Contract Report

Entanglement of minke whales in Scottish waters; an investigation into occurrence, causes and mitigation

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Executive summary

Entanglement of whales in static fishing gear is a widespread and global phenomenon that is gaining increasing attention, not least from the International Whaling Commission that requires such mortalities to be included in calculations for sustainable takes of whales.

In Scotland minke whales are relatively numerous but they and other baleen whales are known to become entangled in creel lines and other ropes. Little is known about the scale of the problem, but European member states are required to establish means of monitoring such mortalities.

In Scotland 30 baleen whales have been subjected to post mortem examination since 1990 and for 16 of these entanglement was considered the probable (2) or actual (14) cause of death. Some other animals that had not been subject to a full post mortem are also known to have died due to entanglement.

In more than half of entangled baleen whales examined, there was evidence of rope lesions around the head or mouth, but other body parts were also often affected, so it is hard to make inferences from dead animals about which parts of the body are entangled initially.

Geographically, minke whales appear to strand with roughly equal probability depending on coastline length for all administrative regions, expect for Orkney and Shetland where they are reported more frequently and less frequently than predicted by coastline length respectively.

Only three whales were subject to post mortem examination during the study, though 23 were reported stranded. Most were in too advanced a state of decomposition to warrant examination, and some were logistically inaccessible. Two of the three animals examined showed evidence of entanglement.

About 11 or 12 baleen whales strand every year in Scotland and about half of them appear to have died due to entanglement. Not all animals that become entangled will die or become washed ashore.

The nature and extent of creel fishing activity was determined from official landings records, from interviews and from sightings of creel marker buoys collected during the summer of 2008 from a research vessel platform in the Hebrides.

Although there are over 1100 vessels that fish with creels, most seem to do so only on a part time basis. There may be as few as 300 vessels fishing with creels full time. The main target species are brown and velvet swimming crabs, lobsters and Nephrops. The main landing sites are Scrabster, Stromness, Ullapool and Kirkwall.

While the number of days at sea appears to be greatest around the Firth of Forth, this is likely due to many small boats or boats that only report occasional use of creels. Most of the catch is taken from the northern and western coasts.

We interviewed 50 vessel operators (skippers or crew) from 19 ports and visited another 30 ports to obtain background information. We covered the entire coastline including the northern and western isles.

Larger boats (>15m) tend to target crabs, especially in the northern regions, while Nephrops creels are mainly used on the west coast and by smaller vessels. Lobster is the main target for many of the smaller boats in all regions.

Most creels are steel framed, are fished in strings of typically 20 or 100, with a single main line to which the creels are attached by short ropes, and with two end ropes attached to buoys or dahns at the surface. End lines are 1.33 times the depth of the water. A buoyant synthetic rope ("polysteel" ™) is most widely used. Rope diameters are from 8 to14mm with 10mm being the most commonly reported. Total number of creels used varied from 80 to 3000 per boat. String lengths varied from 300m to 4km with a mean of 1.1km in our sample. Average amounts of rope used per boat were around 24km, with a clear relationship with vessel length.

Creel losses amounted to 7-8% of those fished per boat per year. On average this is about 90 creels per year per boat.

Assuming a fleet of just 300 boats there would be around 7,500 km of creel lines in the water throughout most of the year around Scotland. The true total is likely much higher than this when part time boats are included.

Derived estimates of rope length being used on a regional basis, based on vessel size and our interview results, suggest that the Firth of Forth and Orkney regions have the highest km.days of rope use. Parts of the Inner Hebrides are also areas of high rope use.

Sightings records of creels per km travelled in the Hebrides in the summer of 2008 suggest that the highest creel densities are to be found in the Sound of Sleat and the Inner Sound off the coast of the Applecross pensinsula.

Photos of minke whales have been collected since 1990 and a photo-library of at least 133 individual whales is held by the HWDT. Two analysts both investigated photographs of minke whales to determine the proportion of animals that bore evidence of previous entanglement – mainly through the identification of rope-like scars around parts of the body.

From these analyses an entanglement code (high, ambiguous, low or unknown likelihood of previous entanglement) was ascribed to each animal encountered. At least 5% of animals were given high likelihood entanglement codes, while up to 22% of animals had high or ambiguous codes.

Among four body sectors, the head region had the highest incidence of entanglement-like scars, suggesting possible entanglement during feeding.

There were insufficient re-sightings of scarred animals to determine the accumulation rate of entanglement scars.

The observed scarring rates are low compared with those reported in humpback whales in the Gulf of Maine (Eastern USA) and south-eastern Alaska. Using such observations to estimate the number of lethal entanglements will require some estimate of the proportion of entanglement events that result in the death of the entangled whale, which we have yet to address.

Encounter rates of minke whales in Hebridean waters have been plotted by 250km^2 grid cells, based on sightings data collected over a 20 year period. Highest encounter rates are found in the Minches. Inshore encounter rates were lower.

These encounter rates are compared with sightings rates for creel markers collected by the R.V. Silurian, using a ‘risk of entanglement measure’ (REM) that essentially provides a high value when both whales and creels are abundant and lower values where the overlap in distribution is least pronounced.

Highest REM values in the Hebridean region are found around Skye and off North and South Uist.

The same measure is applied to sightings rates of minke whales and estimates of creel density at a coarser spatial scale for all of Scotland. Highest rates are still found in the Hebrides, around Skye, but elevated REMs are also predicted for the coasts of Angus/Fife and Orkney.

Potential mitigation measures are described with reference to the measures being adopted in the US to minimise endangered whale species entanglement in the Gulf of Maine regions. Measures adopted there include Dynamic Area Management, where all gear must be removed from the water for 15 day periods when and where aggregations of whales are observed, as well as a series of gear modifications. These include the mandatory use of weighted end lines, the use of weak links connecting end lines to marker buoys, the use of sinking rope on the creel main lines, and a maximum of two buoy lines per string.

Such measures are required in the US because right whales are critically endangered. No such immediate conservation threat has been identified in Scotland. The experience in the US should help determine any potential measures that might be useful in Scotland if, in consultation with industry, it should be deemed useful to try to minimise whale entanglement, perhaps in certain high risk areas.

Further work should be directed at fine scale studies of whale movements and feeding behaviour in areas where creels are used to try to understand the risk of entanglement more clearly.

Introduction

Minke whales (*Balaenoptera acutorostrata*, Lacépède, 1804) are the smallest and most numerous of several species of baleen whale that frequent the waters around Scotland. They have occurred regularly in the records of the UK cetacean strandings investigation programme since its inception in 1990, and it has been noted that many of the carcasses that have been examined show signs of having died through entanglement in ropes of one form or another.

Entanglement of baleen whales in ropes, notably from static fishing gears such as lobster creels and gillnets, is a well known phenomenon in many parts of the world. Member states of the International Whaling Commission (IWC) regularly report in excess of 200 such entanglements worldwide annually (see e.g. IWC 2009, Annex J), and these are mainly just those that end up on the market.

Northern right whales (*Eubalaena glacialis*) are subject to critical levels of entanglement mortality in lobster pot and gillnet fisheries in the north-eastern US and Atlantic Canadian waters (Kraus 1990, Caswell *et al*. 1999). Humpback whales are also known to become entangled not infrequently in both Canadian and US Atlantic waters (Lien 1994, Robbins and Mattila 2001), with between 48 and 65% of whales photographed every year bearing some evidence of previous entanglement. Neilson *et al*. (2007) found that between 52 and 78% of humpback whales in the northern end of Southeast Alaskan (Panhandle) waters bore evidence of entanglement.

Other species known to be affected include grey whales (Baird *et al.* 2002, Bradford *et al.* 2009) and minke whales (Glass *et al*. 2008, Kim 1999), though it is probably true that any species of baleen whale that inhabits coastal waters runs some risk of entanglement in ropes and lines that people use for fishing and for other purposes.

The purpose of the present report is to review what is known about this issue, and what more can be deduced or discovered, for Scottish waters. Scotland has a large number of creel fishermen who use pots (creels) to catch lobsters, crabs and prawns (Nephrops). Minke (as well as a few humpback and fin) whales are found right around the coasts, and entanglement is known to be one of the more commonly recorded causes of death among stranded whales. Although there is no *a priori* reason to suspect that entanglement of whales might represent a conservation issue in Scotland, all incidental catches or killings of cetaceans need to be examined in order to address obligations under the Habitats Directive. Furthermore, minke whales in particular are subject to annual hunts by Norwegian and Icelandic whalers in adjacent waters, and from the same biological stocks. The IWC's management procedure for baleen whale populations explicitly requires that mortality from bycatch in fisheries be taken into account when setting allowable catch levels for whaling. Any mortality due to entanglement in Scottish waters would therefore need to be taken account of by the IWC in setting catch limits for Norwegian and Icelandic whaling operations. In addition to this, entanglement of whales in fishing gear, even when not fatal to the whale, can cause considerable economic loss to the individual whose gear is removed.

The objectives of the project were set out as follows:

1. Collate and review available data on past and present minke whale strandings where entanglement is a contributing factor.

2. Conduct full scale necropsies on stranded minke whales where incidence of bycatch is evident, with the purpose of informing the origin of rope marks.

3. Investigate the extent of the implicated fisheries in Scotland (including the identification of areas of high activity) and gear configurations.

4. Using existing sightings networks, investigate whether there is evidence of previous entanglement in live whales.

5. On the basis of the above information, determine the likelihood of co-occurrence between minke whales and fisheries, including any evidence of seasonality in such occurrences.

6. Identify areas around Scotland where the "risk" of entanglement is high, with recommendations for possible mitigation proposed in these areas.

The report is divided into four chapters. Chapter 1 deals with data collected under the UK strandings scheme, and addresses objectives 1 and 2. Chapter 2 addresses objective 3 and deals with creel fisheries in Scotland. Chapter 3 addresses objective 4 by examining photographic data held by the Hebridean Whale and Dolphin Trust (HWDT). Chapter 4 addresses the final two objectives (5&6) and identifies areas of highest likely risk to minke whales and creel fishermen. Some initial thoughts on routes to the development of possible mitigation measures are elaborated. Each chapter has its own brief discussion.

During the project, at the request of Scottish Government, a leaflet was also prepared describing the aims and objectives of the project. This is included as Appendix 1. Appendix 2 shows a protocol we have developed for further work, while Appendix 3 is an MSc thesis from the University of St Andrews that deals with an analysis of the photographic database that is described in Chapter 3 in more detail.

Chapter 1: Stranded Animals:

Objective 1: Collate and review available data on past and present baleen whale strandings

Analysis of Strandings Data

Data from the UK strandings scheme that have been collected since 1989 indicate that nearly three hundred baleen whales have been record as stranded over these twenty years throughout the UK. Most of these (255 or 86%) have been minke whales *Balaenoptera acutorostrata*, the remainder has included fin *Balaenoptera physalus* , humpback *Megaptera novaeangliae* and sei whales *Balaenoptera borealis*. The majority of UK baleen whale strandings have occurred in Scotland (69%), and three quarters of all minke whale strandings have occurred in Scotland.

Table 1: Records of baleen whale strandings in the UK 1989 to 2009, by species.

Baleen Whale Species	Totals	Scotland	England	Wales	Northern Ireland	Isle of Man
Minke	255	192	50	5	7	1
Sei	3	1	2			
Fin	27	6	18	3		
Humpback	12	5	5	1	1	
All 4 species	297	204	75	9	8	1

Within the UK as a whole, only 44 of the 297 stranded baleen whales have had a cause of death officially attributed to them, of which 17 (38%) were known or inferred cases of entanglement. Other causes of death included starvation, live stranding, still birth and physical trauma such as boat strikes. However, the cause of death is usually only affirmed when an animal has been necropsied and a veterinary pathologist has inspected it. Sometimes necropsied animals may be suspected of having died due to entanglement, though the cause of death is recorded as unknown. Other cases may involve animals that have not been necropsied and for which no cause of death has been officially recorded, but for which circumstantial evidence, such as the presence of ropes wrapped around the animal, can strongly suggest entanglement as a factor.

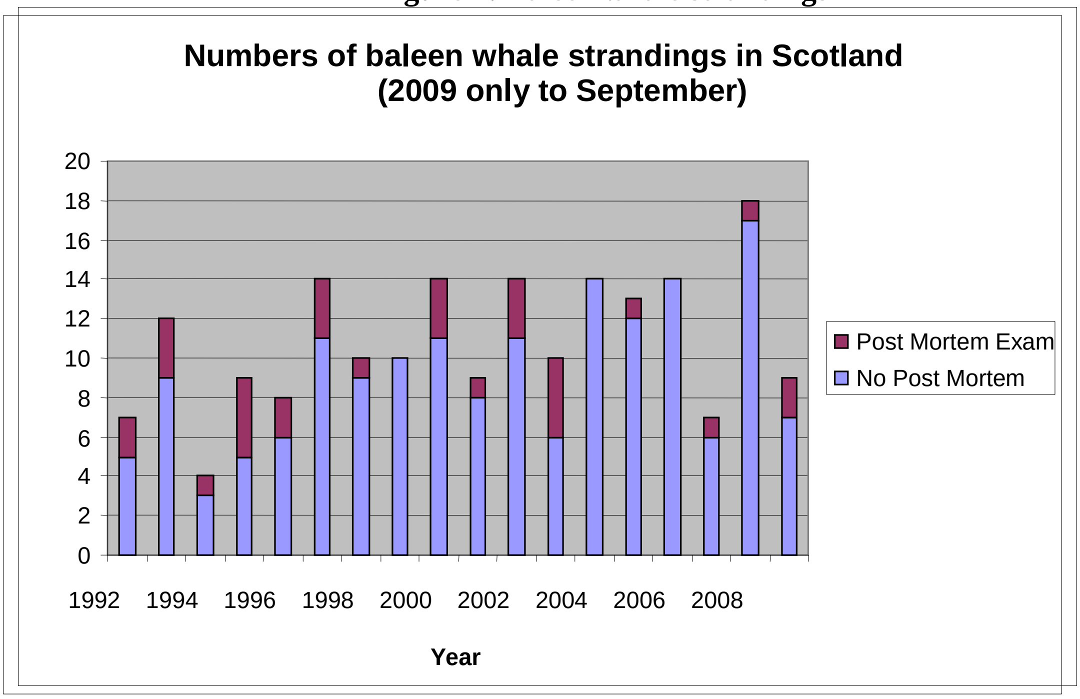
Strandings records for Scotland from 1992 to September 2009 were reviewed in more detail. A total of 202 records of baleen whale strandings (6 fin whales, 5 humpbacks and 191 minke whales) were recorded stranded in Scottish waters during that time period. Of these, some 30 (17% of baleen whale strandings) had been subject to post mortem examination. In 16 cases of those examined (53% of post mortem examinations of baleen whales) the cause of death was thought probably (2) or actually (14) to have been due to entanglement. Of the remainder, 4 were live strandings, 2 were stillborn foetuses, 2 were thought to have died of post weaning starvation, and in 6 cases the cause of death had not been determined. Entanglement is the largest single identified cause of death among baleen whales subject to post mortem examination, and is reported much more frequently among Scottish animals than those from elsewhere in the UK.

We also found that there was some evidence for entanglement for another four animals (ropes reported around the carcase) for which no post mortem examination had been conducted.

Overall, there was evidence of entanglement for 20 of the 202 stranded baleen whales in Scotland, though for many strandings that were not examined in detail evidence for entanglement could have been missed, while the advanced state of decay in many cases would have limited the possibility of detecting any rope marks.

The trends in strandings, the numbers of animals examined post mortem and numbers of cases of probable entanglement-caused death are shown below in Figures 1 and 2.

Figure 1: Baleen whale strandings



Existing post mortem reports for 28 baleen whales examined by the SAC between 1992 and September 2007 were studied with the aim of summarising the types of skin damage reported for animals whose cause of death was attributed to or suspected of being due to entanglement. One reason for this exercise was to determine which parts of the body are most often scarred through entanglement in order to assist in determining the frequency of non-fatal entanglement among live whales that have been photographed.

Figure 2: Causes of death determined at necropsy by SAC staff

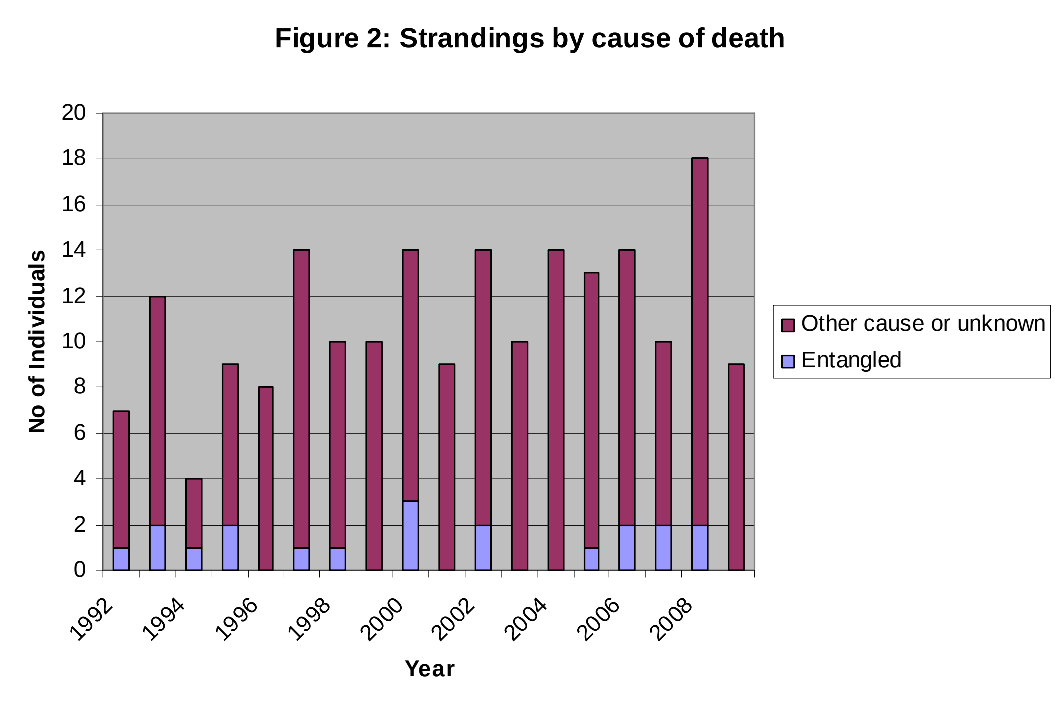


Table 2: Summary of Relevant Information from Scottish Post Mortem Reports

SAC Ref No	Summary account of damage associated with entanglement	Stomach contents[1]	Photographs?
M2239/92	'Damage' to tail, flippers, head	Fish present	No pictures
M2895/92	Several skin lesions looked old;	Stomach full	No pictures of lesions
M0961/93	Abrasions on upper surface of tail flukes (diagramme in PM report)	Some food in stomach	Yes - photo of tail stock
M1667/93	Net caught across back of mouth -> necrosis		Yes.
M1190/94	Corner of jaw to eye; dorsal surface of tail stock		No Pictures
M1723/95	Skin missing; baleen missing; too rotten	Fresh food in oesophagus	No Pictures
M2124/95	Rope marks back of mouth; mid body area, dorsal fin torn	Food in oesophagus	No Pictures
M2193/97	Rope marks around tail stock and flukes	Fish in stomach	Yes - rope marks
M0803/98	Ante-mortem damage to angle of jaw- possibly rope; maxilla absent, mandible missing; baleen gone	Stomach empty	Yes - head and damage to mouth
M053/00	Rope cuts dorsal and ventral tail stock; skin damage around angle of jaw	Stomach full	Yes - "including tail stock"

[1] Presence of food in the stomach usually indicated a traumatic death rather than death due to starvation or disease.

M070/00	Skin missing too rotten	Stomach with fish	No pictures of lesions
M192/00	Small cuts in jaw; creel rope in mouth	No food	Yes - rope marks in mouth
M005/02	Rope marks on flukes, cut in tail stock	Large amount recent	No Pictures
M086/02	Rope marks mouth to mid body	Food present	No Pictures
M209/07	Rope or cable marks on epidermis lateral right flank	Not examined	Yes- cable marks - flank
M211/08	Rope marks on epidermis – flank, tail	Not examined	Yes- probably rope marks

Table 3: Summary of location of rope marks by body region

Total number of descriptions	**16**
No recent damage recorded / discernible (usually no skin left)	3
Damage to mouth / head region	9
Damage to tail stock or flukes	7
Damage to mid region of body	6

A summary of the findings is shown in Tables 2 and 3. A fin whale examined on November 1st 2007 and a minke whale examined on 16th January 2008 under the present project have also been included in this table. In 9 out of the 16 minke whales (56%) evidence of entanglement was associated with the mouth. This suggests entanglement in these minke whales has occurred while feeding. In seven cases skin lesions were reported around the tail stock, although in three of these there was also evidence of entanglement in the mouth region. In only one case was there any record of damage to the dorsal fin associated with entanglement.

These observations, though limited in number, suggest that entanglement may often occur when the mouth is open, or while feeding, although it is also entirely possible that some fraction of entanglements also occur by the tail region alone (suggested in three or 19% of 16 cases). These observations also suggest that only a small proportion of fatal entanglements result in damage to the dorsal fin, the most obvious and easily photographed part of whales seen at sea, although in six out of 16 cases (37%) damage was evident in the mid region, which might be visible in a live whale from the surface. Marks on the head and tail are usually less easy to detect on live animals from the surface.

An important assumption here is that the marks left on a whale after a fatal encounter with fishing gear will have similar characteristics (in terms of distribution over the body surface) to those observed in live whales that have survived an entanglement. It is conceivable that rope lesions to some parts of the body are more frequent in fatal entanglements that in entanglements that result in the animal escaping.

Aside from helping to identify the types of lesions associated with entanglement, the above analysis also helps to inform on how entanglements might occur. While a majority of entanglements involve some lesions to the head region and especially the mouth, it is clear that whales can become entangled in a variety of ways. This suggests that there is no simple single behavioural characteristic involved.

Geographical Distribution

As a final part of our review of the strandings data we have also examined the geographical distribution of stranded baleen whales around Scotland. To this end we have examined the number of reported strandings 2002-2008 for all Scottish regions and compared these with the length of coastline for each region. Coastline lengths for unitary authorities were taken from the online Scottish Environment Statistics for 1998 published by the Scottish Office (http://www.scotland.gov.uk/library/stat-ses/sest2-1.htm). We have compared the number of reported strandings with the expected number assuming that strandings should be in proportion to coastline length. Pearson's Chi squared test was used to determine whether strandings conformed to the null hypothesis that baleen whales strandings records are distributed by region in proportion to coastline length.

Our initial assessment is that strandings are not recorded in proportion to coastline length (Table 4: χ^2= 64, 13 df, p<0.001), but by far the greatest discrepancies are found in Orkney and Shetland, where 31 and 8 baleen whales strandings have been recorded respectively, whereas 15 and 26 should have been expected based on the lengths of their respective coastlines.

Table 4: Whale strandings by region & coastline length: Scotland including Northern Isles

All regions including Northern Isles	All reported strandings	% of Scottish Coastline	Expected no of strandings (rounded)	Chi Squared
Region				
Aberdeenshire	9	2.02%	4	2.64
Angus	2	0.58%	1	0.34
Argyll and Bute	39	21.14%	43	0.43
City of Edinburgh	1	0.36%	1	0.07
Dumfries and Galloway	3	3.65%	7	6.59
East Lothian	4	0.64%	1	1.81
Fife	7	1.65%	3	1.89
Highland	57	27.86%	57	0.00
Moray	3	0.82%	2	0.59
North Ayrshire	3	1.59%	3	0.02
Orkney	31	7.24%	15	8.50
Shetland	8	12.76%	26	40.68
South Ayrshire	1	0.76%	2	0.30
Western Isles	36	18.92%	39	0.19

When these two regions are excluded, baleen whale strandings are indeed reported around Scotland in proportion to the lengths of coastline by region (Table 5: χ^2=15.17; 11df, p=0.17). This suggests that whales (or their carcases at least) are present in broadly similar densities around the mainland part of the country and that there are no discernible biases in reporting *by* *region* at least. Baleen whales by virtue of their size are not easily overlooked and also take a long time to disintegrate. A humpback whale first reported at Auchmithie beach by Arbroath in February 2007 was still largely intact in July 2009. This helps to maximise the probability that a stranded whale is reported. Human population density is therefore less likely to affect reporting efficiency for whales than for smaller cetaceans.

Table 5: Whale strandings by region & coastline length: Scotland excluding Northern Isles.

Region: excluding Northern Isles	All reported strandings	% of Scottish 'Mainland' Coastline	Expected No of Strandings	Chi Squared
Aberdeenshire	9	2.53%	4	2.59
Angus	2	0.72%	1	0.33
Argyll and Bute	39	26.42%	44	0.54
City of Edinburgh	1	0.45%	1	0.07
Dumfries and Galloway	3	4.56%	8	6.84
East Lothian	4	0.80%	1	1.79
Fife	7	2.06%	3	1.85
Highland	57	34.83%	57	0.00
Moray	3	1.03%	2	0.57
North Ayrshire	3	1.99%	3	0.03
South Ayrshire	1	0.95%	2	0.32
Western Isles	36	23.66%	39	0.26

Although there is little difference in the numbers of observed and expected whale strandings among the mainland *regions*, it is noticeable that all the eastern regions (unshaded cells in the region column) have marginally more strandings than expected while all the western regions (shaded cells) have marginally fewer than (or the same as) expected. When west coast regions are compared to east coast regions there are in fact significantly more than expected strandings down the east coast and significantly fewer on the west coast. (χ^2=8.95; 1df, p=0.0028). This suggests either that there are more whales dying and stranding on the east coast or that reporting of carcases is better on the east coast which is more densely populated. If whales stranded on the west coast as frequently per km of coastline as those on the east coast, one would expect about ten more whales per year to be reported from west coast locations. It is not possible to say whether this difference might be explained by under-reporting. The possibility of higher abundances and/or more whales dying in east coast waters is revisited in Chapter 4.

Overall, while there is reasonably good agreement between the number of whales reported stranded by region and the coastline lengths, this is not true for the Northern Isles. About one whale more than expected is reported from Orkney coasts every year, and about one whale per year less than expected is reported from Shetland. Again, this may be due to reporting efficiency or to differences in whale densities (more whales around Orkney than Shetland) – or more importantly, differences in the numbers of whales dying in Orcadian waters compared to those around Shetland.

Necropsies

Objective 2. Conduct necropsies of stranded whales where incidence of bycatch is evident, with the purpose of informing origin of rope marks.

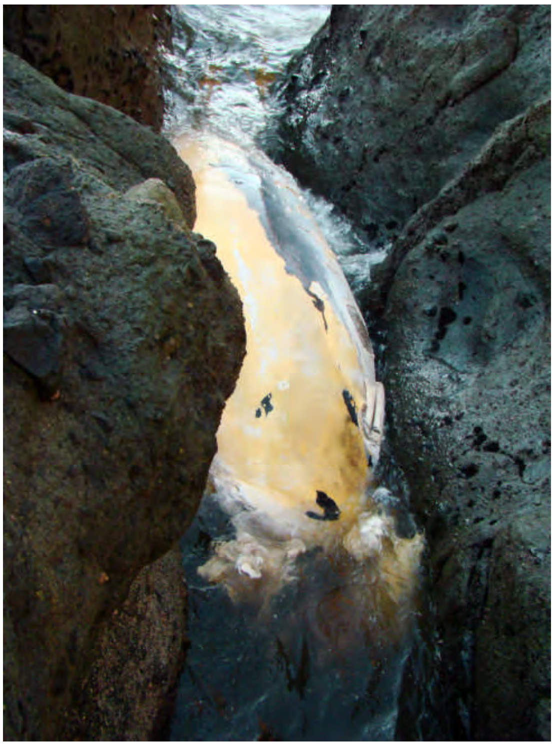
Over the course of the project (October 2007-July2009)23 baleen whales were reported stranded in Scotland. Two of these were fin whales and the rest were minke whales. Many of these animals were in remote places and most were clearly in an advanced state of decay where there is little hope of determining cause of death. Often, photographs sent by local authorities or members of the public can confirm that there is little point in attempting a necropsy (see Figure 3 for example).

Figure 3: Minke whale in advanced state of decomposition: Port William, Dumfries and Galloway, March 2008.

Of the 23 stranded baleen whales in Scotland between October 2007 and July 2009, 14 were in advanced to skeletal stages of decomposition. Of the remaining 9, 2 had live stranded, so that only 7 were in fresh / fair to moderate states of decomposition. Not all of these could be examined owing to various logistical constraints. One was disposed of promptly by a local council, while remoteness and staff availability constrained other cases. Figure 4 shows another minke whale at Kincraig Point, close to St Andrews, that could not be accessed for safety reasons.

Overall, three baleen whales were subject to post mortem examination during the project. For two of these – a fin whale at Stoer in Highland and a minke whale at Westray in Orkney, the cause of death was determined as probably entanglement (a third animal – a minke at Islay had been hit by a ship). Another animal was reported floating at sea entangled in creel lines, though it was well decomposed.

Figure 4: Minke whale wedged in a gully at Kincraig Point, Fife November 2008



There were therefore only two animal carcasses that were examined by SAC staff and that had evidence of entanglement. The first was a slightly decomposed fin whale that stranded at Stoer near Lochinver in the Highlands in October 2007. This animal was in a moderate state of decomposition and had several linear braided abrasions running around at least part of the abdomen of the animal. These abrasions or impressions appeared to have been made by ropes or cables of around 5cm in diameter, and appeared rusty in colour, suggesting they may have been metal wires. The impressions had been made ante-mortem, as subcutaneous haemorrhaging associated with the impressions was detected. The cause of death was given as probable entanglement. (See Figures 5-8). An examination of the stomach contents was made at the site, but no evidence of recent feeding was found..

The second animal that was examined was a moderately decomposed minke whale that stranded at Westray in Orkney in January 2008 (see Figures 9-12). This animal also had several linear rope marks round parts of the trunk, and again the cause of death was diagnosed as probably entanglement. A sketch of the scarring patterns was made at the time, but this prompted us to develop a more systematic template onto which we could in future record any rope marks, scars or abrasions on any stranded whales in future. This is shown in Appendix 2.

In addition to these two animals that were examined on the beach, another minke whale was reported floating at sea, entangled in creel lines, at Gills Bay on the North Coast of Caithness east of Thurso. A humpback whale was also found alive and entangled in creel lines at Stronsay in Orkney in May 2008. This was released alive, but some of the pictures taken at the scene illustrate the ways in which creel lines can become caught around a whale's tail (Figures 13 and 14 below).

Figure 5: Stranded fin whale at Stoer, Highland, October 2007

Figure 6: Rope marks (possibly metal) on the flank of the animal

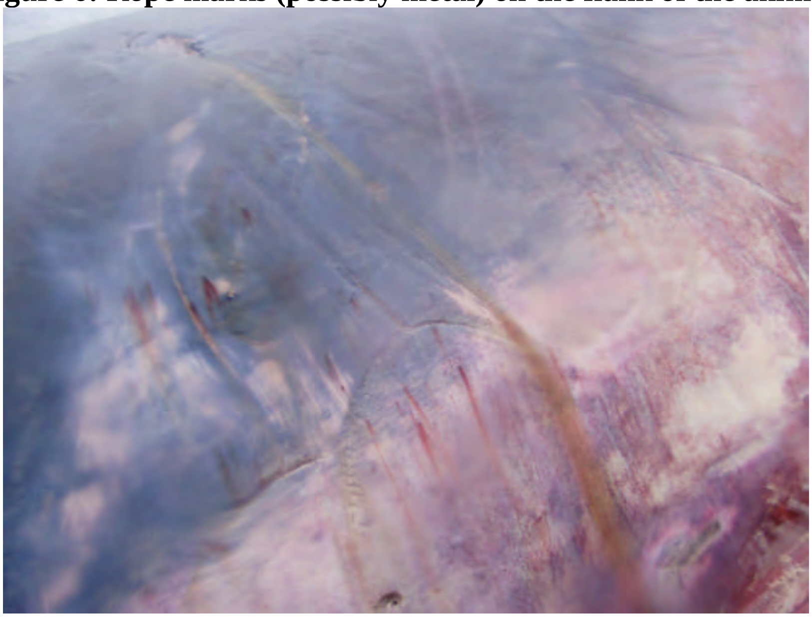


Figure 7: Rope marks showing braiding with scale

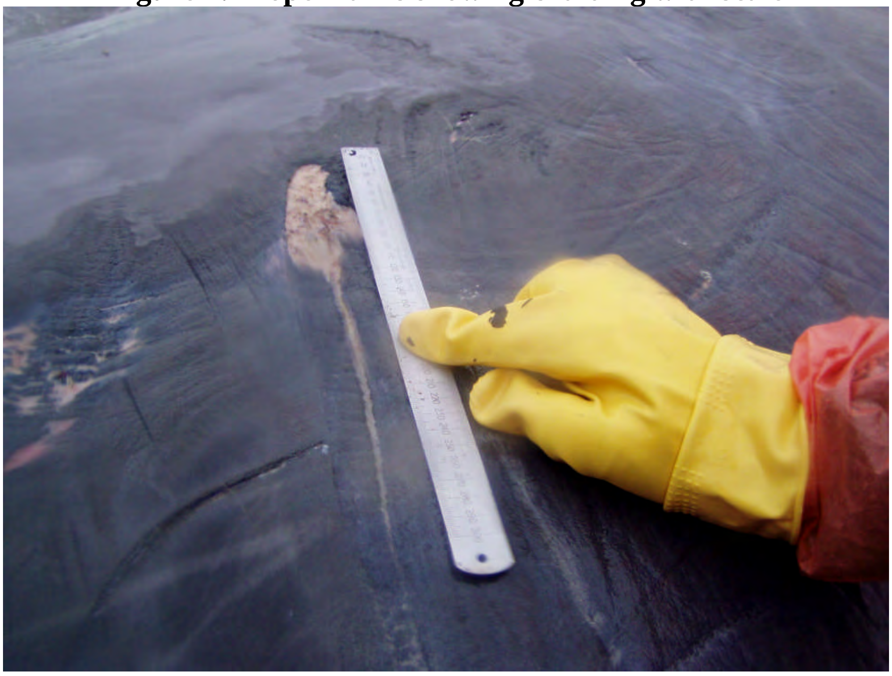


Figure 8: Subcutaneous haemorrhaging associated with rope marks

Figure 9: Minke whale stranded at Westray, Orkney, January 2008

Figure 10: Tail showing marks typical of rope entanglement (see also Fig 14)

Figure 11: Probable rope marks – too decomposed to determine braiding

Figure 12: Further possible rope marks on Westray Minke

Figure 13: Humpback entangled in Creel line at Stronsay in Orkney

Figure 14: Close up of trail of Stronsay humpback

The fin whale at Stoer appears to have become entangled in some heavy cables or wires, such as those used by trawlers for example, and the 50mm wide abrasions do not suggest any interaction with creel boats. We are unable to do more than speculate on the cause or circumstances of the entanglement.

The minke whale at Westray was too decomposed to make any detailed assessment of the types of rope involved in its entanglement, but these appear to have been more in line with the size of ropes used in creel fisheries or other static gear (typically 6 – 14mm polypropylene ropes).

The two whales encountered at sea were both entangled in creel lines.

Although every effort was made to attend as many strandings as practicable, logistical issues, access and the decomposed state of many animals limited our ability to assess rope marks on many animals. As a result of the present project SAC and SMRU have agreed to continue to collaborate on this issue in the future and will continue to examine suitable whale carcasses for evidence of entanglement to try to elucidate how whales become entangled and by which sorts of ropes and fishing gear. SAC will use the agreed template (Appendix 2) to record the locations of any rope marks on further stranded whales.

Discussion

Our examination of the strandings reports suggests that at least half of all baleen whales that strand in Scotland may have died due to entanglement. Creel lines are specifically mentioned in several instances. There are about 11 or 12 baleen whale strandings reported every year in Scotland so it is not unreasonable to suppose that 5 or 6 of these are likely to have run foul of creel lines or other fishing gears. Not all entangled whales will wash ashore. The proportion of whales that become entangled but escape is unknown. The proportion of whales that strand once they have died is also unknown.

Our examination of previous records did not suggest any obvious single way in which whales become entangled. At least half appear to have ropes associated with the head region, but for some it is just the tail. Further work will be needed, possibly involving more detailed examination of live animals to elucidate this issue.

We found that slightly more whales than expected are reported from Orkney and fewer than expected from Shetland. There were also slightly fewer than expected on the west coast compared to the east coast. It is not possible to say whether these differences are due to actual differences in the numbers of dead whales present in these regions or to differences in human reporting efficiency, though the longevity of whale carcases (which may make them more likely to get reported) might suggest there is a difference in the number of carcases present. Whether this has any relationship with entanglement issues is a moot point.

The examination of dead whales in order to determine whether and how entanglement may have occurred is difficult both because of the remoteness of many strandings sites and because many of the stranded whales are very well decomposed by the time they become stranded. Careful examination of freshly dead whales in the future may reveal more, but this will take time.

Chapter 2: Creel Fisheries.

Objective 3: Investigate the extent of the implicated fisheries in Scotland (including the identification of areas of high fishing activity) and gear configurations.

Introduction.

Whale entanglements in various sorts of rope are clearly not uncommon. We assume here that most such ropes are associated with creel fisheries. The reasons for this are that other potential sources of rope for entanglements are much less abundant in the marine environment than the ropes associated with creel fishing and because creel or pot lines are frequently cited as the cause of entanglement in strandings reports. Other potential causes of entanglement might include lines associated with trawling, with moorings or with other forms of static gear such as gillnets. Trawl entanglement seems inherently less likely than static gear entanglement, because the warps and lines associated with trawls when they are in the water are usually taught, providing little opportunity for a whale to wrap a line around itself. Furthermore, there is relatively little line associated with each trawl – perhaps a few hundred metres. Any close encounter between a whale and a trawl would seem more likely to end with the animal becoming caught in the trawl and possibly entangled in the webbing. Abandoned trawl netting is widespread and at least one minke whale appears to have been killed through 'entanglement' with a piece of trawl netting.

Mooring ropes could theoretically entangle a whale, but these are usually only found in a very restricted proportion of the sea-space, mostly in harbours and anchorages where one might expect whale abundance to be very low. By far the most common form of rope in the water around the UK belongs to static fishing gears, as anyone who has seen the number of marker buoys in coastal waters around the UK can attest. The two major fishery types are static nets and creels or pots. In Scotland creel fishing dominates this sector. In 2008 there were just 738 fishing days at sea by Scottish boats using all forms of gillnets and nearly 56,000 days by Scottish boats using pots or creels.

In this section we have assessed the nature and extent of creel fisheries, aiming to determine the amount of rope typically deployed in coastal waters, and the distribution of creel fishing effort around the country.

Methods

In order to better understand the nature and scale of Scottish creel fisheries we relied upon three sources of information. Firstly we used the existing landings records collated by Marine Scotland to determine the overall scale of fisheries in terms of the numbers of boats and distributions of landings of shellfish taken in creels. Secondly, by touring the ports of the country, we interviewed creel fishermen in as wide a range of locations and as wide a range of vessel types as possible. Thirdly, for the west coast alone, we have collated sightings data of creel marker buoys in inshore waters, as recorded during research cruises by the HWDT vessel Silurian. With these sightings we have compared the observed and the reported fishing effort distribution, and can also observe some of the fine scale patterns of creel deployment.

Fleet statistics are collected by fishery officers around the country. All boats over 10m in length are required under EU law to complete logbooks that detail the methods of fishing employed, the number of days at sea and the landings. Data on under-10m boats are mostly collated from landings slips and sales notes. These data are primarily intended to monitor landings, and the associated effort data are therefore not always as reliable as could be hoped, but nevertheless provide an overview of trends through time and of effort distribution by region. Data are held in Edinburgh, but also provided to the Marine and Fisheries Agency in London who hold a UK database of fishing fleet activity. Data were provided by the MFA to include the landings by ICES rectangle and by gear type on a trip by trip basis, which includes the duration of each trip. "Days at sea" is therefore the unit of fishing effort. Some data are held on more detailed fishing effort, but previous analyses of these same data has shown that the recorded effort data (e.g. number of pots or gillnet lengths used) are not a reliable reflection of actual fishing effort. There is no mandatory requirement to report detailed fishing effort so we have only used days at sea as a primary record of the amount of fishing effort.

Because effort data were made available by trip we could also determine how many vessels in which areas are recorded as having made fishing trips using creels.

Interviews were conducted by one of us (A. Cargill) during many trips along and around the coast. Interviews were semi-structured. The interviewer did not use a form, but rather engaged correspondents in conversation bearing in mind a short number of key questions and a long number of less essential ones. Assessments were made at some ports where no fishermen could be found, based on visual inspection of the boats tied up and from conversations with other fishermen or port officials.

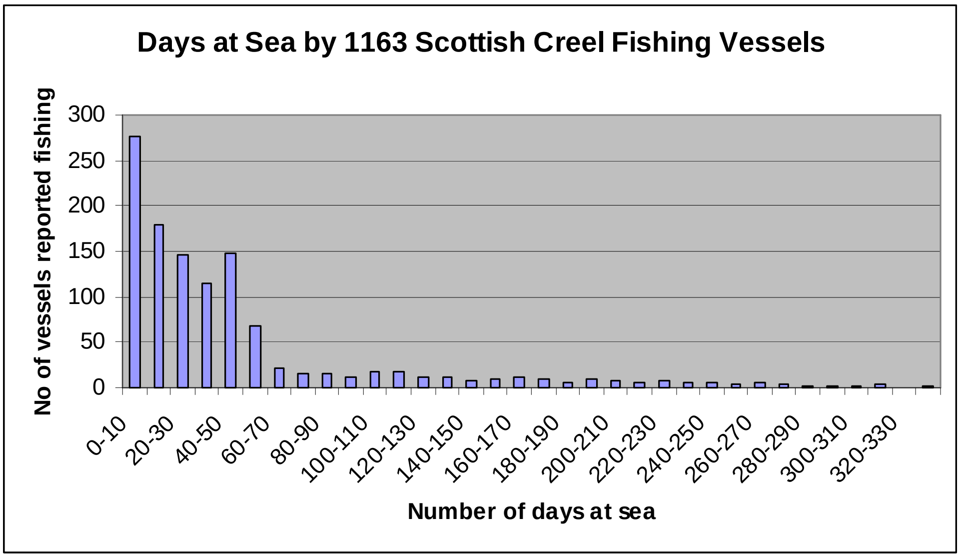
The Silurian is a 16m ketch that is used by the HWDT to survey the coastal waters of western Scotland for whales, porpoises and dolphins every summer. During the summer of 2008, observers on board the Silurian also collected sightings records of creel buoys that mark the ends of lines of creels, in order to map the distribution of creel fishing effort in coastal waters. Sightings of creels have been standardized by tracklines length to provide an index of creel density at the 10 minute scale.

Results

Official Statistics

In 2008 there were 1163 Scottish registered vessels recorded as having fished with pots (=creels). By examining how many days each of these vessels had been reported to have fished with pots, it becomes clear that a majority are probably part time vessels (see Figure 15).

Figure 15: Distribution of fishing effort by vessels in the Scottish fleet



Some vessels known to us as trawlers appeared among the list of boats as having fished with creels. Small amounts of creel fishing effort by vessels that are primarily trawlers may be recorded in order to maintain a track record in a fishery as a hedge against any future fishing restrictions. Of the 1163 boats recorded as fishing with creels in 2008, 866 were reported to have fished for fewer than 50 days, and 457 of those for fewer than 20 days. Discounting vessels that were recorded as having fished for less than 50 days leaves a ‘more-than-minimal-time’ fleet of 297 vessels. Even among these vessels however, there are appear to be a large number of part-time or seasonal boats. A full-time boat might be expected to fish for at least 150-200 days per year - allowing for poor weather, maintenance etc. Only 92 vessels were reported to have fished with pots for more than 150 days in 2008.

By examining the landings of shellfish taken by creels on a port by port basis, we can also determine something of the spatial distribution of creel fishing around the country. There were 222 landing creeks at which creel landings were recorded in Scotland in 2008. For only 124 of these did landings exceed 10 tonnes. The top thirty ports, in terms of live weight of tonnes landed, are shown in Table 6. Total landings exceed 13,800 tonnes live weight. The main species are lobster (1 Kt), crabs (brown crab (7.5Kt) and velvet swimming crab (2.7Kt)) and Nephrops (1.7Kt). Green crabs (205t), whelks (271t), crawfish (6t) and a few other species make up the rest.

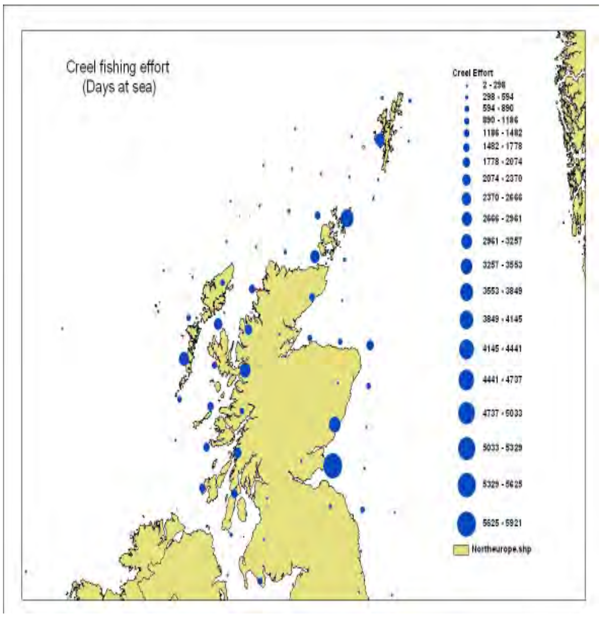
Table 6. The 30 main creel landings ports as defined by tonnages of reported landings, broken down by species.

Landing port	Total tonnage landed by creels	Velvet crabs	Brown crabs	Crawfish	Green Crab	Lobsters	Nephrops	Whelks	Others
Scrabster	935.51	10.14	905.89		0.02	19.31			0.14
Stromness	903.42	44.54	818.35		21.34	15.58		1.67	3.61
Ullapool	832.64	0.15	782.81		0.05	6.01	43.20		0.42
Kirkwall	565.64	363.91	113.70	0.04	49.77	21.56	0.06	9.21	16.61
Westray	473.33	93.77	348.92	0.01	6.61	19.23			4.80
Loch Scridain (Isle of Mull)	396.06	36.67	311.77	0.18	1.44	24.02	21.90		0.07
Tingwall	370.49	176.91	159.44	0.01	15.79	18.32			0.02
Fraserburgh	345.38	32.69	300.00			8.32	0.98		3.38
Portaskaig	311.17	131.57	152.13	0.09	5.03	18.75	1.22		2.37
South Uist and Eriskay	291.89	72.35	102.28	1.80	3.72	36.79	74.23		0.72
Fionnphort	261.61	25.57	229.62		1.51	3.13	1.69		0.09
Wick	257.48	9.39	174.46			6.49		67.14	67.13
Lerwick	200.67	128.49	17.44		5.25	4.56	44.94		0.00
Pittenweem	200.17	28.23	88.91		0.04	23.71	1.66		57.63
Arbroath	184.93	84.48	47.50			51.46			1.48
Erribol	179.34	2.15	68.25	0.00		104.54	4.37		0.03
Tarbert	173.22	60.93	24.21	0.09	4.05	4.88	75.15	1.01	3.93
Torridon	168.27	2.74	89.53	0.13	0.23	0.28	75.34		0.02
South Harris	162.44	8.75	32.75	0.03		8.87	112.04		0.00
Oban	161.87	25.42	67.24		1.71	4.96	62.00	0.55	0.54
Tiree	153.40	85.67	41.35	0.72	0.52	24.84			0.29
South Ronaldsay	151.99	30.88	95.22		3.01	22.56			0.32
Kyle	151.34	3.31	14.32	0.00		0.33	133.31		0.07
Stornoway	148.20	29.95	89.15		0.21	4.14	24.77		0.00
Tobermory (Isle of Mull)	145.53	33.87	101.92	0.00		6.29	3.45		0.00
Portree	138.52	9.11	52.29	0.00		1.21	75.90		0.01
Castlebay	138.28	33.22	73.02	0.19	3.23	23.95	4.54		0.13
Port Ellen	132.94	59.20	61.10	0.01	2.23	9.90	0.42	0.03	0.07
Northmavine	129.25	2.39	125.41			0.64			0.80

Fishing effort can be plotted by ICES rectangle, which is the smallest unit by which it is recorded in the official statistics. Each fishing trip is recorded together with the total number of days at sea during the trip, and the landings by species and by weight from each ICES rectangle fished during the trip. Most trips only record landings from a single ICES rectangle, but some vessels fish in more than one ICES rectangle during a trip. In most cases it is therefore straightforward to allocate all the days at sea for that trip to a single ICES rectangle. Where landings are recorded from more than one ICES rectangle there is no easy way to determine how much effort should be allocated to each rectangle. We have pro-rated the effort among ICES rectangles based on the proportions of the catch taken from each rectangle. Thus a 3 day trip making equal landings from two ICES rectangle would results in each of the rectangles being attributed 1.5 days at sea.

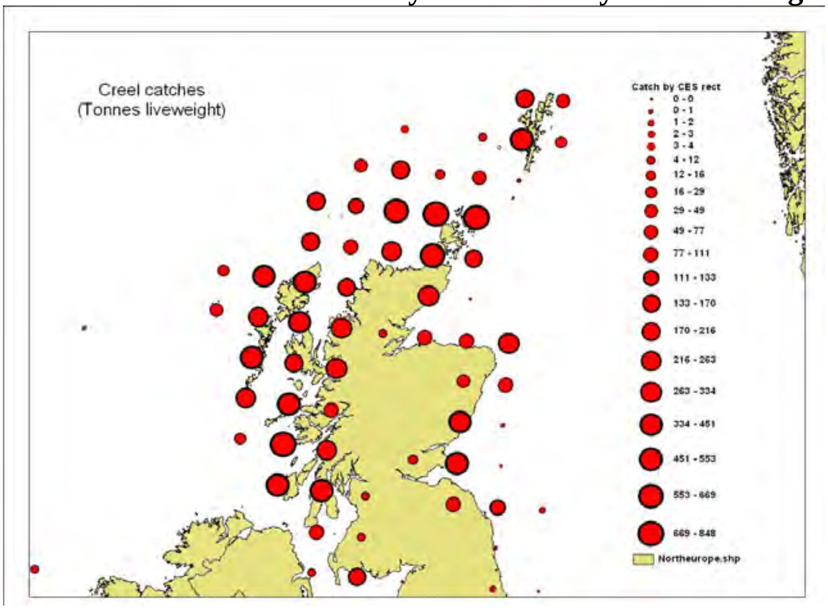
We have summed the effort (days at sea) for the entire Scottish fleet by ICES rectangle (1 degree of longitude by ½ degree of latitude). The resulting map of fishing effort is shown in Figure 16.

Figure 16: Distribution of reported days at sea by Scottish creel boats (2008)



Mapping out the number of days at sea in this way reveals that the greatest fishing effort appears to be focused in ICES rectangle “41E7”, which covers the east coast from just south of Arbroath to Dunbar. This area is home to a large number of small boats, but is not normally considered to be the centre of creel fishing. Most of the larger boats, that fish the greatest number of creels, are based further north and indeed on the west coast. If landings as expressed by tonnes live weight by rectangle of capture are presented, a rather different picture emerges, with most ‘fishing’ now focused around Orkney and along the west coast (See Figure 17).

Figure 17: Distribution of catches by creel boats by ICES rectangle (2008)



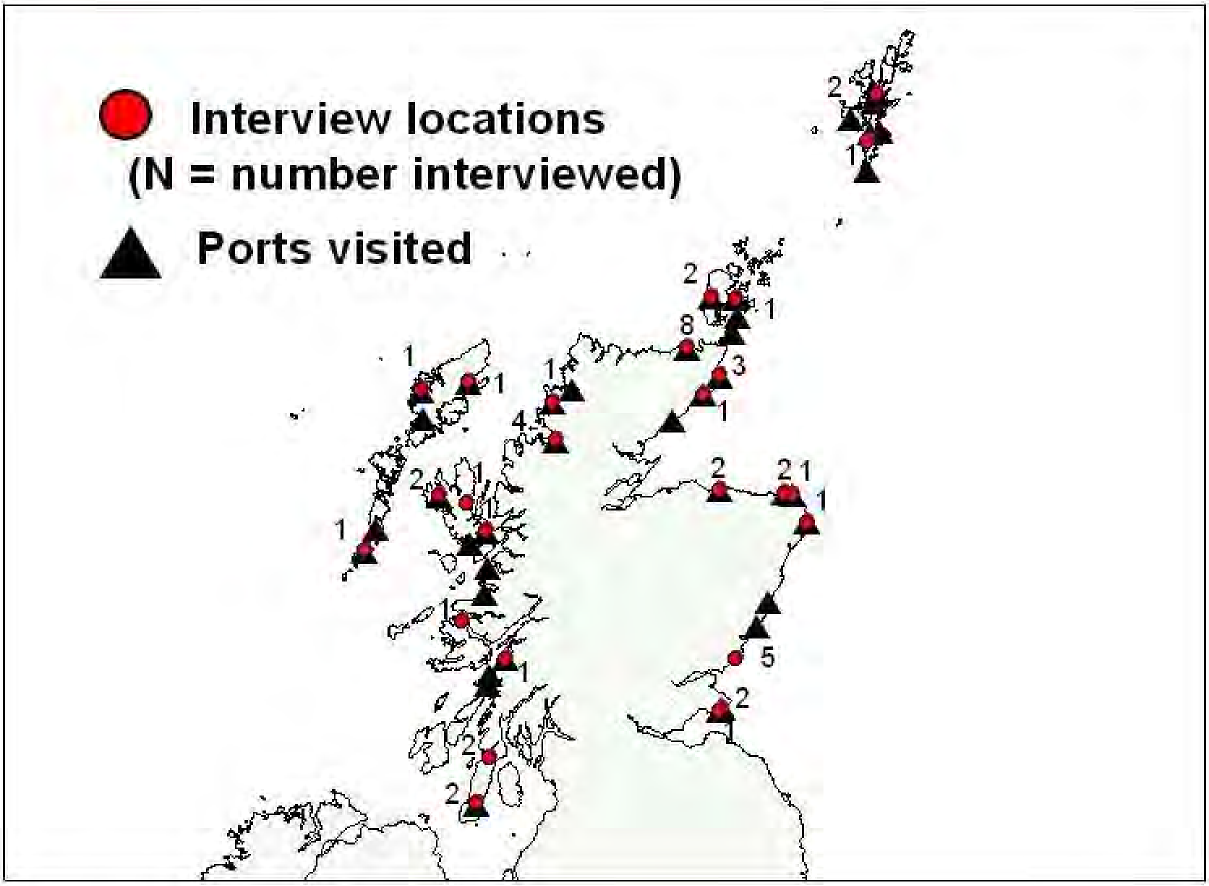
The problem with interpreting these data in the context of minke whale entanglement is that neither of these figures adequately represents the number of creels nor the amount of rope in the water. Smaller boats would be expected to set fewer creels, so that days at sea do not give a reliable indication of the distribution of creels nor the ropes associated with them. Likewise, catch rates per creel are unlikely to be the same throughout the fishing zone, especially as several species of shellfish are being targeted, so that landed weight does not necessarily give a good indication of the number of creels either. To obtain a better picture we have relied upon interviews to determine the nature and extent of creel fishing operations.

Interviews

In total 49 ports were visited (of 222 at which creel landings occurred in 2008), but it is not always possible to locate relevant vessel operators during such visits. Interviews were conducted with 50 individuals (skipper or crew members) from 50 vessels in 19 different ports. The geographical spread of ports visited and of interviews made is shown in Figure 18. Visits to ports where no-one could be located were used mainly to validate the information supplied during interviews and to ensure that there were no major discrepancies with our overall description of the fisheries concerned. Limited information on the types of creels being fished and the creel boats in harbour were collected.

The locations of ports visited and the locations of vessel home ports from interviews shown in Figure 18 suggest that geographical coverage of the country is good, which we hope will help pick up any broad scale geographical differences in creel fishing.

Figure 18: Distribution of 50 interviews and other port visits during the project



Overview
Of the 50 boats interviewed 6 described their main target species as crabs, 32 as lobsters and 11 as Nephrops. Generally speaking the larger boats focused mostly on crabs, and the lobster vessels (higher value, lower volume landings) tended to be smaller boats (all <15m). Regionally, all the boats (n=14) interviewed on the east coast (Moray to Berwick) considered lobsters to be their main target, and all were under 10m. In the Northern Isles and North coast ports (n=18), crabs and lobsters were both mentioned and there were several boats over 10m, and one of 18m. On the west coast, lobsters, crabs and Nephrops were all mentioned as primary target species (18 vessels), and again there were a number of larger vessels involved (maximum 37m).
In summary Nephrops fishing was reported confined to the west coast, all six vessels over 15m reported crab was their main target, as did a few of the smaller boats. There did not seem to be any difference in size between lobster and Nephrops boats.

Gear description
Traditionally, creels themselves were made from wood and netting, and would have been weighted individually with stones (or concrete). Most creels are now made from a steel frame, which is often covered in rubber, and netting. Examples are shown in Figures 19 & 20.

Fig 19: Wood and plastic creel with concrete weight.

Fig 20: Parlour creel with rubber coating on steel frame

Creels in this survey were mostly made of steel (93/96 including boats observed in ports when no interviews were made), with just three of 96 using wooden and plastic creels.

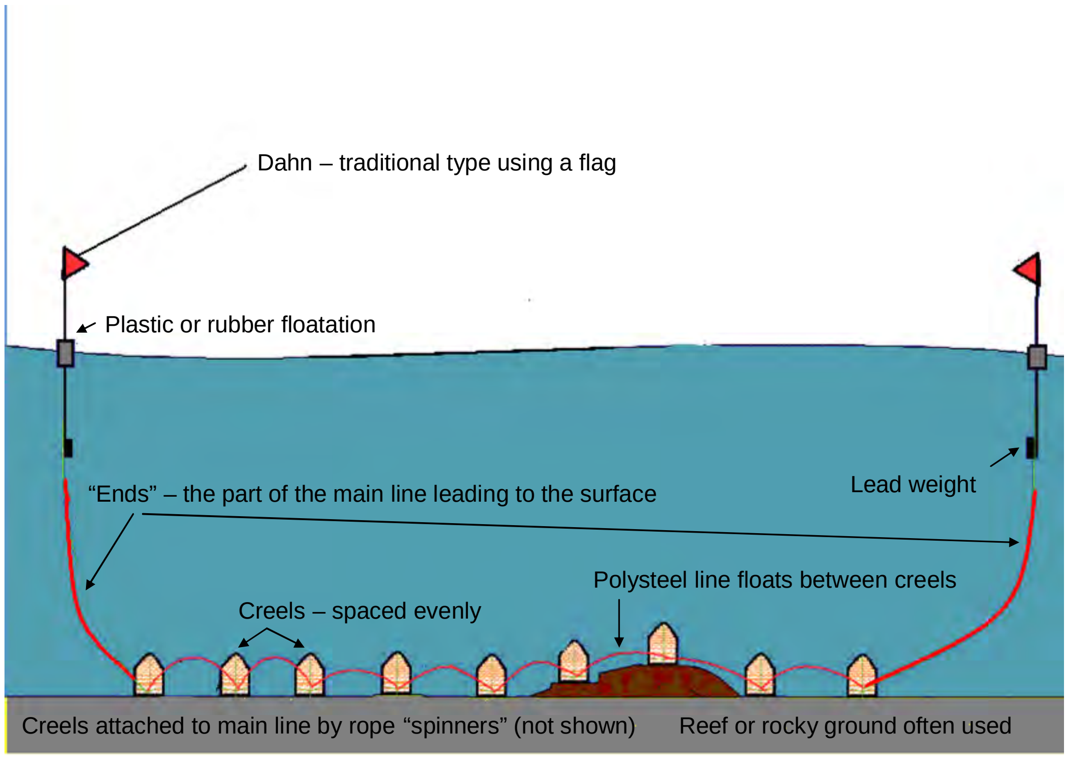
Creels are fished in strings, each attached by a short piece of rope (a spinner) to the main line. Ropes ('ends') run from each end of the string back up to the surface, where marker buoys or dahns enable the ends to be located and retrieved. Weights or anchors may also be used, but are not always used as the creels themselves are heavy. Sometimes only one end may be used, but usually both ends of the creel line are linked to the surface. All of 20 respondents on this specific question said that both ends of a creel fleet were attached to a dahn or buoy. The basic layout is shown in

Figure 21. The rope between creels usually floats up away from the bottom, in part to keep it clear of rough ground on which it may snag.

All respondents reported using polysteel rope. One reported using polyethylene rope too. Port interviews confirmed that almost all rope used in creel fisheries is polysteel. Polysteel is a trade name for a type of rope made from an extruded co-polymer (Polyethylene and polypropylene) that is variously described as being "twice the strength of [2]" or as having "approximately a 14% higher breaking load"[3] than the standard polypropylene ropes, and also as having excellent abrasive resistance. Polysteel has a typical specific gravity of 0.91[4] and will therefore float. It is used for a wide variety of marine applications including towing, mooring, lifting and securing, and is widely recognised as the rope most widely used by creel fishermen".

Rope diameters reported used were 8, 9, 10, 11, 12 and 14mm, with 42% being 10mm. The thickest ropes were used by the larger boats fishing deeper water. The diameter of the ropes used may help to compare with rope marks left on animals.

Figure 21 – Schematic diagramme of creel fishing



[2] http://www.randburg.com/ca/polysteel.html
[3] http://www.findtheneedle.co.uk/products/2110843-poly-steel-rope.asp
[4] http://www.gaelforcemarine.co.uk/ProductDetails.aspx?product_id=36171

Fishing patterns

Of 40 vessels for which an answer was given, 37 fished all year, and only 3 did not fish in the winter. 12 out of 45 reported removing or reducing the number of creels in the winter time, while the remainder reported keeping creels in the water permanently, only to be removed and replaced when they were damaged. All but two reported the summer or autumn as the best seasons.

Respondents were fairly evenly split between those who landed once a week, twice a week and every day. The routine depends largely on the port. Where buyers are local or where a processing plant exists (eg at Northbay), landings can be made every day. Otherwise landings routines may be driven by the collection routines of the buyers. Both crabs and Nephrops are fished on soft or muddy bottomed grounds, while creels for lobsters are set on broken ground, rock or rock shingle edges. This may be important when considering interactions with other species.

Vessels under 10m all reported fishing within 20 miles of their home ports, often within 10 miles. Boats larger than 10m worked grounds up to 80 miles from their home ports. Maximum depths fished ranged from 5 to 80 fathoms (9-146m) with most in the 20-30 fathom (36-55m) zone.

Quantities of gear used.

In order to determine how much rope is being used one needs to know how many creels are used per string, and what the spacing is between them, and how many strings are used. One also needs to know how long the ends are and it may help to know the length of the spinners too.

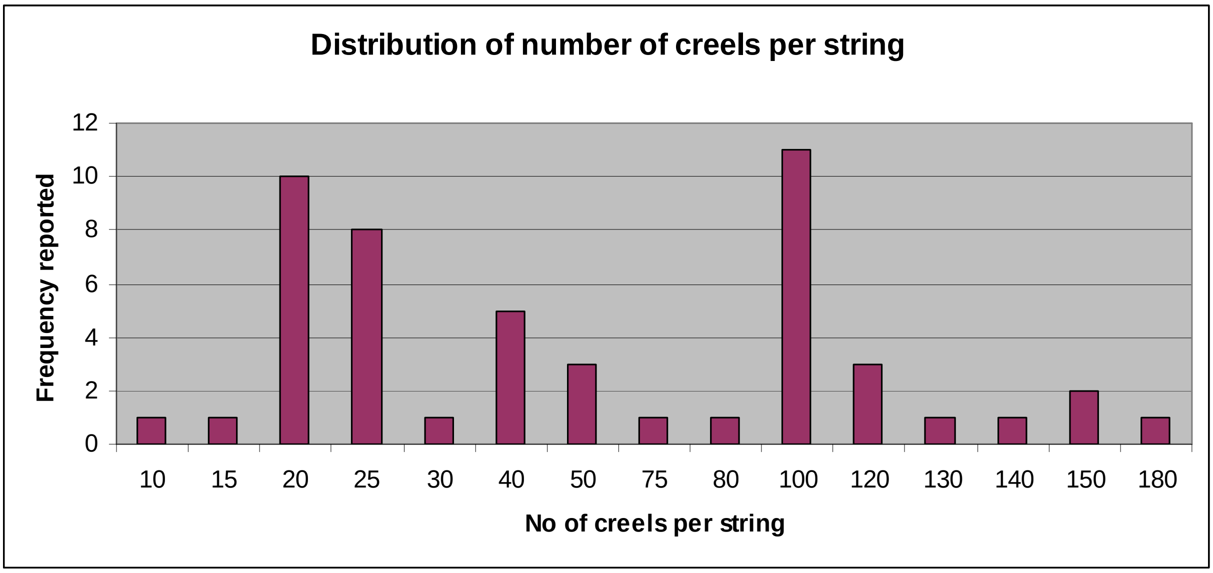
The number of creels used per string varied from 10 to 180 in the interviews, with a mean of 63. In fact the numbers of creels used is almost always a round number, with two distinct modes at 20 and 100 as shown in Figure 22.

The number of creel strings or fleets used per boat varied from 6 to 50 with a mean of 24. The number of strings used does not depend on the length of the boat. Lobster fishermen used between 6 and 50 strings, while crab boats (generally larger) used between 15 and 30, and Nephrops from 10 to 30.

The spacing of creels was closest for Nephrops at an average of 14m, then for lobsters at an average of 18m and greatest for crabs with an average spacing between creels of 24m.

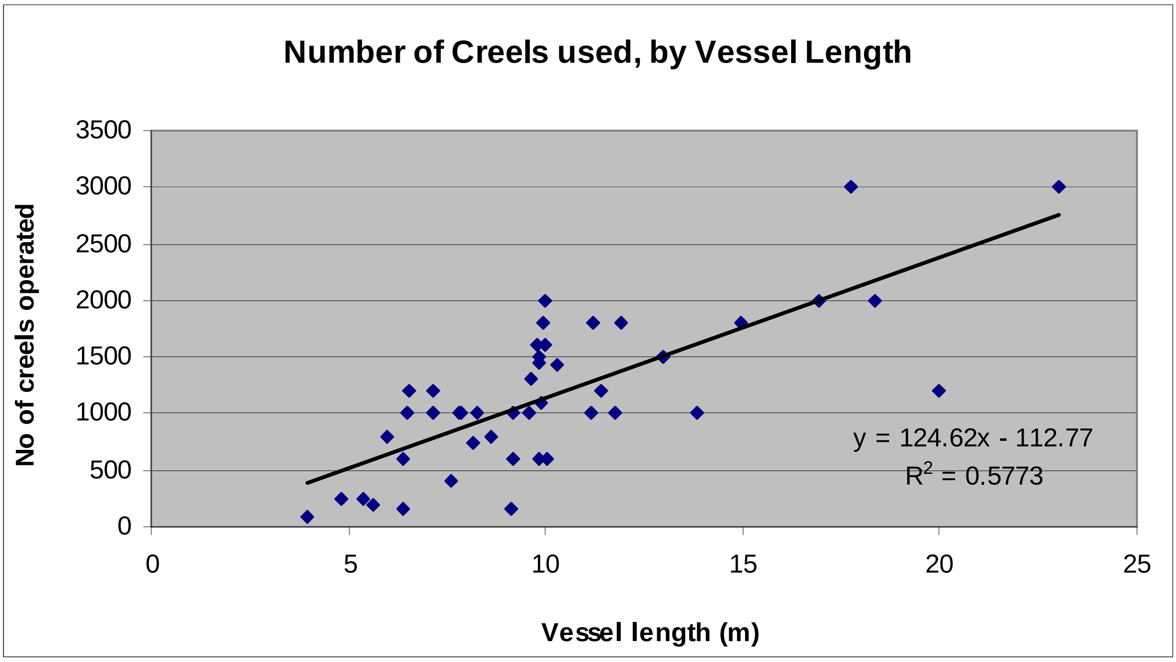
Every one of the interviewees and all the information gleaned from ports suggested that there is a universal rule that the end ropes of creel strings are “one and a third” the depth of the water being fished. Sometimes a part of the end line may be leaded to keep the line vertical, but apparently not often, as this was recorded only once, though no specific question on this issue was asked.

Figure 22: numbers of creels reported per string



The total number of creels carried per boat varied from 80 to 3000. There is a clear linear relationship between vessel length and number of creels, but the fit is not particularly good (see Figure 23). We have left out one vessel of 37m from this analysis. Until recently this vessel had been using gillnets, and it was reported to be carrying 3000 creels, which is fewer than would be expected of a vessel of this exceptional size, so we have treated this as an outlier and excluded it from the analysis on the assumption that the number of creels may not yet be optimal for this boat. This would be the largest creel boat in the Scottish fleet, there having been only two other boats larger than 20m fishing creels in 2007.

Figure 23: Number of creels used per vessel



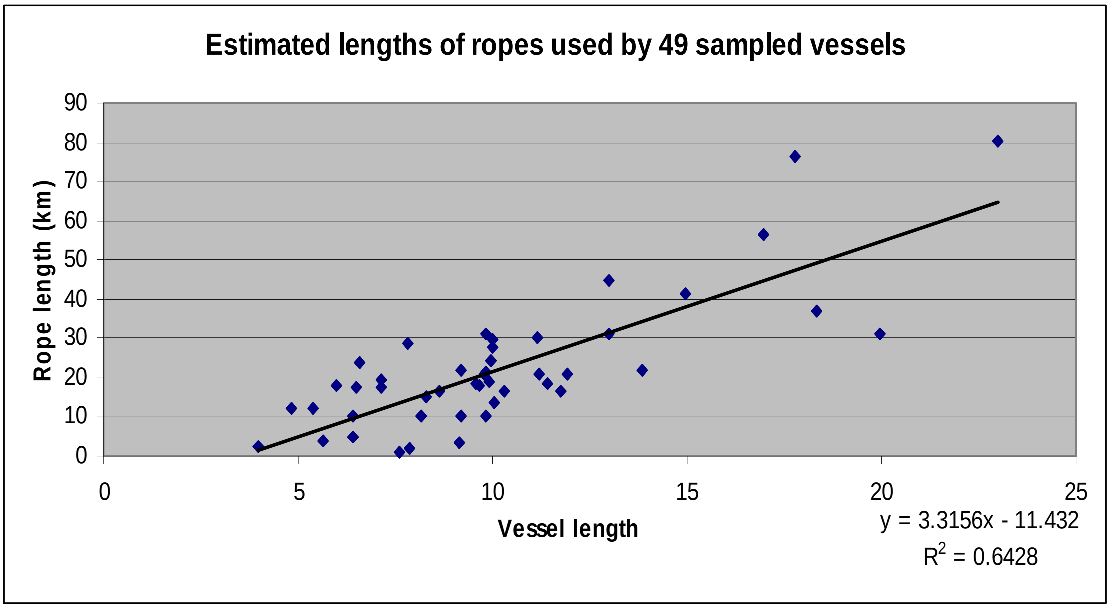
It is clear that factors other than length, including target species, number of crew and deck space (boat layout), and possibly local competition, are likely to influence the number of creels a boat can handle. There appear to be step-changes in the numbers of creels used that are associated with boat length – notably around 10m, but we are unaware of any obvious reason why this might be the case.

From an entanglement perspective, however, the number of creels carried is less important than the actual lengths of rope being used. We have assessed this on a boat by boat basis among 49 of the vessels sampled, based on the answers given from our survey. We used the number of creels per string (less one), and the inter-creel distance, plus an estimate of 1.3 times the maximum water depth to estimate the mean length of an average string of creels for each boat. String lengths ranged from just over 300m to just under 4km with a mean of 1.1km.

Strings lengths for each boat were then multiplied by the number of strings reported by that boat to obtain an estimate of the total amount of rope in use for all 49 boats. Separately we also used the number of coils of rope used per string (assuming a coil in 125 fathoms or 229m) and the number of strings used as reported on a boat by boat basis. These two metrics gave estimates of the average amount of rope used per boat of 23.55 and 25.55 km respectively among our sample.

We may have over-estimated the amount of rope used in the 'ends' of each fleet, as we have used the maximum depth fished for each boat rather than the mean depth (which we did not have), but it is encouraging that the quantities estimated from the data on number of coils of rope used per boat gave similar results overall to the estimate based on number of creels per string, inter-creel distance and number of strings. On average about 12% of the rope in the water may be attributed to the 'ends', though as stated this may be an overestimate.

Figure 24: Rope lengths used

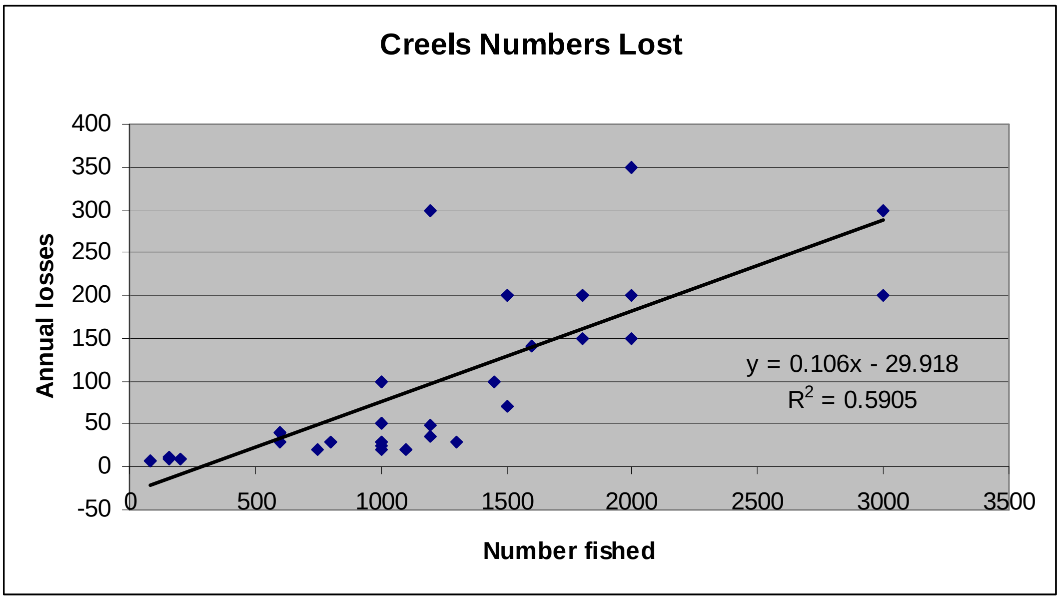


There was no obvious effect of target species on rope length, and the amount of rope is again related to vessel length, but the relationship is linear. This provides us with a means to estimate the total amount of rope in use by the Scottish fleet, but more usefully, based on recorded fishing effort (days absent) should enable us to determine the relative amounts of rope by ICES rectangle around the country.

Creel Losses

The number of creels lost per year depends on the number being fished, but on average around 98 creels or 7 to 8 % of creels that are fished may be lost per year (See Figure 25 below). Most reported that the worst season for losses was the winter, and only 3 of 37 said there was no seasonal pattern.

Figure 25: Reported creel losses



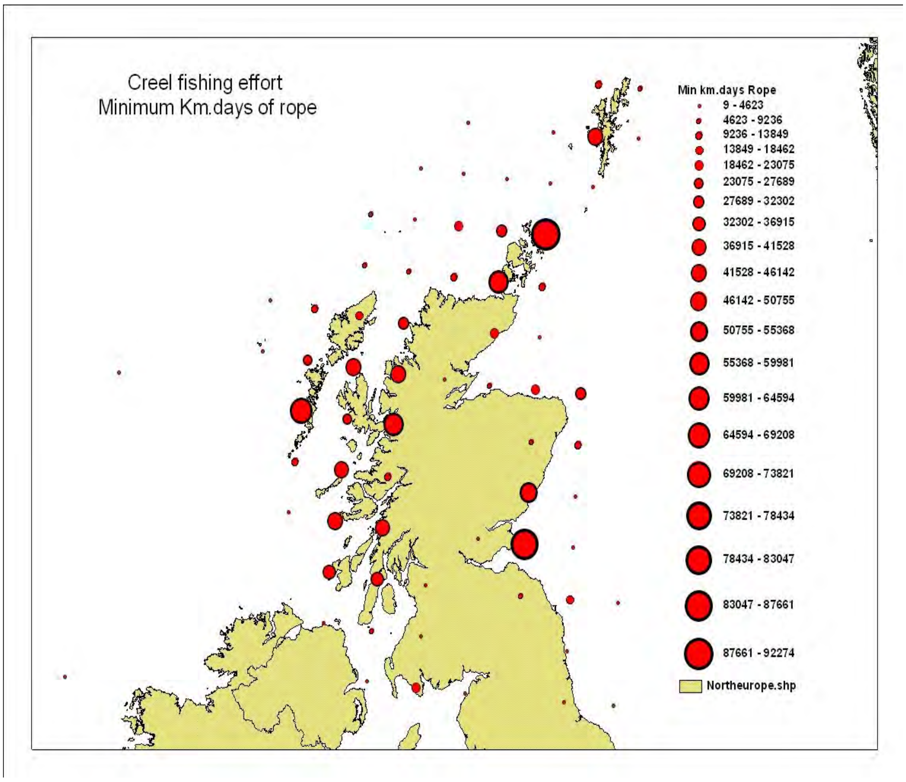
Amount of rope in use

In 2007 there were 1163 vessels that reported some level of fishing with creels. Assuming an average of 24km of rope in use by each boat this would amount to some 28,000 km of rope potentially in use in the waters around Scotland. Not all of these 1163 vessels are fishing full-time, and indeed effort by many of them appears to be very low indeed. The number of vessels fishing close to full time appears to be closer to 300, which would suggest around 7,200 km or rope in use much of the time, and perhaps about 10% of this would be running vertically from the sea bed to dahns or marker buoys and 90% in loops along the sea-bed.

It is not possible from the available statistics to say how much rope is deployed per day or even per month, because days at sea are reported when boats are at sea setting or emptying creels and not for the days that the creels are in the water and when the boats are in port. We know that most boats that fish full time do leave creels in the water most or all of the time. Calculating the exact amount of rope is not however, particularly important. It is more important to be able to assess the relative amounts of rope between areas and seasons.

To provide an overview of the relative amounts of creel rope in the water we simply assume that each recorded day at sea by any boat equates to one day of creel lines in the water, with the amount of rope determined by that vessel's length according to the regression formula in Figure 25. We recognize that this grossly under-estimates that actual amount of gear in the water, as much of it remains in place even when boats are in port, but we are interested in the relative amounts of gear by area, and therefore assume there are no geographical biases in the proportions of boats fishing part time and full time from different ports around the coast.

Figure 26: Derived distribution of relative amounts of creel line rope in the water



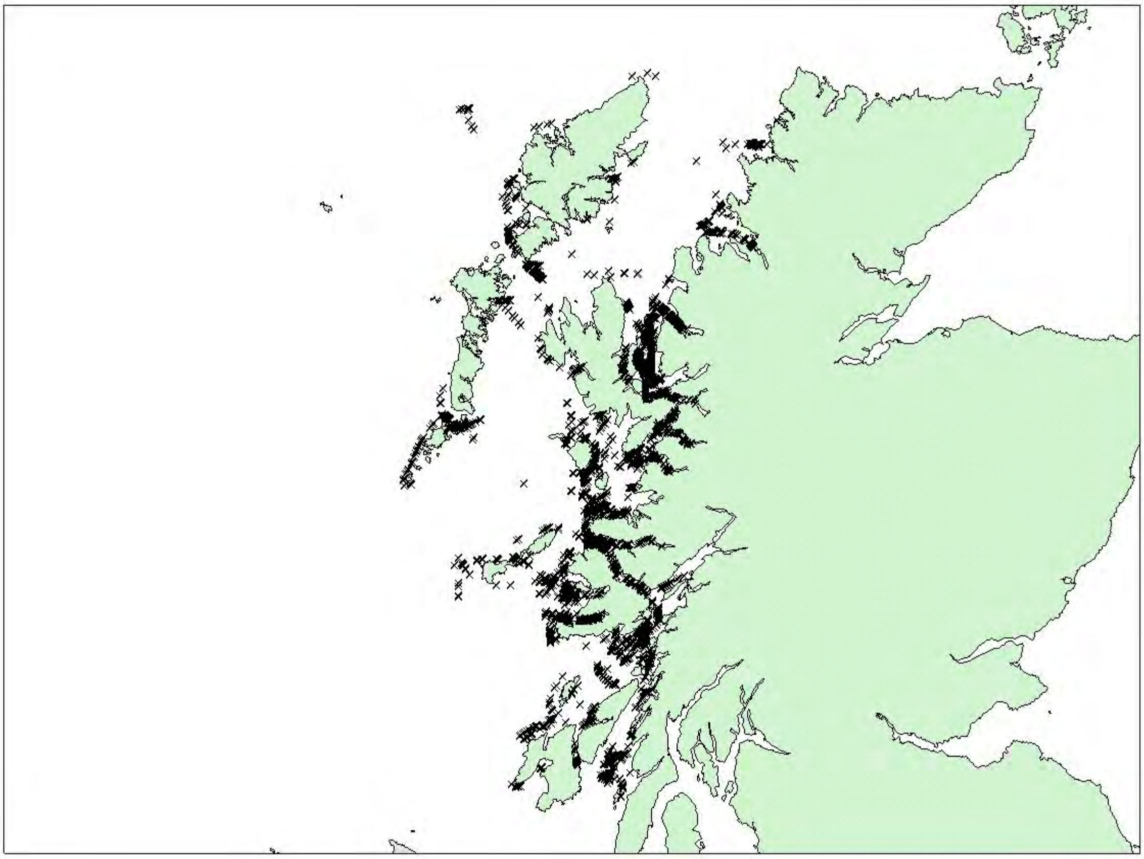
On this basis, Figure 26 shows the relative amounts of creel fishing gear – as minimum km.days of rope -by ICES rectangle. This picture differs somewhat from those describing either landings or days at sea by creel boats (Figures 16 and 17 above). The greatest amounts of 'rope effort' are around Orkney. Fife and Angus also show a large amount of rope effort, despite relatively low landings recorded from this region.   Elevated levels are also evident on the west coast between the Oban and Lochinver, with greatest concentrations of creel rope in rectangles that include South Uist and the Sound of Sleat and the Inner Sound on the mainland sides of Skye.

Aside from providing an overview of aspects of the Scottish creel fishing fleet, the work described above also enables a potentially more accurate assessment of the risk of entanglement to minke and other baleen whales in the waters around Scotland which is continued in Chapter 4.

At Sea Surveys of Creel Fisheries

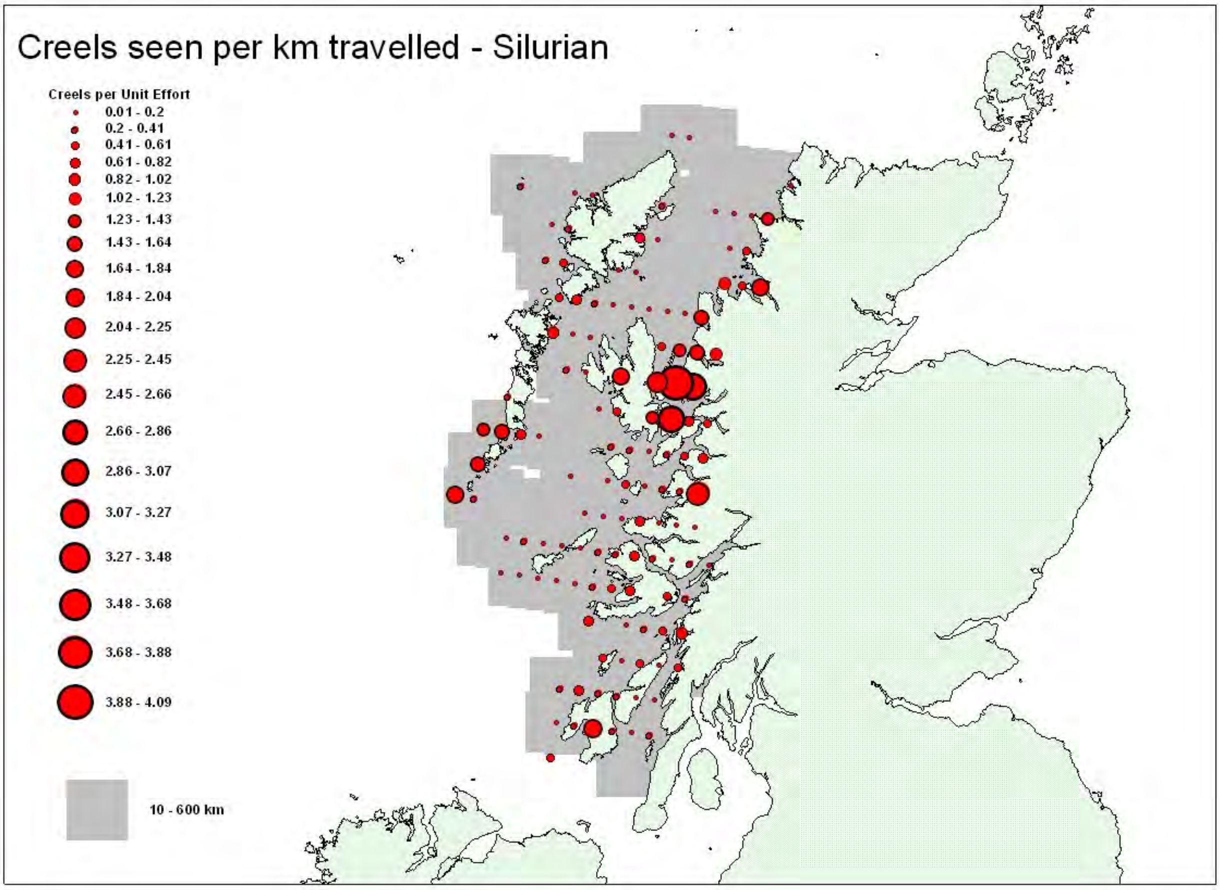
An alternative means of assessing creel fishing effort sightings of creel marker buoys were collected by the research vessel Silurian between April and September 2008. A total of 10,318 km were sailed under observation, and over 4000 creel buoys were sighted. Raw sightings locations have been plotted in Figure 27. These data have also been split up by 10 nautical mile grid cells, and the amount of trackline (km travelled) and number of creel buoys sighted have been used to generate a sightings rate for each 10 square mile cell. Sightings rates are shown in Figure 28 as red circles, with a maximum of just over 4 creels per km of trackline in any one cell. The survey area (defined as any cell where more than an arbitrary 10km was travelled) is shown in grey shading.

Figure 27: locations of creels sighted from the RV Silurian



This fine scale assessment of creel fishing effort shows some concordance with our Figure 26 above, as both show higher rates in similar places, though at different scale.

Figure 28: Sightings rates of creels from the Silurian



Discussion

The main problem with assessing creel fishing effort in Scotland is that the effort measure that is available – the days at sea by vessel, does not provide a very useful measure of the amount of gear being fished. Although it is possible to estimate how much gear each vessel would be using, from its length, it is much harder to estimate how much of the time each vessel leaves its gear in the water. As lobsters and crabs can remain alive in pots for a very long time it would be entirely feasible for a vessel that was at sea for only 20 or 30 days a year to have gear fishing every day of the year (though perhaps unlikely due to the possibility of creel loss when unattended). Interview samples are not very helpful, as there is a clear bias in our sampling towards full time vessels. Part time vessels are by their nature much more difficult to track down. From the official landing statistics it would appear that there are only about 100 boats at sea more than 150 days per year, about 300 at sea more than 50 days a year and about 700 at sea more than 20 days a year. This describes a very irregular fleet, which is difficult to characterise simply.

Our results suggest that the areas with highest densities of rope in the water are firstly around Orkney (where we also found higher than expected strandings rates of baleen whales) and the around Angus and Fife. High densities are also predicted in inshore waters close to Skye and also those around the Uists. The use of the Silurian to demonstrate creel fishing density appears to be a useful way of obtaining proxy fishing effort data with which to corroborate or refine existing effort data from official sources. Furthermore, sightings data like these could be used for finer scale modelling of the overall distribution of the creel fleet, based on bottom type or topography.

Reported creel losses amount to about 7 or 8% of all creels fished per year per vessel in our survey. Assuming, for the sake of example only, that an average boat uses 1220 creels and 115 coils of rope in fishing (from our survey), then about 90 creels per year and about 8 coils of rope (125 fathoms each) may be lost per vessel. Fitted creels retail for about £50, and coils of rope fetch £30-£40 depending on gauge. Very crudely, the average vessel therefore loses just under £5000 per year in lost gear. Lost gear must therefore cost the Scottish creel fleet in excess of £1 million per year. The causes of lost gear are usually unknown, and it is certainly true that the impacts of bad weather and towed gear (trawls and dredges) may well account for most of these losses. Nevertheless, whale entanglement should be seen as another factor in the overall loss to the industry.

The specific details of the rope types in use should also help us in future to match rope marks found on animals on beaches to particular types of rope that may be used in different creel sectors.

Chapter 3: Live sightings

Objective 4: Using existing sightings networks, investigate whether there is evidence of previous entanglement of live whales.

Introduction

We have analysed photographic records of minke whales collected by Sea Life Surveys – a commercial whale and other wildlife watching company based in Tobermory – and the Hebridean Whale and Dolphin Trust. Most of the photographs were taken in an area stretching between Rhum and Eigg in the north and east to the Treshnish islands in the south and west, and all were within the Inner Hebrides.

Photos were taken with the intention of developing a photo-id catalogue, starting in 1990. Between 1990 and 2003 only photos of identifiable individuals were stored and catalogued. Descriptions of methods are given by Gill (1994) and Gill and Fairbairns (1995). After 2003, photos from all encounters were stored and catalogued, though at first photographers focused on parts of the body that would be most easily enable individuals to be recognised, especially the dorsal fin. From 2007 photographers were asked to try to photograph as much of the body of every animal as possible, to increase the chances of detecting evidence of previous entanglements.

Our analysis of these data fell into two phases. Initially the HWDT photo catalogue had only been catalogued up to 2004, so using the photographs from 1990 to 2004, Mirjam Held Wirz made an initial analysis (as an MSc project at the University of St Andrews) of the scarring of minke whales in the catalogue over this time period. She used just the animals that had been identified and given an identification code. Her thesis is annexed to the present report (Appendix 3).

Subsequently we have updated the HWDT/SLS photo database with photographs taken up to 2008. A separate analysis was then conducted on the entire photo-library, but using much the same methodology as that described by Held Wirz. Some of the photo library has been made available on line at:

http://www.whaledolphintrust.co.uk/research-photo-identification-gallery.asp

Methods

Photographs are stored or filed firstly at the encounter level, with a minimum of one photograph per encounter, and sometimes many tens of photographs during the same encounter.

Within each encounter all photos are examined and grouped if more than one individual was present during the encounter, into individuals within encounters. Photos for each individual and for each encounter were then examined with two aims – firstly to find identifiable individuals, either repeat sightings of known individuals or to characterise new individuals, and secondly to categorise photos of each animal within each encounter depending on the body part photographed, the photo quality and any evidence of scarring.

Photos were categorised according to the body part or parts visible. Right or left side of the animal was the first criterion, and following that, four body segments were identified – head, dorsal fin, flank or caudal peduncle.

Figure 29: Anatomical regions for photographic analyses

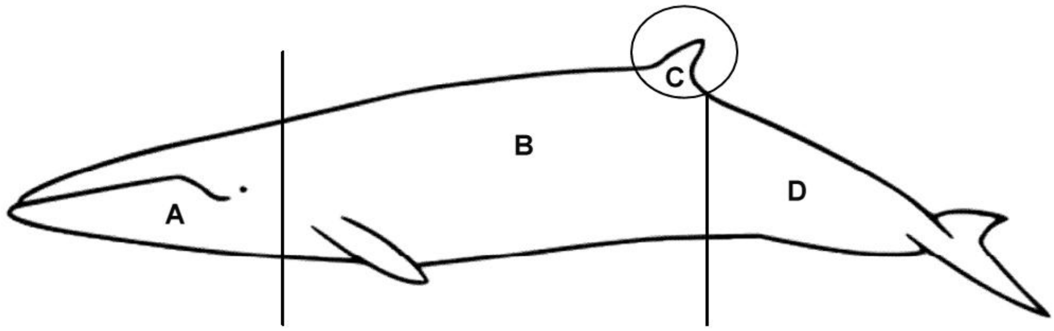


Figure from Held Wirz 2008, (Appendix 3), adapted from a line drawing by Chris Huh.

Thereafter each photo was coded according to its photographic quality (PQ):
3: Photo in focus, well lit such that any marks on the skin would be easily visible.
2: Poorly lit photograph. Nicks and scratches can still be seen but with much less clarity
1: Out of focus or silhouetted. Body part and large nicks from dorsal fin can be seen, but little other detail
0: Unusable.

Each photo was assessed to determine whether there was evidence of scarring that might have been caused by entanglement. Following Robbins and Mattila (2001) and Woodhead *et al*. (2001), a scar code (SC) was allocated based on this analysis:
4: Obvious evidence of previous / current entanglement. Ropes/straps visible.
3: Linear scars or wounds which wrap around the feature
2: Noticeable nicks or chunks missing from the trailing edge of the dorsal fin, or small indentations on the leading edge.
1. Slight, non-linear, apparently randomly arranged marks, or small indentations on the trailing edge of the dorsal fin

Finally, where possible, an entanglement code was given to each animal at each encounter. Entanglement codes (EC), based on the characteristics described by Robbins and Mattila (2001), Woodhead *et al*. (2001) and Neilson *et al*. (2007) were given as follows:
4 (High): An animal with any SC4 code photos indicating that the animal is or has been entangled
3 (Ambiguous): Any SC3 marks- suggesting the animal has likely been injured or entangled by fishing gear or some other anthropogenic interaction.

2: marked dorsal fin (treated separately- all animals coded 2 also given a 0, 1, 3 or 4 SC code, because marks to dorsal fins are common and difficult to interpret).
1 (Low): No marks of SC3 or above and at least one complete side of the animal with a PQ value of 2 or more in all sections. The animal apparently exhibits no marks or scars that might be indicative of entanglement. Previous serious entanglement deemed unlikely.
0 (Unknown): PQ is not 2 or more for all body sections of at least one side of the animal. Photographic evidence is insufficient to make assumptions about entanglement marks.

Results

In the first analysis of photos taken between 1990 and 2003, Held Wirz found that 55 individuals had been identified from left hand side photos and 62 individuals from right hand side photographs among 191 encounters. Table 7 is taken from her thesis (Appendix 3):

Table 7: Numbers and percentages of identified minke whales by entanglement code category and for left and ride hand side photos.

Left hand side photos

EC	No of individs	Percentage
Low	42	76
Ambiguous	7	13
High	3	5
Unknown	3	5
Total	55	100

Right hand side photos

EC	No of individs	Percentage
Low	45	73
Ambiguous	7	11
High	6	10
Unknown	4	6
Total	62	100

On the basis of her analyses of this initial set of photographs Held Wirz suggested that somewhere between 5% and 18% (LHS) and 10% and 21% (RHS) of animals photographed had high or 'ambiguous' levels of evidence of previous entanglement.

The relatively small sample size and the consequent disparity between left and right hand side estimates of rates of entanglement suggest that these estimates should be regarded as very preliminary. Nevertheless there is a suggestion that at least 5-10% of minke whales in inner Hebridean waters show some evidence of previous entanglement, while the true number could be closer to 18-21%.

The second analysis included photographs from 1990 through to 2008. 400 encounters with individual animals were photographed between 1990 and 2008, more than doubling the sample size in the first analysis. Among these encounters at least 133 individuals have been identified, and there are about another 60 encounters where animals have been given preliminary identifications by HWDT.

Among the 133 identified animals, 3 were now classed as EC4 and 27 as at least EC3 or possibly EC4. The second analysis (conducted without reference to the results of the first, and by a different analyst (A. Coram)) again suggested similar levels of entanglement with perhaps 30/133 = 22.5% of individuals that had high or ‘ambiguous’ levels of evidence of previous entanglement.

Of the 133 individuals it was only possible to say that 26 (19%) definitely had no evidence of any entanglement scars while for the remainder (133-56= 77), some 58%, photo quality or coverage was too poor to be able to say one way or the other.

Examination of the body parts most often affected by entanglement scars suggests that there are some differences in scar accumulation by body part. Whereas among stranded animals that had been diagnosed as having died due to entanglement there was no clear difference among the different regions of the body regarding rope marks, on live animals there was a clear difference. Considering only photos that were PQ grades 2 and 3, there were clear and significant differences in the numbers of animals with evidence of entanglement (SC 3 and 4) in different parts of the body. Highest rates of entanglement or ambiguous entanglement were recorded around the head and abdominal regions of the photographed animals, lower rates were noted around the dorsal fin and caudal peduncle. This may be because evidence of entanglement is more visible in these areas, or because entanglement in the head region for example occurs more often but is less likely to lead to the animal’s death.

Table 8: Distribution of SC3 and SC4 category damage by body region

Body segment	Left hand side	Right hand side
Head	28.57%	11.54%
Abdomen	4.11%	6.88%
Dorsal fin	1.86%	1.57%
Peduncle	0.55%	5.26%

We also examined the data to see if we could determine the rate of accumulation of scars, but re-sighting rates were not high enough to allow this and no animals that were sighted more than once showed evidence of scar accumulation.

Discussion

The data from live sighted and photographed animals are subject to a lot of potential interpretation errors, and it is important therefore to interpret such data with caution. We must rely for example on the skill and interpretation on the part of the photo-librarian in making matches between individuals sighted and photographed in different years. We must also rely on the judgement of the photo analyst in deciding what marks are likely to be rope marks and what are not. Among the identified animals in the HWDT catalogue, most have been checked by at least one individual with experience of such photographic databases elsewhere. Regarding the entanglement codes ascribed to individual photos, it is encouraging that two researchers in our study came to very similar conclusions regarding the proportions of individuals with SC3 and SC4 codes. An earlier study of the same data set by Gill et al 2000 found evidence of creel rope entanglement in three of 74 (4%) individually identified whales around Mull

It is unfortunate that so far insufficient photos are available to be able to assess the accumulation rate of scars, but if further work can be done to integrate the photos held by the HWDT with other photo libraries available for minke whales in Scottish waters, a larger sample size might shed some light on this aspect of the work.

Overall the analyses above suggest that perhaps as many as 20% of minke whales in the Inner Hebrides show some evidence of previous entanglement, though a very conservative estimate using just SC4 values would be closer to 5%. The work described above of course assumes that all entanglement events result in identifiable scarring, which need not be the case, and entanglement rates could therefore be higher than the analyses here suggest.

The significance of such entanglement events at the population level are unknown, because we have no idea what proportion of entanglement events result in mortality or serious injury, and it is entirely plausible that many animals become entangled while very few are actually killed. Nevertheless a high entanglement rate would have serious consequences for creel fishermen, who lose a large number of creels every year.

The relatively high proportion of animals bearing SC3 and SC4 grade markings on their heads may suggest that ropes get caught in open mouths, while whales are feeding. If that is the case then it becomes important to know where in the water column minke whales feed - whether close to the bottom, where the main line linking creels together rises off the sea bed by only a few metres, or whether they are more vulnerable to the end lines that run up from the sea bed to the surface. More detailed studies of whale feeding habits in Scottish waters could help elucidate this question.

The entanglement rates suggested here – possibly up to 22% of animals bearing scars of previous entanglement events, are low compared with the rates reported for humpback whales elsewhere. Robbins and Mattila (2001) reported that between 48 and 65% of whales photographed every year bore some evidence of previous entanglement in the Gulf of Maine (NE USA), while Neilson *et al.* (2007) found that between 52 and 78% of humpback whales in northern southeast Alaskan waters bore evidence of entanglement. Nevertheless, the rate of non-lethal entanglement is probably less important than the rate of lethal entanglement, which cannot be estimated from photographs of live animals alone without some estimate of the proportion of entanglement events that end up being lethal (Robbins *et al.* 2009).

Chapter 4: Comparing fishing distribution with whale distribution.

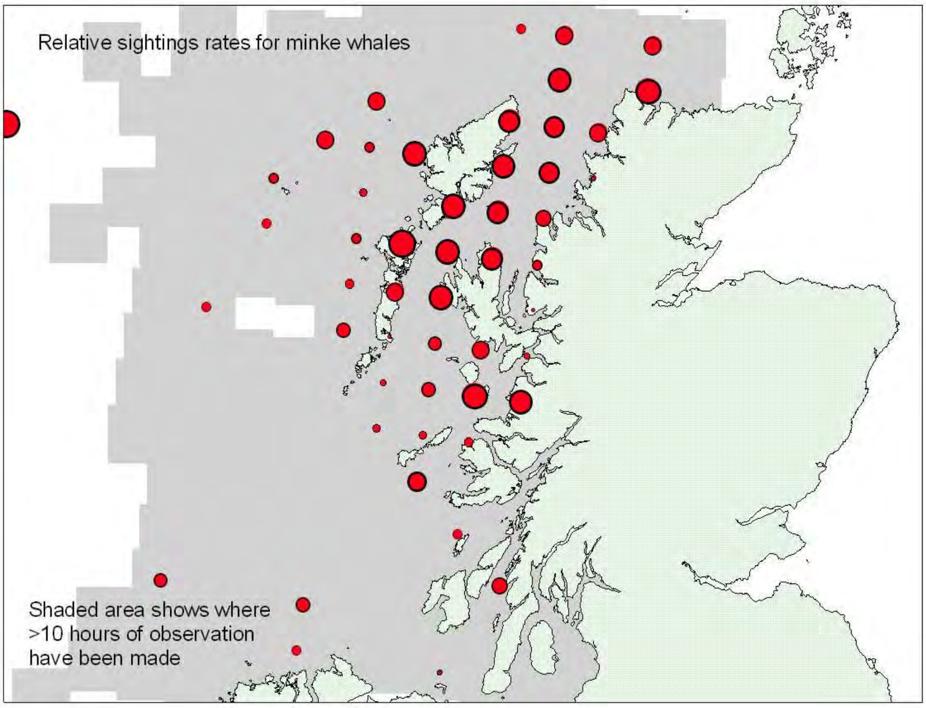
Objectives 5 and 6: Determine the likelihood of co-occurrence between minke whales and fisheries and identify areas around Scotland where the "risk" of entanglement is high, with recommendations for possible mitigation proposed in these areas.

Minke whale distribution in the Hebrides

We have used data on minke whale sightings from data collected by SMRU, Joint Nature Conservation Committee's seabirds and cetaceans team and the Sea Watch Foundation that form the basis of the Atlas of cetacean distribution in north-west European waters (Reid *et al.* 2003). Data on minke whale sightings were used to produce distribution maps in the atlas at a scale of ¼ ICES rectangles – or about 15 by 17 nautical miles. Whale sightings are expressed as number of animals seen per hour of searching, and are corrected or standardized for sea state; a species-specific scaling factor is used to adjust the time spent searching in different sea states. Sightings were collected from 1979 to 1998. More recent data have been collected but are in various formats and there is an ongoing project to standardize data structures so that an updated data set can be used to revise the sightings rates for all species. At present however these more recent data are unavailable. The methodology for plotting the distribution of sightings rates is described in more detail in Reid *et al*.(2003).

The distribution of minke whales by ¼ ICES rectangle has been plotted using the same data as in Reid *et al.* (2003) but initially just for the area covered by the Silurian and described in Chapter 2, and shown in Figure 28. This is in order to compare expected minke whale densities with observed densities of creels recorded by Silurian in the summer of 2008 for the Hebridean region. Minke whale sightings rates are shown in Figure 29. Highest sightings rates are found in the Minches, and relatively low sightings rates were found in the areas around the Sounds of Raasay and Sleat. Higher sightings rates are also seen in the Sea of the Hebrides around Rhum and Muck. These sightings rates can be compared directly with Figure 28, but it is difficult to interpret the degree of overlap between the two.

Figure 29: sightings rates (individuals per hour) of minke whales in the Hebridean region (data from Reid *et al*. 2003).



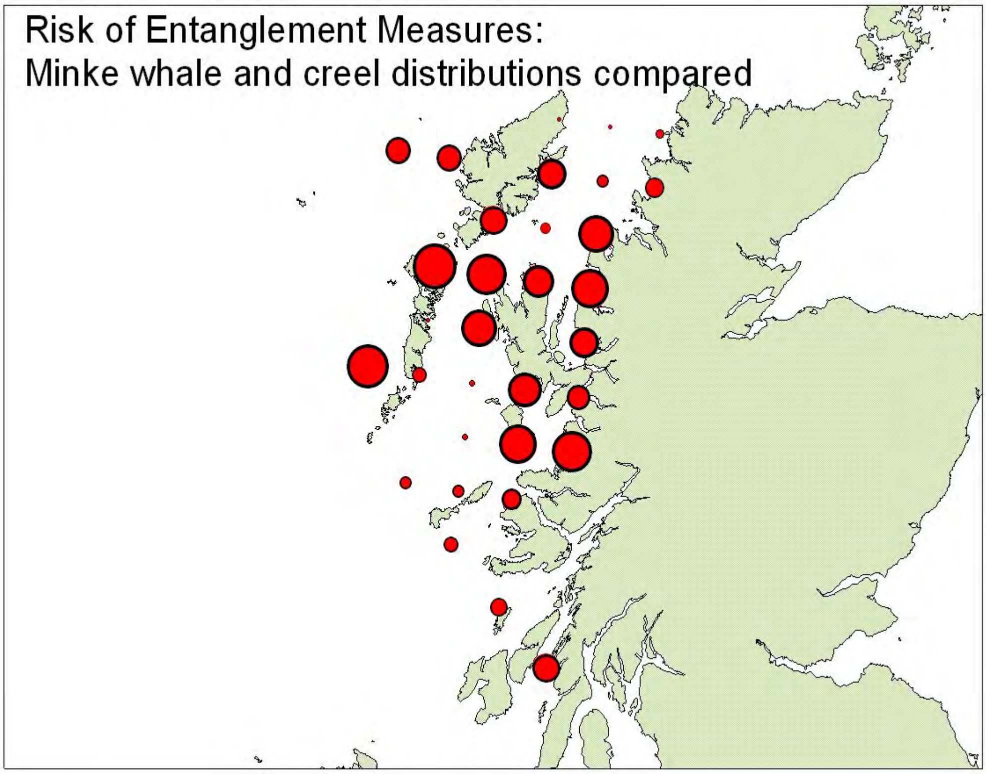
Risk of Entanglement: co-distribution of whales and creels

A more useful way of comparing the distribution of minke whales and of creel strings would be to display the degree of overlap on the same map and at the same scale. To this end we have reformatted the data on creel buoy sightings into ¼ ICES rectangles, so that the two data sets are available at the same resolution. We have then developed an index of co-occurrence to identify areas of highest risk of entanglement. Such an index should indicate a zero risk where there are no reported sightings of whales or no reported creels, and a high risk where there are high sightings rates and a lot of creels. For both minke whale sightings rates (W) and creel sightings rates (C) we have calculated the mean sighting rate over all the grid cells in the area as Ŵ and Č respectively. For each grid cell a measure of the difference from the mean sightings rate is given by W/ Ŵ for whale sightings rates and C/ Č for creel sightings rates. Thus areas of average whale or creel sightings rates have a value of 1 by definition, and areas of relatively high sightings (=density) have a value greater than 1. The product of the two of these measures gives an index of the risk of co-occurrence and therefore of entanglement:

$$\text{Risk of Entanglement Measure (REM)} = W/\hat{W} * C/\check{C}$$

A plot of the risk of entanglement is given in Figure 30 where we have first reformatted the creel sightings rates into ICES sub-rectangles.

Figure 30: REM for minke whales in the Hebridean region; data at ¼ ICES rectangle scale



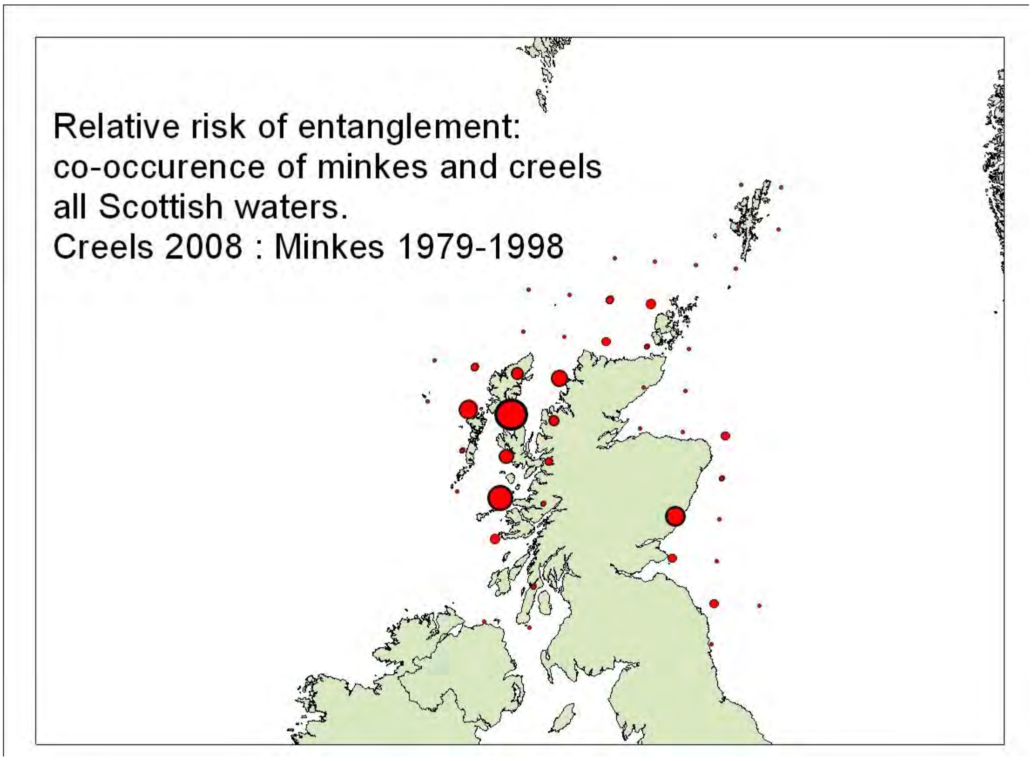
This figure provides a view of the relative ‘risk’ of entanglement, suggesting that the overlap of minke whales and creels is greatest in coastal waters from Loch Broom to the Ardnamurchan peninsula, coastal waters of Skye, North Uist and the Atlantic side of South Uist. Even though sightings rates may not be particularly high in some of these waters, creel densities raise the risk of co-occurrence and entanglement.

Risk of entanglement for the rest of Scotland

We do not have such detailed information on creel distribution for the rest of Scotland as we do for the west coast. We have therefore repeated the above exercise using the creel fishing effort data by ICES rectangle (1 degree of longitude by half a degree of latitude, or roughly 34 nautical miles by 30), having aggregated minke whale sighting to the same ICES rectangle scale. The expected distribution of creels based on official fishing effort statistics and our interview data was elaborated in Figure 26 in Chapter 2. The REM for the whole of Scotland is shown below in Figure 31

The wider picture, though at a coarser scale, shows again that the areas with greatest risk of overlap between creel fisheries and minke whales are likely to be the Sea of the Hebrides region and the Little Minch. After these two areas, the rectangle with the highest risk or entanglement measure is on the east coast of Scotland off Angus. Thereafter, there are 5 more on the west coast in the same general area – Uists and the Hebrides, and the rectangle with the ninth highest risk of entanglement measure is off Orkney.

Figure 31: REM for all of Scotland, data at ICES rectangle scale



Whether these metrics described above are reliable indicators of risk of entanglement is unclear, but they provide a rationale for focusing in on specific areas in the future. One of the weaknesses of the present implementation, however, is that the sightings data for minke whales were collected from 10 to 30 years ago, and distributions may have changed. It would therefore be useful to collate more recent sightings data in order to obtain a more up to date picture.

Despite this potential weakness, the results presented above give some clear indications as to where interactions between whales and creels are most likely, namely the west coast from about Mull to about Loch Broom, around Skye and the Uists. Other areas that may have higher than 'normal' levels of co-occurrence or risk of entanglement could include the areas of Angus and off Orkney.

Potential mitigation strategies

It would be premature at this stage to propose any significant changes to creel fisheries in the hope of reducing minke whale entanglement, as we do not yet fully understand either the scale of the problem (though we have a clearer idea than we did), nor the ways in which minke whales become caught.

Development of bycatch mitigation measures usually requires some understanding of the mechanics of the way in which animals become caught or entangled. In this case we found that dead animals have rope marks on their heads (and mouths), abdomens and tails, while live animals tend to have more evidence of scarring on the head region. This may suggest that non-fatal encounters are most often associated with feeding. A study of minke whale entanglement in Korea also showed that 64% of whales entangled in pot lines had become attached at the mouth (Song et al 2010). A better understanding of how these whales are feeding in the water column might help develop an understanding of the mechanism of entanglement, and specifically to determine whether it is the end ropes or the main line that loops along the seabed that is most often involved in entanglements. In the Korean study most entanglements (97%) were attributed to the main or ground line and branch lines rather than the ends or buoy line. A Canadian study in contrast found that ground lines were typically raided by only 1-3m above the seabed and suggested that this was too low to present a high risk of entanglement to right whales at least (Brillant and Trippel 2010)

These same uncertainties have also been explored in the north-eastern US where 3 species of whale that are listed under the US endangered species act (fin, humpback and northern right whales), are all impacted by entanglement in very similar fisheries to those operating in Scotland. The Atlantic Large Whale Take Reduction Team has been tasked with developing mitigation strategies to protect these three endangered species and also, it is acknowledged, to benefit the non-endangered minke whale.

In order to specifically protect endangered right whales, short term area closures are mandated when aggregations of right whales are detected. Dynamic Area Management enables the National Marine Fisheries Agency to require the removal of all static fishing gear from a specified region for 15 days (Federal Register: January 30, 2009, Volume 74, Number 19). More generally, there are several regulations that apply to pot or creel fisheries in the region:

- Groundlines must be made of sinking line. Floating groundlines are prohibited;
- All buoy lines must be made of sinking line, except the bottom portion of the line, which may be a section of floating line not to exceed one-third the overall length of the buoy line;
- Fishermen are allowed to use two buoy lines per string; and
- A weak link with a maximum breaking strength of 600 lb (272.4 kg) must be placed at all buoys.

Further information is available online at: http://www.nero.noaa.gov/whaletrp/. These appear to be the only officially mandated mitigation measures directed towards minimising baleen whale entanglement anywhere.

There is still controversy over how effective these measures might be, but the issue in the US is more critical because the population of right whales numbers in the low hundreds. By way of contrast, estimates of minke whale abundance in the Northeastern Atlantic are around 65,000 (Schweder *et al.* 1997) and there is no obvious conservation threat posed by entanglement.

Nevertheless, emerging practices and experience in the US may in future help identify measures that could be adopted in Scottish fisheries should whale entanglement become a more pressing concern, perhaps in specific small areas such as those highlighted in Figures 30 and 31 above.

The specific measures that might be useful in a Scottish context could include ensuring that the main line is not allowed to float too high. This could be achieved by using denser rope with a specific gravity of more than 1 as is required in the Gulf of Maine, or by ensuring some weight is attached to the line between creels.

Limiting creel lines to two buoy lines (ends) would not make much difference in Scottish fisheries as this is the normal procedure. Sinking buoy lines might be a useful approach, if it could be proved that this is the line that most often entangles whales. Contradictory evidence on this point has been put forward by Korean and Canadian researchers (Song et al 2010 and Brillant and Trippel 2010). Weak links between creels could be adopted, but this would make maintenance and construction more difficult and may lead to further creel losses due to snagging on the sea bed.

The costs and benefits of any such proposed mitigation measures would need to be discussed with practitioners and assessed in detail before any thought of implementation, but there are at least some potential measures to consider.

Overall, there is still too little information on the mode of interaction between minke whales and creel lines to be sure which of the proposed measures would be most useful in Scottish waters. Further research to investigate the feeding and diving habits of minke whales could help elucidate these issues, as would more detailed examination of the elevations of creel lines in lobster, crab and nephrops creel fisheries worked in Scottish waters.

Discussion

The highest risk of entanglement for minke whales appears to be in the central Hebrides, notably around Skye and also around the Uists. The areas around Fife and Angus and Orkney may also have a relatively elevated risk of minke whale entanglement. This might be investigated by focusing any further work in these areas.

As yet we have no clear idea of the overall scale of the problem, except that it seems perhaps 5 or 6 stranded whales per year may have been victims of entanglement, though this must be a minimum estimate. There is no *a priori* reason to suppose that such entanglements pose any threat to the conservation of baleen whales in the region, though the impacts should be considered by the IWC in setting catch limits for whales of the same stock in adjacent waters. If our predictions are correct then there may be an elevated risk of entanglement in some restricted areas. If this turns out to be the case then local fishermen may like to consider potential mitigation strategies, such as those being pursued in the US. Such strategies might help reduce whale mortalities or injuries, but could also help limit some of the considerable loss of creels that creel fishermen experience.

Further work should be directed at fine scale studies of whale movements and feeding behaviour in areas where creels are used, and into rope configurations and elevations on creels that are being fished, to try to understand the risk of entanglement more clearly.

Chapter 5: Conclusions and recommendations

Minke whales are a strictly protected species within the EU, being listed on Annex IV of the Habitats Directive. They are nevertheless subject to hunting in neighbouring countries (Iceland and Norway). The International Whaling Commission considers there is a single management stock in the Northeastern Atlantic, though some population sub-structure is evident within the stock region. The number of minke whales in the Central and Northeastern Atlantic stocks combined has been estimated at around 174,000. In North-western European Union waters (North Sea and shelf waters west of the British Isles), the recent SCANS II project estimated that there were around 18,800 minke whales present during the summer of 2005, though this estimate excludes the survey blocks tthat were subject to aerial survey such as the Scottish west coast. Around 600 minke whales are taken annually by Norway and Iceland. Annual minke whale quotas are established nationally by Iceland and Norway and whales are taken under an Objection to the IWC's 1985 moratorium on whale catching, as permitted under the Whaling Convention.

Minke whale deaths due to entanglement in fishing gear, principally in creel lines, represent the single most frequently documented cause of anthropogenic mortality in Scottish and UK waters. Roughly half of all examined dead baleen whales from Scotland are thought to have died due to entanglement. Although this amounts to only about 5 or 6 animals per year on average, not all such deaths will result in carcases that are reported.

Among animals photographed off Mull, at least 5% and possibly as many as 22% of minke whales bear some evidence of previous entanglement. These figures compare, for example, with equivalent figures of 52-78% for humpback whales photographed in the Gulf of Maine.

We have not been able to assess how frequently Scottish minke whales are entangled because we have not been able to assess the accumulation rate of scars. In the US, about 12% of the humpback whales in the Gulf of Maine appear to become non-lethally entangled annually. It is also thought that among all humpback entanglements in the Gulf of Maine, about three quarters are not fatal while about one quarter of all entanglements are considered likely or actually to have been fatal. From these figures, Robbins et al (2009) suggest that on average about 19 to 29 humpback whales may die as a result of entanglement annually (2-5% of the local stock). On average on about 3 humpbacks per year are actually recorded as having died as a result of entanglement.

These figures cannot be used to infer a great deal about minke whale entanglement in Scotland, where there are larger numbers of minke whales than there are humpbacks in the Gulf of Maine, and fewer programmes to monitor whale entanglement. However, the US experience shows that even with intensive monitoring of whales, as occurs in the Gulf of Maine, it is likely that reported fatal entanglements underestimate the actual number to a considerable extent.

Improving our understanding of the interactions between baleen whales and static fishing gear will clearly be important if the obligations of Article 12 of the Habitats Directive (which requires monitoring of incidental catches of Annex IV species) are to be met. Clearly with such low levels of entanglement compared with the high levels of fishing, standard observations of fishing activity are not likely to be useful in determining the true scale of minke whale mortality. A more fruitful approach would be to document entanglement events through continued careful examination of all stranded animals, but also through further development and better co-ordination of the photo-identification catalogues that are being compiled in various parts of Scotland. Examination of photographs of known animals through several years can enable scar accumulation rates, and hence non-lethal entanglement rates, to be assessed. To be truly useful these non-lethal scarring rates must be linked to some estimate of the proportion of entanglements that are lethal compared with those that are not; this is an area that needs further investigation.

Considering aspects of the creel fisheries, there are clear difficulties in the interpretation of the fleet activity data, where over 1100 boats are reported to have used creels in 2008, yet only about 300 appear to fish regularly. The data collected by the Silurian, recording locations of creel dahns, is another approach to estimating creel fishing effort, and one that could easily be explored further and extended to other parts of the coast. The existing data should at least tell us something about relative density of fishing effort, though an absolute measure of fishing effort would be more helpful in trying to determine entanglement probabilities.

Comparisons of relative creel fishing density and whale sightings density in this report have suggested three or four areas (the Sea of the Hebrides and the Little Minch, in Fife and Angus and in Orkney) that would appear to have the highest levels of whale and creel overlap. These areas could be investigated in more detail, but updating and improving the seasonal whale sightings data would also be helpful in this context. In the present report we used sightings rates calculated from data which extended back to the 1980s.

Overall, we cannot presently say that entanglement of minke (or other) whales in Scottish waters represents a serious conservations threat, but it is an issue that should receive continued attention, because of the strictly protected status afforded to these animals, and because any whale entanglement represents a potentially serious economic loss to the individual fisherman involved.

There is also an international perspective to be considered, because any anthropogenic mortality of whales, such as their unintentional entanglement in fishing gear, should be included in any catch limit calculations undertaken for the purposes of setting whaling quotas. At present neither Norway nor Iceland include figures on entanglement when estimating their domestic quotas for minke whale harvests, and as neighbouring states that exploit whales that are strictly protected within the European Union, this should be an issue of concern to the European Union. Entanglements are also likely in other EU member states.

Areas of further work

- Detailed examination of as many stranded baleen whales as is practicable should be continued, with careful attention to the placement, orientation and fine structure of any rope like scars.

- Monitoring of live animals in inshore waters should be encouraged with the aim of determining how they typically feed. Proximity to the sea bed while feeding is important if (as appears to be the case in Korea) ground ropes are the main cause of entanglement. This might be done most effectively through suction cup tagging using data loggers to record depth, pitch and roll during several dives (Hooker et al 2007).

- Further work is needed to characterise the creel fishing fleet in Scotland, which consists mainly of part time vessels. This is most likely easiest to achieve through direct observations at sea and through interview surveys rather than by relying on landings and effort records which are subject to considerable uncertainty.

- Characterisation of typical creel rope profiles and elevations should be undertaken to assess the potential entanglement risks of the various configurations in use (including for example inter-creel distance and bottom type)

- The continuation, expansion and co-ordination of photo-id studies should be encouraged, in order to obtain a better picture of non-lethal entanglement, and specifically of scarring frequency and of the anatomical distribution of rope scars.

- Defining areas of highest risk could be improved if more recent sightings data could be collated and used to determine seasonal changes in distribution and link these with seasonal changes in creel density, and if more detailed data on creel distribution could be obtained for the whole year and for the whole coast, rather than simply the summer months on the west coast. This could be achieved through sightings surveys or by seeking information on creel fishing locations from active fishermen.

- Local work, including at sea observational records of whales and creel fisheries should be encouraged in the areas defined in this report as having the greatest risk of entanglement.

- Further work would be required to assess the costs effectiveness and feasibility of any mitigation measures, such as the use of sinking lines in creel fisheries, should any such measures be deemed warranted.

References:

Baird, R. W., P. R. Stacey, D. A. Duffus, and K. M. Langelier. 2002. An evaluation of gray whale (*Eschrichtius robustus*) mortality incidental to fishing operations in British Columbia, Canada. Journal of Cetacean Research and Management 4:289-296.

Bradford, A.L., Weller, D.W., Ivashchenko, Y.V., Burdin, A.M., and Brownell, R.L., Jr., 2007 Anthropogenic scarring of western gray whales (*Eschrichtius robustus*). Paper presented to the Scientific Committee of the International Whaling Commission 15pp SC/59/BRG37

Brillant, S.W. and Trippel, E.A., 2010. Elevations of lobster fishery groundlines in relation to their potential to entangle endangered North Atlantic right whales in the Bay of Fundy Canada. ICES Journal of Marine Science 67:335-364

Caswell H, Fujiwara M, Brault S. 1999. Declining survival probability threatens the North Atlantic right whale. Proc Natl Acad Sci U.S.A. 96 (6):3308–3313.

Gill, A. 1994. The photo-identification of the minke whale (*Balaenoptera acutorostrata*) off the Isle of Mull, Scotland. MSc Thesis, Aberdeen University. 67 pp.

Gill, A. and Fairbairns, R. 1995. Photo-Identification of the Minke whale *Balaenoptera acutorostrata* off the Isle of Mull, Scotland. *In* Whales, Seals, Fish and Man (ed. A.S. Blix, L.Walløe and Ø. Ulltang), pp. 129-132. Elsevier Science, Netherlands

Gill, A., Reid, R., & Fairbairns, B.R. 2000. Photographic and strandings data highlighting the problem of marine debris and creel rope entanglement to minke whales (*Balaenoptera acutorostrata*) and other marine life in Scottish waters. In Proceedings of the Fourteenth Annual Conference of the European Cetacean Society (eds P.G.H. Evans, R. Pitt-Aiken & E. Rogan), Cork, Ireland.

Glass, A.H., Cole, T.V.N., Garron, M., Merrick, R.L. and Pace, R.M. III. 2008. Mortality and serious injury determinations for baleen whale stocks along the United States Eastern Seaboard and adjacent Canadian Maritimes, 2002-2006. US Dept Commerce, Northeast Fisheries Science Centre Ref. Doc. 08-04, 18pp. Available from NMFS, 166 Water Street, Woods Hole, MA 02453-1026, USA

Hooker, S., Biuw, M., McConnell, B., Miller, P. Sparling, C., 2007. Bio-logging science: logging and relaying physical and biological data using animal-attached tags; *Deep Sea Research Part II: Topical Studies in Oceanography*; 54:177-182

International Whaling Commission 2009. Report of the Sub-Committee on Estimation of Bycatch and Other Human-Induced Mortality. Journal of Cetacean Research and Management. Volume 11 Supplement Annex J (April 2009).

Kim, Z.G. 1999. Bycatches of minke whales in Korean waters. Journal of Cetacean Research and Management 1 (Supplement): 98-100.

Kraus, S.D. 1990 Rates and Potential Causes of Mortality In North Atlantic Right Whales (*Eubalaena glacialis*). Marine Mammal Science, 6, 278-291.

Lien, J. 1994. Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979-1990). Reports of the International Whaling Commission 15 (Special Issue):149-157.

Neilson, J. L., J. M. Straley, C. M. Gabriele, and S. Hills. 2007. Non-lethal entanglement of humpback whales (*Megaptera novaeangliae*) in fishing gear in northern Southeast Alaska. Journal of Biogeography, Special Issue. 13 pp.

Reid, J. B., P.G. H. Evans, and S. P. Northridge. 2003. Atlas of cetacean distribution in north-west European waters. Joint Nature Conservation Committee, Peterborough. 76 pp.

Robbins, J. and D. K. Mattila. 2001. Monitoring entanglements of humpback whales (*Megaptera novaeangliae*) in the Gulf of Maine on the basis of caudal peduncle scarring. Paper presented to the International Whaling Commission, Scientific Committee. SC/53/NAH25. 14 pp.

Robbins, J., Landry, S. and Mattila, D.K., 2009**.** Estimating entanglement mortality from scar-based studies. Paper presented to the Scientific Committee of the International Whaling Commission, June 2009, Madeira, SC/61/BC3.

Schweder, T., Skaug, H.J., Dimakos, X.K., Langaas, M. and Øien, N. 1997. Abundance of northeastern Atlantic minke whales, estimates for 1989 and 1995. Report of the International Whaling Commission 47:453-483.

Song, K-J, Kim, Z.G., Zhang, C.I., Kim, Y.H., 2009. Fishing gears involved in entanglements of minke whales (*Balaenoptera acutorostrata*) in the East Sea of Korea. Marine Mammal Science 26(2): 282-295.

Woodhead, C., M. Weinrich, J. Robbins, and S. Brault. 2001. A technique to screen humpback whale populations for risk of serious entanglement using fluke photographs. Paper presented to the International Whaling Commission's Scientific Committee. SC/55/BC3. 15 pp.

Appendix 1: Project leaflet.

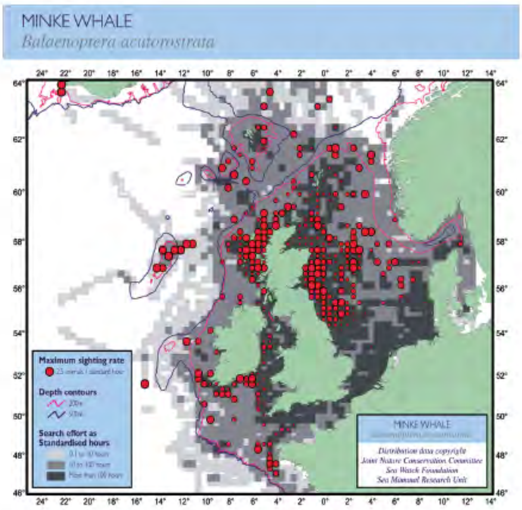
Cetacean Strandings and Entanglement

By examining post mortem records of minke whales that have been found on Scottish beaches over the past 15 years, it is clear that as many as half of them may have died as a result of becoming entangled in fishing gear. The numbers involved are small and unlikely to have any impact on the overall population of minke whales. Some entangled may drown, without then being washed ashore, while many more probably become entangled and escape leaving a trail of damaged lobster pots.

Analysis of photographs of live minke whales that have been collected by Sea Life Surveys and the Hebridean Whale and Dolphin trust over the past 15 years show that perhaps 20% of minke whales in the waters around Mull may have become fouled in some form of line, net or other material leaving associated scars. In many of these cases fishing gear will have been destroyed or removed by the whale.

Lobster creels are probably the type of fishing gear most frequently involved with minke whale entanglements. Lines of 10-20 or more creels are set along the sea bed and at each end of such a string of creels a surface line is attached to a buoy. Minke whales feeding in the same area may scoop part of a line into their mouths or manage to wrap a part of the line around their tails. Sometimes they manage to free themselves, but occasionally they do not.

Examining the habits of creel fishermen, and in particular mapping out the amounts of creel line deployed in the water around different parts of Scottish coastal waters, and comparing this with what is known about minke whale distribution should give us an idea of where the most likely areas are for this kind of interaction. Early indications suggest that the west coast, where minke whales are relatively common, is the area with most overlap. By examining the ways in which creels are set and used, and by considering what we know of the movements and feeding habits of minke whales, we hope ultimately to be able to make some suggestions as to how the risk of entanglement might be reduced, and will discuss such options with members of the fishing industry in the relevant areas.



Map by Reid J., Evans P. and Northridge S., 2003.
Atlas of cetacean distribution in north-west European waters. JNCC.

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The Scottish Government

SCOTTISH STRANDINGS

Cetacean Strandings and Entanglement

Whales, dolphins and porpoises (cetaceans) often get washed ashore (stranded), usually after they have died, but sometimes while they are still alive. Defra, theWelsh Assembly Government and the Scottish Government fund a national strandings scheme (www.ukstrandings.org) under which any stranded cetacean is reported by the relevant local authority – or by members of the public – to one of three national strandings coordinators based in London, Inverness and Cardigan. Where it is appropriate and under a set of nationally set numerical limits, a sample of these animals is subject to a detailed veterinary post mortem. In this way it is possible to keep track of the development and incidence of diseases and pathogens within cetacean populations that may either be of concern to human health, or may be implicated in epidemics that periodically affect all mammal populations.

Photo By Bob Reid SAC

One aspect of this work is to examine cetaceans for evidence of accidental death, for example due to entanglement in fishing gear. Drowning due to entanglement is occasionally found to be the cause of death among animals later recovered from beaches. Fishing gear is much more abundant than mooring lines in the sea and is thought that fishing gear is the most frequent cause of entanglement. Even whales may become entangled in fishing gear.

Photo By Susannah Calderan HWDT

Under a project funded by the Scottish Government Marine Directorate, minke whale entanglement has been examined in more detail, with the aim of discovering how widespread such events are and whether there are any simple measures that might be taken to lessen the risk to both the whales and the fishing gear. A minke whale entangled in fishing gear, whether or not it escapes, may cause a significant amount of damage to the gear involved.

If you find a stranded whale, dolphin, seal or turtle in Scotland, please phone strandings co-ordinator on 01463 243030

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Appendix 2: Necropsy protocol for entangled animals

Date: Rope and Net Marks Ref Number:

Species: