An overview of toothed whale depredation mitigation efforts in the Indo-Pacific region

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Depredation by toothed whales

The extent of depredation on longline catches throughout the Indo-Pacific has been summarised by Nishida and Shiba (2005) and Nishida (2007). Depredation rates of up to 25% were reported for yellowfin tuna within Seychelles waters annually, and up to 100% on a daily basis.

False killer whales depredating a black marlin on a longline.

Depredation takes the form of bait loss or target fish loss. The result is the same: lost product and probably enhancement of toothed whale populations.

The mechanism of depredation is not well known. Toothed whales may encounter a longline randomly or may detect fishing operation sounds from a vessel, sonar equipment or struggling fish as well as vessel lights. Only one study has conclusively demonstrated a link between a vessel's acoustic signature and toothed whale depredation, namely an engine or hull wallowing sound at the beginning of fishing operations. One study demonstrated the attraction of albacore tuna to an acoustic signature of a troll vessel's gearbox.

More acoustic work is required. All methods to minimise detection of fishing operations by toothed whales are probably worthwhile.

Passive acoustic reflector systems

Based on Japanese longline fishery experience, Nishida and Tanio (2001) determined that since 1959, commercial fishing experience has been that tail-wrapped fish are often not depredated upon when trace wire and gear is wrapped around and along the body length of each fish. Nishida (2007) observed that longline target fish species entangled in fishing gear that included metallic components were usually not depredated upon. Fish entangled in monofilament gear, however, were usually depredated upon. The status of longline fishery depredation mitigation work around the Indo-Pacific by 2007 was summarised by the Indian Ocean Tuna Commission Depredation Workshop (Nishida 2007). This workshop described at least three mitigation methods under development that involved the entangling of captured fish with a variety of materials. Additional methods were considered although they were never regarded as being suitable for pelagic longlining operations.

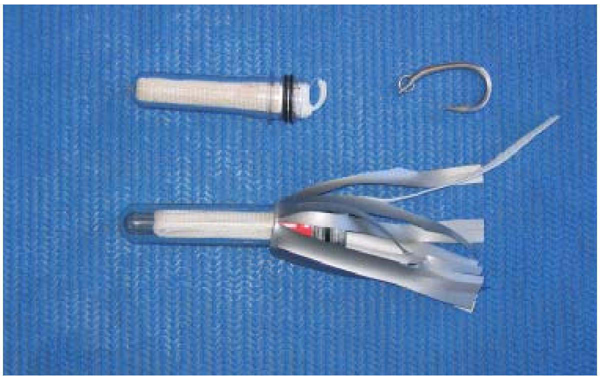
McPherson et al. (2007, 2008) described the sonar basis for toothed whale depredation. Even in clear oceanic waters, toothed whales use their sonar systems during depredation events. The sonar target strength[2] and target definition of the point of attack in hooked tuna was discussed, and helped explain why fishermen observe that whales can detect swallowed hooks and also conduct depredation during hours of darkness. Therefore, what may appear to be a mechanical impediment to depredation is, in fact, a passive sonar reflector of variable capability.

McPherson et al. (2008) described a streamer system based on electric fence tape that had been trialed in the Coral Sea for approximately 50 fishing sets. Streamers of electric fence tape with broadly distributed stainless steel wire to maintain target strength were deployed from a polycarbonate tube. When a fish strikes, the streamer is pulled from the tube and entangled around the tuna.

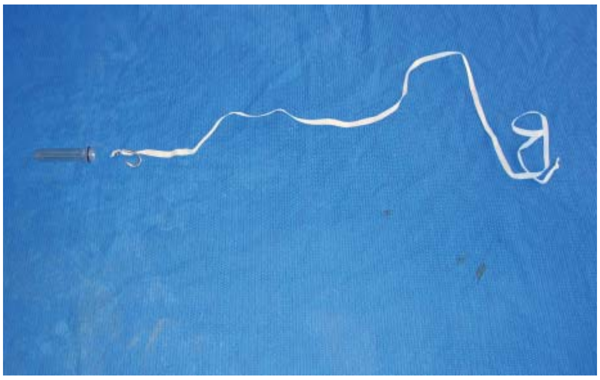
Variations of streamer holders included hollow plastic squid lures. Variations on streamer types were also used where both visual and presumed acoustic reflection was maximised to offer a combined mechanical and acoustic impediment to depredation. Attachment complications occurred when branchlines were made entirely of monofilament, in some instances this was done because of regulatory requirements.

[1] The authors were presented with the International Fishers Forum 5 Award (Taipei 2010) for work done on depredation mitigation in the Indo-Pacific.

[2] Target strength is a measure of the reflecting power of a sonar target, which is expressed in decibels. The target definition is the number of peaks or highlights in the return signal.



Two variations of polycarbonate streamer containers holding wire-embedded electric fence tape. The typical hook-to-tube distance was 50 cm.



A deployed electric fence streamer that tangled around free-swimming tuna, dolphin fish and swordfish during Coral Sea operations.

At the end of the experiment, it was fond that depredation appeared to be reduced even to the point of toothed whales terminating an attack on a tuna despite initial bites on the fish. The cost of the tube and variations was always low for better incorporation into the fishing industry. Despite the small size of the tubes (125 mm long x 22 mm in diameter) the space occupied by hundreds of tubes hanging off the outside of branchline stacking boxes on deck became logistically difficult.

Research conducted in Seychelles waters demonstrated that a streamer device of multiple strands of monofilament, referred to as a "spider", had considerable potential to reduce depredation rates (Guinet 2007; Rabearisoa et al. 2009). The spider was maintained a few metres from the hook, and slid down over the hooked fish after the bait was attacked. The streamers were of low sonar target strength stiff monofilament.

Rabearisoa et al. (2009) concluded that logistical aspects of deploying this streamer device well exceeded the requirement to deploy large numbers of hooks at an industry standard approaching every six seconds. The spider device did not function well with large fish (e.g. swordfish), which exceeded the entangling length of the filaments. The spider did outperform (logistically and as a depredation mitigation device) a sock-type physical protection cover that enclosed the hooked fish.

Rabearisoa et al. (2010) are further extending this work with enhanced visually reflective devices. Improving the streamer deployment mechanism is also a priority.

The streamer systems of Guinet (2007), McPherson et al. (2008), Rabearisoa et al. (2009) and Rabearisoa et al. (2010) are based on simple materials that the fishing industry could construct themselves. The approaches were specifically designed to provide industry with an example of how the passive sonar and mechanical approaches could best be applied by industry on a local or *ad hoc* basis. Toothed whales use a combination of sonar and vision during depredation events.

Nishida and McPherson (2010) used high target strength sonar materials (small air-filled spheres, McPherson et al. 2008) to develop a multiple streamer system (modelled with the help of United States and Australian defence-based sonar engineers) that would dominate sonar returns from tuna being attacked. The higher target strength returns were intended to highlight the fact that gear had actually entangled the tuna and interfered with the clarity of sonar returns to the toothed whale. The materials chosen in the streamer trials appeared to have a greater target strength than the probable target strength of the base of the brain case of tuna, where most false killer whales direct the primary attention of their initial depredation attack.

Trials of depredation mitigation streamers by Nishida and McPherson (2010) were conducted on Japanese High School fishery training vessels in high seas areas south of Hawaii, where depredation rates were very high during 2008. Trials were also conducted in Chinese fisheries and in Seychelles fisheries. Results again showed that deploying this simple system with the highest modelled target strength, though offering promise, did not warrant the effort required to deploy large numbers of the streamers where fish catch was often patchy.

Hawaii Longline Association fishermen have also trialled a variation of the passive acoustic streamer. Hawaii Longline Association vessels developed a system based on fine wire cable specifically designed to reduce bait depredation. Their results, based on 60,000 hook sets, found that fine wires did not mitigate bait depredation, and that higher target strength material was required.

Current conclusions for the passive acoustic streamer methods clearly indicate that the logistics for deployment (time taken to set and size the equipment) are not suited to high seas and large-scale longline activity. Cost would also be a factor where gear loss to sharks and lancetfish are high.

On more limited scales of longlining and trolling where depredation occurs, the technique offers more potential. The methodology has been particularly useful for troll fisheries where significant toothed whale depredation mitigation has been documented.

Passive sonar reflection is maximised when the wavelength of each incoming toothed whale species' sonar system is matched with the dimensions and sonar reflectivity of the reflector. An added complication is that the highlighted sonar and hearing frequencies must consider the age of the whales as their hearing capability changes with age.

Additional high target strength materials for longline use have been identified, and these are better suited to the sonar of not only older toothed whales but for larger species such as killer whales.[3]

The role of toothed whale sonar systems in depredation

In order to better assess the type of fishing equipment that could be used to further enhance the passive acoustic interference approach, the Hawaii Longline Association will support a two-stage assessment of sonar target strengths of fishing gear and parts of tuna bodies.

The Hawaii Longline Associate will task a sonar engineer with theoretically modelling the target strengths of all gear components. Sonar engineers will then test the target strengths of components with exposure to false killer whale echolocation clicks. In that way, optimal reflector components will be determined as well as giving an indication of how to assess target strengths of any future gear components. Fishermen will be made aware of the materials with the highest passive reflection capability in order that industry can make its own passive acoustic reflector streamers that suit their own fishing conditions.

The work is due to take place in late 2010.

Dolphin dissuasive device acoustic pingers in depredation mitigation

Depredation of target species of gill nets and longlines by marine mammals has been well documented by the International Whaling Commission (IWC). In 1993, the IWC considered that depredation would become as much of a problem as bycatch in a few years, and that prediction has been confirmed.

Acoustic pingers[4] were developed to mitigate bycatch of porpoises, dolphins, whales and dugongs in gill net fisheries (McPherson et al 1999; Werner et al. 2006). Acoustic pingers are devices that generate a range of sounds, based on species and application, simply intended to alert inattentive marine mammals or those in turbid or low light conditions of the presence of the pinger and the net to which they are attached. Mammals with sonar capability such as dolphins are warned to enhance vigilance with their sonar systems to avoid entanglement. Mammals with passive acoustic listening capability such as whales, dugong and dolphins may detect the sound of the nets in the water on which the pingers are placed, or by an increasing sound field when an animal approaches a net with appropriately spaced pingers.

Acoustic pingers were developed in the mid 1980s to avert the massive world bycatch of marine mammals in gillnets. Currently they are obligatory in most US East and West coast offshore waters, and subject to a range of regulations in EU water. They are also used throughout Northeast Australia, South America and increasingly through parts of Asia, all areas where gillnet fishing is common. They are perhaps not well known in the South Pacific where gillnets are not as common.

Recent developments in pinger technology have established a capability for some pingers to specifically mitigate depredation of gillnet and line caught catches by toothed whales. The mechanism of this process is poorly known.

The Hawaii Institute of Marine Biology determined that a large pinger (made by SaveWave) reduced the echolocation capability and decision-making speed of false killer whales (Mooney et al. 2009). With time, the whales' echolocation performance increased to 85% on known targets under careful experimental conditions. The range at which this occurred was not suited to longline operations.

Nishida and McPherson (2010) tested a dolphin dissuasive device (DDD) acoustic pinger that was designed to dissuade toothed whale depredation from longline, trawl and purse-seine type gear. Paired vessel tests were conducted on Japanese High School vessels in the Pacific south of Hawaii over an eight-week period in early 2010. High depredation rates due to false killer whales have been reported from the areas assessed. Initial assessment is that the DDD pingers significantly reduced depredation rates in oceanic waters.

The DDD pinger is also being tested by fisheries in both the North and South Pacific, and the Indian Ocean where depredation is a major problem. Depredation by killer whales is being assessed.

An interactive DDD (DiD) pinger, triggered by echolocation clicks, has been developed by engineers at STM Products (Italy). The pinger is only activated by echolocation clicks of toothed whales. The type of pinger signal is constantly under review.

The interactive DiD pinger is currently being tested under longline fishery conditions by Japanese Fishery High School vessels in a high depredation fishery area in the central Pacific.[5]

[3] Fishermen interested in developing their own passive acoustic depredation mitigation methods for their specific circumstances, including toothed whale species, may contact Geoff McPherson at Engineering and Physical Sciences, James Cook University in North Queensland (geoff.mcpherson@jcu.edu.au).

[4] A pinger is a device used underwater to produce pulses of sound.

[5] For further information on these DiD pinger project, please contact Dr Tom Nishida (tnishida@affrc.go.jp) or Martin Ipuche at STM Products (martin.ipuche@stm-products.com).

Global detection systems depredation detector buoy

The fishing industry has long been aware that depredation behaviour is associated with active sonar activity and whistling behaviour. McPherson et al. (2008) demonstrated the sonar basis for depredation and the enhanced whistling behaviour of false killer whales during depredation events.

Whistles are exchanged between individuals as they share food during depredation events on fishing gear, including longlines. Whistles propagate equally in all directions from animals moving around their depredation targets. The distance of whistle propagation in oceanic conditions can only be modelled at this stage but it is of the order of distance spacing between longline radio or GPS locator buoys.

Hardware for the global detection systems buoy

Existing GPS buoys used in longline fisheries have the capability of sending narrow bandwidth signals considerable distances to receivers on vessels. Acoustic buoys with a mammal whistle wide, signal bandwidth usually reserved for marine mammal monitoring, cannot transmit long distances over water.

A prototype GDS buoy with two hydrophones.

The global detection systems (GDS) approach uses existing GPS buoy transmission systems to send existing position and water temperature information, as well as information relating to toothed whale whistling occurrences in the vicinity of longline gear (Clarke et al. 2007). Whistles in isolation and at high occurrences and intensity expressed within specific time periods are coded and transmitted to the receiver on the fishing vessel.

The GDS buoy will detect the close presence of depredation activity when it is positioned on a longline. A special purpose hydrophone, developed with higher detection sensitivity than normal hydrophones, is able to detect whistles. Sonar or electrical engineers have spent a considerable time on longline vessels in the Coral Sea to develop this equipment and impart better gear "survival" rates. Information about the proximity of toothed whales will provide Fishing Masters with information that they can use to alter fishing strategy. Options include hauling sections of line where depredation has not occurred, or terminating setting when depredating whales are found to be following the vessel.

No decision has been made yet regarding the GPS-equipped range and direction finding buoy to which a hydrophone system and whale classifier and detector chip is to be added. Existing vessel signal transmission and receiver systems (GPS buoys) are considered to be cost-effective for the fishing industry. Existing receiver systems installed on vessels would be used.

Software for the GDS buoy

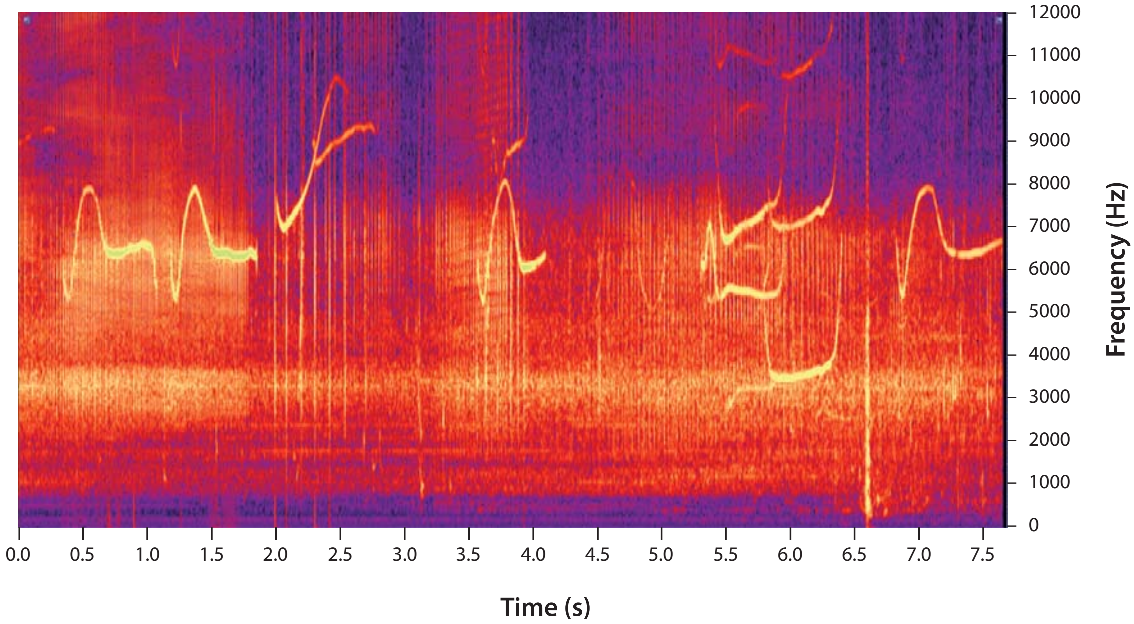
A whistle detection algorithm has been developed for this project in association with the School of Engineering and Physical Sciences at James Cook University in Townsville, Australia and JASCO Applied Sciences (also in Townsville), based on a process used to detect organisation within whale and dolphin calls, as well as structure in ancient languages and texts. The system has, to date, outperformed a range of automated energy detection systems for temperate cetacean species. The automated detection system has also outperformed experienced human observers.

A variety of toothed whale species are involved with bait and target fish depredation throughout the Indo-Pacific, each with varying acoustical signatures. Existing automated systems require detailed statistical information on the frequency and time features of whistles of each species. It is unlikely that these data would ever be available for the current application.

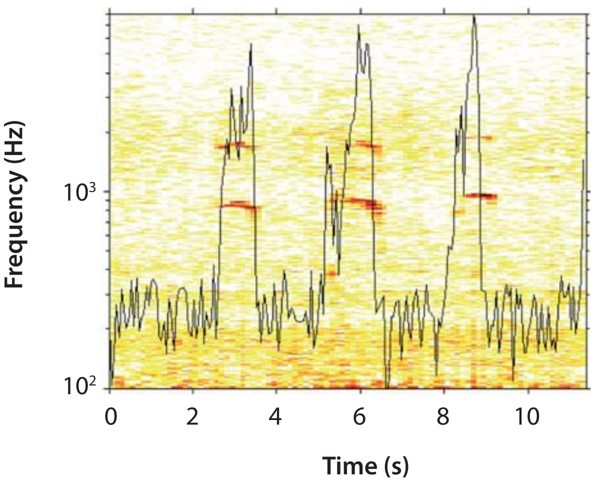
Whistle variation exists between individual depredation events by toothed whales and prey species. In one depredation event alone, 15 distinct whistle types were recorded. Isolated social whistles appear to have less variation, suggesting that whistles generated during depredation may have their own level of signal organisation.

The advantage of the GDS software is that it is not species specific. The GDS system would not experience problems associated with incomplete statistical datasets for whistles associated with toothed whale species. The software looks for patterns of organisation in the recordings permitting individual and group whistles to be detected.

Present longline position indicating buoys transmit a GPS location to the vessel via radio frequency. If a GDS buoy (and longline section) cannot be located by a vessel, GDS offers as an option a buoy localisation via satellite to a land station and then by email to the vessel.



Worse-case scenario spectrogram of a depredation event occurring next to a loud fishing vessel. A restricted number of false killer whale whistle types, broad frequency range echolocation clicks, overlap each other. The loud constant frequency noise from the vessel dominates the lower frequencies.



A spectrogram of beluga whistles enclosed within a line of entropy detection probability (Data provided by JASCO Applied Sciences). Detection occurs when the recording organisation probability exceeds a specified level.

Project status [6]

A broad range of whistles that are associated with bait and target fish depredation has been, and will be, sampled using a GDS developed acoustic recording ground truth buoy. This buoy has been developed to determine the total range of isolated and depredation-associated whistles from toothed whales over a range of open water and depredation-associated events. It is being used to determine the efficiency of the detection rate of the detector buoy. Sampling is about to begin in Australian and Hawaiian waters, and we would be pleased to hear from interested organisations in the South Pacific region.

A working prototype buoy for testing in Australian, Hawaiian and South Pacific waters will be ready before the end of 2010.

Summary

The depredation mitigation work summarised in this article is taken from a variety of projects that have been working in cooperation around the Indo-Pacific region since the early 2000s. Work is ongoing.

The methods are all seen as being mutually supportive. Some fishery sectors may find some methods more appropriate than others for their situation.

Acknowledgements

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6 For more information about the GDS buoy project, please contact Marketing (marketing@gds.com.au) or Geoff McPherson (mcpherson.geoff@gmail.com).

Hawaii Longline Association, Hawaii Institute of Marine Biology at the University of Hawaii, and the Western Pacific Regional Fishery Management Council.

The International Fishers Forum (IFF) series (Yokohama 2006, Puntarenas 2007 and Taipei 2010) provided an ideal opportunity to share depredation mitigation system methods with the Indo-Pacific fishing industry for the benefit of all, particularly passive acoustic entangling systems. We thank IFF organisers for supporting our attendance at these gatherings.

We also wish to thank the commercial fishery operators within the Indo-Pacific region (Japan, Hawaii, Seychelles and Australia) for their sharing of practical suggestions and honest appraisals of all our depredation mitigation versions. While we may make a variety of suggestions based on the acoustic capability of the toothed whales the definitive methods to reduce depredation will essentially come from the fishing industry.

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