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MONITORING MARINE MAMMAL INTERACTIONS IN THE SMALL PELAGICS FISHERY: STAGE ONE PILOT STUDY

REPORT TO THE AUSTRALIAN FISHERIES MANAGEMENT AUTHORITY

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Monitoring marine mammal interactions in the Small Pelagics Fishery – Stage One Pilot Study

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Executive Summary

Fatal interactions between marine mammals and fishing gear are a common problem worldwide, with many hundreds of thousands of dolphins and seals estimated to die in fishing gear each year. Dolphins and seals are also killed in fishing gear in Australian fisheries, particularly purse seine and trawl fisheries.

Effective quantification and mitigation of marine mammal interactions has been hampered by the generally rare and/or sporadic nature of interactions, demanding a high level of observer coverage to build robust datasets, combined with the practical difficulty of observing mammal interactions with fishing gear underwater. As a result, past research has generally been unable to produce definitive results as to the success or failure of a diverse range of mitigation practices trialled.

This project was initiated by the Cetacean Mitigation Working Group (CMWG), a group formed after 17 dolphins were caught by mid-water trawl in Zone A of the Small Pelagic Fishery (SPF), in late 2004. The objectives developed by the CMWG for this pilot study were as follows:

1. Assess and source underwater camera technologies that are effective under normal commercial operating conditions at monitoring the environment inside and surrounding the trawl net.
2. Use underwater cameras on the trawl net to:
 - a) characterise the net and excluder device geometry during normal commercial fishing operations including hauling, turning, deployment and towing;
 - b) characterise the events recorded on the video footage with a view to developing efficient protocols for analysing large amounts of video footage;
 - c) characterise ranges of target and non-target species (fish and mammals) behaviour in and around the trawl.
3. Determine optimal camera placements in the trawl net to record critical events.
4. Develop crew-based competencies for camera operations and preliminary data handling.
5. Develop protocols for collection of data from mammal by-catch and sightings by crewmembers.

This study was conducted from aboard the FV *Ellidi*, a mid-water trawling vessel fishing for redbait and jack mackerel in Zone A of the SPF. Over a six week period in May-July 2005, an underwater camera system was attached to the trawl net, in the region of the SED, to



record marine mammal interactions. Video footage was available from 19 trawl shots with individual recording time limited to three hours.

No dolphin interactions or mortalities occurred during the study period. Three Australian fur seal entanglements, including 2 fatalities were recorded during the study period though, due to recording time limitations, no footage of these events was captured. However, video footage did reveal that seal interactions with the fishing gear were common, with over 1800 separate events captured of seal/s in the field of view of the camera, providing significant insight into the level and nature of interactions between seals and the trawl gear. Analysis of footage of seal behaviour in and around the trawl gear showed:

- seals fed heavily around the escape opening of the SED, both individually and in groups of up to six;
- total seal footage recorded per shot gradually increased within the study period and generally increased within most trips;
- seals entered the body of the net to feed on 13 occasions, using the escape opening of the SED as point of entry and exit on the majority of occasions; and
- seals appeared to be selective feeders, selecting larger fish over smaller fish passing through the net in the region of the SED.

Analysis of net geometry, SED configuration and seal behaviour during fishing indicated that aspects of fishing gear and fishing practice pose an increased risk to cetaceans and pinnipeds and other megafauna (e.g. large sharks, rays, sunfish, billfish etc.):

- The position and lack of rigidity of cargo mesh barrier in the SED used during this study did not effectively direct mammals or other megafauna out of the escape opening, and in several instances apparently contributed to the temporary entanglement and disorientation of seals that fully entered the net.
- Modifications to minimise fish loss from the escape hatch, including net curtain and ribbons, apparently encouraged seals to venture further into the net to feed, and obscured the escape opening when seals fully entered the net, contributing to disorientation.
- Reductions in towing speed during net deployment, retrieval and turning resulted in a collapsing of the net and partial closing of the escape opening of the SED, reducing the chance of any mammals or other megafauna in the body of the net exiting safely.

Efficient data management and analysis protocols are critical to the successful analysis of the large volume of complex data collected for this project. For the more extensive survey planned for Phase 2, we recommend that all footage is archived to DVD immediately at the conclusion of each trawl shot, and a logsheet accompany footage, detailing critical details of each shot. With a laptop installed aboard the *Ellidi* for the purpose of archiving footage, we believe that the skipper on the *Ellidi* could routinely perform both tasks, reducing the amount of time scientific staff would need to be at sea, and making summarising and analysis of footage of mammal interaction as efficient as possible.

The camera system used in this project, while proving the potential for using underwater video to study mammal interactions while fishing, showed a number limitations which need to be overcome for further research to be successfully conducted. We recommend that an improved camera system should include:

- Two camera units to simultaneously monitor entry and exit through the SED and the net mouth.
- Hard drive recording units and battery system with the capacity to record continuously for at least 10 hours, to cover the majority of shot durations likely during routine commercial fishing;
- Systems pressure rated to 200 m depth to cover the majority of shot depths likely during routine commercial fishing;



- Low intensity LED lighting in association with a low-light sensitive camera to reduce modification of fish and mammal behaviour due to illumination;
- Easy access to video footage and replacing depleted batteries to facilitate ease of use during routine fishing; and
- System to be light and low volume to minimise drag and deformation of fishing gear when deployed;



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1. BACKGROUND

1.1 General

The incidental capture of marine mammals (cetaceans and pinnipeds) in commercial fishing gear is a topical and controversial issue that is associated with all major types of fishing gear, and in particular gill nets, drift nets, purse seines and trawls (Fertl and Leatherwood, 1997). Mortalities in fishing gear has been reported for almost all common species of marine mammals and is believed to be a major threat to the integrity of many small cetacean populations throughout European waters (Northridge, 1991; Spencer *et al.*, 1999).

The International Whaling Commission have estimated that between 65,000 and 86,000 marine mammals are caught annually in commercial fishing gear (Northridge, 1991). More recent data, including expanded U.S. by-catch data, in combination with FAO fleet composition and fisheries landings data produce higher estimates with annual global by-catch reaching 132,724 ($\pm 18,964$), consisting of pinnipeds (68,605 $\pm 26,236$) and cetaceans (64,120 $\pm 15,130$) (Read *et al.*, 2003). However, due to the absence of information from many fisheries, these estimates are almost certainly conservative and a more realistic figure may be in the several hundreds of thousands of marine mammals (Alverson *et al.*, 1994; Read *et al.*, 2003).

Adequately quantifying marine mammal by-catch requires a high level of observer coverage (20-35% coverage recommended as a rule of thumb for fisheries with frequent by-catch events) to be able to provide accurate estimates and associated confidence levels around estimates (Northridge and Thomas, 2003). Levels of coverage vary by nation and fishery, but often fall short of this mark due to the costs involved in maintaining independent observer programs, resulting in the majority of by-catch records being anecdotal (and potentially under-reported) rather than quantitative (Northridge, 1991; Lewison *et al.*, 2004). The lack of systematic monitoring prevents the true extent and potential impacts of marine mammal/fishery interactions from being fully understood (Northridge, 1991; Morizur *et al.*, 1999).

1.2 Mitigation measures

The mechanism by which marine mammals, cetaceans in particular, become entangled in fishing gear is poorly understood and is the subject of considerable conjecture (Northridge, 1991; Spencer *et al.*, 1999). Although by-catch events tend to be rare, those that involve dolphins occasionally include large numbers of individuals, by reason of the cohesive behaviour of dolphin groups (Fertl and Leatherwood, 1997; ACE 2002). The capture of small cetaceans is believed to be related to their well-developed acoustic sensory capacities; thus many acoustic devices have been proposed as potential mitigation measures (Nelson, 1990, *cited in* Fertl and Leatherwood, 1997). Pingers (acoustic deterrent devices), acoustic harassment devices, acoustically reflective netting, net modifications (filament thickness, number of filaments, gear visibility) and dummy dolphin carcasses have been adopted by commercial operators in an attempt to minimise cetacean fatalities, but with little clear success (CMWG, 2005).

Exclusion devices (selection grids) have been used recently in attempts to mitigate megafauna by-catch for commercial trawlers (Tilzey *et al.*, 2004). An exclusion device within



the extension of a trawl net enables target species to pass through the grid or mesh whilst larger animals that are unable to pass through are steered out through an escape opening made in the net (Spencer *et al.*, 1999; Sea Mammal Research Unit, 2002). Turtle exclusion devices have been successfully evaluated and are now mandatory for trawlers operating in the Australian Northern Prawn Fishery, and in Thailand and the Gulf of Mexico shrimp fisheries (King, 1999 in Spencer *et al.*, 1999).

Non-gear specific management strategies to minimise by-catch include fishery closures in association with by-catch trigger limits, effort reduction and time/area closures (DEFRA, 2003; Tilzey *et al.*, 2004; CMWG, 2005). In some fisheries, an industry code of practice has been adopted to reduce the level of interactions with marine mammals, including practices such as cessation of fishing operations when marine mammals are sighted, movement away from areas where marine mammals are present, and temporal (time of day, season) and spatial restrictions on fishing operations to periods of lowest risk of interactions.

Overall, modifications of gear and/or fishing practices have produced equivocal results for marine mammals. The same issue that makes quantifying mammal by-catch difficult hampers evaluation and refinement of any mitigation strategy; interactions are relatively rare and/or sporadic, and are combined with the difficulty of observation of mammal interactions with fishing gear underwater during routine fishing operations.

1.3 Marine mammal interactions in Australian fisheries

In Australia, cetaceans and pinnipeds are protected under the *Environment Protection and Biodiversity Conservation Act 1999*. Many mid-water and demersal trawl fisheries from around the world have recorded levels of cetacean and pinniped by-catch and Australian trawl fisheries are no exception. Approximately 720 seals are caught each year in the South East Trawl Fishery, with approximately one third of all seals released alive (Knuckey *et al.*, 2002). In the Zone A Small Pelagic Fishery, five separate incidents involving 25 dolphin mortalities have been reported off eastern Tasmania since October 2004, with four seal captures, including one seal released alive, since May 2005. In the Pilbara trawl fishery, four dolphin fatalities were recorded over 13 survey trips (427 trawl shots, 100 days at sea) (Stephenson and Chidlow, 2002). Recently, 19 dolphin fatalities were recorded over a 5 month period in the South Australian pilchard fishery (purse seine), resulting in the temporary closure of this fishery pending the finalisation of an industry code of practice designed to minimise interactions (McEwen, 2005).

The Cetacean Mitigation Working Group (CMWG) was established in late 2004 in response to the incidental capture of 17 dolphins between October and November 2004 in the Small Pelagic Fishery. The working group was tasked to develop a long-term management strategy to mitigate interactions between cetaceans and the fishery. Initial responses to the problem included enlarging the escape opening in a Seal Exclusion Device (SED) in the trawl net, introduction of interim agreements between industry and Government on fishing practices to lower the risk of mammal interactions, a key component being the avoidance of fishing in areas where dolphins were sighted, and a high level of observer coverage.



1.4 Objectives

The current project, originally entitled “An investigation of underwater camera technology to assess dolphin and seal bycatch mitigation strategies for mid-water trawlers operating in the Small Pelagic Fishery,” was initiated by the CMWG as a pilot study, recognising the need to understand the behaviour of marine mammals in relation to the fishing gear while working towards effective mitigation of interactions.

The objectives developed by the CMWG were as follows:

1. Assess and source underwater camera technologies that are effective under normal commercial operating conditions at monitoring the environment inside and surrounding the trawl net.
2. Use underwater cameras on the trawl net to:
 - a) characterise the net and excluder device geometry during normal commercial fishing operations including hauling, turning, deployment and towing;
 - b) characterise the events recorded on the video footage with a view to developing efficient protocols for analysing large amounts of video footage;
 - c) characterise ranges of target and non-target species (fish and mammals) behaviour in and around the trawl.
3. Determine optimal camera placements in the trawl net to record critical events.
4. Develop crew-based competencies for camera operations and preliminary data handling.
5. Develop protocols for collection of data from mammal by-catch and sightings by crewmembers.



2. METHODS

In order to record marine mammal interactions with trawl fishing gear, a low light underwater camera system (Fig. 1) was hired from the Australian Maritime College for a period of approximately six weeks between May and July 2005. The camera system incorporated a black and white video camera, connected to a tape-based recorder, which limited recording time to a maximum of three hours. A halogen light provided illumination during recording.

The camera was used exclusively on the commercial fishing vessel *Ellidi*, a mid-water trawler that operates in Zone A of the Small Pelagic Fishery (SPF), off the east and south coasts of Tasmania. The camera unit was attached to the trawl net in several positions in the vicinity of an exclusion device located within the net extension and immediately in front of the codend (Fig. 2). Four camera positions were trialled:

- Position 1 - forward facing (towards net mouth), within the net and in front of the exclusion device;
- Position 2 - backward facing (towards codend), within the net and in front of the exclusion device;
- Position 3 - backward facing, outside of the net and in front of the exclusion device and escape opening; and
- Position 4 - forward facing, outside of the net and posterior to the exclusion device and escape opening.



Fig. 1: The crew of the *Ellidi* lashing the camera system to the trawl net, adjacent to the escape opening of the exclusion device.

The exclusion device comprised a soft mesh (“cargo net”) barrier, with a mesh size of approximately 17 – 20 cm, occluding the cod end. A diamond shaped escape opening, approximately 3 m long with edges reinforced with plastic rods was positioned above the barrier in the top of the trawl net, to permit the exit of any marine mammals or other



megafauna upon reaching the barrier. During the survey period the escape opening was either left clear or covered with two different types of mesh (ribbons or curtain of mesh) attached to the leading edge of the opening (Fig. 3). Mesh covers were trialed in an attempt to reduce the loss of fish through the escape opening (Table 1). For the most part the vessel crew assumed responsibility for deploying the camera gear and retrieving tapes. TAFI staff were on board for three of the eight trips for which camera footage was obtained. The crew and TAFI staff (when on board) routinely examined the exclusion device for any marine mammals or other megafauna by-catch as it was hauled over the trawl deck (at the conclusion of pumping the catch onboard).

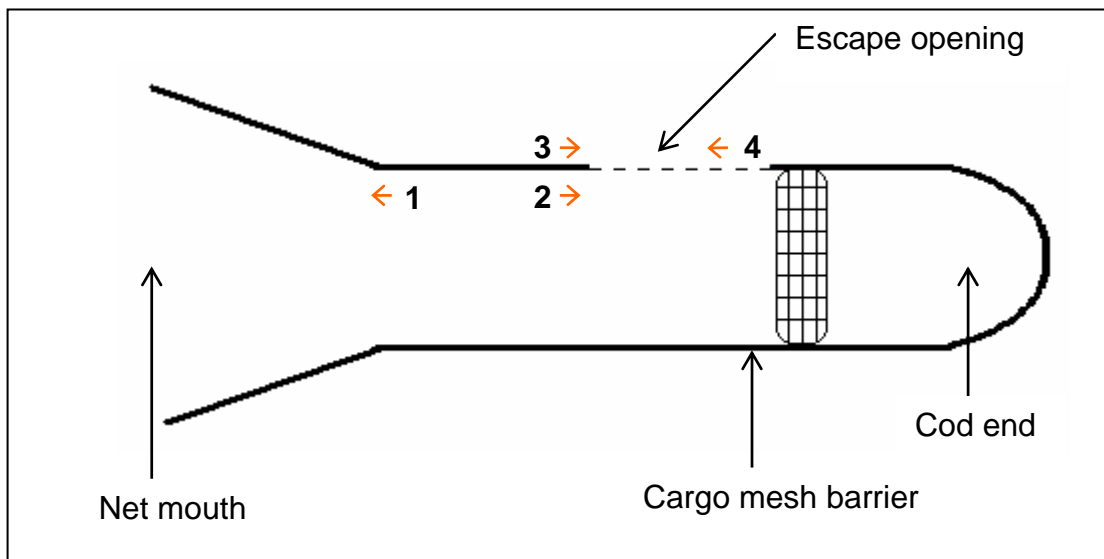


Fig. 2. Diagram of the net indicating key net features as seen from the side, camera positions 1, 2, 3 and 4, and the direction the camera faces in each position (as indicated by arrows) (not to scale).

During the study period, all fishing activity was focused on targeting redbait marks situated off St. Helens, on the east coast of Tasmania. Video footage was obtained from 19 shots, between 30/05/2005 and 07/07/2005 (Table 1). Owing to limitations of tape recording time (maximum of 3 hours continuous recording), it was only possible to capture the first three hours of each shot on tape, amounting to a total of 57 hours of tape footage, including over 54 hours of actual underwater video footage. In effect, this meant that it was not possible to monitor entire trawl shots using the available technology.

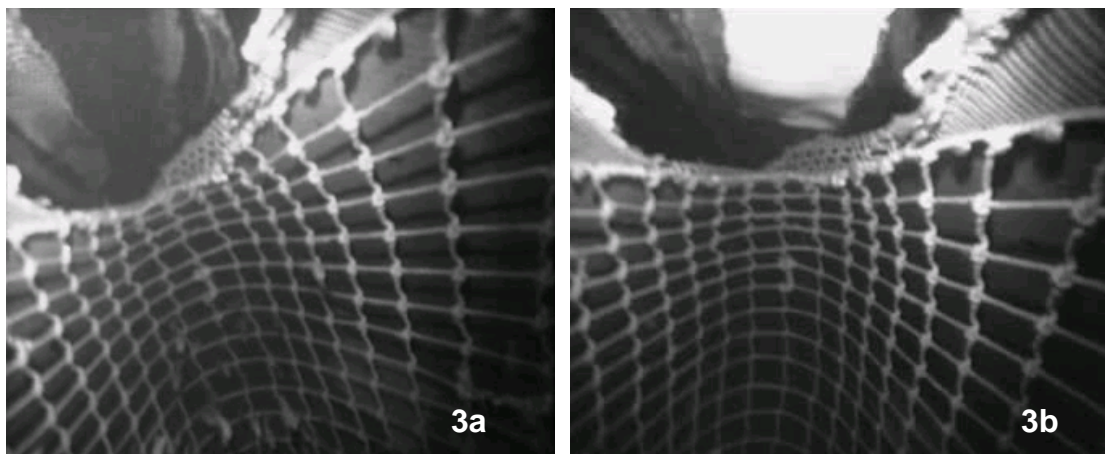


Fig. 3: Escape opening modifications used to minimise fish loss. Net ribbons (a) and curtain (b) viewed from camera Position 2. The cargo mesh barrier is clearly evident.

Table 1: Shot details for which video footage was recorded.

Escape opening cover - Open: No cover. Ribbons: Long/narrow strips of net material attached to the net, forward of escape opening (Fig. 3a). Curtain: Wide section of net material covering the entire escape opening, attached to the net forward of the opening (Fig. 3b). No record: No view of escape opening from video footage, and not logged by crew; [§] Based on total time where camera was underwater, including time taken for gear to reach fishing depth, * indicates shots when TAFI staff were onboard, † indicate shots when seals were captured.

Trip No.	Shot No.	Shot date	Camera position	Escape opening cover	Underwater video footage [§] hh:mm:ss	Shot duration hh:mm
1	1	30/05/2005	4	Open	2:50:06	5:25
	2*	2/06/2005	3	Open	2:55:38	4:40
	2*	3/06/2005	3	Open	2:55:49	6:05
	2*	4/06/2005	3	Open	2:55:43	5:29
	2*	5/06/2005	3	Open	2:55:39	4:51
	2*	6/06/2005	1	No record	2:51:06	5:50
3	7	7/06/2005	1	No record	2:49:44	4:15
3	8	7/06/2005	3	Open	2:54:56	9:00
3	9	8/06/2005	2	Open	2:53:48	5:00
4	10	11/06/2005	3	Ribbons	2:49:36	6:00
5*	11	16/06/2005	2	Ribbons	2:50:45	3:40
6	12	22/06/2005	3	Ribbons	2:52:15	4:30
6	13	23/06/2005	3	Curtain	2:50:50	3:30
6	14	24/06/2005	2	Curtain	2:43:47	4:42
7	15	1/07/2005	3	Curtain	2:47:35	4:28
7	16	2/07/2005	4	Curtain	2:55:41	3:05
7	17	2/07/2005	3	Curtain	2:53:04	3:40
8*†	18	6/07/2005	2	Open	2:44:31	4:30
8*†	19	7/07/2005	2	Open	2:49:57	11:30

TAFI staff undertook the review and analysis of video footage. For the purpose of quantifying seal interactions, an interaction was recorded when at least one seal was observable in the



field of view of the camera, without a break of more than five seconds. The duration of each interaction, number of seals visible, whether seals were engaged in feeding, whether they entered the net and if so to what extent (upper body or entire body), and for those seals wholly within the net, the period of time in the net, were recorded. In addition, the number of successful and unsuccessful feeding attempts (i.e. a lunge at a fish with mouth open), the number of successful feeding attempts with the seals upper body inside the net (via the escape opening), and the species of fish consumed was recorded for shots 1-11.

For all shots, other variables recorded included fishing location, start and finish times, fishing depth, catch composition, and in most instances tow speed.

The TAFI staff member onboard for both instances when seals were captured in the trawl gear followed AFMA observer protocols, photographed and examined the dead seals for obvious external injuries and obtained tissue samples.



3. RESULTS

3.1 General

No dolphins were observed in the underwater video footage and no dolphin captures were reported during the study period¹. Seals however, were commonly observed in the underwater footage, with 17 out of the 19 shots (89%) monitored involving seals sighted within or in the vicinity of the net. On two occasions seals were captured in the net, one incidence involved a single individual and the other involved two seals, one of which escaped alive (refer section 3.6). Seals involved in interactions recorded in this study may have included both Australian fur seals, *Arctocephalus pusillus doriferus* and New Zealand fur seals, *Arctocephalus forsteri*, as both are known to occur in the study area and interact with fisheries. Accurate identification of seals from the type of footage collected in this study is problematic as both species are very similar morphologically (D. Pemberton, *pers. comm.*)².

3.2 Camera positioning

It became obvious during the course of the study that seals primarily interacted with the net in the vicinity of the exclusion device, feeding at the entrance to the escape opening or entering and/or exiting the net through the escape opening. Thus, the most informative camera positions were the backward facing positions 2 and 3, with an average of over 20 minutes of seal interactions recorded for each shot (range 4-52 minutes) (Fig. 4). Position 4 was trialled twice, with an average of almost 7 minutes per shot of seal footage. Footage recorded from position 4 is likely to have missed many interactions that occurred behind the escape opening. The camera was also installed in position 1 for two shots but with only a single seal interaction was observed, that of a seal swimming outside and above the net. Apart from the possibility of observing seals (or dolphins) moving forward into the net extension or individuals entering the extension from the net mouth, camera position 1 would fail to record any activity that occurred in the vicinity of the exclusion device. Therefore, unless otherwise indicated, shots in which the camera was at position 1 (shots 6 and 7) have been excluded from subsequent analyses.

¹ Dolphins were observed by TAFI staff aboard the *Ellidi* in a single instance during the study period, on 15/6/05. The skipper immediately ceased fishing operations, retrieving the trawl net and steaming 10 nm away from the area.

² Dr David Pemberton, Tasmanian Museum and Art Gallery, GPO Box 1164, Hobart, Tasmania, 7001, Australia. Firm identification of the species of fur seals retained in the net during the study is pending genetic analysis of tissue samples collected and forwarded to the TMAG.



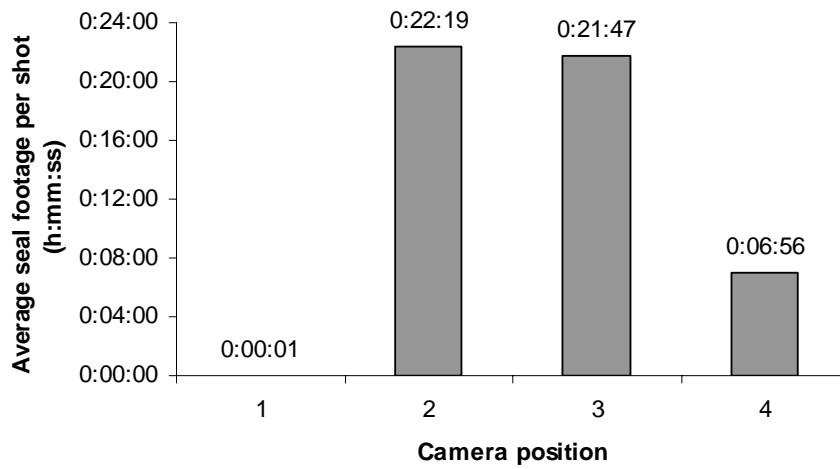


Fig. 4: Average length of seal footage recorded per shot for different camera positions.

3.3 Duration and number of interactions

Of the underwater video footage recorded, seals were in view for over 12% of the time, representing a total of 1864 interactions, over 80% of which involved a single individual. A steep decline was observed in the frequency of interactions as seal group size increased, with a maximum of six seals observed on a single occasion (Fig. 5).

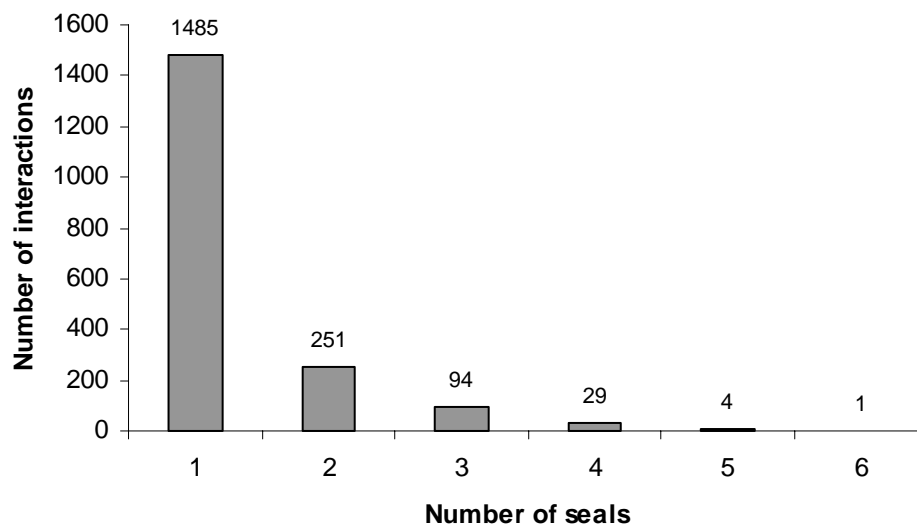


Fig. 5: Numbers of seals involved in all interactions recorded in this study.



The total duration of seal footage recorded per shot exhibited an upward trend throughout the study period, especially between late May and late June (Fig. 6), possibly reflecting an aggregation response by the seals to the fishing operation, noting that fishing was concentrated in a relatively small area off St. Helens during the study period. Seals were not observed in shot 8 (7/06/2005) while the greatest quantity (over 52 minutes) of seal footage was recorded from shot 13 (23/06/2005).

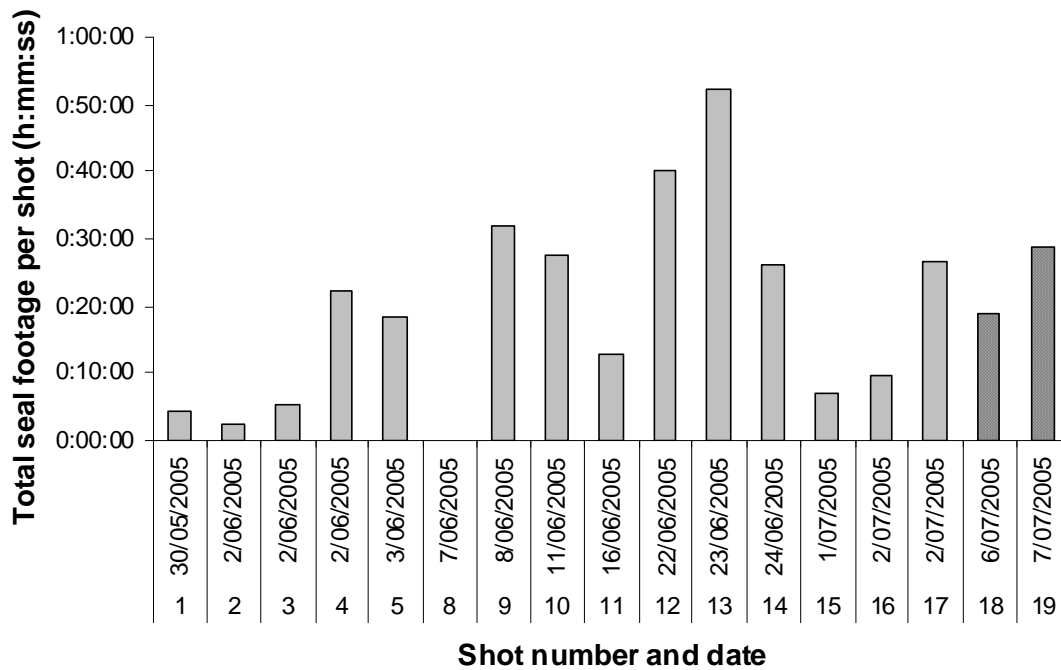


Fig. 6: Total seal footage recorded from each shot (excluding shots where the camera was located in position 1). Note: Darker shaded columns represent shots where seal fatalities occurred.

3.4 Seal foraging behaviour

Seals were successful in feeding in 637 of 877 (73%) attempts. All fish were swallowed whole. Jack mackerel, *Trachurus declivis*, were the most common prey consumed by number (44%); followed by redbait, *Emmelichthys nitidus* (32%) and spotted warehou, *Seriola punctata* (3%) (Fig. 7). Unidentified fish made up 21% of prey, but were most likely either jack mackerel or redbait. Over the shots where seal feeding was quantified, approximately 15% of the catch was estimated to be jack mackerel with redbait representing 85% of the total, suggesting that seals selectively targeted the larger jack mackerel over redbait when there was an excess of fish passing through the net.

Seals were also observed feeding on fish meshed in the ribbon netting covering the escape opening when few fish were passing through the net, in one instance tearing a ribbon.

On several occasions towards the end of a tape, seals were recorded catching and immediately releasing both redbait and jack mackerel, without apparently being motivated to eat them. It is possible that the seals become satiated yet continue to interact with the gear whilst it is fishing.





Fig. 7: The proportion of fish species consumed by seals during observed interactions.

3.5 Risk level of interactions

Seal behaviour was broadly classified based on perceived risk of harm from the interaction with fishing gear. The lowest level of risk (minimal) occurred when seals remained wholly outside of the net, often feeding on fish that had escaped through the escape opening or were meshed in the net. The next level of risk (low) occurred when the upper body of the seal was inserted into the net, generally as the seal attempted to feed on fish concentrated in the net or at least investigate the interior of the net. Interactions were classified as having a moderate level of risk when the seal wholly entered the net via the escape opening, usually to feed, but then exited the net more or less immediately (less than 7 seconds). Interactions that involved a seal entering the net (either via the net mouth or escape opening) for periods greater than 7 seconds were considered to be associated with the greatest level of risk.

In considering seal behaviour based on risk categories it was necessary to limit the assessment to those shots in which the escape opening was clearly visible (note that where the curtain mesh was used and the camera was in position 3 it was not possible to see the escape opening and behaviour of seals within the net). Seals were observed in 13 (93%) of the 14 shots in which the escape opening was visible and in 12 (86%) of these, seals were observed with their upper body inserted into the escape opening. Seals were recorded fully entering the net in 8 (57%) shots. Of these, seal interactions involved a moderate level risk in four (29%) and a high level of risk in six (43%) of the shots (Fig. 8).

Almost 16% of interactions involved at least one seal with its upper body within the net, either attempting to feed or investigating the net. Seals were observed fully within the net on 13 separate occasions (<1% of all interactions) (five low risk and eight high risk interactions) and in each instance only one seal was present within the net at any one time. Of these interactions, 10 involved seals entering and exiting the net via the escape opening; two involved seals that had obviously entered via the net mouth and exited through the escape



opening, while there was one instance where a seal entered the net via the escape opening and swam forward in the net and out of camera range, not to be sighted again (refer section 3.6).

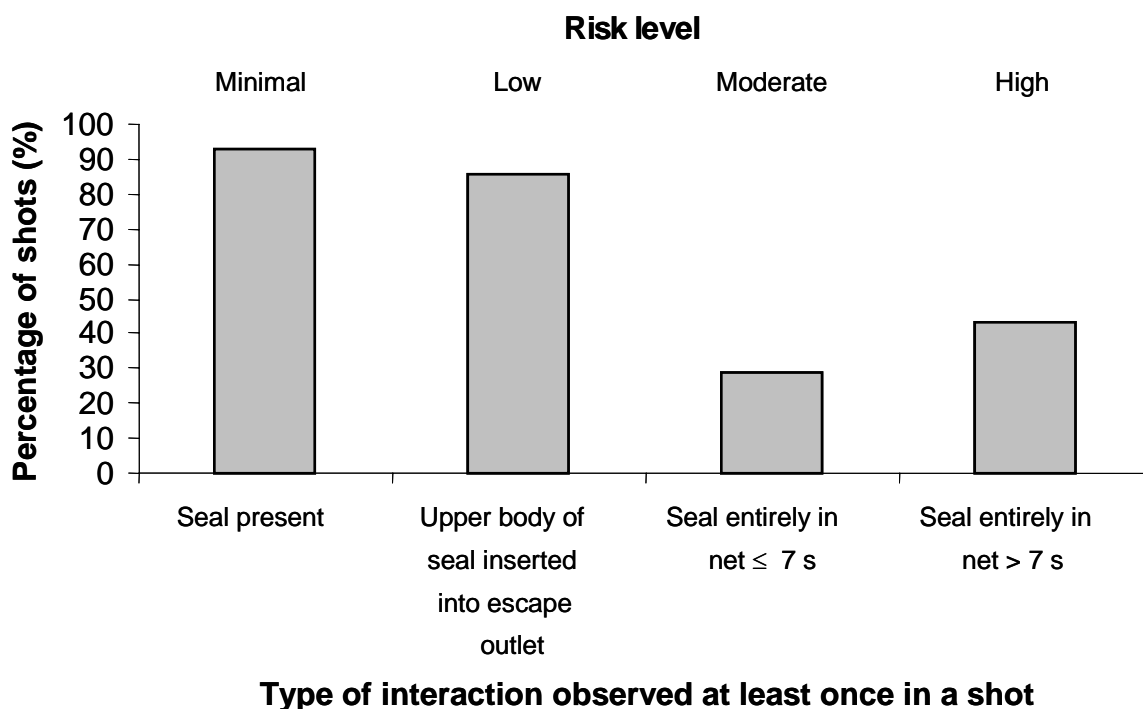


Fig. 8: Percentage of shots where various types of seal interactions were observed and their risk level (excluding shots where the escape opening was not visible i.e. camera positions 1 and 3 when curtain present over escape opening).

Of the total video footage from the 14 shots where the escape opening was visible (over 40 hours recorded) less than 1% of tape time involved seals fully within the net, equating to over 7% of footage involving some seal interaction. The total time seals spent within the net ranged from 1 second (seal entering and exiting net via escape opening) to 8 minutes 40 seconds (seal entering net via mouth and exiting through the escape opening). On two occasions, seals became temporarily entangled in the cargo mesh barrier during their efforts to forage and access the escape opening.

The two longest interactions within the net, lasting for 8 minutes 40 seconds and 6 minutes 31 seconds, involved seals becoming apparently lethargic and spending extended periods of time against the cargo mesh barrier before exiting the net via the escape opening. During period when the seals were in contact with the cargo mesh barrier, it was obvious that the water pressure and the lack of rigidity of the cargo mesh did not passively direct the seals out of the escape opening, and was hampering the seals attempts to actively swim and search for the exit. It was estimated that the maximum dive time for seals at trawl depth (100-120 m) and at the level of activity observed within the net would be approximately 10 – 12 mins (M. Hindell, *pers. comm.*)³. Hence the longest interactions recorded, taking into account time

³ Dr Mark Hindell. Antarctic Wildlife Research Unit, School of Zoology, University of Tasmania, Private Bag 5, Hobart, Tasmania, 7001, Australia.



taken to swim to depth and locate the net, and then return to the surface, would have been nearing the upper limit for seal breath hold.

3.6 Seal captures

Among the 19 shots observed over the study period, two (shots 18 and 19) resulted in seal captures, with three seals involved. A seal was found dead in both shots, entangled in the exclusion device, with a second seal alive within the area of the net extension in shot 19. In the latter instance the seal was brought on board the vessel and by the end of the pump-out had bitten a hole in the net and escaped to sea.

Unfortunately, as result of the limited recording time, underwater video footage from these two shots was not informative about the way the seals had become entangled in the net. Video footage recorded from shot 19 did, however, reveal a seal entering the net via the escape opening prior to the net being fully open and taut (within the first 45 minutes of 3 hours of footage). This seal was not observed again in the camera field of view for the remainder of the taping period (over two hours), suggesting that it had either exited by way of the net mouth (or potentially a hole in the net) or had died out of view of the camera and only become entangled in the exclusion device after the video camera stopped recording (possibly during hauling).

3.7 Net geometry

It was common practice during this study for the vessel to run across an area and then slow down, winch the net closer the surface turn, and then trawl back over the same ground without retrieving the net. On a number of occasions the net was observed to partially collapse, a consequence of the vessel making such a turn. Although no seals were observed within the net during turns, it is likely that these events pose a risk to seals and dolphins if in the net; the reduction in net tension and resultant collapse of the net may result in the animal becoming disorientated and unable to recognise the point of escape, or even become entangled in the net.

Limited video recording duration precluded observation of net performance during the hauling operation but it is likely that this operation will also result in substantial changes in net geometry, representing increased risk to marine mammals interacting with the gear at that time.

3.8 Other observations

3.8.1 Target fish species

The video footage indicated that fish were 'chased down' by the trawl, swimming parallel to the direction of trawl, and showing some evidence of swimming harder in the region of the SED barrier before passing through into the cod end. However, fish displayed little reaction to or avoidance of predation from seals, especially at night. No fish were observed actively swimming through the net towards the cod end, although during periods of good fishing,



where large volumes were passing through the net, fish showed less ability to orientate to the direction of the trawl.

Video footage recorded during daylight hours revealed that some fish exited the net through the escape opening, formed schools alongside the net and broke away once schools reached a certain size. At night the behaviour of fish was clearly different, with the fish appearing disorientated once outside of the net and displaying a limited tendency to school.

3.8.2 Non-target and rare fish species

A single eagle ray, *Myliobatis spp.*, was observed exiting the net through the escape opening after encountering the mesh barrier. Other non-target species observed passing through the mesh barrier of the exclusion device and into the cod end in small numbers included spotted warehou (*Seriolella punctata*), blue mackerel (*Scomber australasicus*), barracouta (*Thyrsites atun*), arrow squid (*Nototodarus gouldii*), lantern fish (*Lampanyctodes spp.*) and trawl puffer (*Allomycterus pilatus*). These species were also observed (not including the eagle ray) in pump outs on deck during catch sampling by TAFI staff.



4 DISCUSSION

While the current project was unable to provide any insight into the behaviour of dolphins interacting with the fishing gear and thus the reasons for incidental capture, it did provide extensive data on the foraging behaviour of seals in and around the fishing gear, and the operational parameters required for successful monitoring of mammal interactions.

4.1 *SED design and mammal interactions*

Several aspects of the exclusion device were noted for improvement based on the data and observations from this study. Most notable of these was the material and orientation of the mesh barrier. The cargo mesh used in the exclusion device did not appear to cause harm to any seals, even when partially entangled, but it was not effective in guiding seals out of the net. The mesh was not sufficiently rigid and on several occasions, under the weight of a seal, deformed considerably, sometimes leading to partial entanglement, and reducing the ability of the seal to return to active swimming. Furthermore, the vertical orientation of the barrier ensured that fish pass through the exclusion device with minimal resistance but provided no passive assistance to seals to pass through the escape opening (and by inference would not for other megafauna). An angle of 40° to the vertical has been previously suggested for a rigid selection grid to provide minimal resistance to fish passing through the net whilst still guiding larger animals out of the net (Sea Mammal Research Unit, 2002). A lip, located where the barrier and escape opening met, also appeared to hinder the efforts of some seals to exit the net. This lip appeared to prevent seals from swimming directly up and out of the net when they were being held against the exclusion device by the hydrostatic pressure during towing.

In the small number of instances where seals spent long periods of time in the net in the region of the exclusion device and escape opening, they often appeared disorientated by the geometry of the net, even when the opening seemed an obvious exit point. This issue would be further exacerbated if net retrieval or turning caused the net geometry to change when a mammal was in the net. This finding clearly indicates that the design of successful exclusion devices cannot rely entirely on the 'problem solving' or sensory capabilities of marine mammals to navigate to the escape opening. Rather, they must be directed to exit the net whether actively searching/swimming or not, and alterations to the orientation and rigidity of the barrier, and the proximity, shape and size of the escape opening would assist in this.

In the majority of occasions where seals entered the net via the escape opening, fish were present in front of the barrier. While the ribbon netting and curtain material appeared to be effective in reducing the loss of fish through the escape opening, it appeared to motivate seals to go to greater lengths, associated with a greater risk, to reach into the net to feed on the fish. On one occasion, the net curtain over the escape outlet appeared to prevent a seal from recognising the opening as an exit.

Hence, key aspects of current fishing gear and fishing practice were identified as posing an increased risk to pinnipeds and cetaceans interacting with the fishing gear including:

- 1) exclusion device barrier material and angle;
- 2) size and orientation of the escape opening, and the escape opening covers implemented to minimise fish loss; and
- 3) changes in net geometry as the vessel towing speed slows to turn and haul the net.



A general increase in the amount of seal footage recorded per shot was noticed over the study period. An increase in the amount of seal footage per shot was also observed within the majority of trips, potentially indicating an increase in the occurrence of seals aggregating and foraging around the vessel during a trip. This increase may be related to the constant fishing of redbait marks reliably found on the shelf break off St. Helens during the study period times. Seals may have become accustomed to approaching and interacting with the net, recognising that it represented an easy source of food, making their foraging more efficient (Fertl and Leatherwood, 1997). Hence it may be that continuous fishing in a restricted area was leading to an increase in seal interactions, as more seals recognised trawling activity as an easy food source, and as they become more effective at foraging around the gear.

4.2 Recommendations for sampling protocols

4.2.1 Camera position

With respect to the position of the camera, future projects should ensure that cameras are placed in the most informative locations, these being camera positions 1 and 2. Camera position 1, whilst not informative over the duration of the current study, is necessary to monitor the behaviour of marine mammals entering the net from the mouth and whether any seals that enter the net through the escape opening successfully navigate the net and exit via the mouth. Camera position 2 provides footage of the majority of the exclusion device and also the area to the aft of the opening. A camera mounted in this position would enable the majority of the exclusion device to be monitored whilst providing some form of indication as to the status of any seals or dolphins that encounter the exclusion device. We recommend two underwater video camera systems are installed to monitor mammal interactions, with cameras located at net positions 1 and 2 in any future research.

4.2.2 Data storage and sampling protocols

Due to the large volume and complexity of the data to be recorded by the camera units, it is recommended that all video footage is burnt to DVD immediately after each shot by the skipper or a crew member aboard the *Ellidi*. This is to be archived along with a corresponding logsheet covering critical information for each shot. The information should include shot start and finish time, the number, time and duration of turns, average tow speed, any problems leading to the delay in net hauling, the length of any delay, and the number of dolphins and/or seals observed around the vessel during fishing. These protocols will reduce the time scientific staff are required to be onboard during routine fishing (apart from an initial instruction period) and in doing so will provide detailed marine mammal-fishery interaction data covering the majority of fishing activity, and making the review and analysis of video footage as efficient as possible. In the event of any mammal fatalities, a crew member should be allocated the responsibility of following AFMA observer protocols, including recording critical body measurements, photographing the carcass and collecting tissue samples.

4.3 Camera system recommendations

4.3.1 Recording duration and operational depth

Shot times during the study period ranged from 1 hour 44 minutes to 11 hours 30 minutes whilst video footage covered a maximum of 2 hours 37 minutes worth of fishing activity.



Based on commercial logbook records (EFT01/SWT01), over 89% of all shots recorded in the SPF since 2003 have been less than 10 hours in duration, with almost 70% ranging between two and eight hours, with shots that range between four and six hours being the most common.

The tape based camera system used for this project could not record for more than 3 hours and the moving parts were a significant drain on battery life. It is recommended that future projects should use a hard drive recording system and battery setup that will have the capacity to record for at least 10 hours. Current portable video hard drive recorders are capable of recording and archiving well over 10 hours of footage. Using such a device would ensure the capacity to record all mammal interactions in view of the camera for the majority of shots, with recording only limited by battery performance.

Over 98 % of all fishing activity occurs at bottom depths of less than 175 m with almost 90 % of fishing activity occurring in depth ranges of 75 – 175 m. Therefore it is recommended that the camera system be capable of operating safely to depths of 200 m.

4.3.2 Illumination

An important aspect that needs to be considered when studying mammal interactions is the degree to which artificial light may alter the behaviour of marine mammals and fish in front of the camera. Fish passing through the net may potentially use this light source to orientate themselves within the net and may explain why the passage of fish apparently slows as they approach the exclusion device. The presence of a light attached to the net also may provide seals with a number of benefits including making it easier for the seal find the net in the first place, and, although fur seals are proficient at feeding during the day and night (M. Hindell, *pers. comm.*), making it easier for the seals to feed. Due to the depths being fished at, regardless of time of day, a source of illumination is required for the adequate monitoring of mammal interactions. It is, therefore, recommended that a low-light sensitive camera and a low intensity LED light source be used to minimise any potential impacts on animal behaviour.

4.3.3 Access to video footage, battery rotation and unit size

Accessing the video footage and replacing depleted batteries is an important consideration and must be straightforward so it can be preformed at sea easily and quickly by the crew. The system also needs to be of low volume and low weight to minimise drag and its effect on the geometry of the fishing gear.



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