# Marine Mammal Scientific Support Research Programme MMSS/001/11

SSI:

Report

# Seals and wild salmon fisheries

Sea Mammal Research Unit
Report to
Scottish Government

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# Contents

# 1 Executive Summary

This document reports on the progress made during 2014 with regard to marine mammal research at wild salmon fisheries. The objectives were: to continue studies into the effectiveness of Acoustic Deterrent Devices (ADDs) and the modification of salmon nets to mitigate the effects of seals on these fisheries; collect shot seals for dietary analysis and provide support to district salmon fishery boards (DSFBs). Activities primarily focused on two sites in the Moray Firth, Portmahomack and Crovie.

During 2013 the salmon net fishery at Portmahomack reported that seals were regularly seen at the net and that salmon landings were damaged by seals despite the use of an ADD. During 2014 seal sightings and salmon landings data were collected and photo-identification of seals from land-based photography was used to identify individual seals. Images were collected (n=1197) and all seal sightings at the net while the ADD was 'on' were attributed to adult male grey seals. Photo-identification revealed only two adult male grey seals were prepared to visit the salmon net while the ADD was 'on'.

During 2013 tests began on the effectiveness of an ADD at Crovie. This work continued in 2014 through the collection and processing of underwater video footage to study the rate at which seals entered the net. The deployment of a C-POD was trialled to provide information on the presence of cetaceans during ADD 'on' and 'off' treatments; however, the elevated noise levels during ADD 'on' periods compromised the C-PODs ability to detect cetaceans. Dolphins and porpoises were regularly detected on the C-POD during ADD 'off' periods. Land-based observations recorded dolphins during both ADD 'off' and 'on' periods. Seal sightings were between five and six times higher during ADD 'off' periods compared to ADD 'on'.

At Crovie in 2014 the evaluation of net modifications continued by examining the effectiveness of a different size of net entrance. Results from the 2014 study suggested that the new design increased salmon landings and reduced fish hesitation in the outer part of the net, an important aspect of reducing depredation from this area.

In April 2014 a report on the diet of seals shot at salmon nets from 2005 to 2013[1] was produced. The most frequently encountered prey was whitefish, sandeels and flatfish. However, an increase in the proportion of seals testing positive for salmonid DNA since the introduction of ADDs and net modifications may suggested that fewer 'transient' seals are now being shot with lethal control becoming more targeted to those consuming salmon.

Sea Mammal Research Unit (SMRU) personnel have continued to provide presentations on these studies and have provided support to river fisheries when requested. Where requests for support have been received this has led to the formation of a channel of communication between those working in river fisheries and SMRU that is beginning to form the basis for good collaborative work.

This project is continuing to produce encouraging results from the use of ADDs and net modifications at mitigating the effects of seals on these fisheries, and is maintaining positive and open relations with both net and river fisheries.

[1] This report can be found at www.smru.st-and.ac.uk/documents/1975.pdf

## 2 Introduction

There is a long history of conflict between salmon fisheries and seals due to highly visible damage to fish or observed depredation, leading to a widespread belief among fishermen that seals adversely affect both salmon stocks and landings (Butler *et al.* 2011). Until recently, this conflict was often resolved by shooting individual seals. Since 2010, however, shooting has only been allowed under licence to protect fish and fishing gear from seals. While non-lethal measures are preferred, these are still not effective in all cases and the option of killing should now be seen as a last resort.

The issue at coastal bag net fisheries is particularly severe, as these are traditional non-capital intensive enterprises, often employing just a few people, but also in rural communities where employment opportunities are limited. Developing effective non-lethal measures to minimise damage to fish can only be done effectively with the assistance of a suitably resourced outside agency such as the SMRU, which has experience of both seals and fisheries.

Bag-nets are a traditional form of fish-trap used to catch salmon in Scottish coastal waters. There are two typical bag-net designs: the single bag-net and the double bag-net (Figure 1). Bag-nets float from the surface, rarely extending deeper than 5m and are anchored and attached to the shore. The leader (a net ‘fence’ often between 80 and 100 yards in length) typically runs perpendicular to the coast and makes use of the behaviour of migrating salmon to funnel fish into a trap from which they find it hard to escape. In its construction no mesh size smaller than 90mm or mono-filament net can be used, and its design must not gill (enmesh) salmon. Furthermore, no fishing is permitted on weekends (18:00 Friday – 06:00 Monday) and the overall duration of the fishing season may differ between districts. In Scotland, enforcement of these regulations falls to the District Salmon Fishery Boards (DSFBs) rather than Marine Scotland Compliance that oversees compliance in other marine fisheries in Scotland. Fisheries make annual returns each year and salmon and sea trout landings statistics are available from Marine Scotland (www.scotland.gov.uk[2]).

The perception that seals significantly decrease bag-net landings has been validated at certain locations but has been less easy to validate at others (Harris *et al*., 2014a, 2014b). Seals are known to intercept and remove whole salmon at the leader and to enter traps and remove whole fish from the cleek, doubling and the fish court (Figure 1). Seal presence around nets may also scare fish away from nets that may otherwise have been caught. Salmon are also damaged by seals attacking the outside of the net when salmon become trapped in pockets of net or when panicking fish trap themselves and become enmeshed in the side walls of the trap. Alternatively panicking salmon may exhaust themselves, falling to the floor of the trap where they become easier to depredate.

The majority of the impact may be inflicted by a few seals that habitually return to net sites to depredate salmon (Harris, 2012a; Harris *et al.*, 2014a). Observations of aggression between seals at net sites may suggest that habitual visitors are defending a food resource from other seals, further helping to limit the number of ‘problem’ seals at nets. However, it is not known whether or how quickly these ‘problem’ seals would be replaced if they were removed (for example by shooting). The likelihood of replacement may be higher when seals receive food rewards when first visiting bag-net sites and are therefore motivated to return. Removing or greatly reducing the availability of fish to the seals is therefore important. Studies in Scotland and the Baltic, where similar nets are used, suggest this may be achievable through developing new net designs or by modifying existing nets to reduce the effects of seals on salmon catches (Harris *et al.*, 2014b, Lehtonen & Suuronen 2004; Lunneryd *et al.*, 2003). Some Scottish fishermen have introduced their own modifications, such as strengthening areas of the net that are frequently targeted by seals and removing tight corners where fish can be trapped by seals. Others, however, feel that such modifications only reduce catches as salmon are hesitant to enter reinforced areas of bag-nets.

The legality of net modifications within Scotland, as well as the feasibility of their introduction to the Scottish industry in terms of the practicalities of deployment or implementation, needs to be assessed. Perhaps most importantly, the effects of any such modifications on net fishing performance need to be assessed against existing nets before fishermen may be willing to accept them. These factors need to be carefully considered before a practical long-term solution can be found for Scottish salmon bag-net fisheries that will minimise the need for them to shoot seals.

[2] These data can be requested from Marine Scotland Science at ms.catchform@scotland.gsi.gov.uk

Seal research at Scottish salmon bag-nets has recently been focused on two main areas: the effectiveness of Acoustic Deterrent Devices (ADDs) at bag-nets and the modification of nets to reduce seal damage and depredation. Previous studies have demonstrated encouraging results using both these methods (Fjälling *et al*., 2006; Harris *et al.,* 2014a, 2014b; Lehtonen & Suuronen 2004; Lunneryd *et al.,* 2003). Below, recent developments in both of these areas are presented.

Salmon fisheries may protect their nets and catches against serious damage from seals by lethal control under licences issued under the Marine (Scotland) Act 2010. Licences are considered for coastal nets and inland rod and line fisheries as well as aquaculture and limits are issued accordingly by Marine Scotland. Licence holders are required to report the numbers of each species removed on a quarterly basis and to make an attempt to recover carcasses whenever possible. Post-mortem reports on each recovered carcass are held by the Scottish Rural College (SRUC) Scottish Marine Animal Strandings Scheme (SMASS) and tissue samples made available to benefit a range of scientific studies.

## Reported here:

Following on from previous work (Harris *et al.,* 2014a, 2014b; Harris 2011; Harris 2012a, 2012b) progress on marine mammal research and support for wild salmon fisheries during 2014 has been made. The main objectives during 2014 were to:

- Continue trials of ADD use in the Moray Firth. Specifically to assess the cause of the poor results reported in 2013 (Harris *et al.,* 2014b) following four years of successful Lofitech ADD deployments at Portmahomack (Ross and Cromarty).
- Continue the AirMar ADD trial at Crovie (Banffshire) in order to test the effectiveness and ease of use of a different sound source that is also mains powered.
- Build upon the previous bag-net modification trial (Harris *et al.,* 2014b) and evaluate a wider fish court entrance that would reduce hesitation by fish but continue to exclude seals. This follows results that showed that a new fish court opening design could exclude seals but also resulted in the hesitation of fish in the doubling and thus increased predation from the doubling.
- Collect shot seal carcasses and store gastro-intestinal tracts for dietary analysis.
- Provide support to DSFBs with regard to seal management issues and ADD installations.

Several additional tasks were also addressed. These included an assessment of the calorific content of kelts (which appear to be subject to frequent predation by seals in rivers), an assessment of the feasibility of catching problem seals and field tests of the source levels and signal characteristics of ADDs being tested at bag net stations and in use in rivers, as there have been some concern that these may not always match manufacturers' specifications, especially after extended periods of use in extreme conditions.

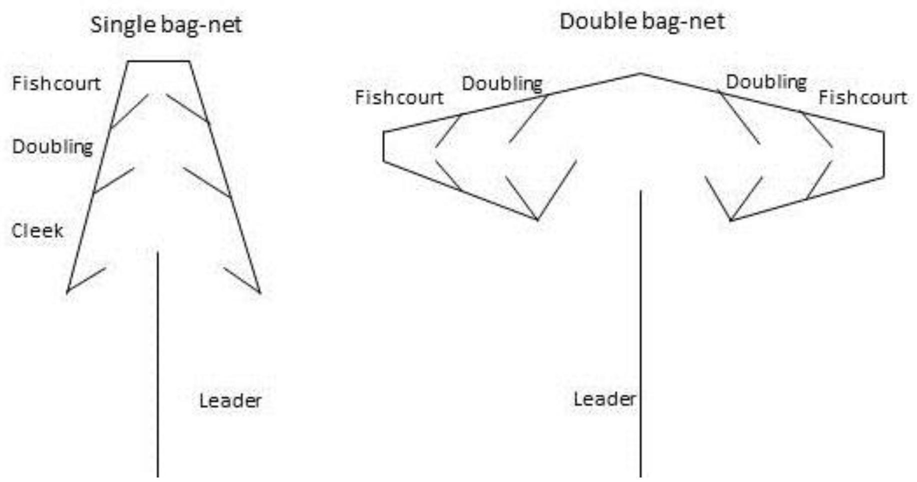


**Figure 1.** Plan view of a single bag-net and a double bag-net showing the sequence of chambers that make up the salmon trap - cleek, doubling and fish court.

# 3 Moray Firth – Portmahomack 2014

## 3.1 Introduction

William Paterson and Sons Ltd. fish for salmon along a section of coastline near Portmahomack on the Tarbet Ness Peninsula (Ross and Cromarty). The fishery generally operates for a relatively short period during the salmon net season targeting returning salmon during July and August (primarily grilse). One double bag-net has been set at this station for more than 15 years and has had the use of a Lofitech ADD for five fishing seasons since 2009. The effectiveness of the ADD was trialled experimentally (involving control periods) during 2009 and 2010. The study found that although the ADD did not completely exclude seals, the ADD was an effective seal deterrent at this site with significantly fewer seals sighted at the net and significantly more salmon landed during ADD 'on' treatments compared to 'off'. Results suggested that these findings were a direct result of the ADD reducing seal presence at the bag-net. During the study 56% (n=43) of seal sightings were photo-identified. This resulted in 14 different seals being identified. The majority of these, however, were 'transients' (seals seen on just one or two occasions) with two grey seals making up the majority of sightings (63%).

In 2011 the ADD deployment at this site was fishery-led, whereby landings and seal information was recorded by the fishery. The ADD was 'on' continuously while the net was in the water and the fishery reduced the number of net hauls per day by approximately half. The average of 2.4 hauls per day during 2011 represented a considerable saving in effort and resources where before fishers were regularly checking the net for fear of losing fish to seals. The fishery reported five seal sightings during 2011. However, all were outside the net's anchor trip buoys (implying all seals were further than 80m from the net). No seal-damaged fish were reported, although fishermen reported difficulties in maintaining battery voltages above 12v.

During 2012 and 2013 the ADD deployment was again fisher-led, although the ADD was not continuously 'on'. Many of the ADD 'off' periods were attributed to occasions when the fishery decided not to deploy the ADD or when the ADD had to be recovered for battery charging. On a number of occasions the ADD was recovered with battery voltage low enough to affect ADD acoustic output. Although three seal sightings were reported in 2012 while the ADD was 'on', the ADD was regarded by the fishermen as a very successful deterrent over the four years to 2012. However, during 2013 the numbers of reported seal sightings increased and seal damaged fish were landed during ADD 'on' periods, leading to the fishermen reporting a resurgent problem with seals at the fishery. It should be noted that, as in the previous four years, the undamaged catch per unit effort (CPUE) figures remained higher when the ADD was 'on' than during ADD 'off' periods.

An objective of the 2014 season was therefore to investigate the reported seal problem at Portmahomack, and specifically to determine whether the damage was attributable to a rogue individual, or whether several seals were involved.

## 3.2 Methods

During the 2014 salmon net fishing operations at Portmahomack a SMRU observer was present to record landings, seal damage, seal sightings and collect photo-identification data of seals. In addition the observer helped maintain the ADD and recorded battery voltage as well as environmental conditions.

The ADD was the same device as used in previous years: a Lofitech ADD was deployed with its power supply, two Haze 75 amp-hour gel batteries (Haze Battery Co.), in a modified Peli case (Peli Products Ltd.). Sound pressure measurements were made before the start of fishing operations. The Peli cases' buoyancy was sufficient to float its weight and that of the batteries and ADD (~ 65kg) and was moored close to the bag-net by attaching a mooring line to one of the bag-net's anchor lines. Additional water-proofing modifications were made to the ADD electronics case and batteries to further improve water-proofing in the event that the Peli case flooded. The transducer cable was routed along the bag-nets anchor line to position the sound head within 2m of the bag-net. Unfortunately the additional water-proofing of the system meant that batteries could not easily be replaced at sea and therefore the system had to be brought ashore twice a week for recharging. This effectively left the net without an ADD for approximately 12 hours each week. Therefore the weekly routine generally saw the bag-net and ADD deployed at 06:00 on Monday, the ADD was recovered for recharging on Tuesday night or Wednesday morning before being redeployed after recharging, the ADD was then recovered before 6pm Friday and recharged over the weekend.

A decision was made by the fishermen to leave the ADD 'off' during the 5th week of the season to test their theory that the ADD was causing the observed poor salmon landings.

An attempt was made to reduce seal damage by deploying a new ADD on the 6th August, but unfortunately it was only possible to deploy the new ADD for two days before the season ended prematurely due to adverse weather conditions. The new ADD was a redevelopment of the Airmar dB Plus II, referred to as the Mohn Aqua Group (MAG) ADD. Part of the redevelopment has resulted in improved power requirements making it more suitable for battery operated deployments.

## 3.3 Results

Operations began on Tuesday 1st July and ended on the 8th August, two weeks earlier than planned due to poor weather conditions. A total of six weeks of data were collected. The fishery expressed a wish that absolute numbers of salmon not be presented in this report and therefore undamaged landings (catch) per unit effort (UCPUE) are presented as an index. This was carried out by taking the average of the three UCPUE rates (Lofitech 'on', MAG 'on' and ADD 'off') and dividing each UCPUE value by the combined average. As ADD 'off' periods were not distributed in a random fashion, being confined to a short period each week while batteries were recharged and then the entire 5th week of the season, they do not represent true control data and a formal comparison would be unwise. However, the observed difference in landings, seal-damaged catch and seal presence between Lofitech 'on' and 'off' periods suggests that although seals were a problem during 'on' treatments the Lofitech may have reduced seal presence and damage when 'on', possibly resulting in the higher CPUE figures (Table 1).

Installing the MAG ADD appears to have had a positive effect on CPUE, catch damage and seal presence at the net. However, it is difficult to infer much from these data after just a single 54 hour deployment (Table 1).

**Table 1**. For both ADDs and ADD 'off' periods net fishing effort in hours are reported, an index of undamaged landings per unit effort, the percentage of catch damaged and the proportion of net hauls with recorded seal activity at the net (seal presence) .

| ADD | Effort (hours) | UCPUE index | Catch damaged | Seal presence |
|---|---|---|---|---|
| 'Off' | 199 | 0.3 | 19% | 0.6 |
| Lofitech 'On' | 360 | 0.9 | 5% | 0.3 |
| MAG Airmar 'On' | 54 | 1.7 | 0 | 0 |

### 3.3.1 Observer and photo-identification

During fishing operations a SMRU observer carried out 137 hours of observations (22 hours during ADD 'off', 94 hours during Lofitech 'on' and 21 hours during MAG 'on') this represented coverage of approximately 22% of total fishing effort for the season. Seal sightings were categorised as near the net if they were within 80m of the net based on the position of marker buoys. While the Lofitech ADD was 'on' only adult male grey seals were seen near the bag-net. During observation periods adult male grey seals were regularly photo-identified based on scars and natural pelage markings. During observations where seals were recorded close to the net while the Lofitech was 'on', known adult males were identified in 12 out of 17 (71%) observation periods, and all the identified seals could be attributed to just two individuals (Figure 2). Five sightings of seals swimming away from the net with whole salmon were recorded, all of which occurred during Lofitech 'on' periods.

During ADD 'off' periods seal sightings near the net was comprised mainly of adult male grey seals, a female grey seal and an adult harbour seal (*Phoca vitulina*). No cetacean sightings were seen during any treatment and one otter sighting was recorded close the net's leader during an ADD 'off' period.

**Figure 2**. Two male grey seals photographed at Portmahomack with identifiable marks highlighted.

## 3.4 Discussion

The objective of work at Portmahomack in 2014 was to assess the extent of the seal problem at the Portmahomack bag-net site. The main aim was to photo-identify seals that visited the double bag-net while the Lofitech ADD was 'on', providing an indication of the number of seals prepared to ignore the device. Photo-identification revealed two adult male grey seals that were regular visitors to the net while the Lofitech was 'on'. Sightings of seals swimming away with salmon suggest they were successful in utilizing the area to predate salmon. Although a formal comparison between 'on' and 'off' periods would be unwise from this study, the sightings of a female grey seal and a harbour seal near the net during ADD 'off' periods and the absence of any other seals during ADD 'on' periods may suggest that the Lofitech ADD was effective at keeping the majority of seals away from the net. This is supported by findings from previous photo-identification studies at Portmahomack, and at other bag-net sites, over a similar time frame/observer effort where at least 11 different seals were identified (Harris, 2012a).

Clearly, seal presence, damaged fish and poor landings were sufficient to change the fishermen's perception of the effectiveness of the Lofitech ADD despite higher UCPUE when the device was on. However, from a seal management perspective the ADD at this site may still be effective as it allows management action to focus on those habitual net seals that ignore the ADD in order to feed from a known food source, rather than transient animals that appear to avoid the nets when ADDs are in use. The question of whether or how quickly other seals would replace these existing seals if they were removed is an important one and may ultimately determine ADD effectiveness.

The short term deployment of the MAG ADD was encouraging and it is hoped to build on this in the future and to explore the implications relating to the effectiveness of novel versus differing sound sources.

# 4 Moray Firth - Gamrie Bay 2014

## 4.1 Introduction

Previous studies on the effectiveness of ADDs on salmon bag-net catches have focused on the Lofitech ADD at Portmahomack. However, there was a need to assess other commercially available ADDs and to develop new test sites involving other fisheries. Gamrie Bay provided that opportunity, as well as a chance to further test net modifications.

The Scottish Wild Salmon Company purchased salmon fishing rights to Gamrie Bay and adjacent areas and began operations in 2012. A limited number of seal licences were issued by Marine Scotland and a number of seals were shot in 2012, resulting in considerable conflict with the local community over seal shooting and subsequent carcasses washing ashore near the village of Crovie. In 2014 up to nine bag-nets were operated at eight sites (Figure 3).

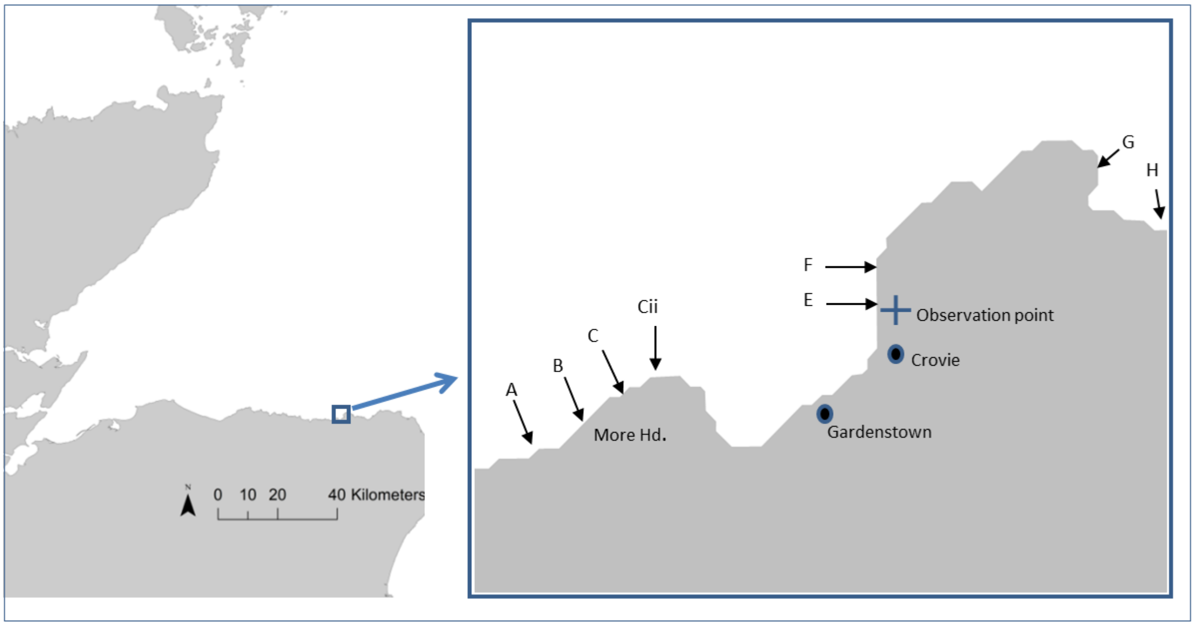


**Figure 3.** Locations of the observer's position and Scottish Wild Salmon Company's salmon net sites at Gamrie Bay in 2014: Site A – March (1 single bag-net), Site B – Skate and Outrigger (2 single bag-nets), Site C – Middle (1 single bag-net), Site Cii – More Head (1 double bag-net), Site E – Peter (1 single bag-net), Site F – Wirren (1 single bag-net), Site G – Downie (1 double bag-net) and Site H – Castle (1 single bag-net).

The aim at Gamrie Bay was to continue the study initiated in 2013 on the effectiveness of the Airmar ADD at reducing the need to shoot seals, through reducing seal presence at nets and thereby reducing seal damage to and depredation of fish.

In 2013, an Airmar ADD was installed at the Peter net site (Site E, Figure 3). This represented the first experimental study of an Airmar device at a Scottish bag-net. A land-based approach to the deployment of this ADD was also evaluated which enabled the use of mains power (Harris *et al.*, 2014b) thereby overcoming a number of practical problems associated with self-contained floating power supplies that were used at other sites. Results suggested that the ADD had been effective at keeping seals away from the net during 'on' treatments. However, seal occurrence at Gamrie Bay was low in comparison with inner Moray Firth sites and so the difference between "on" and "off" treatments was not so striking. For example, at Balintore in 2012 seals entered the doubling of a bag-net on average once an hour, whilst at the Peter net site at Gamrie Bay in 2013 seals entered the doubling on average once every 20 hours. It was agreed with Scottish Government that given the relatively low rate at which seals were observed entering the Peter net, at Gamrie Bay, at least three seasons would likely be needed to determine efficacy.

During 2012 William Paterson and Sons Ltd. provided the location (Balintore) and infrastructure to run experimental trials of net modifications developed by the Scottish Wild Salmon Company (SWSC) which are claimed to reduce seal damage to landings and reduce seal depredation from bag-nets. SWSC had been using these net modifications since at least 2009. However, other fisheries refused to make changes fearing the modifications may reduce landings. SMRU therefore felt it important to provide an independent verification of the efficacy of these modifications. Results in 2012 suggested that the modified net landed almost twice as many undamaged salmon as the traditional (control) net. This difference was significant ($p=0.006$), even when other contextual variables were accounted for.

However, the proportion of damaged fish from the modified net was also higher than from the traditional net (12% versus 8.5% respectively). Furthermore underwater video footage collected during the trial suggested that seal depredation had increased in the doubling (see Figure 1) of the modified net compared to the traditional net. This increase in depredation was probably caused by salmon hesitating at the modified entrance to the fish court (salmon took 4.5 times longer to pass from doubling to the fish court, and a larger proportion of salmon swam back out of the doubling). Therefore the aim of the study in 2014 was to reduce seal depredation opportunities in the doubling whilst maintaining the efficiency of the net to catch and retain salmon. By evaluating the effect of increasing the size of the fish court door it was hoped to reduce the time fish spent in the doubling whilst continuing to exclude seals from the fish court and to prevent an increase in the escape rates of salmon from the fish court.

Whilst in 2012 work was carried out in collaboration with William Paterson and Sons on the first net modification trial, in 2014 it was decided to work with SWSC at their Gamrie Bay location. This was primarily due to the longer fishing season (5 months as opposed to 1 or 2 at Balintore), which gave the opportunity to collect a greater amount of data in a field season. SWSC provided the location and infrastructure as well as the fabrication and installation of a new wider fish court entrance.

## 4.2 Methods

Working with SWSC, a mains powered ADD was re-deployed at the Peter net site near Crovie village (site E, Figure 3) in April 2014 in an attempt to collect a second year of data on its effectiveness as a seal deterrent at this location. In addition, SWSC agreed to alternate the size of the fish court entrance to enable evaluation of the effect of this net modification on salmon and seal behaviour, as well as on landings. This was done by the fishery despite considerable risk to its profitability.

The typical fishing method for Scottish bag-nets requires a net to be brought ashore at regular intervals to be cleaned. At that time the net is usually replaced with a clean net to keep the site fishing. At the Peter site two nets were alternated, the two nets were the same design and size, with the exception that one net had a fish court entrance approximately 160mm wide (denoted P1) and the other had an entrance approximately 190mm wide (denoted P2).

The installed ADD system was an Airmar dB plus II with a single transducer, with a fundamental frequency of 10 kHz, pulse duration of ~2.5 seconds and a duty cycle of ~25%, attached to a 200m transducer cable that allowed the power supply and the main electronics box to be housed onshore. The transducer cable was fixed to the foreshore via regularly placed 12mm steel anchoring bolts. The final 100m of cable was weighted and routed underwater to the net while a buoy maintained the sound head at a depth of 2m and approximately 8m to the south of the Peter net fish court. As this ADD deployment method had no direct attachment to the bag-net it did not interfere with fishing operations. The ADD was installed and maintained by SMRU and trialled in an experimental fashion involving control periods. Control periods or ADD 'off' treatments were decided each morning by the observer flipping a coin to determine ADD status. The ADD was switched 'on' or 'off' while fishermen were checking the net each morning. If the fishermen did not check the net then the treatment was allowed to overrun until the next time the fishermen were at the net.

During April and May land-based observations were carried out to record environmental conditions and marine mammal activity at the Peter site. However, during June, July and August there was a switch from using land-based observations as a method for recording marine mammal information to underwater video recording to detect seal activity in the doubling (see Figure 1) and installed a C-POD to log cetacean activity. The fishermen (SWSC) recorded landings and seal damage data onto reusable waterproof slates and the information was collected daily by an observer. The observer also recorded environmental conditions approximately four or five times per day during daylight hours.

Four underwater cameras (Prove Systems Ltd.) were placed in the doorways of the doubling and fish court to monitor seals and fish entering/leaving these areas of the bag-net (see Figure 1). Cables were routed back to a housing containing a hard-drive and 100 amp-hour gel battery (Haze Battery Co.) which was attached to the bridle of the net close to the cleek pole in a floating waterproof container (Peli Poducts Ltd.). Cameras typically recorded from 02:00 to midnight during June, 03:00 to 23:00 during July and 04:00 to 22:00 during August. The floating containers that housed the hard-drives and batteries were recovered at the end of each week or sooner if bad weather was forecast, to recover data and recharge batteries.

Seal information from the underwater cameras was used both to assess the effectiveness of the ADD and the effectiveness of the fish court door to keep seals out. Fish information was collected to enable the effectiveness of the wider fish court door to be assessed. The time fish passed through the doubling door and then the fish court door was recorded and thus the duration fish spent in the doubling. The number of fish that hesitated in the doubling and swam back out of the doubling along with the number of fish that swam back out of the fish court was also recorded.

### 4.2.1 Statistical analyses methods

All statistical analyses were performed using the statistical programme R v3.0.2 (R Core Development Team, 2013).

*Model One*

A quasi-binomial GLM was fitted to the presence/absence of seals corrected for the number of hours of underwater video footage available for each observed fishing operation. This was often different to the fishing duration of each operation because there was no video footage during the hours of darkness. The data were restricted to only include those hauls with associated video footage (n=55). Candidate explanatory variables included ADD status (on or off), net (P1 or P2 – with different fish court entrance widths), the day of the season, the wind direction (onshore, offshore, variable and cross-shore) and the sea-state (Beaufort scale 0-4). All variables were included as factor variables, with the exception of the day of the season which was included as a continuous variable. A backwards stepwise model selection was carried out, dropping the variable with the highest p-value (determined by an ANOVA) at each step.

*Model Two*

A second model was fitted to the salmonid landings (catch) per unit effort (CPUE) from the Peter net. The data were restricted to exclude the hauls that took place in April because catches were extremely low and the environmental observations were not always available for each haul. All hauls between May and the end of August (n=102 hauls) were included. A Poisson generalised estimating equation (GEE) was fitted to the catch data and included an offset term to account for the duration of each haul, thus modelling CPUE as the response variable. Candidate explanatory variables included ADD status (on or off), net (P1 or P2), the day of the season, the wind direction (onshore, offshore, variable and cross-shore) and the sea-state (Beaufort scale 0-4). All variables were included as factor variables, with the exception of the day of the season which was included as a continuous variable. A GEE was fitted because there was evidence of temporal autocorrelation in the residuals of the model fitted using a generalised linear model (GLM) and GEE models allow specification of a blocking unit within which observations can be correlated (Hardin & Hilbe, 2003). A temporal blocking unit of one day was included in the GEE to account for the temporal autocorrelation in the data at this scale. It was decided to carry out hypothesis-based model selection using p-values and backwards stepwise selection. However, the p-values from a GEE model indicate the significance of the difference between factor levels and not the contribution of the factor covariate to model fit. Therefore for model selection the p-values given by an ANOVA on the fitted model object were used, whilst the p-values from the GEE were used for inference purposes. After fitting each model an ANOVA was conducted on the fitted model object and the covariate with the highest p-value was removed and the GEE model re-run. This was repeated until all terms remaining in the ANOVA were significant.

## 4.3 Results

### 4.3.1 Gamrie Bay activity overview

It was possible to collect landings data for all nets during the 2014 season, including the number of salmon and trout (salmonids) landed, number of seal damaged fish and fishing effort from the nine Gamrie Bay salmon net sites. Fishery landing records began on the 9th April 2014 and ended on the 26th August 2014. Landings summary information is provided as Appendix 1.1. A maximum of five bag-nets were shot during April, increasing to nine bag-nets during July and August. Salmon landings were low during April (n=17) and as a result the proportion of seal damaged fish (n=7, proportion 41%) appears large at this time of year. Landings and CPUE peaked in July coinciding with the maximum monthly number of seal damaged fish (n=25, proportion 3%). Seal damaged fish were landed from all sites.

Land-based observations were carried out at the Peter net (the site of the ADD and net modification trials) between the 14th April and 9th June, a total of 75 one hour surveys were successfully completed to record seal and cetacean activity in the area.

Four underwater video cameras were deployed on the Peter net between the 4th June and 8th August. A total of 740 hours was collected and reviewed to provide the frequency and time that seals and salmonids entered or left the doubling or fish court of the Peter net. As a decision had been made to rely on underwater video to provide information on seal activity, a C-POD (Chelonia Ltd.) was also deployed to collect information on cetacean activity in the absence of cliff top observations. A C-POD was deployed at 57° 40.970N, 02° 19.893W approximately 200m off the Peter net between the 16th July and 27th August.

### 4.3.2 The Peter net

Landings data from the Peter net began to be collected on the 11th April. In comparison with other nets within the Gamrie Bay station, the Peter net had relatively high CPUE figures, with CPUE at this site in 2014 being the highest or second highest through April to July and ranked fourth highest during August (Appendix 1.1).

### 4.3.3 ADD results

The ADD was switched 'on' or 'off' while fishermen checked the net for fish, which enabled all hauls to be included in analysis, with the exception of one period when the ADD was switched 'on' halfway through a haul meaning the subsequent landings could not be attributed to either an 'on' or 'off' treatment. This haul was therefore not included in any analysis. There was little difference between CPUE figures when comparing 'on' and 'off' periods (Table 2). Eight salmon were recorded by the fishermen as being damaged by seals during 'off' treatments and one damaged salmon was recorded during an 'on' treatment (Table 2).

**Table 2.** The number and average duration of ADD treatments, number of hours of Peter net effort and landings during ADD 'off' and 'on' treatments.

| ADD | No. treatments | Ave. duration (h) | Effort (h) | CPUE | Salmonids | Damaged |
|---|---|---|---|---|---|---|
| **Off** | 15 | 99 | 1489 | 0.13 | 191 | 8 |
| **On** | 14 | 61 | 854 | 0.1 | 87 | 1 |

### 4.3.4 Underwater video system

As it was felt unwise to leave the underwater video system on the net when stormy weather was forecast, coupled with the need to recover the system for recharging, the collected video footage represents a sample of seal and salmonid activity in the Peter net rather than a complete census. Unfortunately, on reviewing the footage there were also a number of occasions where environmental conditions appear to have loosened electrical contacts within the system resulting in a loss of power to one or more of the cameras. This resulted in a further reduction in the size of the video sample available for collecting both seal and salmonid information. This had a greater impact on the fish observation data than on the seal observation data, as usually all four cameras were required to accurately evaluate the time salmonids spent in the doubling whereas seals entering the doubling or fish court could be detected on just two cameras.

### 4.3.5 Land-based marine mammal surveys

From the 14th April to 9th June a total of 75 one hour surveys were conducted from the Crovie observation position to sample marine mammal activity at the Peter net; 25 surveys were carried out when the ADD was 'off' and 50 while it was 'on'. Five grey seals were recorded within 80m of the net while the ADD was 'off' and two grey seals were recorded within 80m while it was 'on' (Table 3). This equates to one seal every 5 hours during 'off' periods and one seal every 25 hours during 'on' periods. No dolphins were seen within 80m of the net regardless of ADD status; however, more dolphin sightings were recorded within the entire area visible from the observation position during ADD 'on' treatments than ADD 'off' treatments (Table 3). In addition to observations during dedicated surveys, incidental sightings were also recorded by the observer while carrying out routine maintenance work on equipment in Gamrie Bay or liaising with fishermen. In total seven incidental dolphin sightings were recorded in Gamrie Bay; five coinciding with ADD 'off' periods and two with ADD 'on' periods.

**Table 3.** Number of surveys, grey seal sightings within 80m of the bag-net (with average number of grey seal sightings per hour of survey) and the number of groups of dolphin sightings within the area visible from the Crovie observation position.

| Crovie | No. surveys (h) | Grey seals | Dolphins |
|---|---|---|---|
| **ADD 'Off'** | 25 | 5 (0.2) | 1 |
| **ADD 'On'** | 50 | 2 (0.04) | 3 |

### 4.3.6 Underwater video footage

All video footage was reviewed and footage where either camera was not orientated correctly, cameras were faulty or during hours of complete darkness were removed. This reduced the sample of video footage for monitoring the rate at which seals entered the doubling from 740 hours to 663 hours. The rate at which seals were observed to enter the doubling during ADD 'off' and 'on' periods is provided in Table 4. Although the reviewed footage from underwater cameras revealed similar sightings rates for 'on' and 'off' periods compared with land-based data, these cannot be directly compared as they occurred at a different time of year and the criteria for defining a sighting were different. However, the relative difference between sightings rates during 'on' and 'off' periods within land-based observations and underwater video are mutually consistent as both indicate sightings rates were five to six times higher during 'off' periods (Tables 3 and 4).

**Table 4.** Number of hours of video footage that was suitable for the collection of seal data, seals were recorded entering the doubling of the Peter net during ADD 'on' and 'off' treatments.

| ADD | Suitable video footage to detect seals (h) | Seals entering doubling | Seal doubling entry rate (seals / h) |
|---|---|---|---|
| **Off** | 351 | 64 | 0.18 |
| **On** | 312 | 9 | 0.03 |

In addition to cetacean sightings from land, a C-POD was deployed approximately 200m from the Peter net. A high-pass filter was set at 20 kHz in an attempt to filter out the majority of ADD noise at its fundamental frequency of 10 kHz and first harmonic at 20 kHz whilst maintaining the ability to detect both broadband dolphin echolocation clicks and porpoise narrow band high frequency clicks. Increasing the high-pass filter above 20 kHz may also increase the misclassification of dolphins as porpoise.

C-POD data were available for 849 hours (Table 5) during control periods (ADD 'off') and 146 hours of ADD 'on' treatments. Unfortunately the increased sound levels above 20 kHz during ADD 'on' treatments impaired the detection of cetacean clicks and the performance of the click train detection algorithm. The proximity to the ADD (~200m from C-POD) coupled with the need to monitor a broad range of frequencies to detect both dolphins and porpoises meant that during ADD 'on' treatments the C-POD rapidly reached its pre-set limit of 4096 clicks per minute, reducing the likelihood of accurately detecting cetaceans. Therefore at this time it is not possible to extract data from the 'on' treatments due to the confounding effects of the ADD. In future it is hoped to deploy sound traps (Ocean Instruments) to provide information on the presence of cetaceans during ADD 'on' and 'off' periods.

**Table 5.** C-POD results from ADD 'off' treatments (849 h) during the period 15th July until 26th August, the number of hours that contained porpoise or dolphin detections and these represented as a 24 hour rate.

| | No. of hours with detection | Average 24h rate |
|---|---|---|
| Porpoises | 88 | 2.5 |
| Dolphins | 13 | 0.4 |

### 4.3.7 Net modification trial

During April and August only net P1 (160mm fish court entrance) was fished and this resulted in more fishing effort being attributed to P1 than P2 (190 mm entrance see Table 6). The date that the nets were installed (replacing the previous net) and the amount of fishing hours attributed to each net are provided in Table 6. The Peter net site was vacated at the end of the season (26th August). Overall P2 caught twice as many salmonids per unit effort as P1 (Table 6). However, some of this difference may be attributed to P1 effort during April when catch rates were lower (P2 did not fish until late May). Nevertheless it is of interest that P1 CPUE was also lower than P2 for the remainder of the season (Table 6).

**Table 6.** Fishing effort and landings for nets P1 and P2

| Net | Date installed | Effort | Salmonid | CPUE |
|---|---|---|---|---|
| **P1** | 11/04/2014 | 574 | 38 | 0.07 |
| **P2** | 27/05/2014 | 213 | 43 | 0.2 |
| **P1** | 10/06/2014 | 252 | 27 | 0.11 |
| **P2** | 23/06/2014 | 326 | 91 | 0.28 |
| **P1** | 07/07/2014 | 274 | 40 | 0.15 |
| **P2** | 21/07/2014 | 181 | 53 | 0.29 |
| **P1** | 31/07/2014 | 558 | 45 | 0.08 |
| **P1 (Total)** | | **1658** | **150** | **0.09** |
| **P2 (Total)** | | **720** | **134** | **0.19** |

From video footage salmonids were recorded entering the doubling and subsequently entering the fish court or alternatively returning back out of the doubling. Fish were also recorded if they re-entered the doubling from the fish court. Video footage revealed that fish often appeared to make several circuits of the doubling before either entering the fish court or swimming back out of the doubling. A higher proportion of fish swam back out of P1's doubling than P2's (21% (n=5) versus 15% (n=9)). Of the fish that were observed entering the fish court there was suitable footage available for assessing passage time through the doubling to the fish court for 64 adult salmonids (Table 7). On average fish spent less time in the doubling of P2, suggesting that the fish took less time negotiating P2's fish court entrance than P1's, and they were therefore less likely to leave the doubling before progressing into the fish court. Fish spent on average 2 minutes 18 seconds in the doubling of P1 compared with an average in P2 of 1 minute 23 seconds (Table 7, Figure 4). The percentage of fish that escaped the fish court of P1 and P2 was comparable at 3% and 4%. Five fish entering the doubling of P2 were not recorded leaving via the doubling or fish court door suggesting that they may have become enmeshed in the net out with the view of cameras. This is consistent with reports from the fishermen suggesting that fish occasionally become enmeshed in the doubling.

**Table 7.** Number of salmonids and the average time spent in the doubling of nets P1 and P2.

| Net | No. salmon | Average time | Min. | Max. |
|---|---|---|---|---|
| **P1** | 19 | 02:18 | 0:07 | 5:05 |
| **P2** | 45 | 01:23 | 0:05 | 4:14 |

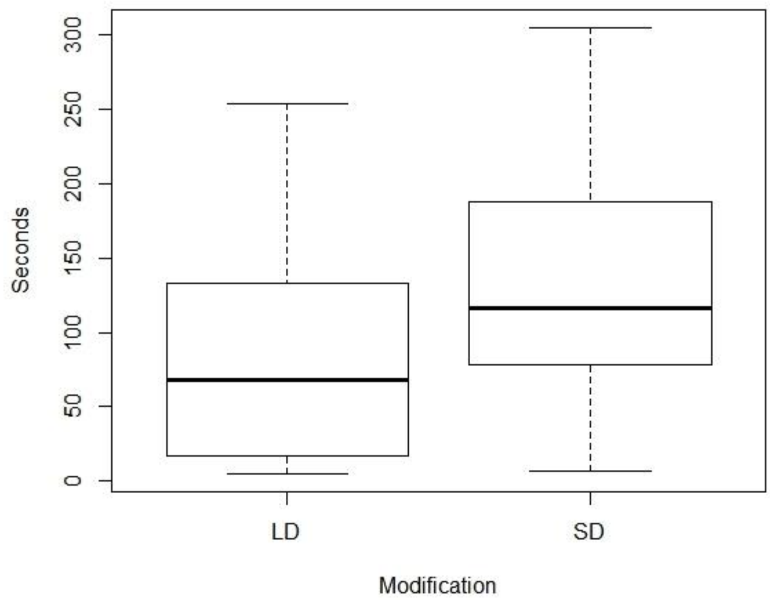


**Figure 4.** Box plot of the distribution of duration of time fish spent in the doubling of the two nets (LD = net P2 and SD = net P1).

### 4.3.8 Statistical analysis results

*Model One*

Day of the season and ADD status were both retained in the best model fitted to seal presence/absence per haul data. Both significantly contributed to model fit ($p<0.05$ for both variables, determined by an ANOVA). There was a significant negative relationship between seal presence and day of the season ($\beta_1$= -0.047, $p<0.05$, Figure 5), and significantly fewer seals present when the ADD was 'on' compared with 'off' ($\beta_2$ = -2.44, $p<0.05$, Figure 5). Net (P1 or P2), wind direction and sea state were not significant and were dropped during the model selection process.

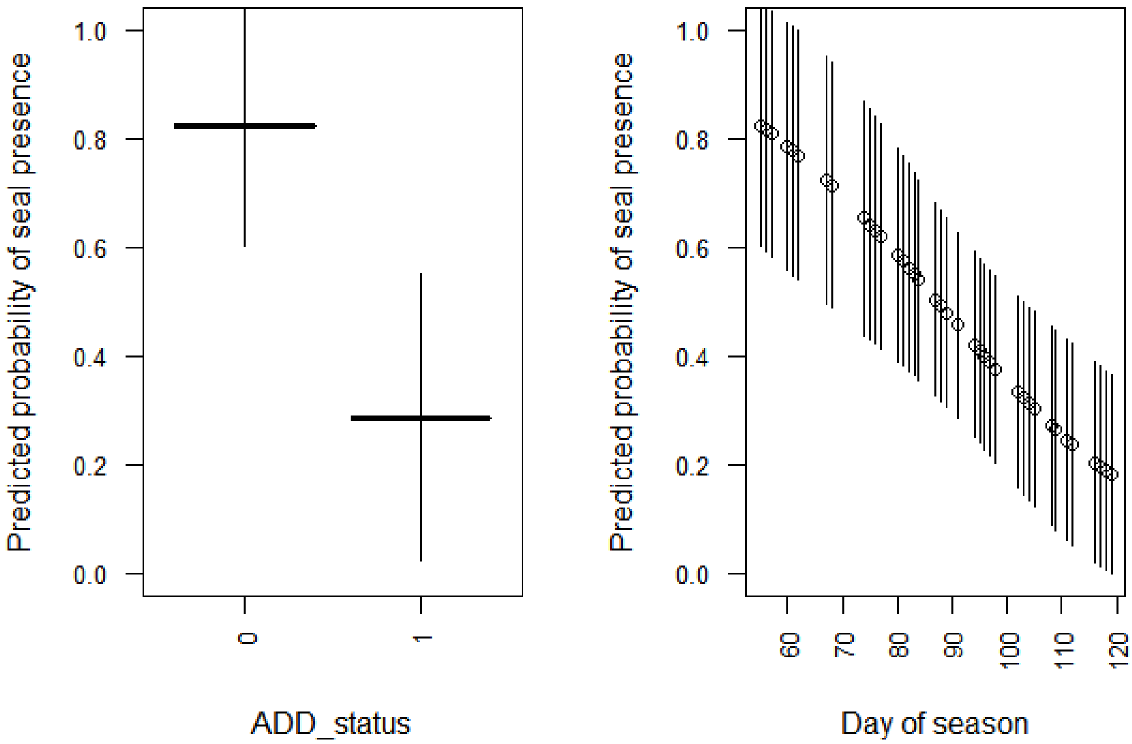


**Figure 5**. Predicted probability of seal presence during a period fixed at the average length of video footage within a haul (11.4 hours) for the different levels of ADD status when day of season was fixed at day 55 (first day of video observations, left panel) and for each day of the season when ADD status was designated as "off" (right panel). The vertical lines represent 95% confidence intervals around the mean. Note: the video footage was only available for June and July.

*Model Two*

The model looked at variables affecting CPUE and only wind direction and net were retained in the best fitting model, with both factors significantly contributing to model fit ($p<0.05$ for both factors, determined by an ANOVA). The coefficients and p-values from the GEE indicated that the P2 net had a significantly higher catch per unit effort than the P1 net ($p<0.05$, Figure 6), and all wind directions had a higher catch per unit effort when compared to offshore winds ($p<0.05$ in all comparisons, Figure 6). ADD status, day of season and sea state were not significant and were dropped from the model during model selection.

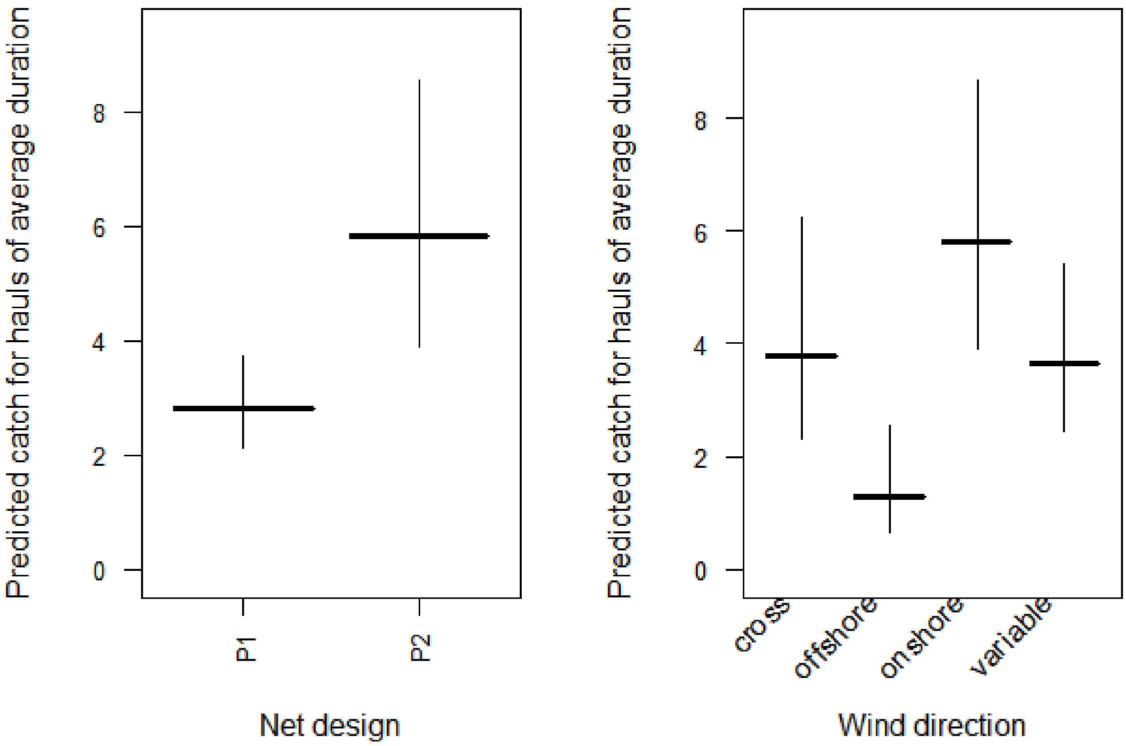


**Figure 6.** Predicted catch for each net design (left panel) when haul duration was fixed at the average haul duration for the season (20.3 hours) and wind direction was designated as onshore and for each wind direction (right panel) when haul duration was fixed at the average haul duration for the season (20.3 hours) and net design was designated as P2. The vertical lines represent 95% confidence intervals around the mean.

## 4.4 Discussion

The majority of work at Crovie, Gamrie Bay centred around three questions:

- What was the frequency with which seals entered the Peter net during ADD 'on' treatments compared with ADD 'off' treatments?
- Did seals enter the fish court of either net P1 or net P2?
- Did net P2 reduce fish passage rates through the doubling compared with net P1?

During the 2014 season there was a switch from collecting marine mammal data using a series of 1 hour land-based observation periods spread out over the day, to using an underwater video system and C-POD. The underwater video system, developed with Prove Systems Ltd. over the past three years for use at bag-nets as well as at aquaculture sites, provides a valuable and unique insight into seal and fish activity at nets. Video observations allow for a greater amount of observational data to be collected than would be achievable by a single clifftop observer. However, the underwater video system required considerably more resources, in terms of the time necessary to process and review the underwater footage. In addition, weekly deployment and recovery of the system was required. It is hoped to continue to develop these underwater systems in 2015, primarily to make the system more robust in adverse weather conditions thus increasing the range of observable conditions and perhaps also increasing the systems' capability to detect seal activity after dark. C-POD evaluation will continue and it is hoped to deploy sound traps in 2015 to assess cetacean occurrence and monitor ADD sound output.

### 4.4.1 Effectiveness of the Airmar ADD

Previous work at Portmahomack had found that Lofitech ADD status can have a significant effect on CPUE whereby landings were higher during ADD "on" treatments. This is thought to be through a reduction in seal presence (Harris *et al.*, 2014a). However, no such effect on CPUE at the Peter net has been found so far. This is perhaps not surprising given the low frequency with which seals visit the Peter net, as seal activity at nets was far higher at Balintore and Portmahomack.

The change in observation method mid-season hampered analysis that included seal data from the whole season. This effectively meant splitting the data into smaller sub-sets for analysis. Despite this, and the generally low levels of seal activity at this site, there was still a clear relationship between seal presence / absence and ADD status, with seals detected in fewer ADD 'on' treatments than control periods during June and July when video footage was available. However, seal presence appears to have had minimal effect on CPUE at this location hence the lack of a relationship between ADD and CPUE. This result was comparable with results from the land-based surveys (primarily April and May data). There was little available marine mammal data for August due to adverse weather conditions preventing the deployment of the video system.

Based on the sample of video footage that was suitable for monitoring the rate of seal entry of the Peter net (663 hours), it appears that the ADD was also effective at reducing the rate at which seals entered the doubling. Additionally, the fishermen recorded relatively few seal-damaged fish at the Peter net; eight whilst the ADD was 'off' compared with only one whilst 'on'. Interestingly, no observations of seal depredation of whole salmon was observed on the underwater video, when this form of depredation was seen relatively regularly on camera at Balintore. On a number of occasions seals were observed attacking fish from outside the fish court and although fish were damaged, they were generally left intact. One fish even recovered enough to begin swimming again, perhaps suggesting that some of the seals at the Peter net were not particularly adept at depredating from the fish court of bag-nets. Underwater video was sufficient on a number of occasions to identify individual seals and it is hoped that photo-identification capture histories of seals will allow a better understanding of how individual behaviour and ability to depredate or individual interest in nets varies. For example, a preliminary analysis of these data suggests that all visits to the net while the ADD was 'on' may be attributed to one grey seal.

### 4.4.2 Effectiveness of net modifications

No seal was seen to enter the fish court of either P1 or P2 suggesting that the larger door width of 190mm was also effective at keeping grey seals out. Based on a preliminary assessment of the photo-identification data, the number of different grey seals that attempted to force their way through the fish court door was relatively small and no harbour seals were seen at the net. Further assessment of the effectiveness of this door size against different sized seals is needed.

Based on the time that fish took to enter the fish court it suggests that the wider door in P2 eased fish passage through the doubling. This is important as seals may depredate salmon that spend longer in the doubling. The reduction in time that salmon spent in the doubling may also have reduced the likelihood that salmon swim back out of the doubling, helping to increase landings and possibly explain the higher catches observed in P2 compared with P1.

### 4.4.3 Summary of the Gamrie Bay efforts

The behaviour of seals at the Peter net is of interest although it is perhaps important to keep in mind that this is a relatively 'new' net site (operations began in 2012) with perhaps a greater number of naïve seals than may be expected from sites that may have been fishing for several decades and where more seals may be familiar with nets and methods of depredation.

Wind direction had a significant effect on salmonid landings and these results from Gamrie Bay support earlier findings from Portmahomack and Balintore (Harris *et al.*, 2014a, 2014b). This highlights the need to account for environmental conditions when using landings data as a measure of the effectiveness of different mitigation measures. It is hoped to improve recording of environmental conditions, in particular wind direction, in 2015 by deploying a weather station near Gamrie Bay to allow constant weather monitoring whilst reducing the requirement for dedicated observers.

# 5 Seal Diet

## 5.1 Introduction

Within this reporting period the diet of seals shot by fisheries under licence has already been reported (Harris *et al.,* 2014c). Diet was described for 36 seal carcasses shot at bag-net sites. Gadids and perciforms (in particular sandeels) were the most prevalent prey from seals that were shot and recovered at bag-nets. Seals shot at bag-nets that tested positive for salmonid DNA (36%), typically held other prey items suggesting that these seals were not specialising solely on predating salmonids from nets. There was one exception, a large male grey seal whose gut contents suggested a diet of only salmon. Although the numbers of shot seals may be reducing at some sites, information on the proportion of carcasses testing positive for salmonid DNA suggests that the proportion of salmonids in the diet of shot seals may be increasing. This increase in the proportion of salmonids in the diet has come about since the introduction of ADDs and net modifications.

The use of ADDs may have reduced the number of transient seals shot as only those seals determined to predate from nets appear to attempt to depredate from nets with ADDs. This has resulted in lethal control becoming more selective to those seals responsible for the majority of the damage. At Portmahomack in the four years prior to ADD use, ten seals were shot and sampled. Only one seal tested positive for salmonid DNA. In the subsequent six years only two seals were shot and both tested positive for salmonid DNA (note that both seals were shot during ADD ‘off’ periods).

At sites where the entrance to the fish courts have not been modified to reduce seal access, seals are occasionally found trapped inside and are unable to find a way out. These seals are subsequently shot by licensed fisheries. Interestingly, few seals shot this way (recovered from inside bag-nets) tested positive for salmonid DNA (n=2, 17%). This is perhaps not surprising with the knowledge gained from the underwater video; that net specialist seals (those responsible for the majority of observed depredation) are able to negotiate these chambers of the net with ease and that it is therefore naïve seals unfamiliar with bag-nets that become trapped.

The gastrointestinal tracts (GITs) of the seals shot and recovered in 2014 (see below) will be subject to hard-part analysis and tested for the presence of salmon and trout DNA when sufficient funds are available. This work will be scheduled once a larger number of GITs has been accumulated, including those from fish farms, rivers and other unexplained seal deaths where an assessment of seal diet before death is of interest.

## 5.2 Results and Discussion

During 2014 there were continued efforts to recover shot seal carcasses. Two seal carcasses were recovered and transported to SMASS at Inverness for post mortem (Table 8). A further three carcasses were unfortunately lost after initially being secured (by rope) by either the fishery or an observer, but were subsequently lost to the tide before they could be collected or sampled.

**Table 8**. Details of two recovered grey seal carcasses, the relevant seal management zone, location and organisation responsible for the recovery, transport and sampling of shot seal carcasses.

| Zone | Location | Recovered | Transported | Sampled |
|---|---|---|---|---|
| **Moray Firth** | Balintore | Fishery | SRUC | SRUC |
| **East Coast** | Lunan Bay | SMRU | SMRU | SRUC |

In 2015 it is hoped to improve the response time to react to these carcass reports and also increase the number of observers who are able to remove GITs on site rather than relying on carcass recovery teams to arrive. It would also be useful to identify those fisheries who have not recovered any of their shot seals to enquire whether this statistic can be improved. Ideally all shot seals should be recovered and a greater emphasis should be placed on seal licence holders to recover seals. Belief by some marksmen that carcasses are of no interest to anyone should be corrected as there is value in collecting carcasses, not only in providing dietary information but also life history parameters and for exposure to pollutants and biotoxin studies.

# 6 District Salmon Fishery Board (DSFB) support

During this reporting period support was provided to two DSFBs regarding seal presence in the rivers Dee and North Esk. This has primarily involved providing advice on monitoring seal river use, river surveys, site visits, attendance at meetings and providing advice on the deployment of non-lethal methods in rivers (ADDs in most cases and how they can be used / deployed). Photographic equipment and an ADD were also loaned to DSFB. DSFBs contributed staff resources and covered SMRU mileage costs. Details of the interactions and collaborations between SMRU and river DSFBs can be found in Appendix 1.1.

# 7 Additional tasks addressed

## 7.1 Calorific content of salmon kelts

A component of previous research was to look at the temporal patterns of seal activity in rivers. Results found some variation between rivers and years although, in general, seal activity in rivers was highest during winter, coinciding with spawned adult salmon (kelts) leaving the river (Graham & Harris, 2010). Known seals were observed to return each winter and were observed to predate up to four salmon (kelts) per survey. One grey seal was shot under licence by a river fishery during this peak of river seal activity and digestive tract analysis revealed a diet of only salmon.

In collaboration with the Kyle of Sutherland DSFB 14 salmon kelts were collected to study the calorific content of these fish and their potential contribution to seal diet. Fish were weighed and measured at the time of collection and stored frozen. The processing of these fish and the study of their calorific content formed part of a University of St. Andrews undergraduate project in 2014. In brief, fish samples were processed using a Parr oxygen bomb calorimeter (Model No. 6200) to measure the energy content of samples. Sample energy content values were then projected, taking into account water loss, to give an estimate of the calorific content of the collected kelts (Figure 7).

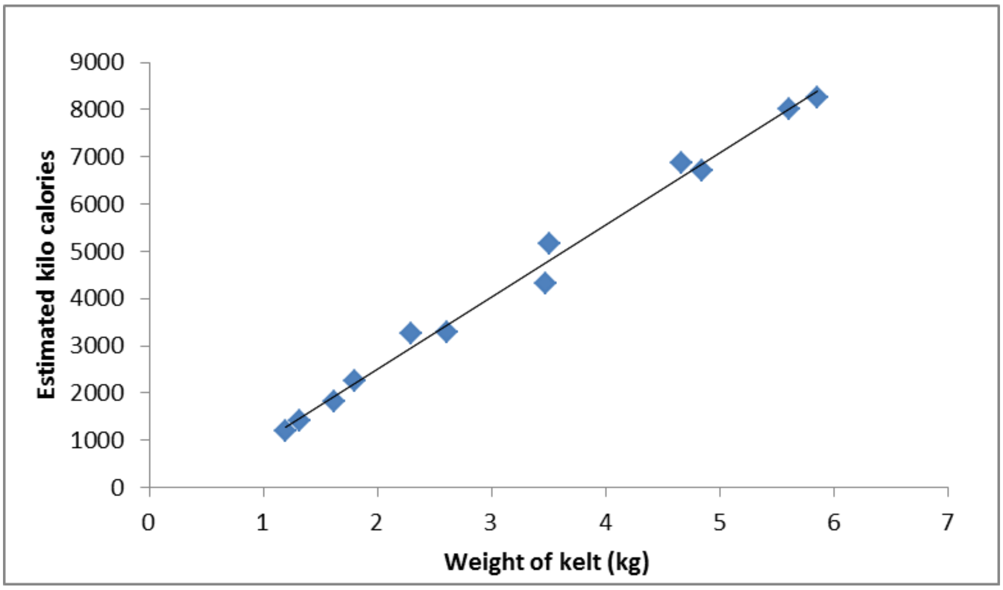


**Figure 7**. Estimated calorific content of salmon kelts

This undergraduate study also made an assessment of the possible impact of seal predation on kelts based on the number of seals using the river, an estimate of the size of the salmon stock (based on river rod catches and fish counter data) and the proportion that survive to migrate downstream as kelts, the energy requirements of seals, an average energy content and the assumption that during this peak in seal activity river seals consumed only kelts. The study suggested that grey seal predation may account for the annual removal of a third of emigrating kelts from the Kyle of Sutherland and perhaps 60% of kelts from the river

Conon (another river where seal information was available). Harbour seal predation on kelts was not included. Results suggest that grey seal predation on salmon kelts may provide one explanation for the low proportion of repeat spawners in Scottish east coast rivers compared to elsewhere (Malcolm *et. al.* ,2010).

Salmon kelts are important, particularly in declining or fluctuating populations, as those that survive to repeat spawn help to mitigate the effects of poor maiden recruitment (Mills, 1991). In addition these fish are on average larger and have a higher ratio of females to males than maiden spawning fish and therefore their contribution to stocks may be higher per capita. For example, in the Canadian Miramichi river repeat spawners may account for 15% to 20% of the stock in numbers, yet these fish have been estimated to account for 25% to 40% of egg deposition in the river (Miramichi Salmon Association[3]). It is of interest that many of the rivers that report high proportions of repeat spawners come from areas where grey seal populations are low, for example Norway, or where winter ice cover may offer emigrating kelts some protection from river seal predation.

This undergraduate study was intended to help develop methods for investigating the calorific content of seal prey and highlight the potential need for further work into the impact of grey seals on salmon populations. The information will be used to better inform seal diet studies and the potential impact of seals on salmon populations.

It is hoped to continue to collaborate with the DSFBs to further investigate the potential for impact. It would be beneficial for improving seal consumption estimates to expand the study of the calorific content of seal prey and to include other prey species, including ‘fresh run’ salmon to provide comparative data and information for a prey consumption study.

## 7.2 Assessment of the feasibility of catching problem seals

During 2014 the feasibility of developing a trap to capture problem seals at bag-net sites, rivers and at salmon aquaculture sites was discussed from both a practical point of view and possible Animal (Scientific Procedures) Act seal licensing/ethical review process. Following discussions and meetings within SMRU and contact with the Home Office, in principle no significant obstacles were identified and the process appears feasible from both a practical and licensing point of view. Seal traps have been developed in other countries and their use has been effective at trapping problem seals at both aquaculture sites and salmon bag-net sites. However, the problem may not be in the trapping of seals but what should be done with seals once they have been captured. Seals could be released with tags to study their behaviour in more detail either at the capture site or if relocated to other areas. Alternatively seals could be transferred to temporary holding facilities where animals are often required for short term studies for example, the SMRU captive research facility. However, the problems associated with releasing animals back to the wild remains.

## 7.3 Source levels and signal characteristics of ADDs

Field trials were conducted at the start of the field season to measure the source levels and signal characteristics of ADDs used during this study to compare with the claims of the manufacturers. Repeat measurements were made at increasing distances from both the Lofitech ADD and Airmar ADD. In addition, measurements were made from an ADD device used by bag-net fishermen on the north coast of Scotland, the SeaMetrix ADD, which was found to have a signal similar to that of the Airmar although with a lower sound pressure level than either the Lofitech or the Airmar. Anecdotal reports from the fishermen suggested that this device was not effective at keeping seals away from bag-nets. However, the robust construction and size of the SeaMetrix device was simple and easy for bag-net fisheries to operate and may offer one practical solution for ADD deployments at bag-net fisheries.

[3] This information can be found at: http://www.miramichisalmon.ca/programs/kelt-tracking-updates/#keltbio

# 8 Publications and presentations

Four presentations on this work were made during 2014:

- Crovie Preservation Society, April 2014, Crovie
- Marine Scotland hosting Japanese delegates, May – June 2014, Portmahomack, Balintore, Cromarty (2 days)
- Marine Mammal Scientific Support Steering Group meeting, September 2014, Victoria Quay
- Salmon Net Fishing Association of Scotland's AGM, October 2014, Banff

Two reports and one publication have become available online in 2014:

Harris, R. N., Harris, C. M., Duck, C. D. & Boyd, I.L. (2014) The effectiveness of a seal scarer at a wild salmon net fishery. *ICES Journal of Marine Science*, **71**: 1913-1920. (reported as "in press" in 2013 annual report)

Harris, R. N., Fowden, D., Froude, M. & Northridge, S. (2014) Marine mammal research at wild salmon fisheries. Annual Report for 2013, Report to Marine Scotland, Sea Mammal Research Unit, University of St Andrews, St Andrews (www.smru.st-and.ac.uk/documents/1976.pdf).

Harris, R. N., Sievers, C. & Northridge, S. (2014) Seal diet at salmon net fisheries. Report to Marine Scotland, Sea Mammal Research Unit, University of St Andrews, St Andrews (www.smru.st-and.ac.uk/documents/1975.pdf)

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# 11 Appendices

## 11.1 Appendix 1.1 Salmon and trout landings from Gamrie Bay, 2014

| | Net site | No. Salmon | No. Trout | Effort | CPUE Salmonids | No. damaged | % damaged |
|---|---|---|---|---|---|---|---|
| **April** | Peter | 5 | 0 | 280 | 0.02 | 3 | 60.0 |
| | Wirren | 4 | 0 | 321 | 0.01 | 3 | 75.0 |
| | Downie | . | . | . | . | . | . |
| | Castle | . | . | . | . | . | . |
| | More Head | 1 | 0 | 244 | 0.00 | 0 | 0.0 |
| | Outrigger | . | . | . | . | . | . |
| | Middle | 3 | 0 | 324 | 0.01 | 0 | 0.0 |
| | Skate | 4 | 1 | 323 | 0.02 | 1 | 20.0 |
| | March | . | . | . | . | . | . |
| **May** | Peter | 30 | 5 | 388 | 0.09 | 2 | 5.7 |
| | Wirren | 8 | 2 | 372 | 0.03 | 0 | 0.0 |
| | Downie | 5 | 0 | 264 | 0.02 | 0 | 0.0 |
| | Castle | . | . | . | . | . | . |
| | More Head | 9 | 3 | 373 | 0.03 | 0 | 0.0 |
| | Outrigger | 3 | 0 | 281 | 0.01 | 2 | 66.7 |
| | Middle | 4 | 8 | 373 | 0.03 | 0 | 0.0 |
| | Skate | 9 | 1 | 345 | 0.03 | 1 | 10.0 |
| | March | . | . | . | . | . | . |
| **June** | Peter | 63 | 6 | 530 | 0.13 | 2 | 2.9 |
| | Wirren | 52 | 3 | 531 | 0.10 | 2 | 3.6 |
| | Downie | 17 | 0 | 545 | 0.03 | 0 | 0.0 |
| | Castle | 11 | 6 | 408 | 0.04 | 0 | 0.0 |
| | More Head | 30 | 1 | 532 | 0.06 | 2 | 6.5 |
| | Outrigger | 23 | 4 | 533 | 0.05 | 1 | 3.7 |
| | Middle | 38 | 4 | 532 | 0.08 | 8 | 19.0 |
| | Skate | 88 | 2 | 534 | 0.17 | 4 | 4.4 |
| | March | . | . | . | . | . | . |
| **July** | Peter | 131 | 0 | 622 | 0.21 | 2 | 1.5 |
| | Wirren | 155 | 1 | 693 | 0.23 | 4 | 2.6 |
| | Downie | 45 | 3 | 678 | 0.07 | 5 | 10.4 |
| | Castle | 42 | 0 | 681 | 0.06 | 5 | 11.9 |
| | More Head | 74 | 0 | 695 | 0.11 | 0 | 0.0 |
| | Outrigger | 55 | 0 | 694 | 0.08 | 3 | 5.5 |
| | Middle | 77 | 0 | 695 | 0.11 | 1 | 1.3 |
| | Skate | 124 | 3 | 764 | 0.17 | 3 | 2.4 |
| | March | 85 | 2 | 594 | 0.15 | 2 | 2.3 |
| **Aug** | Peter | 44 | 1 | 558 | 0.08 | 1 | 2.2 |
| | Wirren | 127 | 8 | 616 | 0.22 | 12 | 8.9 |
| | Downie | 3 | 1 | 131 | 0.03 | 0 | 0.0 |
| | Castle | 8 | 1 | 131 | 0.07 | 0 | 0.0 |
| | More Head | 59 | 1 | 616 | 0.10 | 3 | 5.0 |
| | Outrigger | 22 | 1 | 592 | 0.04 | 6 | 26.1 |
| | Middle | 8 | 1 | 192 | 0.05 | 1 | 11.1 |
| | Skate | 82 | 1 | 592 | 0.14 | 0 | 0.0 |
| | March | 13 | 1 | 335 | 0.04 | 0 | 0.0 |

## 11.2 Appendix 1.2 DSFB support

### 11.2.1 River Dee

The River Dee DSFB record seal sighting reports from fishermen and DSFB staff. There are approximately 50 reported seal sightings held for each of 2012, 2013 and 2014. Although numbers are difficult to interpret due to a lack of information on observer effort, a similar temporal pattern exists between years, with a general increase in seal sightings between February to April and a second peak during September and October. An assessment of the number of fishermen on the river through the year may provide a useful index of effort. The salmon fishing season on the river extends from the start of February to mid-October. Both harbour seal and grey seal sightings have been reported above the Lofitech ADDs installed as a barrier to reduce seals travelling upriver, the devices are located near the A90 road bridge over the River Dee. Difficulties in creating an effective barrier due to too few sound heads and difficulties in maintaining an adequate power supply through most of 2013 may have increased the rate at which seals developed a tolerance to the barrier.

Together with River Dee DSFB staff a river survey protocol was set up to monitor seal occurrence and the frequency with which seals passed the Lofitech ADD installation. Standardised river surveys were designed to collect seal data; initially observers were asked to walk a 2km route along the river bank recording any seal sightings. However, given the difficulty in crossing the A90 road bridge in Aberdeen and a preference by the observers to remain stationary, it was decided instead to scan the river for seals within 500m of the ADD barrier. Surveys were timed to coincide with Aberdeen's published high water time and were two hours in duration, often beginning one hour before high tide and ending one hour after high tide.

Environmental data, tidal height, river height and seal information were collected during 18 surveys (13 surveys were carried out by DSFB staff, 4 surveys by a SMRU observer and one survey by both DSFB staff and a SMRU observer) between December 2013 and April 2014. Seals were detected on just one survey during December with a total of three seals identified (two harbour seals and one grey seal). All were seen above the ADD barrier. Problems with the ADDs power supply suggested that the ADD was not operating optimally during this period. The power supply problem was resolved on 16th January 2014. Seals exposed to weaker ADD signals may be more likely to habituate even when devices are returned to full power. A decision to abandon the surveys was made in April due to constraints on staff time and the lack of seal sightings that perhaps suggested a need to re-evaluate the survey methodology. It is hoped to revisit this with the Dee DSFB in 2015.

A site visit was made to the River Dee on the 11th February 2014 by SMRU. Boat support was provided by the DSFB making it possible to use underwater video cameras to assess the position of the ADD sound heads. Images revealed that one sound head had been dislodged, resulting in most of the sound energy being directed at the river surface and river bed rather than downstream (the direction of approaching seals). This orientation would likely lessen sound propagation and possibly further reduce ADD effectiveness. Sound head orientation was corrected by diver during February.

This work has highlighted the difficulties in using ADDs in salmon rivers, in particular maintaining sound head position / orientation and power supply, which are possibly the two most difficult and critical issues. Through the close links between SMRU and Dee DSFB staff valuable knowledge was gained into the installation and use of ADDs in rivers.

On the 14th February 2014 a meeting with representatives from Marine Scotland, the Association of Salmon Fishery Boards, SMRU, the Dee DSFB and River Dee stakeholders met to discuss a way forward regarding the problem of harbour seal sightings in the River Dee. The group decided in the first instance to attempt to identify the number of different harbour seals passing upriver of the ADDs through photo-identification. An attempt to return harbour seals to the sea should then be made using a boat fitted with an ADD, a method that proved successful in the Kyle of Sutherland.

SMRU have provided the Dee DSFB with the loan of a 300mm camera lens to attempt to discover how many different seals are prepared to pass the ADD barrier. This process has been challenging as getting an observer in place, with the camera at the right location and time is often difficult. To date only one suitable image of a harbour seal upriver of the ADD barrier is available and expanding this capture history will need more investment, either in staff time or in the form of more cameras being distributed to river users or perhaps a greater investment in systematic surveys with photographic equipment similar to those discussed earlier. SMRU have also provided the loan of an ADD to be used from a boat as a mobile method for encouraging seals back to the sea. There has not yet been an opportunity to attempt this method. However, the Dee DSFB plan to carry out regular boat surveys, with an ADD, sweeping down the river during the start of the 2015 fishing season in an attempt to remove seals from the river.

### 11.2.2 River North Esk

In February 2014 a river fishery from the River North Esk who had installed a Lofitech ADD in the river to act as a barrier to seals moving up river, reported that a harbour seal was regularly travelling up the river past the ADD. A licence to shoot the harbour seal was refused by Marine Scotland and SMRU was contacted to provide advice. It was agreed that an attempt should be made to photo-identify seals in the river to discover if more than one harbour seal was using the river. This would be needed before any decisions could be made on the appropriate management action to be taken. It was advised that maintenance on the ADD installation should be carried out as a matter of urgency as battery voltage was frequently found to be low. The fishery was in agreement that a mains power supply was needed and this was to be investigated. In addition to low voltage, the ADD sound head was found to be lying on the river bed, a position that would greatly reduce the sound propagation of the device and likely reduce its effectiveness on seals determined to travel up river.

### 11.2.3 River Ythan

Following communications and discussion with the Ythan DSFB it was agreed that personnel from SMRU will provide information or a presentation on seal salmon interactions and non-lethal options for river fisheries in the near future. No date has yet been set.

### 11.2.4 River Kyle of Sutherland

Following communications and discussion with the Kyle of Sutherland DSFB the DSFB would be grateful if SMRU could provide information/presentation on the progress of seal research under the Moray Firth Seal Management Plan. No date has yet been set.