Long term Effectiveness of an Acoustic Deterrent for seals in the Kyle of Sutherland

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Summary

During three consecutive winters, two ADDs were installed, on opposite banks of the Kyle of Sutherland at Bonar Bridge, to investigate whether they could form an acoustic barrier preventing seals from travelling upstream into the river system. The study consisted of a number of 'on' and 'off' treatments, with duration of treatments varying between 3 and 13 days. During 'on' treatments, significantly fewer seals were seen both upstream and downstream of the ADDs compared to when it was "off" and significantly fewer were seen above when it was "on" compared with below. During 'off' treatments there was no difference between the number of seals seen above or below the ADDs which provides strong evidence that ADDs in rivers can be effective seal deterrents. Over the course of the study there was no difference in the effectiveness of the ADDs as a barrier to seals. Although the sample size was small, photo-identification of seals during 'on' treatments suggested that individual seals either passed the ADDs during their first 'on' treatment or were never identified to have passed the barrier. The consistent level of effectiveness over the three years, combined with sightings of known individuals, provides rare insight into habituation to ADD by seals. These results contradict the current thinking that long term effectiveness is potentially compromised by individuals developing increased tolerance to acoustic deterrents over time.

Introduction

Conflict exists in the Moray Firth between salmon fisheries and seals driven by the belief that seals have a significant negative impact on salmon fisheries (Butler et al. 2011). The Kyle of Sutherland is a river estuary that separates Sutherland from Ross-shire in the northern highlands. It flows into the Dornoch Firth and is fed by the rivers Oykel, Cassley, Shin and Carron. These rivers support important salmon populations and fisheries and the Oykel and Cassley have been designated Special Area of Conservation (SAC) for salmon. The Dornoch Firth is an important site for both grey and harbour seals and has been designated a SAC for harbour seals. The shooting of seals by fisheries may have been a factor in the decline of the Moray Firth harbour seal population (Thompson et al. 2007). Declining populations of seal and salmon populations on the Scottish east coast has exacerbated the conflict and, coupled with the need to meet EU Habitats Directive requirements, the Moray Firth Seal Management Plan (MFSMP) was introduced in 2005. The MFSMP is a pilot study exploring possible strategies to meet the needs of stakeholders and the conservation needs of both seals and salmon (Butler et al. 2008). Through the MFSMP, research is conducted as part of the Seal and Salmon Research Program including this study and previous work (Butler et al. 2006, 2011; Graham et al. 2009, 2011). One objective of the management plan is to explore and develop effective non-lethal methods of seal management in areas such as rivers and estuaries based on sound science.

Acoustic deterrents that produce loud sounds which become painful to seals that approach too close, are sometimes known as Acoustic Harassment Devices (AHDs) or, as referred to here, Acoustic Deterrent Devices (ADDs). Originally developed to keep seals away from marine salmon farms ADDs have been used for over thirty years, yet views on their effectiveness remain divided (Quick *et al.*, 2004; Sepulveda and Oliva, 2005). Such a divide might be due to site specific factors (Vilata *et al.*, 2010) with habituation possibly limiting their long term effectiveness (Richardson et al. 1995; Jefferson & Curry 1996). Success at wild salmon netting sites may have been linked to careful deployment and maintenance of the equipment (Fjalling *et al.*, 2006). In addition, a previous Scottish ADD trial that included studies from two rivers reported a significant reduction in seal sightings upstream of the ADD installation by approximately 50% in both rivers, although it was suggested that the reduction may have been higher had the power supply been more reliable (Graham *et al.*, 2009). However Olesiuk *et al*. (1996) found an ADD did not reduce the upriver occurrence of harbour seals. Given the number of ADD manufacturers and devices, each with their own sound characteristics, source levels, widely differing sites, unique propagation characteristics and the potential for species, sex and age effects on the target species, as well as individual effects given a particular seals motivation then it is perhaps not surprising that there are many differing opinions and results on ADD effectiveness.

Graham et al. (2011) found that although the abundance of seals in rivers was relatively low, ≤ 1% of the local population, there was considerable temporal variation coinciding with peak run times of salmon arriving in rivers or with salmon kelts leaving the rivers. The largest peak in seal activity occurred during the winter, between October and February, when kelts were leaving their river. Another finding was the possible existence of river specialist seals, individuals that were repeatedly sighted in a river. In addition the photo-identification of seals in the Kyle of Sutherland, as in other rivers, revealed that some seals returned to the river each winter and that these individuals were not identified to use the river at any other time of the year. Thus, in the present study, installing ADDs in the river each winter (the time when 'river specialist seals' return to feed on salmon kelts) and evaluating the response of these individuals that repeatedly return may provide rare data on habituation which possibly occurs when these scaring techniques are used to protect fish concentrations from seals (Mate 1993; Richardson et al. 1995). Behavioural habituation can be defined as the progressive waning of responses to stimuli that are learnt to lack significance (Thorpe 1963). This specific phenomenon is therefore difficult to measure and has been rarely demonstrated in wild individuals.

The aim of the study was to determine whether acoustic deterrents could be used to create an acoustic barrier preventing seals from moving up river in the Kyle of Sutherland. Mains power supply was available on both sides of the river at Bonar Bridge allowing a mains powered acoustic deterrent system to be evaluated. The study was carried out over three consecutive winters to evaluate long term effectiveness and how the tolerance of known individuals to the barrier might change over time.

Materials & Methods

At Bonar Bridge two ADDs were installed under the bridge on opposite banks where the river is approximately 100m wide and approximately 2m deep, here, river depth fluctuates with rainfall and spring high-tides can increase depth to approximately 4m. The river shallows and broadens 200m downstream, as it approaches the inner Dornoch Firth. ADD 1 was positioned 1m out from the bank and approximately 1m from the river bed (being approximately 0.3m deep during low water levels and approximately 2m deep during spring high tides). It was held in a relatively swift flow of water by a length of piping that also served to protect the cable and allowed the transducer to be removed for cleaning/maintenance purposes. ADD 2 was installed directly opposite the first installation, approximately 10m from the opposite bank and 0.3m above the river bed (in approximately 1.5m depth at winter low water levels). The distance between the ADDs was approximately 90m. ADD 2 was attached to the exposed fluke of a modified fisherman anchor with its opposite fluke sunk into the river bed, small additional plates were added to the stock arms of the anchor to further stabilise the anchor. The anchor was placed by hand during low water conditions to ensure it was seated correctly; the anchor and transducer were out of the main river flow. As a precautionary measure lead weights were added to the end of the cable to help the transducer hang vertically in the water flow. River bed substratum generally consisted of clay or bedrock overlaid with small river-worn stones and rocks.

The ADDs used in this study were Lofitech Seal Scarers (Lofitech Seal Scarer, Lofitech AS, Leknes, Norway), each powered from a single 12 volt battery that was on permanent charge from a 'mains' supply (battery voltage was maintained at approximately 13.5volts). The output power for the ADD claimed by the manufacturer was confirmed by measurements made before the trial commenced. The device produced a pure tone with a source level of ca. 189 dB re 1 μPa at 1 m, generated for ~ 500 ms at 15 kHz, harmonics were detected in varying degrees. The second harmonic was 15-40 dB lower than the fundamental signal and the third harmonic was 20-50 dB lower than the fundamental. The frequency of these harmonics was within the auditory range of seals. No energy was detected below 5 kHz. We investigated the pulse emission pattern using a 15 min recording, which resulted in 213 pulses with a mean interval of ca. 5 sec and a maximum interval not exceeding 60 sec.

The study consisted of three trials over three consecutive winters, each timed to capture the peak in seal activity that occurs when large numbers of salmonid kelts are likely to be present in the lower stretches of the river. Trials began in October 2008 and ended in January 2011 as seal activity had previously been shown to peak during November and December. The first trial started in 2008, the second in 2009 and the third in 2010 ending in January 2011.

Trials consisted of a number of alternate 'on' and 'off' treatments which lasted for 3 to 11 and 7 to 13 consecutive days respectively and observations were distributed over the experimental and control treatments. 'On' and 'off' treatments coincided with both spring and neap tides. Observations were carried out from a fixed position approximately 40m downstream of the ADD 'barrier' to estimate numbers of seals above and below the 'barrier'. The observer had a clear view of approximately 1km stretch of river with the observation position and ADD barrier positioned halfway along this stretch. Photo-identification, in conjunction with time and location of seal surfacings, was used to estimate seal numbers. Seal images were captured using a Canon EOS 50D camera with 840mm lens.

To ensure that no seals were above the barrier when the ADDs were activated, a downstream sweep that included approximately 28 km of waterways above the barrier was carried out. These 'sweeps' were carried out by small boat fitted with an ADD and two observers, the boat slowly drifted downstream allowing any seals to move steadily ahead of the boat until the seals were returned to the firth. The 'swept' area included areas that were used by seals based on incidental seal sightings and telemetry data from one seal.

Data analysis

All statistical analysis was performed in R 2.13.1 (R Development Core Team, 2011).

To test whether the ADD affected the number of seals above and below the ADD we fitted a poisson Generalised Estimating Equation (GEE). The response variable was number of seal sightings per hour. Candidate explanatory variables included day, year, location (above or below ADD), ADD status ('on' or 'off'), and presence/absence of ice (presence was when complete coverage of the inner firth occurred). All variables were included as factors with the exception of day, which was included as a smoothed function (base spline) with one knot fixed at the mean of day because the plotted relationship between day and seal sightings appeared non-linear. We also included an interaction term between location and ADD to identify differences between above and below the ADDs when 'on' and 'off'. The model was fitted using backwards stepwise selection, with the variable/factor with the highest p-value (determined by an analysis of variance) being dropped at each step. The GEE approach was adopted because after fitting a poisson Generalise Linear Model (GLM) we found significant temporal autocorrelation remaining in the model residuals. The temporal autocorrelation was found to decline to close to zero after 3 days and therefore we included a 3-day blocking unit in the GEE. GEEs can be used to estimate the parameters of a GLM when the correlation between outcomes is unknown and they are robust to mis-specification of the variance structure.

Results

In total 132 seal sightings (102 grey and 30 harbour seal) were recorded from the observation point at Bonar Bridge during 152 surveys. Approximately 67% of sightings occurred during 'off' treatments and 90% (80 sightings) were seen upstream of the ADDs, compared to only 33% of sightings occurring during 'on' treatments of which just 21% (9 sightings) were seen upstream of the ADDs (Table 1).

Table 1. Monthly breakdown of the number of surveys (observation periods), number of seal sightings and the number of those seen upstream of the ADDs during 'on' and 'off' treatments

	ADD 'off'			ADD 'on'		
Month/Year	Surveys	Seals	Seals upstream	Surveys	Seals	Seals upstream
Oct-08	13	8	5	7	1	1
Nov-08	10	16	16	13	14	5
Dec-08	9	17	17	9	8	0
Jan-09	1	0	0	0	-	-
Total	33	41	38	29	23	6
Oct-09	2	0	0	1	0	0
Nov-09	7	7	7	11	3	0
Dec-09	9	14	13	9	6	1
Jan-10	3	0	0	0	-	-
Total	21	21	20	21	9	1
Oct-10	4	2	1	4	1	0
Nov-10	10	13	9	11	8	2
Dec-10	5	0	0	7	2	0
Jan-11	7	12	12	0	-	-
Total	26	27	22	22	11	2
Grand Total	**80**	**89**	**80**	**72**	**43**	**9**

Observation periods were of varying durations due to weather conditions or tidal factors. In general, observations lasted between two and three hours (average 2.2hrs; max. 3hrs; median 2.2hrs). An observation period of two hours and ten minutes comprised two hours at the observation position and ten minutes observing from the road bridge at Bonar Bridge. This higher vantage point allowed the observer to check for any seals that might be hauled-out in vegetation on the banks of the river. Longer observation periods of over 2hrs10mins and up to 3hrs took place during spring tides when the larger tidal volume made it easier for seals to enter the rivers earlier in the tidal cycle. The observer started observations up to 1hr30mins before high water at Meikle Ferry. Meikle Ferry is the closest tidal port, 14km downstream. Observations were carried out at Bonar Bridge during the run up to high tide and ended shortly after the high tide when the majority of seals appeared to return to the firth.

Several observation periods were cancelled due to severe weather conditions. No seals were recorded in the river when the inner Dornoch Firth was completely frozen (no visible channels through the ice). There were sixteen observation periods where the amount of ice was recorded as having reached these levels. They only occurred during December and January and occurred 9 times during ‘off’ treatments and seven during ‘on’ treatments, see below for year and treatment breakdown:

2008 – 1 ‘off’
2009 – 3 ‘off’ and 2 ’on’
2010 – 5 ‘off’ and 5 ‘on’

Model Results

All explanatory variables/factors were retained in the model as significant contributors to model fit and the relationship between each variable/factor and the response variable can be seen in Figure 1. In terms of temporal variables, year as a factor was only significant at the $p<0.1$ level but the inclusion of year improved model fit and so it was retained in the model. Comparing levels within the year factor, there was a significantly lower number of seals seen in year 2 compared with year 1 ($p<0.05$) but no difference between year 1 and 3 or year 2 and 3. The smooth term for day was highly significant ($p<0.001$) verifying that the numbers of seals seen over time was not linear. The presence of ice coverage in the firth was highly significant ($p<0.001$) with significantly fewer seals being sighted when ice was present. Similarly, the ADD was highly significant (p<0.001) with significantly fewer seals being sighted when the ADD was ‘on’. Location contributed significantly to the model overall (p<0.001) but there was no significant difference between the factor levels, above and below. However, the interaction term between ADD and location was highly significant (p<0.001) and showed that when the ADD was ‘off’ there was no significant difference in sightings between the two locations, but when the ADD was ‘on’ there was a significant reduction in sightings above the ADD. Additionally the model indicates a reduction in seal sightings below the ADD when the ADD was ‘on’ compared to when it was ‘off’. The model explained 48% of the variance in the data.

Model predictions of seal sightings per hour across years for scenarios when the ADD was either completely ‘off’ or ‘on’ (and all other variables were as observed) suggest that:
(1) there was an 87.8% reduction in sightings above the ADD when it was ‘on’ compared with ‘off’,
(2) there was a 45.7% reduction in sightings below the ADD when it was ‘on’ compared with ‘off’,
(3) there were 77.6% fewer sightings above the ADD when ‘on’ than seen below and
(4) there were no difference in the number of sightings above and below when the ADD was ‘off’.

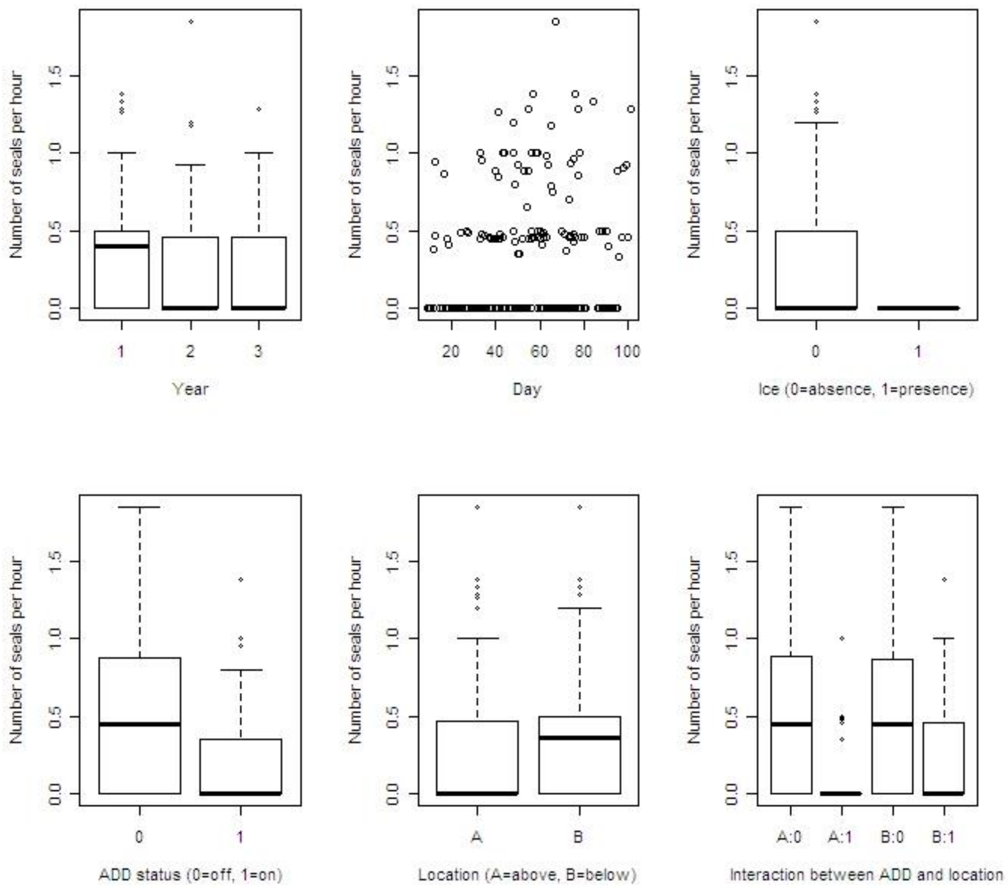

Figure 1. Number of seal sightings per hour against the five explanatory variables, year, day, ice (where 1 = complete blockage of inner firth), ADD status (0= ‘off’, 1= ‘on’), location (A=above, B=below) and the interaction between ADD and location

Photo-identification results

During the study 132 seal sightings were recorded and 72 sightings were identified as individuals based on their unique pelage markings. 50% of the individuals were identified in more than one year and three grey seals were seen in every year of the study. These three seals accounted for a total of 26 recaptures, with just 4 occurring during ‘on’ treatments and these individuals never passed the barrier when ‘on’ (Table 2.). Of seals seen during ‘off’ treatments a higher proportion (62% - 55 sightings) were identified compared to those seals seen during ‘on’ treatments when 40% (17 sightings) were identified (Table 2.). A total of fourteen different seals were identified during the study. Four seals were identified to pass the barrier when it was ‘on’; all doing so during the first occasion they were sighted/identified, however, three were identified in only one ‘on’ treatment and interestingly two were harbour seal pups (Table 2.).

Table 2. Number of seals identified from pelage markings, winters they were detected, total number of recaptures and the number of recaptures during ‘on’ and ‘off’ treatments with the proportion seen above the barrier

					Total	*On' Observations (N = 72)*		*Off' Observations (N = 80)*	
Species	Seal ID	Winter 1	Winter 2	Winter 3	Recaptures	Recaptures	Prop.Above	Recaptures	Prop. Above
Grey	Hg008	Present	Present	Present	8	3	0.0	5	1.0
Grey	Hg009	Present	-	-	6	4	1.0	2	1.0
Grey	Hg010	Present	-	-	7	2	0.0	5	1.0
Grey	Hg014	Present	Present	Present	9	Not identified		9	1.0
Grey	Hg.1K	Present	-	-	1	Not identified		1	1.0
Grey	Hg.2K	Present	Present	Present	9	1	0.0	8	1.0
Grey	Hg.3K	Present	-	-	1	Not identified		1	1.0
Grey	Hg.4K	Present	-	Present	4	3	0.0	1	0.0
Grey	Hg.5K	-	Present	Present	8	1	1.0	7	0.9
Grey	Hg.999	-	Present	Present	5	1	0.0	4	1.0
Harbour	Pv.pup1	Present	-	-	3	1	1.0	2	1.0
Harbour	Pv.028	Present	Present	-	6	Not identified		6	1.0
Harbour	Pv.2K	-	-	Present	4	Not identified		4	1.0
Harbour	Pv.pup2	-	-	Present	1	1	1.0	Not identified	
Totals	14	10	6	8	72	17		55	

Discussion

These results demonstrate that during this three year study, ADDs formed an effective barrier to seals and also reduced the presence of seals downstream of the barrier. Model predictions suggest that if the ADDs had been permanently ‘on’ during the study periods there would have been an 88% reduction in the number of seals seen above the barrier and a 46% reduction in the number seen below the barrier. Although it is not possible to directly compare these results to those reported by Graham et al. (2009), these results do suggest a greater level of effectiveness of the ADDs as a barrier to seals at this location. Furthermore this study found a significant overall reduction in the number of seal sightings during ‘on’ treatments that was not reported by Graham et al. (2009), although this may have simply been due to geographical differences associated with the size of the observable area downstream of the barrier and survey method. There are a number of reasons for the apparent increase in barrier performance, for example using two ADDs connected to mains power preventing power loss during low temperatures was an important difference. Regardless both Graham *et al.* (2009) and this study demonstrate that ADDs can be used effectively in Scottish rivers to significantly reduce the number of seals attempting to move upriver to forage on salmonids.

The observation position was approximately 40m downstream of the ADD ‘barrier’ which aided the photography of seals approaching the barrier. Seals that remained further from the barrier were harder to identify. This may partly explain the difference in the proportion of identified seals between ‘on’ and ‘off’ treatments. Photo-identification of seals was achieved at ranges of up to 400m (based on distances to known features along the river banks), although this distance reduced in poor light conditions. Photo-identification data during ‘on’ treatments were limited, partly due to the effectiveness of the ADDs, however capture histories suggest that individuals either always passed the barrier when ‘on’ or always avoided it. No seals were initially identified to remain below the barrier and then to pass the barrier in subsequent treatments. Four individuals were identified to pass the barrier when ‘on’, each doing so during their first recapture during an ‘on’ treatment. Assuming these seals had not previously approached the barrier then these results might lend rare support to the argument that if habituation occurs then it probably occurs rapidly and provides support for the long-term effectiveness of ADDs. This counters suggestions made by Richardson et al (1995) and Jefferson & Curry (1996) that habituation will likely limit the long-term effectiveness of these methods. However as only 40% of seal sightings were identified during ‘on’ treatments and seals may have visited the barrier at times out with observation periods, then it is possible that if habituation took place then it may have taken place over a longer time scale than investigated here.

This study suggests that the majority of seals were not prepared to tolerate the ADDs and this did not appear to change for individuals that were identified in more than one winter. To begin to fully answer the question of habituation much more data would be needed, which could perhaps be achieved by tagging river specialist seals or by increasing the number of cameras and observers at increasing distances downstream of the barrier, allowing a larger proportion of the seal sightings to be photographed and identified. A relatively low proportion of seals were identified during ‘on’ treatments and it was not possible to determine whether seals were habituating to the ADDs out with the immediate study area. Sound measurements at various times through the tidal cycle in the inner firth would provide useful information about whether seals were able to detect the ADDs before being in range of the observer.

During the study a number of maintenance issues were identified that need to be considered and corrected if acoustic barrier systems are to be considered as practical solutions in rivers. The two installations described above, although designed to be temporary installations, stood up well to spates and winter ice. Sound heads needed to be regularly cleared of river weed fouling, especially ADD 1, the device positioned in the main river flow. Fouling may mask the sound signal and increases drag from the river current, causing the sound head to rise to a horizontal position. In this orientation sound propagation from the ADD is reduced. Both sound heads needed additional weights to maintain a vertical orientation. The device installed out of the main current and attached to an anchor on the river bed was subject to less fouling, however the need to position this anchor by hand to ensure its correct seating made this installation difficult to remove and replace for maintenance. The position in relatively shallow water may also have made it susceptible to propeller strikes had it been in place during low river levels during the summer months when boat traffic is more frequent in this area.

Although a direct comparison cannot be made with previous studies that used battery-powered rather than mains-powered ADDs because they were carried out in different locations in different years, Graham et al. (2009) emphasised the problems experienced with maintaining sound output levels in cold weather due to the batteries losing voltage during these extreme conditions. They concluded that relying on batteries may result in higher maintenance and if sound output levels are depressed for any length of time then this may allow for habituation. In this study we did not experience any problems with maintaining power levels as a result of temperature. Despite the extreme conditions during 2009 and 2010 when ice was present in the river. We would therefore recommend that mains power is essential, especially when deploying ADDs in Scottish rivers during winter.

In conclusion, provided they are located and maintained appropriately, the use of ADDs in rivers can provide an effective tool in the management of seal-salmon conflicts. The information from individual seal identification and the modelling results suggest that effectiveness in this study was consistent over the three winters. Although the sample size was small, individual seals either passed the barrier when it was ‘on’ or never passed it and this remained constant for individuals between years. This suggests that seals either learnt to tolerate the barrier quickly or not at all.

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