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Killer whale (*Orcinus orca*) interactions with longline fisheries in New Zealand waters

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Abstract

Killer whales (*Orcinus orca*) interact with longline fisheries around the world, however they have not previously been reported taking fish off longlines in New Zealand waters. Two new killer whale prey species (school shark, *Galeorhinus galeus* and bluenose, *Hyperoglyphe antarchia*) have been recorded. A great deal of effort has been applied, world wide, to reduce killer whale-fishery interactions, but few methods are successful. Fishers in New Zealand have used 'tuna bombs' and shooting.

Key words: Killer whale, *Orcinus orca*, longline predation, fishery interactions, school shark, *Galeorhinus galeus*, bluenose, *Hyperoglyphe antarchia*.

Introduction

Killer whales (*Orcinus orca*) demonstrate diverse foraging strategies, as individuals or groups, that include intentional stranding to capture pinnipeds (Guinet, 1991; Hoelzel, 1991), ambushing penguins (Condy *et al.*, 1978, Guinet, 1992), hunting fish (Bigg *et al.*, 1987), and coordinated hunting for pinnipeds (Baird, 1994; Smith *et al.*, 1981), whales (Goley & Straley, 1994; Jefferson *et al.*, 1991), herring (Similä & Ugarte, 1993), dolphins (Baird & Dill, 1995; Jefferson *et al.*, 1991; Visser, 1999*a*), stingrays (Visser, 1999*b*) and sharks (Fertl *et al.*, 1996).

In addition, killer whales associate with a wide range of fisheries, e.g., they have been found inside tuna traps (Di Natale, 1989), scavenging off fishing boats (Couperus, 1994), and feeding in association with fisheries (Fertl & Leatherwood, 1997; Yano & Dahlheim, 1995*b*). In some areas of the Northern Hemisphere, interactions between killer whales and longline fisheries have been long running, e.g., since the 1960s in Faeroese waters (Bloch & Lockyer, 1988) and Alaska (Dahlheim, 1988), before 1969 off Hawaii (Tomich, 1969) and from at least 1976 off Iceland (Christensen, 1982).

In the Southern Hemisphere, reports of fisheries interactions are widespread e.g., around South Georgia (Ashford, 1996), off Brazil (Rosa, 1995; Secchi & Vaske, 1998), near Marion Island (Dahlheim, 1999), near the Falkland Islands (P. Guilding & T. Betts, Falkland Islands Fisheries, pers. comm.) and around Argentina (S. Macnie, pers. comm.). Again, some interactions have been long term, e.g., since 1952 off the Palau Islands (Iwashita *et al.*, 1963), 1955 off Java (Iwashita *et al.*, 1963), 1956 off New Guinea (Iwashita *et al.*, 1963), 1962 off both the Maldives and Chagos Islands (Sivasubramaniam, 1964), and 1962 in the Timor and Banda Seas (Sivasubramaniam, 1964), 1968 off the west coast of Australia (Iwashita *et al.*, 1963), and the 1970s off Tasmania (McGifford, 1981; Tilley, 1979).

Previously, New Zealand killer whales have been documented employing at least two foraging strategies; benthic foraging for stingrays (Visser, 1999*b*), and herding dolphins (Visser, 1999*a*). This report documents a strategy not recorded previously in New Zealand waters; the taking of fish off commercial longlines.

In New Zealand, killer whales take fish off two types of commercial fishing lines; 'Dahn-lines' and 'Long-lines'. 'Dahn-lines' hang vertically in the water and are usually around 200 m long. They have a heavy sinker at one end and a float at the other. Each Dahn-line has 60 hooks *ca.* $\frac{1}{2}$ m apart, on nylon leaders (ganions) secured to the main line with a detachable metal 'snap'. 'Longlines' consist of a 'groundline' that lays along, or near the sea floor, which can be 4.5 km or longer. Each groundline has 60–100 hooks *ca.* 5 m apart, also on ganions. The groundline is attached at one end to a heavy sinker or anchor and at the other to a float, or can have an anchor and a buoy line running to the surface at each end. Hereafter, both 'Dahn-' and 'Long-' lines are referred to as 'longlines'.

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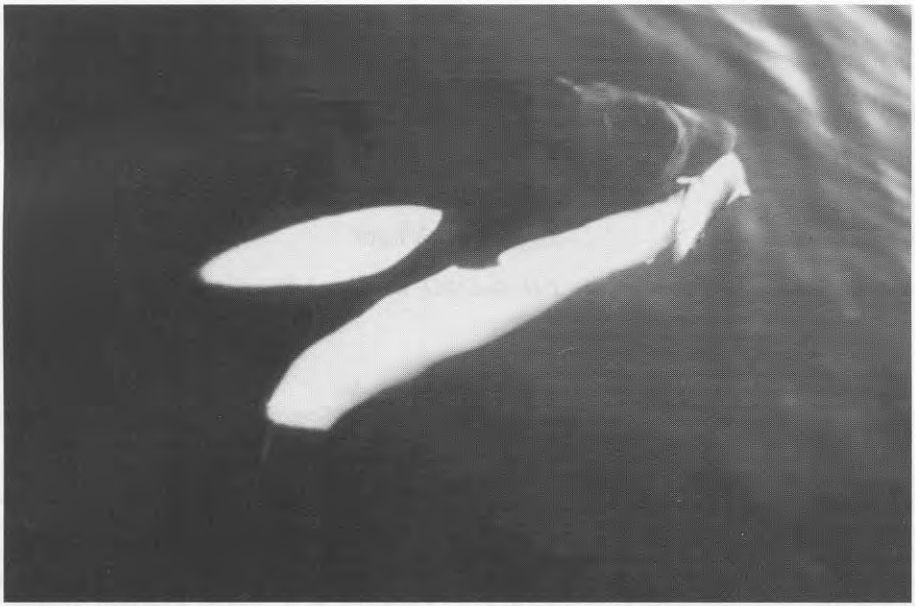

Figure 1. Killer whale (*Orcinus orca*) with school shark (*Galeorhinus galeus*) just below the surface. Photo: Anon.

Materials and Methods

Six New Zealand fishers were interviewed and assured of anonymity. As all cetaceans are protected under New Zealand law, anonymity was required by the fishers, as they realised they could have broken the law.

Identification of species taken by the killer whales was made while the killer whales consumed fish at the surface (Fig. 1), from the remains of the fish still attached to the hooks, and in one three-day period (see below), with underwater observations by the author.

Between 15 and 30 April 1997, the author visited the Three Kings Bank to observe longline predation. Observations were made on three days from a charter boat that did not undertake longline fishing. Killer whales were located by actively searching the area for signs of the animals and by radio calls from fishing boats in the area. Once found the killer whales were classified into age classes and sex, following methods described by Bigg (1982). Briefly, adult males were identified by their dorsal fin that is typically up to 1.5 m, sub adult males were identified by the dorsal fin 'sprouting'—the fin is larger than an adult female's, but is not yet the full size of an adult male. Females were identified by smaller dorsal fins (not more than 0.9 m) and sexed by underwater observations.

Results

The interviewed fishers reported longline predation by killer whales off both the North and South Islands. However, no fishers spoken to had personally experienced predation off the South Island, but had heard about it from other fishers. Although longline predation was reputedly widespread off the north of the North Island, it was most prevalent at the northern offshore banks; Middlesex Bank (35°55′S 172°45′E), Pins Bank (34°26′S 173°29′E), and Three Kings Bank (34°55′S 172°17′E). The earliest record of longline predation appeared around 1984 in the Pins Bank area (M. MacMillan, pers. comm.). More recently, since 1996, killer whales have also started to take fish from longlines off the west coast of the North Island (Visser unpubl. data). Fishers reported longline predation from early February through to the end of April. This coincides with the main fishing period (M. MacMillan, pers. comm.).

The species taken from the longlines are school sharks (*Galeorhinus galeus*) and bluenose (*Hyperoglyphe antarchia*). However, killer whales are never reported to take hapuku (*Polyprion americanus*), a very common species caught on the longlines in the same areas, and often on the same line as the two species aforementioned.

In the three instances where killer whales were found at the Three Kings Islands, they appeared within 50 m of a fishing boat, and within 10 mins of the hydraulic winches engaging the fishing gear and hauling beginning. Five killer whales (two adult females, one adult male, one subadult male and one calf) were photo-identified (catalogue numbers NZ106-110), with three having easily distinguishable marks and clearly photographed (Fig. 2), following methods described by Bigg (1982). All five killer whales were seen on three different days, and were observed both topside and underwater. All five killer whales, during at least one encounter, were observed to take bluenose off the longlines. The calf, although observed taking and consuming at least three bluenose, was also observed under water suckling milk from an adult female.

In New Zealand, the fishers interviewed by the author reported losses of 5–10% per set of line (Visser, unpubl. data) and stated that the killer whales were selective when removing fish, taking only school sharks and bluenose and leaving other species. Predation only occurs as the gear is hauled up to the surface. The killer whales do not remove the hooks, but one fisher reported hooks being straightened (Visser, unpubl. data). Typically, the killer whales remove the whole fish, but also take only the body, severing it just behind the gill-cover and leaving the head attached to the hook. Killer whales have also been observed taking 'floaters' (fish with distended swimbladders, due to fast-hauling from depth). These fish sometimes come off the hooks and float around the boat. Because the 'floaters' cannot sink, fishers normally pick them up after hauling the line. Often, when taking school sharks, the killer whales 'delicately' take the shark by the tip of the tail, using the teeth at the front of their mouth (Fig. 3), and gently pull until the shark 'pops' off the line. School shark predation off longlines has been recorded for both coasts of the upper north of the North Island (north of 37°S). To date, New Zealand killer whales have been recorded preying on either of these species only from longlines, and not as free-swimming prey.

Shooting of killer whales in New Zealand waters was recorded (Visser, unpubl. data). One longline fisher reported shooting an adult male in the dorsal fin and leaving 'holes like buck-shot hits' right through the fin. This killer whale was not photographed, nor photo-identified from the New Zealand catalogue (Visser, unpubl. data) and could be dead. Two other fishers (commercial, but not using longlines) reported that they shot at killer whales on 'various' and 'frequent' occasions (Visser, unpubl. data). In addition, three fishers reported using 'tuna-bombs'—underwater explosives designed to deter the killer whales.

Two records from New Zealand recreational fishers confirmed that killer whales also take bait off rod-and-reel lines (Visser, unpubl. data). In one instance video-footage suggested a killer whale took a big-game fishing lure and snapped the line, and in the second instance, a live-bait yellowfin tuna (*Thunnus albacares*) of approximately four kg was taken off a big-game line, leaving only the head (Visser, unpubl. data).

Discussion

Interactions between killer whales and longline fisheries have been described for many regions around the world. However, prior to 1984, New Zealand killer whales had not been recorded taking fish from longlines. It is not known if they learned this behaviour by observation, or practice in other regions, or if they have developed it independently. Although the calf was consuming bluenose and taking milk from a female, it could have been learning the process of predation off longlines from the adults present. Teaching of young killer whales has been reported for other foraging strategies (Guinet, 1991).

It is not known if bluenose is normally a main food item for killer whales, because these fish usually are found at depths exceeding 250 m (Anderson *et al.*, 1998), and although killer whales regularly dive below 100 m (Baird *et al.*, 1998), the maximum dive depth recorded is 162 m (Baird & Goodyear, 1993). To date, school sharks have been reported only as a prey item when taken off longlines, however, it is likely, given that seven other species of elasmobranchs are taken in New Zealand waters by killer whales (Fertl *et al.*, 1996; Visser, 1999*a*; Visser, 2000; Visser *et al.*, in press; Visser, 2000), that school sharks are also a free-swimming prey item.

School sharks have been commercially fished intermittently since the early 1900s, and during one peak, between 1945 and 1955, it was estimated that 150 000 school sharks (2500 tons) were caught annually (Cox & Francis, 1997). In the 1950s, fishers began targeting mainly migrating pregnant female school sharks and by 1984, a new peak in harvesting was reached of 5600 tons (Cox & Francis, 1997). Due to overfishing, quotas were set up for some shark species, including school sharks (less than half the previous year's catch was permitted) (Cox & Francis, 1997). School sharks remain an important commercial fish and are taken mainly by longlines and set nets (Cox & Francis, 1997). Overfishing is an issue in New Zealand, as elsewhere, and the human-induced reduction of this species could affect the manner in which the New Zealand killer whales now forage for them.

Figure 2(a).

Figure 2(b).

Figure 2(c).

Figure 2. Three of the five killer whales clearly photo-identified at the Three Kings Bank 15, 29, 30 April 1997. Photos: Author.
(a) NZ106, adult female killer whale, broad rounded fin, series of small 'dents' in trailing edge of fin. Not shown; distinguishing marks on left eye patch (indent on lower edge near back).
(b) NZ107, adult male killer whale, small 'dent' in trailing edge, near base of fin.
(c) NZ109, adult female killer whale, notch near top of trailing edge of fin.

Killer whales could be susceptible to entanglement in longlines (Matkin & Saulitis, 1994; Sivasubramaniam, 1964, Ashford, 1996). In New Zealand, on 25 April 1991 a neonate female killer whale stranded alive but later died, on the West Coast of the North Island (Visser, unpubl. data). It had net or line marks consistent with descriptions of by-caught cetaceans, given in Kuiken (1996), and five wounds consistent with either bullet wounds or attacks with a sharp object (R. Parrish, pers. comm.). In addition, on 26 June 1990, off the Bay of Plenty (37°18′S, 178°46′E), a New Zealand government fisheries observer reported a Japanese tuna-longlining boat hooked a killer whale in the back. The animal subsequently allowed itself to be hauled alongside the vessel, where it was cut free and released alive (S. Baird, pers. comm.).

The fact that killer whales only appear when gear is hauled could imply that the animals learn to associate the sound of gear being hauled (or lines strumming under water) with the opportunity to take the fish—a type of 'dinner-bell' effect. Matkin (1986) stated that fishers in the Alaska area agreed that the killer whales used acoustic cues to determine position and activities of the fishing vessels, and began moving rapidly towards the vessel as soon as the hydraulics were engaged and the longline hauled up. Many other aspects of killer whale longline predation in New Zealand are similar to those reported for Alaskan waters e.g., the killer whales are selective when removing fish (Matkin & Saulitis, 1994; Yano & Dahlheim, 1995*a*), predation only occurs when gear is hauled up to the surface (Matkin & Saulitis, 1994), the target fish typically are found at depths exceeding the known dive range for killer whales (Matkin & Saulitis, 1994) and hooks are sometimes straightened (Matkin *et al.*, 1987). Alaskan killer whales do differ in that there is a report of a killer whale carcass found on a beach in Prince William Sound with a halibut hook in its stomach (Matkin & Saulitis, 1994). In addition, some killer whales recently were observed to wait beside the longline buoys until hauling begun (M. Dahlheim, pers. comm.).

Longline losses due to predation by killer whales are reported for many areas around the world (Table 1). Losses can be as high as 100% (Rosa, 1995; Secchi & Vaske, 1998; Sivasubramaniam,

Figure 3. Killer whale (*Orcinus orca*) about to remove school shark (*Galeorhinus galeus*) from a longline by grasping the shark's tail and pulling the shark until it 'pops' off the line. Photo: Anon.

1964) and in areas, such as southern Africa and Brazil where the catch has been totally destroyed, killer whales have been shot (Rice & Saayman, 1987; Secchi & Vaske, 1998). Around Alaska, where the rate of predation off longlines is typically 20–34%, fishers also shoot the killer whales and use underwater explosives to deter the animals (Dahlheim, 1988; Dahlheim & Matkin, 1994; Holleman, 1988; Matkin, 1986). 'Seal-bombs' (underwater explosives, larger, but similar to the 'tuna-bombs' used in New Zealand) were effective in keeping the killer whales a greater distance from the boat, but not far enough away to prevent them from removing fish from the lines (Matkin, 1986). Shooting was not effective either, because killer whales with obvious bullet wounds repeatedly showed up to take fish off longlines (Dahlheim, 1988; Matkin, 1986). Killer whales with bullet wounds in Prince William Sound all belonged to one group and the mortality rate was 8.6% compared to 3.7% for other groups in the area over the same time (Matkin, 1986), suggesting that some bullet wounds eventually proved fatal. In New Zealand, an increase of longline predation could result in an increase of negative interactions between killer whales and fishers, such as shooting and 'tuna-bombing'. These sorts of interactions could already be more prevalent than reported here, but because carcasses of killer whales typically sink (Dahlheim & Matkin, 1994), it is unlikely that such animals would be recovered had they been interfered with.

Rates of predation at the 25% level are considered a '*very real and serious problem*' (Matkin, 1986) and although predation levels are only 5–10% in New Zealand, indications from overseas show that predation tends to increase over time (Matkin, 1986; Sivasubramaniam, 1964; Yano & Dahlheim, 1995a) and therefore is likely to do the same here. Additionally, it may not necessarily remain a problem associated only with killer whales, because other species of cetaceans have been recorded taking fish off a variety of fishing lines, including false killer whales (*Pseudorca crassidens*) around Hawaii (S. Mossman, pers. comm.) and sperm whales (*Physeter macrocephalus*) off Alaska (Dahlheim, 1988), South Georgia Island (Ashford, 1996) and around Argentina (S. Macnie, pers. comm.), and bottlenose dolphins (*Tursiops truncatus*) off Texas, USA (Gunter, 1942).

The widespread documentation on a global scale, and the long-term perseverance of predation from longlines, suggests the problem will continue. All potential solutions investigated so far have drawbacks or are not successful. For instance, options include moving fishing gear, but it is highly likely that areas where predation on longlines occurs are also areas of high productivity for the target fish. Thus, moving to peripheral areas could result in reduced catches (Matkin, 1986). Also, moving the fishing fleet may not prove fruitful in reducing longline predation. A fishing fleet in South Australia moved more than 160 km from the 'problem' area, yet the killer whales still found the boats

(Tilley, 1979). Sivasubramaniam (1964) found fishers who fished consecutive days in the same area also reported the damage done by the killer whales increased on every subsequent day of fishing. This suggests that one measure to avoid an increase in the longline predation could be choosing random fishing days. However, to do this may be impossible for fishers where the fishing area is a long way offshore, (as is the case in New Zealand), and returning to the fishing location frequently, instead of remaining on location, is not economical. Co-operative strategies between fishing vessels, e.g., using radio communication to alert other vessels when the killer whales are with one vessel, thus allowing other vessels to haul, appears to work over a short period. However, eventually the killer whales disperse and target each vessel concurrently (Holleman, 1988).

Another option could be adding 'pingers' or other acoustical or optical scaring devices to the longlines (Dahlheim, 1988; Dawson *et al.*, 1998; Matkin, 1986). However, the killer whales could habituate to the pingers or the pingers could have the opposite effect and attract the killer whales. Jefferson & Curry (1996) reviewed the available data on acoustic methods of reducing marine mammal-fishery interactions. They concluded that it was very difficult to draw solid conclusions about the effectiveness of acoustic methods to reduce interactions, as there was a paucity of information based on controlled experiments.

Yet another solution was offered by an Australian fisher, who recommended slower hauling of lines to prevent 'floaters' (McGifford, 1981); however, when New Zealand fishers were asked about this option they commented that 'floaters' were only part of the problem and killer whales would still continue to remove fish attached to the longlines, regardless of the speed at which the lines were hauled in. In contrast, Sivasubramaniam (1964) suggested hauling gear quickly, thereby reducing the time the killer whales have to prey off the longlines. When this method was suggested to New Zealand fishers they commented that this 'fast-hauling' would rip the hooks from the fishes mouths.

The use of alternative fishing gear may not be appropriate in New Zealand, due to the target species, the fishing locations, and the initial costs of refitting boats, but in Canada, where pot or trap gear is used to harvest sablefish (a fish also harvested on longlines and taken by killer whales, Table 1), killer whales do not prey from fishers (Matkin & Saulitis, 1994, G. Ellis, pers. comm.). In addition, killer whales in Alaska do not remove salmon or herring from purse seine nets or near-shore gillnets, although the animals sometimes pass by and enter the open nets (Matkin & Saulitis, 1994). In 1980, killer whales in Alaska were considered adept at avoiding nets (Matkin, 1980), but since then have been recorded drowned in nets in the area (Barlow *et al.*, 1994) and elsewhere, e.g., Trinadad (Northridge, 1991), California (Heyning *et al.*, 1990), Bering Sea, (Matkin & Saulitis, 1994; Teshima & Ohsumi, 1983), Chile (Northridge, 1991), and Norway (Lien *et al.*, 1988). In New Zealand, although one killer whale has become hooked on a longline, none have been shown to have died due to entanglement in longlines specifically. However, they have died in other fishing gear ($n=6$) (Cawthorn, 1981; Donoghue, 1994; Donoghue, 1995; C. Duffy & R. Parrish pers. comm.; Visser, unpubl. data).

A number of different solutions to the problem of killer whale longline predation still are being offered, but have not yet been investigated. These include the use of rubber bullets to shoot the whales, sparker devices that emit light and sound when fish are removed from the hooks, electrifying the longline to shock the whales, and bubble screens to interfere with whale acoustics (Dahlheim, 1988). Methods that acoustically isolate the winch from the boat hull could allow hauling of fishing gear to be quieter.

Matkin (1986) and Dahlheim (1988) suggested what may be an effective method to deter killer whales from taking fish off longlines; the use of lithium chloride (a powerful emetic, causing severe vomiting) to be used inside decoy fish. However, under the New Zealand Marine Mammals Protection Act (1978) and the Marine Mammals Protection Regulations (1992), use of this product or anything similar, to create such an effect, would be illegal (Part III, 18 (i), 1992). In addition, if lithium chloride was retained in any fish flesh that was destined for human consumption, there could be health hazards. Also, as Matkin (1986) pointed out, if species taken off longlines are also a natural prey item and lithium chloride was used, the killer whales could become negatively conditioned to the species used, and therefore reject them as free-swimming prey items, resulting in decreased fitness through reduced food intake.

In Prince William Sound, it appears that certain individual killer whales (identified as AB pod, and some animals from AI pod) are responsible for much, if not all, of the predation on the longlines (Matkin, 1986). Further investigations in New Zealand waters through photo-identification e.g., (Bigg, 1982) could reveal a similar situation here. A three day repeat sighting, over a short period of time, is not sufficient to draw any conclusions.

Initially in Alaska, regulations under the USA Marine Mammal Protection Act allowed fishers to defend their catch using any means necessary to repel killer whales (Matkin & Saulitis, 1994). Public

Table 1. Location of killer whale interactions with longlines, including species of fish and percent of catch taken.

Location	Species of fish	Amount of catch taken	Measures taken to stop Orca taking fish	Year first recorded	Source
Argentina (Isla de los Estados)	Patagonian toothfish *Dissostichus eleginoides*	not known	none taken so far	1998	(S. Macnie, pers. comm.)
Australia (Tasmania)	Deep-sea trevella *Hyperoglyphe porosa*	lose several hundred fish annually	'older' fishermen suggested hauling gear slower	1970s	(Wilson, 1981) (McGifford, 1981)
Australia (South)	Trevally (Latin name not stated)	not stated	not stated	1970s	(Tilley, 1979)
Australia (West)	Tuna *Thunnus* sp.	not stated	not stated	1968	(Iwashita *et al.*, 1963)
Brazil	Tuna Swordfish *Xiphias gladius*	50% to 100%		1987	(Rosa, 1995), (Secchi & Vaske, 1998)
Iceland	Halibut	not stated	dynamite leave the fishing grounds	1976	(Christensen, 1982)
Indian Ocean	Tuna	'most of lined fishes lost'	not stated	Not stated, but pre 1958	(Nishiwaki & Handa, 1958)
Indian Ocean (Maldive and Chagos Islands)	Yellowfin tuna *Thunnus albacares* Big-eye tuna *T. obesus*	average of 55% but up to 100%	retrieve fishing gear as soon as orca are sighted, move to new fishing ground, haul gear up fast	1962	(Sivasubramaniam, 1964)
Indonesia (Banda and Timor Sea)	Yellowfin tuna Big-eye tuna	average of 55% but up to 100%	not stated	1962	(Sivasubramaniam, 1964)
Indonesia (off Java)	Yellowfin tuna Big-eye tuna Albacore Indian tuna	1850 tons over 224 days	'shock-type sound producing generator' 19mm harpoon gun mounted to front of fishing vessel	1955	(Iwashita *et al.*, 1963)
Marion Island	Chilean sea bass (patagonia toothfish)	not stated	not stated	1998	(Dahlheim, 1999) (Dahlheim, pers. comm.)
New Zealand	Bluenose grouper *Hyperoglyphe antarchia* School Shark *Galeorhinus galeus*	5–10%	shooting, tuna-bombs	1984	this report

Table 1. *Continued.*

Location	Species of fish	Amount of catch taken	Measures taken to stop Orca taking fish	Year first recorded	Source
New Guinea and New Britain	Tuna	not stated	not stated	1956	(Iwashita *et al.*, 1963) (Sivasubramaniam, 1964)
Norway	Halibut	not stated	not stated	'many years'	(Matkin, 1986)
Palau Islands	Tuna	'becoming heavier' 'matter of concern and alarm'	not stated	1952	(Iwashita *et al.*, 1963)
Prince Edward Island	Patagonian toothfish	up to 90%	high frequency sounds emitted from electronic device, orca become immune quickly		(Collin van Schalkwyk, pers. comm.)
South Georgia Island	Patagonian toothfish	25 of 27 lines had interactions 'At times entire catch lost'	certain areas, known to be frequented by orca, are avoided.	1994	(Ashford, 1996)
Alaska (Bering Sea and Prince William Sound)	Sablefish/Blackcod *Anoplopoma fimbria* Greenland halibut *Reinhardtius hippoglossoides* Pacific halibut Arrowtooth flounder *Atheresthes stomias* Searcher *Bathymaster signatus*	20–25% 92.4% and 5.72–68.91%	Abandoned hauling line shooting, 'bang-pipes', 'fool' the whales during gear retrieval, 'tangle-imitators', benign acoustic techniques, 'seal-bombs', 'cracker-shells', acoustic harassment devices, explosives, stop operations, long-range vessel movements (>110 km), change target species, use of dummy buoys, use of pot gear	1960s, and 1977 and 1985	(Matkin, 1986) (Matkin & Saulitis, 1994) (Northridge, 1991) (Matkin *et al.*, 1987) (Yano & Dahlheim, 1995) (Dahlheim, 1988) (Dahlheim, 1990)
Hawaii	Skipjack tuna, *Thunnus sp.*		not stated	not stated, but before 1969	(Tomich, 1969)

concern resulted in changes in the Act, and it is now illegal in the USA to engage in activities that could cause serious injury or death to cetaceans, including shooting (Matkin & Saulitis, 1994). This change in the law has set a precedent for changes in legislation in other parts of the world, where the law allows fishers to protect their catch but where killer whales may need protection due to their predation from longlines and other fishing methods.

Although Regulation 3 (2) of the New Zealand Marine Mammals Protection Regulations (1992) states "*nothing in these regulations applies in respect of any fishing vessel, while the vessel is engaged in commercial fishing*", it seems unlikely that any fisher deliberately causing injury or death to a marine mammal (e.g., shooting with a firearm) would avoid prosecution. Nonetheless, this regulation offers no further definition and thus is open to interpretation, thereby giving fishers the opportunity to interfere with marine mammals that are perceived as competitors. It is recommended that this regulation be further defined and altered, to limit the fisher's protection to only accidental entanglement and foul hooking.

In conjunction with this modification of the Regulations, it would be prudent to monitor the killer whale longline predation situation, so that if predation increases, measures can be investigated and implemented to prevent the problem from escalating. Food is a very positive reward, and this behaviour will be hard to eliminate when it is constantly reinforced. As Matkin & Saultitus (1994) pointed out, to resolve or reduce the killer whale-fisheries conflicts, dialogue among fishers, managers and researchers is essential. Fishers are the key to the solution; they are the ones that experience the problem, and have the most to gain from a resolution.

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Literature Cited

Anderson, O. F., Bagley, N. W., Hurst, R. J., Francis, M. P., Clark, M. R. & McMillan, P. J. (1998) Atlas of New Zealand fish and squid distribution from research bottom trawls. *NIWA Technical Report* 42, 303 pp.

Ashford, J. R. (1996) Interactions between cetaceans and longline fishery operations around South Georgia. *Marine Mammal Science* **12** (3), 452–457.

Baird, R. W. (1994) Foraging behaviour and ecology of transient killer whales (*Orcinus orca*). Ph.D. Dissertation. Simon Fraser University, Burnaby, British Columbia, Canada.

Baird, R. W. & Dill, L. M. (1995) Occurrence and behaviour of transient killer whales: Seasonal and pod-specific variability, foraging behaviour, and prey handling. *Canadian Journal of Zoology* **73** (7), 1300–1311.

Baird, R. W., Dill, L. M. & Hanson, M. B. (1998) Diving behaviour of killer whales. *Abstract submitted to the 12th Biennial Conference on the Biology of Marine Mammals*, Monaco.

Baird, R. W. & Goodyear, J. D. (1993) An examination of killer whale diving behaviour using a recoverable, suction-cup attached TDR/VHF tag. *10th Biennial Conference on the Biology of Marine Mammals*, Galveston, Texas, United States of America.

Barlow, J., Baird, R. W., Heyning, J. E., Wynne, K., Manville, A. M., Lowry, L. F., Hanan, D., Sease, J. & Burkanov, V. N. (1994) A review of cetaceans and pinniped mortality in coastal fisheries along the west coast of the USA and Canada and the east coast of the Russian Federation. *Reports of the International Whaling Commission* **15,** 405–425.

Bigg, M. (1982) An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. *Reports of the International Whaling Commission* **32,** 655–666.

Bigg, M. A., Ellis, G. M., Ford, J. K. B. & Balcomb, K. C. (1987) *Killer Whales: A study of their identification, genealogy and natural history in British Columbia and Washington State*. Phantom Press and Publishers, Nanaimo, B.C.

Bloch, D. & Lockyer, C. (1988) Killer whales (*Orcinus orca*) in Faeroese waters. *Rit Fiskideildar* **XI** (North Atlantic killer whales), 55–64.

Cawthorn, M. W. (1981) New Zealand. Progress report on cetacean research June 1979–May 1980. *Reports of the International Whaling Commission* **31,** 201–203.

Christensen, I. (1982) Killer whales in Norwegian coastal waters. *Reports of the International Whaling Commission* **32,** 633–642.

Condy, P. R., van Aarde, R. J. & Bester, M. N. (1978) The seasonal occurrence and behaviour of killer whales *Orcinus orca*, at Marion Island. *Journal of Zoology, London* **184,** 449–464.

Couperus, A. S. (1994) Killer whales (*Orcinus orca*) scavenging on discards of freezer trawlers north east of the Shetland islands. *Aquatic Mammals* **20** (1), 47–51.

Cox, G. & Francis, M. (1997) *Sharks and Rays of New Zealand.* Canterbury University Press, Christchurch, New Zealand.

Dahlheim, M. E. (1988) Killer whale (*Orcinus orca*) depredation on longline catches of sable fish (*Anoplopoma fimbria*) in Alaskan waters. Unpublished report to the US Department of Commerce, NOAA, National Fisheries Service, Marine Mammal Lab, Seattle, Washington, 31 pp.

Dahlheim, M. E. (1990) Killer whale depredation on longline catches of sablefish in Alaskan waters. *Abstract submitted to the Third International Orca Symposium*, Victoria, British Columbia, 5.

Dahlheim, M. E. (1999) Killer whale fishery interactions. *13th biennial conference on the biology of marine mammals*, Wailea, Hawaii, 42.

Dahlheim, M. E. & Matkin, C. O. (1994) Assessment of injuries to Prince William Sound killer whales. *Marine Mammals and the Exxon Valdez*, T. R. Loughlin (ed), Academic Press, San Diego, 163–171.

Dawson, S. M., Read, A. & Slooten, E. (1998) Pingers, porpoises and power: uncertainties with using pingers to reduce bycatch of small cetaceans. *Biological Conservation* **84,** 141–146.

Di Natale, A. (1989) Marine Mammal Interactions in Fishery Activities: the Mediterranean case. *Paper presented at 1st International Conference on Marine Mammals, Riccione, 30 August–2 September 1989.*

Donoghue, M. F. (1994) New Zealand. Progress report on cetacean research May 1992–April 1993. *Reports of the International Whaling Commission* **42,** 232–239.

Donoghue, M. F. (1995) New Zealand. Progress report on cetacean research April 1993–March 1994. *Reports of the International Whaling Commission* **43,** 265–269.

Fertl, D., Acevedo-Gutierrez, A. & Darby, F. L. (1996) A report of killer whales (*Orcinus orca*) feeding on a carcharhinid shark in Costa Rica. *Marine Mammal Science* **12** (4), 606–611.

Fertl, D. & Leatherwood, S. (1997) Cetacean interactions with trawls: A preliminary review. *Journal of Northwest Atlantic Fishery Science* **22,** 219–248.

Goley, P. D. & Straley, J. M. (1994) Attack on gray whales (*Eschrichtius robustus*) in Monterey Bay, California, by killer whales (*Orcinus orca*) previously identified in Glacier Bay, Alaska. *Canadian Journal of Zoology* **72,** 1528–1530.

Guinet, C. (1991) Intentional stranding apprenticeship and social play in killer whales (*Orcinus orca*). *Canadian Journal of Zoology* **69,** 2712–2716.

Gunter, G. (1942) Contributions to the natural history of the bottlenose dolphin, *Tursiops truncatus* (Montague), on the Texas coast, with particular reference to food habits. *Journal of Mammalogy* **23** (3), 267–276.

Heyning, J. E., Lewis, T. D. & Woodhouse, C. D. (1990) Odontocete mortality from fishing gear entanglements off Southern California. *Presented to the International Whaling Commission Workshop on passive fishing nets and traps.* La Jolla, California, 22–25 October 1990. Paper number SC/090/G24.

Hoelzel, A. R. (1991) Killer whale predation on marine mammals at Punta Norte, Argentina; Food sharing, provisioning and foraging strategy. *Behavioral Ecology and Sociobiology* **29,** 197–204.

Holleman, M. S. (1988) Killer whales stalk black cod fishery. *Alaska* **September,** 21–24 & 52.

Iwashita, M., Motoo, I. & Yukinobu, I. (1963) On the distribution of *Orcinus* in the northern and southern Pacific equatorial waters as observed from reports on *Orcinus* predation. Original title (Japanese): Shachi no shokugai Hokoku ni yoru Taiheiyo Nan-Boku Sekido Kaiiki no shachi no bunpu ni tsuite. *Tokai Daigaku Suisan Kenkyusho Hokoku. Fisheries and Marine Service (Canada) Translation Series No. 3751 (1976).* **1**(1), 24–30.

Jefferson, T. A. & Curry, B. E. (1996) Acoustic methods of reducing or eliminating marine mammal-fishery interactions: do they work? *Ocean and Coastal Management* **31,** 41–70.

Jefferson, T. A., Stacey, P. J. & Baird, R. W. (1991) A review of killer whale interactions with other marine mammals: Predation to co-existence. *Mammal Review* **21** (4), 151–180.

Kuiken, T. (1996) Diagnosis of by-catch in cetaceans. *Conference Proceedings: Diagnosis of by-catch in cetaceans*, Faculte des Sciences de Montperllier, France, 1994, 1–43.

Lien, J., Christensen, I., Lien, M. & Jones, P. W. (1988) A note on killer whales (*Orcinus orca*) near Svolvaer, Norway in November–December, 1984. *Rit Fiskideildar* **XI** (North Atlantic killer whales), 95–98.

Matkin, C. (1980) Marine mammal fishery interactions on the Copper River and in Prince William Sound, Alaska. MSc. University of Alaska, Fairbanks.

Matkin, C. O. (1986) Killer whale interactions with the sablefish longline fishery in Prince William Sound, Alaska 1985 with comments on the Bering sea. Unpublished report. Contract Number 010686. National Marine Fisheries Service, Marine Mammal Division, Juneau.

Matkin, C. O. & Saulitis, E. L. (1994) Killer whale (*Orcinus orca*) biology and management in Alaska. Contract Number T75135023. Marine Mammal Commission, Washington.

Matkin, C. O., Steiner, R. & Ellis, G. (1987) Photo-identification and deterrent experiments applied to killer whales in Prince William Sound, Alaska, 1986. Unpublished report. University of Alaska Sea Grant Marine Advisory Program, Cordova, AK 99574. 16 pp., unpublished report. University of Alaska Sea Grant Marine Advisory Program, Cordova, AK 99574. 16 pp.

McGifford, A. (1981) Assessment of impact of interference from *Orcinus orca* (killer whale) on Tasmanian dropline fishery. Unpublished Report. Australian National Parks and Wildlife Consultancy Preliminary Report for the Tasmanian Fisheries Development Authority, Fisheries Division, Hobart, Tasmania.

Nishiwaki, M. & Handa, C. (1958) Killer whales caught in the coastal waters off Japan for recent 10 years. Scientific Reports of the Whales Research Institute **13,** 85–96.

Northridge, S. P. (1991) An updated world review of interactions between marine mammals and fisheries. *FAO Fisheries Technical Paper*, No 251, Supplement 1. Food and Agriculture Organization of the United Nations, Rome. 58 pp.

Rice, F. H. & Saayman, G. S. (1987) Distribution and behaviour of killer whales (*Orcinus orca*) off the coasts of southern Africa. *Investigations on Cetacea*, G. Pilleri (ed), 231–250.

Rosa, L. D. (1995) Interactions with the longline fishery and information on the feeding habits of the killer whale, *Orcinus orca* Linnaeus 1758 (Cetacea, Delphinidae), in south and southeast Brazil. Masters Thesis. University of Rio Grande, Rio Grande.

Secchi, E. R. & Vaske, T. J. (1998) Killer whale (*Orcinus orca*) sightings and depredation on tuna and swordfish longline catches in southern Brazil. *Aquatic Mammals* **24** (2), 117–122.

Similä, T. & Ugarte, F. (1993) Surface and underwater observations of cooperatively feeding killer whales in northern Norway. *Canadian Journal of Zoology* **71,** 1494–1499.

Sivasubramaniam, K. (1964) Predation of tuna longline catches in the Indian Ocean, by killer whales and sharks. *Bulletin of Fisheries Research Station, Ceylon* **17**(2), 221–236.

Smith, T. G., Siniff, D. B., Reichle, R. & Stone, S. (1981) Coordinated behavior of killer whales, *Orcinus orca*, hunting a crabeater seal, *Lobodon carcinophagus*. *Canadian Journal of Zoology* **59,** 1185–1189.

Teshima, K. & Ohsumi, S. (1983) Note on a newborn killer whale caught alive with a trawl net. *Journal of the Mammological Society of Japan* **9** (4), 208–210.

Tilley, K. (1979) Beaten by killer whales! *The Mercury* **October 10** (Hobart, Tasmania, Australia), 1.

Tomich, P. Q. (1969) *Mammals in Hawaii*. Bishop Museum Press, Honolulu, Hawaii, Honolulu.

Visser, I. N. (1999*a*) A summary of interactions between orca (*Orcinus orca*) and other cetaceans in New Zealand waters. *New Zealand Journal of Natural Science* **24,** 101–112.

Visser, I. N. (1999*b*) Benthic foraging on stingrays by killer whales (*Orcinus orca*) in New Zealand waters. *Marine Mammal Science* **15** (1), 220–227.

Visser, I. N. (2000*a*) Orca (*Orcinus orca*) in New Zealand waters. PhD Dissertation. University of Auckland, Auckland.

Visser, I. N., Fertl, D., Berghan, J. & van Meurs, R. (2000*b*) Killer whale (*Orcinus orca*) predation on a shortfin mako shark (*Isurus oxyrinchus*), in New Zealand waters. *Aquatic Mammals* **26** (3), 232–340.

Wilson, M. A. (1981) Deep sea trevalla research project. *FINTAS* (March/April), 15–16.

Yano, K. & Dahlheim, M. E. (1995*a*) Behavior of killer whales *Orcinus orca* during longline fishery interactions in the southeastern Bering Sea and adjacent waters. *Fisheries Science* **61** (4), 584–589.

Yano, K. & Dahlheim, M. E. (1995*b*) Killer whale, *Orcinus orca*, depredation on longline catches of bottomfish in the southeastern Bering Sea and adjacent waters. *Fishery Bulletin* **93,** 355–372.