time the effect of the sonar pulses wear off and the whales return to again steal fish off the line. Some reports also mention that the whales do return in time, but have adapted their depredation behaviour and are diving deeper to take the fish, albeit consuming more energy in the hunt (Bates, 2012; E. Gutierrez, pers. comm., 2 April 2012).

At around €45,000, implementation of this device would depend on the potential improvements in catch rates, and although it may not eliminate Killer whale depredation, when some fishers are catching $30,000 worth of product per day, it would not take long for the investment to pay itself off and the fisherman be better off for it. There are still many variables and unknowns in this relatively new product and it will be interesting to hear reports over the next couple of years.

Scramblers and Pingers

Scramblers are AHDs and similar in nature to the OrcaSaver device. They emit resonated sounds at different frequencies, strength and patterns in order to deter whales from the vicinity (A.C. Gunderson, pers. comm., 15 May 2012). Pingers are ADDs which emit a programmed sound at a set frequency and noise level to alert marine mammals and sharks of the impending obstacle nearby. They have recently been deployed on shark nets in Queensland and whale entanglements have dropped dramatically (Erbe, *et al*., 2011).

An experiment was run in the Greenland halibut fishery by Norwegian fishers and Møre Research, with the intention of creating a sound barrier to prevent Sperm whales from using their sonar capability to locate fish on the longline. Scramblers and pingers were used. The scrambler was lowered into the water and emitted pre-recorded sounds, with white noise mostly used, but it was also able to send out other sounds and sweeps continuously or periodically. Results showed that the scrambler was effective at the early stages, but once again, whales became accustomed to it soon after and overall did not cause a significant reduction in depredation.

The pingers were battery operated units and up to five were attached along each longline set. They periodically sent out different sounds which were adjusted to match the Sperm whales' echolocation band. Results from this part of the experiment were inconclusive (Dyb, 2006b).

McPherson, *et al*. (2008) also experimented with pingers in Australia's Coral Sea Fishery against large toothed whales but with limited success.

Sonar

The Government-funded Norwegian Defence Research Establishment was contracted to look into what effects the sonar capabilities of new Royal Norwegian Navy frigates would have on herring, killer whales and sperm whales due to the overlap in hearing range and sonar frequency. Background to this study was the thought that whale strandings in 1996 in Greece may have been caused by naval sonar operations (Sevaldsen & Kvadsheim, 2004).

It was found that herring were not affected by the sonar signals. It is known that herring have the most sensitive hearing curve of all fish, so they believe that this sonar should not affect other fish either. Killer whales did not respond to the sonar when they were travelling or socializing. Though when they were feeding, there was an abrupt change in diving behaviour and they ceased feeding and left the immediate area. Sperm whales showed a tendency to stay on the surface in response to the sonar (therefore a reducing foraging activity), though this was not as significant as the Killer whale response (Sevaldsen & Kvadsheim, 2004).

Associated projects also looked at whether 'ramping up' sonar transmission is an effective method to deter whales while reducing the risk of hearing damage to the animal. Instead of producing sonar pulses at full strength without warning, source levels are gradually increased prior to the onset of full level transmission. This is thought to give nearby animals time to move away before sonar transmissions reach maximum levels (Miller, 2010).

The Norwegian Defence Research Establishment were unaware of the work Mustad are doing with OrcaSaver and were interested in the project and believed they may be able to add some expertise in the area.

Natural Killer whale playback

While more work still needs to be done on this topic as results are mixed, there is belief that playing back certain natural Killer whale calls into the water may deter or scare off Sperm whales, as pods of Killer whales attack Sperm whales occasionally.

In Norway, Miller (2010) found that the playback of natural Killer whale calls to Sperm whales resulted in avoidance. This level of reaction appeared to be at least as strong as changes in behaviour observed during sonar exposures mentioned in Sevaldsen & Kvadsheim (2004). This theory was supported by toothfish fishermen in Chile - when both whale species were present, the Sperm whales would stop depredating and aggregate around their young in a defensive formation as the Killer whales would sometimes turn their attention to juvenile Sperm whales (E.Gutierrez, pers. comm., 2 April 2012).

French scientists believe that Killer whale playback would not work for Sperm whales in French toothfish fisheries due to Killer whale attacks not being common as there are not juvenile Sperm whales present, only adult males. They also believed due to these Sperm whales being skilled in depredation, they know the reward of being in close proximity to the vessel, so are willing to risk being in the vicinity of Killer whales. They believe it may be worth trialling at Heard Island due to the Sperm whales not being exposed to Killer whales as much, as well as the fact that they have not learnt to depredate to the same level as those in the French fisheries (C. Guinet & P. Tixier, pers. comm., 28 May 2012).

The SEASWAP team in Alaska have decided not to pursue this approach any further given the relatively poor record of playback studies in reducing depredation (Thode, *et al*., 2012).

Hydrophones

Passive acoustic devices, such as hydrophones, are listening devices that are able to record noise in the water. These devices can be set to listen at different frequencies depending on what specific sound (or species) you are looking for. Hydrophones can be attached to vessels, unmanned drones or left anchored at sea. Depending on how often they are set to record they are able to remain at sea for up to 12 months. Hydrophones have been used to assess cetacean abundance in certain areas by recording whale calls, clicks and creaks and then identify these sounds to species level (J. Ford, pers. comm., 29 June 2012; D. Mathias, pers. comm., 25 July 2012; McPherson, *et al*., 2008).

The SEASWAP team have used hydrophones to locate and track Sperm whales; assess their vocal/echolocation patterns during different behavioural events; set up automated systems for detecting creaks; and are now trying to estimate depredation rates by analysing hydrophone recordings during depredation events (Thode, *et al*., 2006a; Thode, *et al*., 2007b). McPherson, *et al*. (2008) describe a similar process that was studied in a pelagic longline fishery in Australia's Coral Sea.

Using hydrophones at Heard Island to assess Sperm whale abundance at different times of the year could be a useful first step in understanding whale movements and give fishermen insight into what areas to avoid at different times of the year and help slow the depredation learning process down for these whales.

Active decoys

The SEASWAP team have recently experimented with active decoys, a single anchored downline (with a float on the surface) with an attached hydrophone (for listening) and an acoustic playback device that emits engine cue noises associated with hauling, aimed at distracting or delaying whales from true fishing activity. Thode, *et al.* (2012) describe this as their most promising countermeasure towards depredation. In 2011, an active decoy was deployed 10km away from an actual fishing location. Of three Sperm whales originally sighted near the decoy, only one arrived at the true haul, and by that stage 75% of the line had been hauled. This whale is known as a 'skilled individual' and data suggests that he left the decoy and made his way to the true haul 15 minutes after the decoy signal began to fail.

Traps

South Georgia toothfish

In 2000, trap fishing research was undertaken in South Georgia and results were compared to catches using Spanish longlines. Results per 5km of line gave an average of 128kg of toothfish using traps and 2,788kg using Spanish longlines. Suggestions to improve trap catches were larger trap size, hauling more traps per day, reducing trap spacing on the mainline and gaining a better understand of suitable trap fishing grounds (Agnew, *et al.*, 2001).

Chilean toothfish

In 2006-07, Arana (2007) compared catch rates between traps, Spanish longlines and Chilean longlines. As shown by results in Table 2, cachaloteras outperformed the Spanish longlines in catch per hook, and also outperformed traps in terms of catch per unit.

Table 2: Catch rates comparing catch per hook in Spanish vs. Chilean longlines, and catch per unit in Chilean longlines vs. traps (data from Arana, 2007).

	Spanish longline	Chilean longline	Chilean longline	Trap
CPUE	0.13 kg / hook	0.29 kg / hook	2.06 kg / cachalotera	1.44 kg / trap

To summarise, traps do catch toothfish, but CPUE determines that Chilean longlines with cachaloteras are preferred, even though there is still a small amount of depredation occurring with this system.

French toothfish

Results from the 2010 joint venture trapping trip between the French toothfish industry and Austral Fisheries, showed the catch rate with traps was lower than with longlines but direct comparison was not straightforward due to the large number of trap models tested and the large differences in fishing techniques. It was advised that further investigations would be needed to compare catch rates with one type of trap instead of several (Guinet, *et al*., 2010). A second trapping trial was to take place at Crozet in 2011 to compare catch rates but unforeseen circumstances postponed this to August 2012 (C. Guinet, pers. comm., 28 May 2012). Results from this trial have not been released.

French trap supplier, Le Drezen, who supplied the joint venture trip and are supplying Austral Fisheries with the optimal collapsible trap to date for their summer 2012-13 trip, have made modifications to a cylindrical trap that was used during the 2010 joint venture and a small number of these will be trialled in Austral's upcoming trip. These have been successfully trialled in France with recreational fishers.

Canadian sablefish

About 30% of the British Columbia sablefish is taken by trap. This fishery is different to the toothfish fisheries as traps are a profitable gear type. The longline vessels in this fishery are of a smaller nature and catch around 2,000 to 4,000kg per day. The larger trap vessels haul around 220 traps per day and catch around 3,500kg per day, with the better performing vessels averaging around 6,500kg (M. Derry, pers. comm., 29 June 2012). This equates to catches of 15-30kg per pot.

Greenland halibut

Large rectangular collapsible traps were trialled off Greenland for halibut and grenadier species. Grenadier trapping did not work at all, whereas halibut catches averaged between 5kg and 7kg per pot depending on depth. Once again, trap catches are well below longline catches and there is no real incentive to experiment further as currently cod and haddock are catching well in the same fishery, so it is not impacting fisherman if they aren't catching halibut at high levels (J. Kennedy, pers. comm., 15 May 2012).

In Development

Modified Auto-lines – 'SAGO'

Norwegian longline supplier, Fiskevegn have patented a sub-marine catching pod for automatic longlines. The project is named 'SAGO'. The system can be thought of like a combined longline and trapping gear in one. The catching pods (Figure 13a) are released with the longline at the start of each magazine during the shooting phase. Upon hauling, the longline passes through the pod, strips the fish from the hook and the pod is hauled along at the end of each magazine. Fiskevegn's aim is for fishers to use these pods only when there are whales present. It may slow fishing down, but it will not require the fishermen to move locations or change gear types and the whales will be unable to steal the fish off the hook. In other trap or cachalotera fisheries, once the whales realise they cannot successfully depredate, they tend to move on.

The idea for this project started with artisanal Chilean toothfish fisherman approaching Fiskevegn with fiberglass cylinders that they had trialled in 2007 under this same process (Figure 13b). The cylinders worked in principle, so they brought the idea to Fiskevegn to help with commercialisation. Underwater video-recorded experiments were carried out in July 2012 with a smaller prototype in shallow, coastal Norwegian waters. The next step is testing the full size prototype in a flume tank to understand its buoyancy, and study how the main line and fish would flow through. If successful in the flume tank, they will test with local cod to see how to best handle it operationally (E. Moe, pers. comm., 14 May 2012).

Figure 13a (left): The SAGO catching pod.

Figure 13b (right): The original artisanal catching pod (courtesy of E. Moe).

New SEASWAP project

SEASWAP have been granted new funding in 2012 to look further into active decoys, as well as echolocation jammers. The jammers will be mounted on the fishing gear and will broadcast signals designed to either mask or degrade the close-range echolocation ability of the whales. The signals are based on the sounds moths use to defeat predatory bat sonar. Two final countermeasures will also be studied: passive reflectors and deep water bubbles (North Pacific Research Board, 2012). The passive reflectors are poly beads attached to the snood of a longline that will emit the same ‘ping’ as sablefish would to a whale’s sonar. With these beads attached near every hook, it will decrease the perceived depredation success rate of the whale and potentially dissuade the animal because of this. The bubbler system will aim to confuse whales with the air bubbles interfering with their sonar and hopefully decreasing their ability to successfully depredate (D. Falvey, pers. comm., 19 June 2012).

Recommendations

Australian toothfish fisheries are positioned much more favourably than most other demersal longline fisheries around the world when it comes to whale depredation. Many toothfish and sablefish fisheries have resident whales that regularly steal fish from the line and fishermen are past the point of hoping the whales will stop this behaviour of their own accord. Australian operators are lucky that this is not the case at Heard Island or Macquarie Island, and need to be mindful and committed to assuring that when whales are spotted, they are not given the opportunity to depredate and learn that there is an easy source of food in these waters. This has been documented and outlined in an updated Seabird and Marine Mammal Mitigation Plan on Austral Fisheries' toothfish vessels.

There are numerous methods or actions that could potentially work for Australian operators. The first step will be to acknowledge that when a Sperm or Killer whale is sighted, to immediately stop hauling, buoy off the longline gear and steam at least 40 miles away. This is vital as it reduces the likelihood that the whale will associate that vessel as an easy food source. Any new gear must be set at least 40 miles away and the vessel must wait at least 24 hours until they retrieve the original gear.

During any Sperm or Killer whale sighting, a nominated person on board should aim to photograph the whale as per the pending Whale Photo Identification Guide, and compare the identity of the whale with the identification set that French scientists have for the Kerguelen and Crozet fisheries. This will allow operators and scientists to determine whether these animals may already have developed the specialised skill of depredation which they would have learnt in the French fisheries.

Increasing hauling speed from the current 30 hooks per minute to 50 hooks per minute has the potential to decrease depredation rates as the whales will have a harder time locating the fish with their sonar. This, however, runs the risk of breaking the mainline, which increases with hauling speed, so must be done with care.

The relative success of the toothfish trapping trip taking place at Heard Island in December 2012 will play a major part in deciding whether Austral Fisheries will continue to explore the use of traps during the longline off-season.

The next major step will be to speak to Australian acoustic experts on the potential to set up several passive acoustic listening devices around key areas in the fishery. These could stay out at sea for up to 12 months and analysis would be able to tell what time of year and what areas the whales visit.

As mentioned throughout this report there are several projects around the world that are still running and it will be interesting to see what these results find and whether they may be useful in Australia's toothfish fisheries.

Appendices

Contact List

Alaska

Chris Lunsford, Alaska Fisheries Science Center, NOAA

Phillip Rigby, Alaska Fisheries Science Center, NOAA

Dana Hanselman, Alaska Fisheries Science Center, NOAA

Pat Malecha, Alaska Fisheries Science Center, NOAA

Cara Rodgveller, Alaska Fisheries Science Center, NOAA

Kalei Shotwell, Alaska Fisheries Science Center, NOAA

Dan Falvey, SEASWAP

Victoria O'Connell, SEASWAP

Australia

Geoff McPherson, Marine Acoustic Biodiversity Solutions

Derek Hamer, Australian Antarctic Division

Craig McPherson, Jasco Applied Sciences

Belgium

Dirk Verhaeghe, Institute for Agricultural and Fisheries Research

British Columbia, Canada

Lance Barrett-Lennard, Vancouver Aquarium

Caitlin Birdsall, Vancouver Aquarium

Mike Derry, FAS Seafood

Graeme Ellis, Pacific Biological Station

John Ford, Pacific Biological Station

Chile

Marcos Osuna, PescaChile

Enrique Guiterez, PescaChile

Carlos Moreno, University of Southern Chile

Patricio Arana, University of Valdivia

France

Jean Roullot, Le Drezen

Christophe Guinet, Chize Centre for Biological Studies

Paul Tixier, Chize Centre for Biological Studies

Norway

Egil Moe, Fiskevegn

Jakob Hals, Fiskevegn

Trond-Inge Kvernevik, Fiskevegn

Sven Lokkeborg, Institute of Marine Research

Nils-Roar Hareide, Runde Research Centre

Agnes Christine Gunderson, Moreforsking Marine

James Kennedy, Moreforsking Marine

Arne Tennoy, Mustad

Svein Erik Bakke, Mustad

Petter Kvadsheim, Norwegian Defence Research Institute

Lars Kleivane, Norwegian Defence Research Institute

San Diego, USA

Aaron Thode, Scripps Institute of Oceanography

Delphine Mathias, Scripps Institute of Oceanography

Sarah Mesnick, South West Fisheries Science Center, NOAA

Chris Jones, South West Fisheries Science Center, NOAA

Zachary Schakner, California State University, Fullerton

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Plain English Compendium Summary

Project Title:	
Nuffield Australia Project No.:	1201
Scholar:	Rhys Arangio
Organisation:	Austral Fisheries
Phone:	0402 883 195
Fax:	
Email:	rarangio@australfisheries.com.au
Objectives	To see if any whale depredation mitigation techniques currently used around the world will be both effective and efficient in Australia's toothfish fisheries.
Background	There is significant whale depredation occurring in nearby French toothfish fisheries and an increasing portion of longline caught fish in Australian toothfish fisheries means an increased risk of depredation, thus potentially impacting on profit for the fisherman.
Research	Meetings with fishermen, scientists and gear suppliers in Chile, Norway, Belgium, France, USA, Canada and Australia as well as liaising with scientists that have published depredation events in similar fisheries.
Outcomes	Several potential mitigation options are viable, notably traps, passive acoustic monitoring and active decoys. There is no 'silver bullet' but best results will likely be numerous operational strategies such as buoying off lines and steaming away when whales are sighted so as to not allow the whales to develop this skill at will.
Implications	Traps have potential but are a costly operation to work with at current catch rates. Operators may not adopt acoustic monitoring and active decoy recommendations as depredation in Australian toothfish fisheries is currently insignificant. If depredation does become significant, it will be too late to stop if nothing is done before the problem develops further.
Publications	Nuffield Australia