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Seal Salmon Interactions SSI

Annual Report

Seals and Wild Salmon Fisheries

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Executive Summary

This document reports on progress made on marine mammal research at wild salmon fisheries during 2015. The objectives of the research were: 1) to continue studies into the effectiveness and practical application of Acoustic Deterrent Devices (ADDs) and the modification of salmon nets to mitigate the effects of seals on these fisheries; 2) to collect shot seals for dietary analysis; and 3) to provide support to District Salmon Fishery Boards (DSFBs). Activities related to the first two objectives were primarily focused on two sites in the Moray Firth; Gamrie Bay and Portmahomack.

During 2015, trials on the efficacy of an Airmar ADD continued near Crovie, Gamrie Bay, as did the evaluation of net modifications at this fishery by assessing the effectiveness of two different sizes of fish court entrance. Both ADD trials and net modification trials were conducted at the same netting site, with a balanced design of ADD 'on' and 'off' periods across the deployment of the two types of net.

Underwater video equipment collected footage from inside the nets for over 1200 hours. The fishery provided salmonid catch and fish damage statistics for each haul of the net for the entire season, and environmental data were collected from a weather station deployed close to the netting site. Analysis of the collated data showed there was a significantly lower probability of detecting a seal during ADD 'on' treatments compared with ADD 'off' treatments. Furthermore, undamaged catch per unit effort was significantly greater when the ADD was 'on' compared with 'off', but also significantly greater when the wind direction was onshore compared with offshore. Net modification trials enabled the identification of a compromise that excluded seals from the fish court whilst allowing swift passage of fish through the net, reducing depredation opportunities for seals in both chambers of the net.

At Gamrie Bay (More Head) and Portmahomack, support was provided for fishery-led ADD deployments. In both instances the deployments were run entirely by the fisheries who also collected and provided catch statistics and anecdotal observations. The overall perception of the fishers towards the ADD was positive, and was supported by the data which indicated that landings were higher when the ADDs were 'on' and that levels of damage were lower. There was still some evidence however that seals can depredate and damage fish in the nets while ADDs were 'on'.

During 2015, a further twelve shot seal carcasses were recovered from bag-net sites. Diet information from these seals shows that lethal control is becoming increasingly selective, with a greater proportion of the recovered seals having consumed salmonids. This may be the result of the increasing use of ADDs and net modifications which are helping to reduce the shooting of transient seals.

Presentations have been provided on these studies, along with further support to river fisheries when requested, particularly from the Dee Fishery Board. Where requests for support were received, this led to a channel of communication between those working in river fisheries and SMRU, which is beginning to form the basis of 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.

Contents

1 Introduction

Bag-nets are a traditional form of fish-trap used to catch salmon in Scottish coastal waters and there is a history of conflict with seals as a result of damage to fish in nets, or observations of depredation. Seals are known to intercept and remove whole salmon at the leader, which runs seaward perpendicularly from the shore, and research[1] through this project in previous years has resulted in observations of seals entering traps and removing whole fish from the cleek, doubling, and the fish court (Figure 1). More recently, observations using underwater video have also shown salmon being damaged by seals attacking the outside of the net when salmon become trapped in netting, particularly when panicked by the seal. Alternatively, panicking salmon may exhaust themselves, falling to the floor of the trap where they become easy to bite through the mesh. In addition, seal presence around nets may scare fish away from nets that may otherwise have been caught.

The majority of the damage is caused 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 net specialists may defend a food resource from other seals, which helps limit the number of seals present at nets. However, it is not known how quickly these specialist seals are replaced when they are removed (for example, by shooting). The likelihood of replacement may be higher when seals receive food rewards when they first visit a bag-net site and are therefore motivated to return. Removing or greatly reducing the availability of fish to the seals is therefore important.

Research at Scottish salmon bag-nets has focused on two broad areas – the effectiveness of Acoustic Deterrent Devices (ADDs) at bag-nets; and modification of nets to reduce seal damage and depredation. Previous studies have demonstrated encouraging results using both these methods (Lehtonen and Suuronen 2004; Lunneryd *et al.*, 2003; Fjälling *et al.*, 2006; Harris *et al.*, 2014a,b; Harris and Northridge 2015).

Studies in Scotland and the Baltic, where similar nets are used, have been developing and new net designs or modifications of existing nets to reduce the effects of seals on salmon catches have progressed (Lehtonen and Suuronen 2004; Lunneryd *et al.*, 2003; Harris *et al.*, 2014b; Harris and Northridge 2015). Some Scottish fishers 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. Results of assessment trials showed evidence of such hesitation in nets fitted with a narrow fish court opening, when a range of sizes were trialled in the field (Harris *et al.*, 2014; Harris and Northridge 2015). From these studies it was apparent that a compromise must exist between excluding seals from the fish court and allowing swift passage of fish through these net areas. Research efforts in 2015 aimed to provide further data to support an optimum fish court opening size.

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 for 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.

Seals continue to pose a problem for rod and line fisheries due to predation on wild fish (adults and possibly smolts too) and by scaring fish and making rod fishing impossible in some areas. River boards are continually looking for non-lethal ways to minimise this problem, such as previous work with river fishery boards where ADDs were tested to see if this could minimise the number of seals swimming up salmon rivers. Other measures have also been suggested and are discussed here.

[1] http://www.smru.st-andrews.ac.uk/documents/scotgov/SSI_seals_and_salmon_VF1.pdf

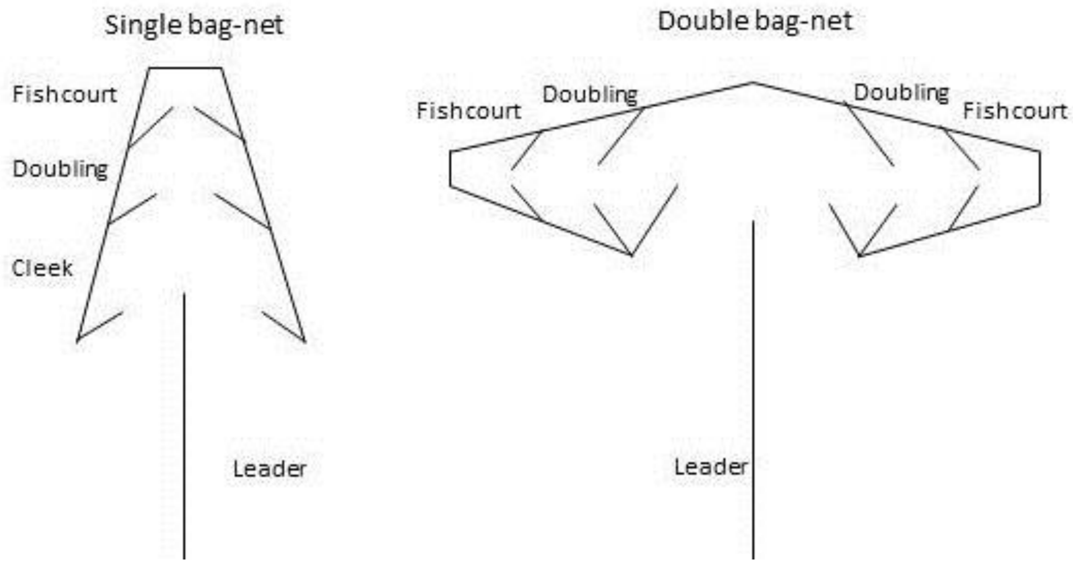

Figure 1. Plan view of a single bag-net and a double bag-net showing the sequence of chambers that make up the salmon trap - cleek, doubling and fish court.

2 Moray Firth – Gamrie Bay 2015

2.1 Introduction

The Scottish Wild Salmon Company (SWSC) began operating the Gamrie Bay Salmon Netting Station in 2012. From the start of operations the company attempted to mitigate the impact of seals on the fishery by making modifications to their traditional Scottish bag-nets. The Company also obtained a licence from Marine Scotland to allow the lethal removal of a limited number of seals.

A study at Gamrie Bay was initiated in 2013 to improve understanding of non-lethal measures to limit seal interactions with bag-net fisheries thereby reducing the need for lethal removal. Non-lethal measures studied at Gamrie Bay included the effectiveness of one type of commercially available ADD and the development of a fish court opening that allowed salmon to enter but prevented seals from doing so.

Previous studies have shown that ADD use can result in increases in catch per unit effort (CPUE) at salmon netting stations and reduce seal damage to landings as ADDs reduced seal presence at the net (Harris *et al.*, 2014a; Fjälling *et al.*, 2006). There is some evidence that the effects of ADDs can wear off over time (Mate *et al.*, 1987). The initial results from the Gamrie Bay studies in 2013 and 2014 were associated with both reduced seal damage and seal presence, as determined from cliff based observations and latterly underwater video. However, no significant difference in CPUE was observed in 2013 and 2014 whether or not ADDs were being used, and seal presence appeared to be minimally correlated with CPUE. This is possibly a result of relatively low levels of seal activity at the study net over the reporting period.

In 2013 at Gamrie Bay, the ADD system was deployed from land using a mains power supply. Previous deployments in other locations had utilised floating housings and battery supplies for the ADD. This site represented the opportunity to assess a land-based deployment approach and determine whether this approach could reduce the number of technical and logistical problems encountered during floating deployments. An important goal of the 2013 season was to improve practical aspects of land based ADD deployment that could be applied at Gamrie as well as at other salmon fishery sites.

An underwater (UW) video system had been developed to monitor fish and seal activity inside a bag-net in 2012 potentially a more efficient way to quantify seal presence than by cliff-based observations. As the system proved successful in 2013 and 2014, a decision was made to rely solely on UW video in 2015 to quantify seal visits to the net. The UW video system also had the advantage that it provided information on fish behaviour in relation to the net. As a result, 2015 represents the first year where UW video equipment was deployed for a complete salmon net season, with the first footage collected during April and May. These early months of the fishing season is the time of year when greatest conflict occurs between seals and bag-net fisheries (e.g., few salmon, seals shot, and highest proportions of damaged catch) and so it was important to capture data during this period.

Previous work had studied the effectiveness of the net modifications made by SWSC at mitigating the effects of seals (Harris *et. al.* 2014b), and had demonstrated the success of these modifications at reducing depredation, increasing landings and perhaps also increasing the number of salmon that escape nets to continue on their migration. However, the study also revealed that the modifications had transferred a proportion of the depredation from the fish court to the doubling, as the restriction to the fish court opening caused fish to hesitate in the doubling long enough to enable seals to intercept and remove them (Harris *et. al.* 2014b). As a result, finding a compromise that excluded seals from the fish court without significantly increasing the depredation opportunities for seals in the doubling was important. Work in 2014 began to address the issue of fish hesitation in the doubling by evaluating a wider steel frame opening (7.5 inches) to the fish court that would continue to exclude seals whilst easing fish passage. Due to the importance of this aspect of net design, a second year's data was required to complement the 2014 data and therefore the evaluation continued throughout 2015.

Overall, the aims of the 2015 fieldwork at Gamrie Bay were to continue the evaluation of ADD deployments and net modifications in reducing the conflict between seals and salmon fishers, while also collecting data on seal and salmonid behaviour to improve understanding of the system and to aid development of future mitigation.

2.2 Methods

An ADD (Airmar dB Plus II) powered by a mains supply from a nearby residential property was deployed and maintained by SMRU at the Peter net site (G in Figure 2) near Crovie village, which was the same deployment set-up as 2014. The operation of the device involved an experimental set-up with 'on' periods and control, or 'off', periods (where the device was attached to the net but not switched on). It was deployed in April 2015 and maintained for five months until the end of the salmon fishing season. In addition to the ADD trial, work also continued with SWSC to evaluate two different entrance widths to the fish court of bag-nets at the Peter net site. The two different net opening dimensions were monitored using underwater video to study the effect on fish behaviour (duration they spent in the doubling and rate at which fish 'escaped' the net) and the ability to keep seals out of the fish court.

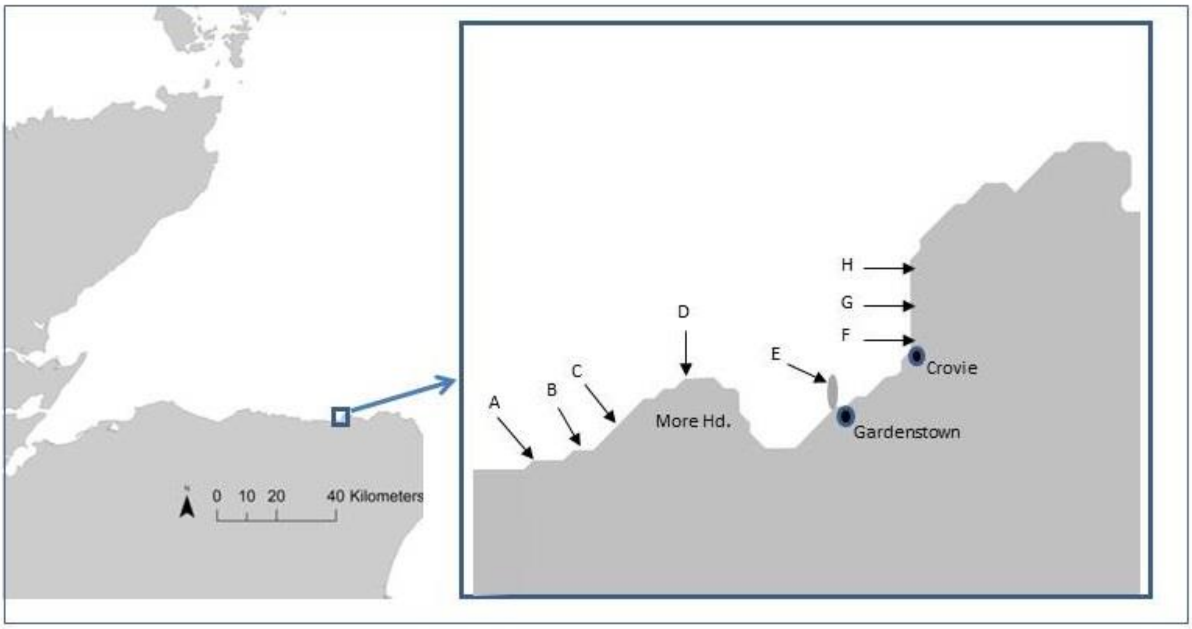

Figure 2. Salmon bag-net sites set within the Gamrie Bay Salmon Net Station in 2015: A – Grip; B – March; C – Skate; D – More Head; E – Rock; F – Crovie; G – Peter; H – Wirren.

The UW video and ADD systems and their deployment method, were the same as in 2014 and a detailed overview is provided in Harris and Northridge (2015)[2]. Although ADD control periods were distributed randomly throughout the season, their frequency of occurrence was reduced for the 2015 season. Control periods were dictated by coin tosses whereby control treatments required two "heads" to be tossed in succession while ADD 'on' treatments required a single "tail".

In previous years land-based observations have been used to collect environmental data and marine mammal sightings. However, in 2015 no land-based observations were carried out. Instead, seal presence data were collected by retrieving the underwater video system every four to five days and reviewing the footage. Seals were recorded as they entered and left the doubling of the bag-net. Environmental data were collected by deploying an automated weather station (www.thewindop.com) and acoustic records of cetacean presence were collected from two Sound Traps (www.oceaninstruments.co.nz). Attempts were made to recover Sound Traps every three days or when weather permitted.

Salmonids were recorded passing through the doubling opening and also the fish court opening by four underwater video cameras. In an attempt to assess whether fish were hestitating at either the 6 inch or 7.5 inch fish court opening the duration fish spent in the doubling was recorded. Salmonids that entered the doubling and subsequently entered the fish court without either leaving the doubling, or being confused by subsequent fish entering the doubling, were timed to provide passage rates through the doubling for both the 6 inch net and the 7.5 inch net.

2.3 Statistical analysis methods

All statistical analyses were performed using the statistical programme R v3.2.2 (R Core Development Team, 2015).

2.3.1 Model One

A binomial Generalised Linear Model (GLM) was fitted to the presence/absence of seals inside the doubling for each period preceding a net haul, corrected for the number of hours of video footage reviewed for that period. This was often different to the inter-haul duration as video was excluded if it was too dark to see seals or if an important camera angle was faulty. The modelled dataset only included those net deployments where video footage was available (n=119 hauls). Candidate explanatory variables were ADD status (on or off), day of the season, fish court opening size (6 inch or 7.5 inch) and wind direction (cross-shore, offshore, onshore, and variable). All variables were included as factors with the exception of 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.

[2] http://www.smru.st-andrews.ac.uk/documents/scotgov/SSI_seals_and_salmon_VF1.pdf

2.3.2 Model Two

A second model was fitted to the undamaged salmonid catch per unit effort (undamaged CPUE). All reported hauls for the Peter net were included (mid-April to the end of August, n=158). A quasi-poisson GLM was fitted to the catch data corrected for the inter haul duration. A quasi-poisson model was used because of over-dispersion in the dataset. Candidate explanatory variables included ADD status (on or off), day of season, fish court opening size (6 inch or 7.5 inch) and wind direction (cross-shore, offshore, onshore, and variable). All variables were included as factors with the exception of day of the season which was included as a continuous variable. As for model 1, model selection was carried out using a backwards stepwise method.

2.3.3 Fish passage rate model

A gamma GLM was fitted to the passage rates of fish through the doubling (in seconds) to determine if there was a difference in the rate between nets with different opening sizes. The data from 2012, 2014 and 2015 were combined which provided data for a traditional net with rope framed opening, and modified nets with steel framed openings that were 5.5 inch, 6 inch and 7.5 inch wide. Net type was included as a factor with four levels.

2.4 Results

The Gamrie Bay salmon net fishing station reduced fishing effort from 17912 net fishing hours in 2014 to 16255 net hours in 2015. In addition, there was a reduction in the CPUE, with an average CPUE (hours) per net of 0.07 in 2015 compared with 0.09 in 2014. Overall, the reduced effort and lower CPUE resulted in 524 fewer salmonids being caught in 2015: 1632 salmonids in 2014 versus 1108 in 2015 (where detailed effort data was available). No assessment has been made of the contribution that the weather (fishing conditions) may have played in this difference, however the data exist to go back and investigate this. Despite the observed decline in catch there was a large increase in the number of seal damaged fish: 130 seal damaged salmonids in 2015 (12% of the catch) compared with 79 in 2014 (5% of the catch). A summary of catch and effort for all sites across the entire Gamrie Bay salmon net station is available in Appendix 1.

Evaluation of the fish court openings was made at the Peter net fishing site, which was also, for the third season, the location of the AirMar ADD trial. ADD control periods were distributed randomly throughout the season although their frequency was reduced for the 2015 season at the request of the fishery. This resulted in considerably more ‘on’ treatments (3x more) than ‘off’ - 1522 hours ‘on’ versus 578 hours ‘off’. During ‘on’ treatments CPUE was double that during ‘off’ periods (0.14 fish per hour versus 0.07) (before explanatory variables were accounted for) (Table 1). During ADD ‘on’ periods 4% (n = 8) of the total salmonid catch was damaged by seals whilst during ADD ‘off’ periods 15% (n = 6 salmon) of the salmonid catch was damaged by seals (Table 1).

Table 1. Total salmonid catch, salmonid catch per unit effort (CPUE), seal damage to fish at the net and seal presence/absence data for the doubling (from underwater video) for each haul of the Peter net for both ADD ‘on’ and ‘off’ periods (haul duration refers to the time interval since the preceeding haul).

Peter net	Hauls (hauls with UW video)	Median haul duration	Total salmonid catch	Total damaged salmonids	Hauls with seal interference	CPUE (hours)
ADD ‘on’	108 (80)	13 hours	216	8 (4%)	11 (14%)	0.14
ADD ‘off’	50 (39)	11 hours	41	6 (15%)	15 (38%)	0.07

The four channel underwater video system recorded 1255 hours of footage at the Peter net and all footage was reviewed by an observer. Footage where faults with individual channels prevented suitable coverage, or periods with insufficient light were excluded resulting, in 1090 hours of suitable video for detecting seals and 717 hours suitable for detecting salmonids. No seals were seen to pass through the fish court opening of either the net with the 6 inch opening or the 7.5 inch opening.

2.4.1 Statistical analysis results

2.4.1.1 Model 1

From the four variables tested, ADD status, day of the season, wind direction and fish court opening size, only ADD status was retained in the selected model fitted to seal presence/absence per haul. There was a significant difference in the probability of detecting a seal between ‘on’ and ‘off’ treatments with a lower probability of seal presence during ‘on’ treatments (β_1=-1.53, p-value=0.001) (Figure 3). The other variables were not significant (at the p=0.05 level) and were dropped during the model selection process.

2.4.1.2 Model 2

The second model investigated variables affecting undamaged CPUE. The selected model retained ADD status and wind direction, as both factors significantly contributed to the model fit to the data (Figure 4). Undamaged CPUE was significantly greater when the ADD was ‘on’ compared with ‘off’ (β=0.74, p-value=0.016), and significantly greater when the wind direction was onshore compared with offshore (β=1.23, p-value=0.0001), cross-shore (β=0.76, p-value=0.005) or variable (β=1.2, p-value=0.007). There was no significant difference between offshore, cross-shore and variable wind directions. Day of season and net opening size were not significant (at the p=0.05 level) and were dropped during model selection.

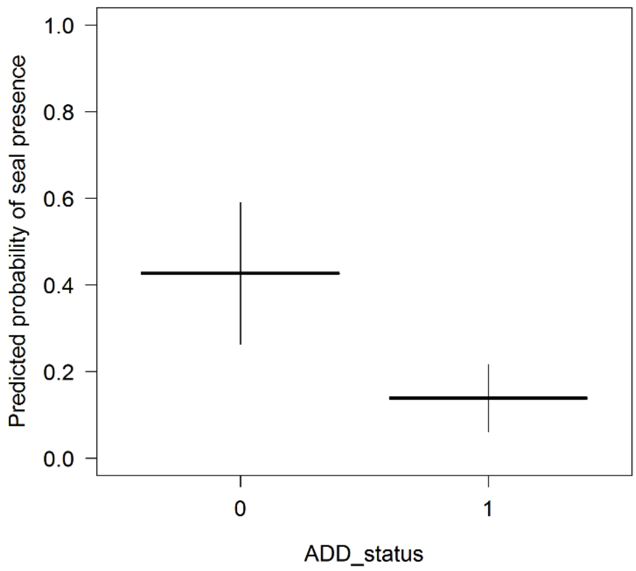

Figure 3. Predicted probability (from the selected model) of seal presence over 8.65 hours (the average length of video footage within a haul) for ADD ‘off’ treatments and ADD ‘on’ treatments.

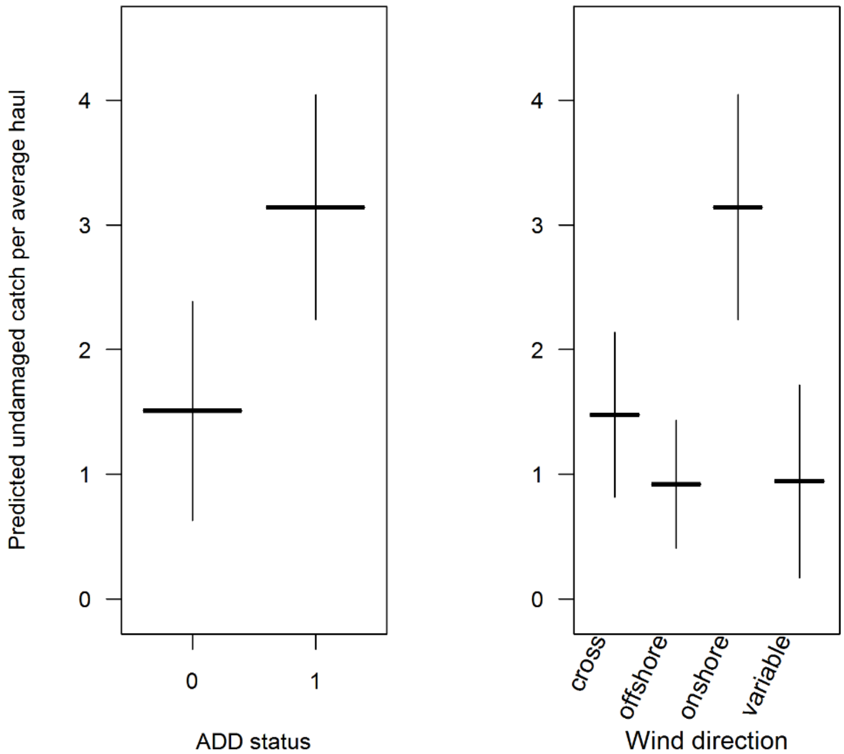

Figure 4. Predicted undamaged catch per unit effort from the selected model. The left panel shows the predicted undamaged CPUE when the ADD was both 'on' (status=1) and 'off' (status=0). For making these predictions the wind direction was fixed as 'onshore'. The right panel shows the predicted undamaged CPUE for all wind directions. For making these predictions the ADD status was fixed as 'on'. For both plots predictions were made for the average haul duration (13.34 hours).

2.4.2 Fish Passage Rates

Salmonids were recorded entering and leaving both the doubling and the fish court of both nets. Fish frequently swam back out of the doubling entrance however few fish swam out of the fish court entrance (two and one escaped from the 6 inch and 7.5 inch respectively). The median, minumum and maximum time fish spent in the doubling of the 6 inch and 7.5 inch net before entering the fish court are shown in Table 2. Results from 2015 were in agreement with those of 2014, as there was a significant difference in passage rates of salmonids between the two nets. Results from 2015 were combined with data from 2014 (Harris *et al.*, 2015) and with data from 2012 (Harris *et al.*, 2014b) and are presented in Figure 5. The traditional net had the fastest passage rate with its standard fish court entrance of a flexible rope frame (no metal) with variable width capable of allowing seals to pass through. The net had a significantly faster passage rate than all the other nets ($\beta>0.01$, $p<0.0005$ in all comparisons), the 7.5 inch net had a significantly faster rate than the 5.5 inch ($\beta=0.004$, $p=0.008$) and 6 inch nets ($\beta=0.004$, $p=0.006$), and there was no significant difference between the 5.5 inch net and the 6 inch net ($\beta=0.0006$, $p=0.628$).

Table 2. Number of salmonids and median time (mins. and secs.) spent in the doubling before entering fish court for timed fish in 2015.

Fish court opening	No. salmonids	Median time	Min.	Max.
6 inch	30	2:45	00:17	15:08
7.5 inch	39	1:33	00:04	06:34

Previous work demonstrated that slow passage rates led to increased depredation from the doubling (Harris *et al.*, 2014b). These observations were supported by the additional video data collected in 2015, as four salmon were observed being depredated from the doubling of the 6 inch net and none were observed being depredated from the doubling of the 7.5 inch net over similar time periods.

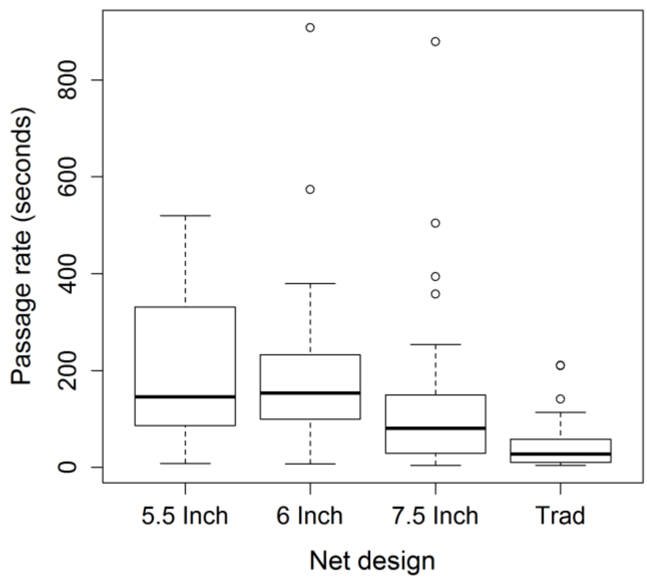

Figure 5. Box plot showing median time (secs.) for passage rate. The plot includes data from 2014 & 2015 (6 inch & 7.5 inch) and data from 2012 (5.5 inch & traditional net).

2.5 Discussion

Working with SWSC at the Gamrie Bay Salmon Net Station, the aim was to answer three main questions:

- Was the Airmar ADD and deployment system effective at keeping seals away from the net?
- Were the 6 inch and 7.5 inch fish court openings effective at keeping seals out of the fish court?
- Did the 7.5 inch fish court opening significantly reduce fish passage times through the doubling compared with the 6 inch opening?

The overall picture from the 2015 salmon netting season at Gamrie Bay was one of reduced catches compared with the previous two years, despite a slight increase in the number of sea trout landed. Interestingly, UW video observers also reported higher numbers of very small salmonids (possibly smolt or finnock) that escaped through the meshes of the bag-net. The number of seal damage fish in 2015 was also higher than in previous years, with 90 damaged in 2013, 79 damaged in 2014 and 130 damaged in 2015.

The effects of ADD status, fish court opening size and wind direction on the probability of seal presence/absence were investigated and found that the only significant explanatory variable that affected seal presence was ADD status. There was a significantly greater probability of detecting a seal during a fishing period when the ADD was ‘off’ than ‘on’. This agrees with the results from the 2014 deployment.

As in previous studies, when CPUE was modelled a highly significant effect of wind direction on catches was found, highlighting the importance of taking wind direction into account when investigating patterns in catch. ADD status was also found to contribute to landings with significantly more undamaged salmonids being landed during ADD ‘on’ periods compared with ‘off’. It is not thought that the operation of an ADD could increase catch by any means other than by reducing seal presence at the net.

Despite these positive results, it was clear that a few seals still visited the net during ADD ‘on’ periods thereby resulting in damage to catches. Finding alternative solutions for these instances is important to prevent the masking of ADD benefits. There are a number of existing, alternative approaches that require investigation. One example would be to change the sound characteristics of the ADD devices as this had an immediate effect on seal presence at the Portmahomack fishery in 2014. Other approaches involve taste aversion to make food from nets unattractive to seals, or trapping and moving individual problem seals. Perhaps the most important method, and the one where investigations have started, is the removal of food rewards for seals that visit nets.

Presumably some seals receive sufficient food rewards to warrant continued visits to the net even during ADD ‘on’ periods. Removing or reducing this food reward may be key in breaking the foraging pattern of the few seals that develop a tolerance to the presence of the ADD. There are, broadly speaking, two methods by which seals get a food reward; 1) by intercepting whole fish in the outer parts of the net and the fish court, and 2) by attacking and damaging fish once these have entered the fish court from outside the bag-net. Removing or reducing depredation by seals from both areas is important in helping to remove any reward for seals. This not only includes salmonids, but also fish bycatch species, as seals were seen on UW video targeting and removing lumpsucker, pollock and mullet from the net. Preventing seals from entering the fish court and reducing the amount of time fish spend in the doubling was shown to reduce depredation opportunities for seals in these parts of the net. The 7.5 inch fish court opening appears to provide a compromise between the smaller doors some fishers were using to exclude seals and the traditional Scottish bag-nets that allowed seals to enter the fish court. Through trials at Gamrie Bay and Balintore it has been shown that the 7.5 inch opening successfully prevented grey seals from entering the fish court whilst offering a large enough opening to reduce hesitation by fish, thereby reducing depredation opportunities for seals in the doubling. Future work would include investigating what, if any, size class of seal may be able to fit through a 7.5 inch opening.

To date, work has focussed on the first method described above by which seals obtain a food reward. The use of the UW video system has provided an initial insight into the methods seals are using to target salmonids held inside the fish court. Future work would include further study of these methods used by seals and the identification of any problem locations within the fish court. Improved understanding of depredation methods would lead to the design and testing of measures to reduce fish court damage. If appropriate, it may be useful to investigate the use of double-skin nets such as those deployed in the Baltic fisheries.

3 Fishery-Led ADD deployments

During the 2015 fishing season, Portmahomack net and the March net at Gamrie bay operated ADDs in addition to the scientific trial site at the Peter net at Gamrie Bay. These two additional deployments were entirely fishery-led and the fisheries agreed to provide SMRU with catch statistics for these sites, with details and perceptions of the devices and deployment methods.

3.1 Moray Firth – Portmahomack 2015

3.1.1 Introduction

The Portmahomack salmon bag-net fishery on the Tarbet Ness Peninsula, Ross and Cromarty, generally operates for a relatively short period during the salmon netting season, targeting returning salmon (primarily grilse) during July and August. One double bag-net has been set at this station for more than 15 years and has been using a Lofitech ADD since 2009. The effectiveness of the ADD was trialled experimentally (involving control periods) during 2009 and 2010 (Harris *et al.*, 2014a). The study found that although the ADD did not completely exclude seals, it 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.

In subsequent years the ADD was deployed by the fishery, with landings and seal information recorded by the fishery largely without scientific observation. In 2011 the ADD was 'on' continuously while the net was in the water and the fishery's confidence in the ADD as an effective mechanism for protecting catch from seal depredation meant they were comfortable in reducing the number of net hauls per day by approximately half, representing a considerable saving in effort and resources. No seal damaged fish were reported.

During 2012 and 2013 there were occasions when the ADD was not deployed by the fishery. This was primarily due to the fishery's belief that the seals had gone elsewhere and partly out of curiosity to test the continued need for the ADD. Furthermore, on a number of occasions following ADD deployment, the ADD was recovered with battery voltage low enough to affect ADD acoustic output. It was during 2013 that the number of reported seal sightings increased and seal damaged fish were landed during ADD 'on' periods, leading to the fishers reporting a resurgent problem with seals at the fishery. However, undamaged CPUE figures were still higher when the ADD was 'on' than during ADD 'off' periods suggesting a continuing benefit to ADD deployment.

A SMRU observer was placed at the fishery in 2014 to investigate the reported seal problem. The resulting information from a photo-identification study suggested that two male grey seals were ignoring the ADD and removing fish and damaging landings. Despite these two seals, landings still remained higher and the proportion of damaged fish remained lower than when no ADD was used, suggesting some level of continued effectiveness. Furthermore photo-identification revealed that fewer seals were prepared to approach the net when the ADD was 'on' compared with 'off'. However, in an attempt to further reduce seal depredation, the ADD was replaced with another ADD model with different sound characteristics. Following the change of device no seals were re-sighted at the net, landings increased and no further damaged fish were landed. Unfortunately, due to bad weather, only two further days of testing were achieved in 2014 and therefore the aim was to continue this work in 2015.

3.1.2 Methods

During the 2015 fishing season, it was not possible to have an observer on site due to commitments at Gamrie Bay. Instead, ADDs and recording forms were provided to the fishery who were responsible for data recording, deployment and maintenance of ADDs. There were no scientific control periods as the fishery operated devices as part of routine fishery operations. However, there were periods when the fishery was without an ADD due to equipment availability or equipment failure.

The Mohn Aqua Group (MAG) (www.mohnaqua.com) again offered the loan of their MAG ADD to enable the continuation of the 2014 work programme. Unfortunately, the device was not ready for the start of the season and therefore the fishery was provided with the original Lofitech ADD device until the MAG ADD was ready.

The Lofitech ADD was powered in the same way as previous years: two Haze 75 amp-hour gel batteries (Haze Battery Co.) in a modified Peli-case (Peli Products Ltd.) with the Peli-case floated beside the net attached to the nets' anchor lines. The entire system needed to be brought ashore for recharging. For the 2015 season the Lofitech pulse duration was reduced from 500ms to 250ms as a power saving modification, thereby reducing the unit's duty cycle from 10% to 5%. It was hoped that this change would prevent the need to bring the ADD ashore during the fishery's weekly open period (108 hours: 6am Monday to 6pm Friday). Ultimately this would provide the fishery with total coverage as opposed to 2014 when the Lofitech ADD had to be brought ashore mid-week to be recharged, leaving the net without ADD protection for approximately 12 hours.

The MAG ADD was powered differently as it was supplied with two sound projectors on 200m long cables. This allowed the electronics to be housed on land and for mains power to be utilised from a nearby property.

3.1.3 Results

At the Portmahomack salmon net fishing station, the fishery operated one double bag-net and provided fishing effort, catch and damage information from 15th June until 26th August 2016, amounting to approximately 10.5 weeks of data. No ADD was available for the first week, following which the fishery deployed the Lofitech ADD for 2.5 weeks until the device failed, leaving the fishery without an ADD for a further 2 weeks until the MAG ADD system became available. The MAG ADD was then used for the remainder of the season, a further 5 weeks. The fishery owner requested that absolute numbers of salmon not be published, therefore undamaged landings per unit effort (UCPUE) are used as an index. This was done by taking the average of the three UCPUE rates (ADD 'off', Lofitech 'on' and MAG 'on') and dividing each UCPUE value by the combined average.

Results provided by the fishery indicated that salmon landings were substantially higher when ADDs were used compared to when they were not. Furthermore 17% of landings were damaged by seals when the ADD was 'off'. Interestingly no damaged fish were landed while the Lofitech ADD was 'on' although the device only operated for 2.5 weeks. In contrast, 4% of the catch was damaged while the MAG was 'on' (Table 3). Results from 2014 have been included for comparison (in shaded columns).

Table 3. Results from both 2014 and 2015 for fishery effort in hours, undamaged catch per unit effort as an index and the proportion of damaged catch for each of the three states, MAG 'on', Lofitech 'on' and ADD 'off' (when no ADD was available).

	Effort (hours)		UCPUE (index)		Damaged (%)	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
MAG 'on'	54	538	1.7	1.9	0	4%
Lofitech 'on'	360	262	0.9	0.7	5%	0
ADD 'off'	199	337	0.4	0.4	19%	17%

3.1.4 Discussion

The use of ADDs at the Portmahomack bag-net fishery demonstrated considerable success over a number of years, although after some time a small number of seals appeared to ignore the original device. Nevertheless, catches still remained higher with a lower proportion of damage compared to when the net was without an ADD. Regardless, this began to raise the question of how to deal with seals that appear to ignore ADDs. In the first attempt to deter persistent seals a different ADD was deployed and this appeared to have been successful. The objective of work at Portmahomack in 2015 was therefore to continue the use of this 'new' MAG device to assess its continued effectiveness at deterring seals from the salmon bag-net.

Given commitments in other areas, it was not possible to have an observer at Portmahomack to carry out photo-identification of seals. However, data recorded by the fishery appears to support their perception of good ADD effectiveness during 2015. Both the Lofitech and MAG devices demonstrated a level of effectiveness that impressed the fishers, although recorded data suggests that seals were still at times able to cause a relatively low level of damage to landings. It is not known if the seals causing damage were the same male grey seals as in the previous year as no photo-identification data were available.

Increased landings during ADD 'on' periods also suggests effectiveness of devices, however these data should be interpreted with caution as environmental conditions, along with other possible factors capable of affecting salmon landings, were not been taken into account.

The available information for the Lofitech deployment provided similar results from 2014, yet very different perceptions from the fishery. In 2014 two male grey seals were prepared to ignore the device causing some damage and presumably some reduction in CPUE. These seals do not seem to have been present at the fishery in 2015, although without a dedicated observer or underwater video it is not possible to confirm this. Regardless, the Lofitech data suggests little difference in performance between the two years but interestingly fishery perception of unit effectiveness was greatly improved for 2015.

The fishery perception of the MAG ADD was one of continued success. This was despite the landing of damaged fish. Overall, the 2015 season at Portmahomack appears to have been reasonably successful in terms of total landings and this may have had an effect on perceptions.

A greater level of understanding of the effectiveness of ADDs requires dedicated observations to quantify seal activity. Future work at Portmahomack and elsewhere would benefit from underwater or land-based observations.

The Lofitech deployment method in 2015 may have contributed to the failure of the device, however it was not possible to confirm the exact cause of the failure. The power saving modification seems to have had some success but unfortunately the 2 x 75Ahr batteries were not quite sufficient to achieve the necessary power levels required for 108 hours of deployment; batteries were often down at approximately 11 volts by the end of the week. Deep discharging of these batteries is not ideal and reduces battery life.

The deployment method employed for the MAG ADD was a great improvement and the preferred option by the fishery. However this method is not suitable for all sites and therefore a reliable and practical alternative is required. The exposure to weather, tide and swell may limit what is possible but most importantly the power requirements of the chosen ADD model will go a long way in governing deployment options. Towards developing a device specifically for bag-nets or similar localised wild fish interests there may be value in trialling a smaller robust unit with lower power requirements, perhaps utilising a relatively lightweight but high energy density power pack with quick release system that allows easy replacement of batteries.

The large difference in CPUE between the MAG 'on' and other states is impressive, however without dedicated seal information or any randomised control periods, the significance of these results is difficult to interpret. Ultimately all studies should include photo-identification to allow a greater understanding of the effects of habituation or waning of effectiveness of ADDs.

3.2 Moray Firth – More Head 2015

3.2.1 Introduction

The Gamrie Bay Salmon Net fishery operated by SWSC operates a number of net fishing sites along a section of coast centred on Gamrie Bay. In an attempt to reduce the impact of seal depredation on landings, SWSC deployed their own ADD for the first time in 2015. They chose to deploy the ADD at the March net site, approximately 4 km away and obscured from the Peter net (the site of the SMRU scientific trial) by More Head. In contrast to the Portmahomack deployment (operating for relatively short seasons), the More Head deployment represented a considerably longer deployment. The deployment was entirely organised, funded and operated by SWSC at their Gamrie Bay Salmon Net Station. The fishery agreed to provide SMRU with information about this deployment at the March net site. The information provided complements and adds to existing knowledge on ADD effectiveness and deployment methods.

3.2.2 Methods

Prior to the start of the salmon net season, SWSC purchased an AirMar dB Plus II with a single projector. Although this device was not part of the SMRU ADD trial, the fishery made note of the times when the ADD was operational and the results are presented here. ADD 'off' periods were not true control periods but rather the result of deployment difficulties or a lack of battery power. In addition, the system was removed from the net rather than simply switching the device 'off' preventing any effect of the presence of the small vessel that housed the power supply and control box from being investigated as a causative factor in the observed results.

The fishery provided landings, fishing effort, seal damage and ADD 'on' or 'off' times. The deployment method chosen by the fishery was a small fibreglass vessel, purpose built and water tight, which had three waterproof hatches fitted to the deck to allow batteries and electronics to be accessed (Figure 6). The ADD was powered by 2 x 165Ahr Victron 12volt AGM batteries linked in series to provide a 24volt power supply. A solar panel and solar charge controller provided some charging capacity to extend the interval between having to recover the boat to shore for recharging. The duty cycle of the ADD was set at approximately 16% although the system's power saving mode would increase the inter-pulse interval to produce a duty cycle of approximately 8% to conserve battery power if battery voltage dropped below 22volts.

Figure 6. Purpose build fibreglass boat used to deploy an ADD at a salmon bag-net.

3.2.3 Results

The ADD was first deployed on 13 April 2015, with the system recovered soon after when poor weather was forecast. The decision to recover the system at the approach of rough sea conditions resulted in the ADD being 'off' for most of the season. It was removed from the sea for the entire month of May and there were also considerable periods during April, June, July and August when it was removed. In total the system was not at the net for 1793 hours of fishery effort compared with 526 hours when the ADD was 'on' (Table 4). No seal-damaged fish were reported while the ADD was 'on' compared with 13 damaged salmonids while the ADD was not attached to the net. There was also a large difference in the CPUE between ADD 'on' and ADD 'off' periods, as considerably more salmonids were landed per unit effort during ADD 'on' periods (Table 4).

Table 4. March net fishery effort and total landings, these are presented as catch per unit effort in hours and the number of salmon and trout damage by seals at the net.

	Effort (hours)	Total salmonids	CPUE (hours)	N. damaged (%)
On	526	61	0.12	0
Off	1793	95	0.05	13 (14%)

The fishery reported difficulties in maintaining suitable voltage in the system. Although no voltage readings were provided, the fishermen frequently reported the device to be on its power saving mode suggesting that voltage was below 22volts.

3.2.4 Discussion

No seal information from March net was recorded during the season preventing a comparison of seal activity between 'on' and 'off' periods. However, fishers did report anecdotally that a seal was seen at the net during a period when the ADD was 'on'. No information exists to suggest any problem with the ADDs output, although it is possible that the device was operating on its power-saving mode at the time which could result in producing a sound signal approximately every 32 seconds, an interval which would be sufficient for a seal to enter and leave a net between pulses. The rhythmical production of sound signals by the Airmar dB Plus II, producing pulses at fixed intervals, probably allows seals to quickly learn to anticipate and predict the arrival of subsequent sound pulses, in which case a randomised sequence of pulses may be preferable.

The lack of any seal-damaged fish while the ADD was 'on' coupled with the substantially higher CPUE, suggested that the ADD system was effective at reducing seal depredation. Whether or not it deterred seals from approaching the net at all is difficult to confirm without seal information from the net. Furthermore no environmental data were recorded, making it harder to assess the observed CPUE results. Wind speed and direction data exist for the nearby Peter net which could be used to investigate this, however the presence of 100m sheer cliffs with considerable variations in aspect may cause unexpected differences in wind direction between the Peter and March net sites and therefore a level of uncertainty would still remain.

The deployment system developed by the fishery had advantages and disadvantages over previous deployments. The autonomous nature of the system was one advantage, allowing the deployment of ADD equipment at remote sites. However the ADD's power requirements were not conducive to an autonomous deployment as, despite the large batteries and solar panel, the system appeared to struggle to last the 108 hours required for the weekly fishing period (6am Monday to 6pm Friday). The potential to improve power efficiency of the Airmar dB Plus II exists and should be seen as an important factor in developing ADD systems for remote locations. The MAG ADD was specifically designed as a more energy efficient system and may be more suitable for remote battery-dependent sites. The capacity for further improvements in power efficiency may ultimately define the suitability of these devices for remote deployments, unless easy access for replacing batteries is possible.

Unfortunately the system deployed by the fishery was not tested in all weathers, which is what is required to protect nets. Previous sealed floating deployments have suffered from over-heating and damage caused to electrical components as a result of violent motion (storm damage). The floating vessel deployed in this situation may still be prone to these problems. A housing unit below the surface or attached to a fixed structure such as the cleek pole may offer one solution provided a power supply solution can be found.

4 Seal Diet at Wild Salmon Bag-net Fisheries

4.1 Introduction

Photo-identification studies at wild salmon bag-net fisheries have demonstrated the existence of net specialist seals, i.e. seals that regularly return to nets over multiple years to depredate salmon (Harris 2012a; Konigson *et al.*, 2013; Harris *et al.*, 2014a). Seal licences are issued in Scotland allow the removal of these seals. The survival of these persistent seals has been put down to a number of factors such as the existence of behavioural traits that make particular individuals difficult or impossible to shoot: for example seals were observed breathing with only the very tip of their nostrils breaking the surface (Harris 2012a).

The high depredation rates observed at some nets and the apparent low numbers of seals involved suggests that seals are capable of meeting their energy requirements on salmon alone at specific times. Furthermore seal depredation rates of 0.24 salmonids per hour (Harris 2012a) and 0.16 salmonids per hour (Harris *et al.*, 2014) are comparable with the landings from some bag-nets.

Underwater video has revealed how net specialist seals are routinely able to enter nets and remove whole salmon (Konigson 2007; Harris *et al.*, 2014). This is in contrast to other seals that find their way into nets but are then unable to find their way out again and perhaps represent those individuals unfamiliar with bag-nets. When these seals become trapped in nets they are shot by marksmen. Interestingly some of these apparently naïve seals that were shot inside Scottish bag-nets, may not have been responsible for any salmonid depredation as recent work found little evidence of salmonid DNA in the digestive tracts of some individuals (17%, n = 12). Furthermore, seals shot inside nets are more easily recovered by fishers than those shot outside nets that may sink or float away, and so may be over-represented in recovered samples. The survival of persistent individuals and the recovery of a greater proportion of those seals unfamiliar with salmon nets among those that are shot, may have given rise to considerable sampling bias in the studies of the diet of those seals found in the vicinity of bag-nets. Previous work has reported salmon in relatively few seals between 19% to 22% of carcasses (Rae 1968; Pierce *et al.*, 1991; Harris *et al.*, 2012).

Seals can be prevented from becoming trapped inside bag-nets by modifying the entrance (Harris and Northridge 2015). Furthermore the use of ADDs also reduces seal presence at nets, although they are not always able to deter seals that are determined to forage at nets (Fjalling *et al.*, 2006; Harris *et al.*, 2014a). However, reductions in seal presence not only reduces the numbers of seals shot, but may potentially allow lethal control to become more selective by reducing numbers of transient seals in the vicinity of nets, leaving only net specialist seals.

Recovering shot seal carcasses is an important aspect in the development of understanding of seal interactions with bag-nets. It provides information on the foraging behaviour of seals associated with nets and contributes to understanding of the effectiveness of individual fishery seal mitigation measures. The aim of this work was to further understand the diet of seals shot at nets employing different mitigation methods, and to help determine whether mitigation has improved the selectivity of seal removal in terms of its focus on net specialist seals.

4.2 Methods

Shot seal carcasses that were made available to SMRU were either recovered by the fishery or reported by the public. Pelage photographs were taken in an attempt to match shot seals with seals seen inside nets from underwater video footage or previous bag-net photo-identifications studies. Where possible seals were either transported to SMASS (Scottish Marine Animals Stranding Scheme) in Inverness for necropsy, or were processed onsite by SMRU. Entire gastro-intestinal tracts (GITs) were removed wherever possible, however only the stomach was removed from seals in an advanced stage of decomposition as the tough muscular structure was often found to be intact when other structures had perished. Entire GITs or stomachs were placed into separate bags and stored at -20°C.

GITs were defrosted at room temperature and the oesophagus and stomach were separated from the intestines. The large intestine (colon) was separated from the small intestine (illium) and, in a change from previous work, a decision was made not to process the small intestine (although it was stored refrozen so that these samples can be revisited if needed). This decision was taken primarily because processing the illium is an extremely lengthy process and previous work had found that it rarely contributed additional information to that from the stomach and colon. Processing the stomach and colon provided the immediate diet (stomach) and the slightly longer term diet (colon) for each seal.

For each sample new disposable gloves and scalpel were used to prevent any cross contamination between samples. Depending on the amount of digesta present, up to three small (5 cm) incisions were made at various locations over the length of the stomach (in case of any stratification of contents) and a 1.5ml Eppendorf was used to extract approximately 1ml of the contents at each location. Likewise, one or two incisions were made in the colon to extract material at up to two distinct locations. Sub-samples were stored at -20°C until DNA extraction.

The stomach was then opened and decanted into a tray, the presence of any intact prey items ingested at the time of death or the presence of pink salmonid flesh were noted. The stomach was then washed over a nest of sieves (4mm, 710µm and 350µm) to collect hard-parts. Stomach contents were then transferred to the nest of sieves in small portions and washed through with water. Hard-parts were extracted from the sieves and photographed, the presence of sea lice (*Lepeophtheirus salmonis*) were noted. The entire contents were checked and otoliths, cephalopod beaks and fish scales were stored. Otoliths were stored dried in Eppendorf tubes, beaks were stored in 75% IMS solution for later identification and scales were stored in envelops. The remaining hard-parts were discarded. This process was then repeated for the large intestine. Otoliths were identified using Harkonen (1986), Leopold *et al.* (2001) and the first author's salmonid otolith reference collection.

The extraction of DNA from sub-samples of each seals digesta was done using Qiagen QIAmp DNA Stool Mini Kits. Using sterile inoculation loops, between 180 - 220µg of each sample was transferred into sterile 2ml Eppendorfs. The extraction process followed the Qiagen protocol and extracted DNA was stored at -20°C prior to DNA analysis.

The extracted genomic DNA was supplied to Xelect Ltd where the samples were tested for the presence of salmonid DNA. All samples were analysed using three quantitative PCR (qPCR) assays designed to detect seal (*Halichoerus grypus* and *Phoca vitulina*), Atlantic salmon (*Salmo salar*) or sea trout (*Salmo trutta*) DNA. The methods used in this process were as described by Matejusová *et al.* (2008). All qPCR analysis was performed in duplicate using a 1:1 dilution of genomic DNA in a 6 µl reaction containing 0.6 µl diluted DNA, a species specific Taqman® gene expression qPCR assay and Brilliant III mastermix (Life Technologies™, UK). Target DNA was amplified using the following amplification conditions: 95°C for 10 minutes followed by 40 cycles of 95°C for 15 seconds and 60°C for 30 seconds. Florescence was measured throughout amplification for the FAM reporter probe and a cycle threshold (Ct) value was reported for each sample, where lower Ct values indicate a greater amount of target DNA in the target sample. A Taqman® Internal Positive Control (IPC) (Life Technologies™, UK) was used to check for PCB inhibitors in the DNA samples where VIC reporter probe measurement and comparisons of VIC Ct value between test samples and a no template control can be used to determine if PCR inhibition has occurred, therefore a true negative result can be distinguished from PCR inhibition.

4.3 Results

Twelve grey seals were sampled from bag-net sites in 2015 (10 female and 2 male). Of these, eight grey seals were from the Moray Firth seal management region and two were recovered from both the East Coast seal management region and the North Coast and Orkney seal management region. Seals were recovered during June, July and August 2015. Both the stomach and large intestine were processed from all seals.

During the analysis of the DNA sub-samples, the IPC assay detected no inhibition in any of the samples and therefore all samples were suitable for detecting the presence of target DNA. All samples tested positive for the presence of seal DNA using the assay designed to *H. grypus* and *P. vitulina* cytochrome b sequences (Matejusová *et al.,* 2008). Results indicated that salmonid DNA was present in six seals. Two seals had both salmon and trout DNA, three seals had only salmon DNA and one seal had only trout DNA. Salmon DNA was detected in the stomachs of four seals and in the colon of three. Trout DNA was detected in the stomachs of two seals and the large intestines of one seal. Prey DNA was not always detected in both the stomach and large intestine, highlighting the need to sample both structures to maximise detection probability.

Fifteen salmonid otoliths were recovered from the same six seals as above, corroborating results from DNA analysis. Salmonid otoliths were identified to species in five seals, however in the sixth seal the small size coupled with the level of digestion made it difficult to confirm species. In total, seven salmon otoliths and four trout otoliths were identified to species, while it was not possible to confirm species for a further four salmonid otoliths, all of which were from the same seal which tested positive for both salmon and trout DNA. All seals that contained salmonid prey also held evidence of other prey species (Table 5).

Otoliths or beaks were recovered from either the stomach or the large intestine of eleven seals, and only one seal held no evidence of any prey.

Table 5. The number of otoliths recovered from different prey groups and their frequency of occurrence in twelve seals (one seal held no prey).

Prey group	Frequency of occurrence	Number of otoliths/beaks
Perciforms	7	416
Salmonid	6	15
Gadids	5	36
Cephalopods	5	11
Cottids	2	39
Pleuronectids	1	28
Clupeids	1	22
Unidentified	1	4
Total	**N = 11**	**571**

4.4 Discussion

From the hard-part analysis perciforms (primarily sandeels) were found to be numerically the largest contributor to diet, although salmonids, gadids and cephalopods were also frequently found. For carcasses recovered from bag-net sites in 2015, salmonid prey was detected in the same six seals using hard-part analysis as with DNA analysis. Although DNA analysis offered little additional information in this instance this is not always the case and it is advised to process samples using both hard-part analysis and DNA methods to maximise probability of detection.

The presence of salmonids in the diet of seals recovered from bag-net sites appears to be slowly increasing in recent years, following a long period where salmon were detected in relatively few carcasses (number in parentheses represents the proportion of samples with salmonid presence - Rae 1968 (0.2), Pierce *et al.*, 1991 (0.2) Harris 2012a (0.2); Harris *et al*., 2014b (0.4) and here in 2015 (0.5)). This may be a result of the adoption of non-lethal seal mitigation measures by a gradually increasing number of fisheries, deterring non-specialist or naïve seals and focusing marksmen’s attention onto net specialist seals.

The presence of a wide range of prey items in the digestive tracts of seals suggests that shot seals recovered in 2015 were not solely targeting salmon, and the presence of gadids, cephalopods and mackerel suggests that seals were not gaining their entire energy requirements from nets. The growing perception of specialist seals at bag-nets is that they are typically male grey seals (Konigson *et al.,* 2013; Harris and Northridge 2015), and therefore it is of interest that the majority of seals recovered in this project were female. Without additional information from marksmen to complement land-based observations or underwater video, it is difficult to say whether shot male seals have a greater probability of sinking or a greater probability of not being shot. However seals seen inside salmon nets on underwater video in Gamrie Bay in 2015 were frequently male grey seals and during a photo-identification study at Portmahomack were almost entirely male grey seals (Harris and Northridge 2015). It would help understanding of the situation if fisheries recovered every shot seal or, for grey seals not recovered, to record sex of the shot seals where possible (male, female or unknown).

Alongside the numbers of seals shot by fisheries (information that is provided directly to Marine Scotland by licence holders), the information on the diet of seals recovered from bag-net sites is contributing to understanding of the effects of seal mitigation measures employed by each fishery, as well as the effectiveness of lethal control.

This work benefits from the involvement of fisheries who are best placed to recover carcases and every effort should be made to facilitate this often difficult and time consuming process. This may be in the form of help with recovery or by a rapid response in collecting carcases from fisheries. In addition, it is important that the results of these collaborative efforts are reported back to the fisheries.

5 River Dee DSFB collaboration and support provided in 2015

5.1 Introduction

In collaboration with the Dee District Salmon Fishery Board (DSFB), seal monitoring programs are being developed to help to evaluate the impact of seals on fisheries and salmonid stocks in the river Dee catchment. This work will also enable assessments of the effectiveness of seal mitigation measures that are being tested by the DSFB. By working closely with the DSFB, it is hoped to gain a better understanding of the processes that will lead to the development of better ways to mitigate the impact of seals on salmonids in rivers.

River Dee fishers, ghillies and river bailiffs report river seal sightings to the DSFB. During 2015, 91 seal sightings (15 grey seal, 38 harbour seal and 38 unidentified seals) were recorded by the DSFB. This represents an increase from previous years when approximately 50 sightings were reported in each year from 2012 to 2014. It is difficult to interpret these river seal sightings without a record of the amount of time spent searching, however the increase in reported sightings appears to come from an increase in reports in November, December and January, outside of the fishing season. This is a time when there are generally fewer people on the river, and therefore less observation effort, but it is important to be aware that this may represent an increased awareness to report sightings rather than an actual increase in seal occurrence. Overall the temporal pattern of seal sightings remains consistent with previous years, with no river seal sightings reported during May to August in 2015.

In February 2015 DSFB staff began carrying out a systematic survey that involved a vehicle visiting access points on the river to search for seals. Surveys lasted the same amount of time at each site, and sites were visited in the same order during each survey. The surveys were carried out approximately three times a week. Unfortunately, the surveys did not appear to be effective at detecting seals and the decision was made to abandon the method after three months. The surveys were recommenced during the autumn/winter when seals typically reappear in the river.

A move by the DSFB to increase the focus on the coastal zone and harbour area led to the development of work programmes in that area. In collaboration with the DSFB, surveys were developed to monitor marine mammal presence in Aberdeen harbour. Dedicated land based observations were carried out from a fixed location for one hour periods. Methodology followed that described in Carter *et al.* (2001) and involved the visible area of the harbour being swept with binoculars for 3 minutes in every 10 minutes. It was decided to follow the methodology of Carter *et al.* (2001) to allow comparisons to be drawn with observations made between 1993 and 1996 and those here. Thirty-nine one hour surveys were completed during November and December 2015 and it is hoped that the DSFB can continue these surveys throughout 2016 with the combined results reported in 2017.

In an attempt to gather photo-identification information on seals using the river Dee, a 300mm canon lens was provided to the DSFB. Relatively few images have been collected to date, possibly reflecting the difficulty in gathering images on an incidental basis. In January 2015 three harbour seal sightings were photographed and additional sightings was photographed in March and November 2015. Three different harbour seals were identified from these five sightings.

To further develop the existing work programme, the study would benefit from dedicated systematic river surveys with photo-id to quantify seal numbers and occurrence in the river. The study would provide an effective platform for monitoring possible effects of mitigation methods deployed in the river such as ADDs and alternative scaring tactics or perhaps trapping. Although an attempt was made to achieve this in 2014, few seals were detected and this may have been due to the position in the river where surveys were carried out (just upstream of an ADD system). Conducting surveys immediately downstream of the ADD installation may provide more seal sightings.

During 2015, the Dee DSFB continued to maintain a Lofitech ADD system with two sound projectors directed perpendicularly across the river and approximately 65m apart at a location in the river that is approximately 80m wide. The system was installed to act as a barrier to seals moving up river. Two ‘known’ harbour seals were identified with both having passed the barrier on two occasions during the spring of 2015. As such, a decision was made to try another ADD system with different sound characteristics in an attempt to prevent the seals moving upriver.

Discussions were held with a second ADD supplier (Mohn-Aqua Ltd.) and the company kindly agreed to loan a new ADD system to the Dee DSFB to replace the Lofitech barrier. The aim was to test the theory that a new acoustic signal/system could discourage the ‘known’ harbour seals from venturing up river past the ADD barrier site. The supplier provided four sound projectors to be arranged in the river in the shape of a diamond, spread over a length of river approximately 140m. Although the initial results appeared promising, the overall lack of seal activity over the summer period prevented the system from being tested thoroughly. During August, faults were detected with the system and it was discovered that two projectors had stopped working it was a number of weeks before the system could be repaired. Seals were detected upriver of the new barrier during October and December 2015. At the end of December record-breaking flood levels caused further damage to the ADDs. The devices were made operational again, however it is uncertain whether they were operating correctly. No sound measurements were made following the first failures which means that it is not possible to determine the intensity of the sound fields generated in the river. These measurements should routinely be made in the future to determine sound field strengths at ADD barrier sites.

An extra Lofitech ADD device with short projector cable and a small battery pack was provided to the DSFB by SMRU to be used as a mobile system from a vessel to ‘sweep’ seals back below the barrier. This approach was deemed necessary to deal with those seals that appear to be ignoring the ADDs. The system was used three times with success to move seals downriver. Although equipment failure led to the system being withdrawn, it is hoped it can be redeployed and tested further for 2016.

5.2 Discussion

Maintaining ADD systems in rivers is a challenge, and developing protocols that allow for regular maintenance checks, in particular the maintenance of power, position and orientation, may not be easy. The ideal configuration of sound projectors in this situation, in a shallow river environment where sound propagation is limited, may be to contain sound projectors in a relatively short section of river to create an intense sound field over a short distance rather than a weaker field over a larger distance. The configuration suggested by the manufacturer may have been a typical configuration for an aquaculture deployment, however it is perhaps less suitable for a river deployment.

Although ADDs have been demonstrated to be effective in rivers (Graham *et al.*, 2009; Harris 2011a), they have never been able to completely exclude seals, requiring the use of additional methods to contend with the few individuals that may ignore ADDs.

It is hoped that the mobile system tested in 2015 can be re-developed into a more user friendly package that can be used proactively to return seals to the sea. Preventing seals from foraging in the river may result in seals choosing to forage elsewhere, breaking river foraging behaviour. The use of ADDs or alternative disturbance/scare tactics to disrupt seal behaviour in rivers may only be effective if seal presence in rivers is detected as soon as they enter rivers and before they have much time to forage (i.e. before being rewarded for the behaviour).

An additional measure may involve the trapping and removal of problem individuals such as the trapping and relocation programme currently used at Tasmanian aquaculture sites (Robinson *et al.*, 2008). A seal live-capture system is being developed with part funding from the DSFB and provides an additional mitigation measure that may help to break river foraging behaviour.

6 An Overview of Potential Non-lethal measures to Reduce Seal Depredation on Salmon

Deliverables under this Topic were as follows:

1. Improved understanding of non-lethal measures to limit seal interactions with bag net fisheries, including options for measures that will reduce the need for licenced shooting, and at the end of Year 1 <u>detailed proposals on how non-lethal measures should be pursued</u>.
2. <u>A report at the end of Year 1 on potential options for further research and development of non-lethal options.</u>
3. Development of field work to assess the long term effectiveness of ADDs including cetacean friendly devices on both seals and cetaceans, and which will progress over the lifetime of the project

The two short reports required under this theme for the 2015-2016 reporting year (underlined above) and presented below.

6.1 Proposals on how non-lethal measures should be pursued in relation to bag net fisheries.

To some extent information on non-lethal measures to limit bag-net depredation has become academic as bag netting has been prohibited in Scottish waters from 2016 for an interim period of 3 years. Nonetheless, work that has been conducted by the SMRU in collaboration with bag net fishery companies over seven (relatively brief) fishing seasons since 2009, has led to some significant and demonstrable reductions in seal depredation at bag net stations, and there would be scope for some clear management recommendations should the bag-net fishery resume.

The two key non-lethal measures that have proven successful have been the use of acoustic deterrent devices (ADDs) and modifications to the structure of the bag-nets themselves. As with all fishing gear related technological measures, improvements have been slow and incremental with lessons learned each year being taken forward to the next season.

Development of these two approaches can be considered still a work in progress, though progress to date, which has been summarised in annual reports to Marine Scotland, makes clear that both approaches should greatly reduce the need for licenced shooting.

6.1.1 Use of ADDs

It was shown that two ADD models were effective in significantly increasing salmon catch per unit effort, by reducing the removal of salmon from the nets by seals, and can usually be effective in minimising the number of damaged salmonids recovered from the nets.

The primary obstacles to the routine use of ADDs in bag net fisheries are:

1) The power supply

2) Cable attachments to the gear
3) Possible diminution of effectiveness over time (habituation), and
4) Possible disturbance of some cetacean species.

Two types of ADD have been tested at three sites. Initially the devices used were Lofitech deterrents, but more recently Airmar devices have been trialled. Both were associated with reduced depredation, though not always a noticeable reduction in damaged fish, but more often an increase in catch per unit effort when the devices were in use.

The Lofitech device has been run from a battery power supply using sealed floating chambers attached to the net which contain batteries and control boxes. Batteries do not always last a full fishing week, and need to be recharged regularly. The floating power supply chamber is vulnerable to physical damage. The Airmar device can also be run from batteries, but has been more successfully deployed using a mains power supply at two of the three sites. Mains power is not always available at bag-net sites, but is clearly the preferable means of supplying power to ADDs and should be implemented wherever possible when these devices are being used. The logistics of power supply need to be worked out by the fishing companies on a site by site basis. Initial concerns with cabling have now largely been addressed and methods for transducer deployment have been described in previous reports.

Habituation appears to be a concern after a few seasons of deployment. Although not necessarily fully resolved, the current work suggests that replacing one ADD type with a novel acoustic signal from a different device re-establishes the deterrent effect. Bag netting companies should therefore be prepared to remove devices where effectiveness appears to wane, and replace the device with another type. Both the Airmar and Lofitech devices appear to be effective at least for several seasons. There is no reason to suppose any other specific ADD types would be any less effective, but an exhaustive trial of the several available models has not been possible.

Disturbance of cetacean species through the use of ADDs at bag-net sites still remains a concern, and it has only been possible to address this issue to a limited extent. The limited data suggest that echo-locating porpoises are absent from the immediate area around bag-nets when ADDs are present (it is not possible to say over what range) while bottlenose dolphins appear less affected or unaffected by ADD operations. The effects of ADDs on dolphins (rather than porpoises) is generally very poorly documented.

6.1.2 Modified bag-nets

Modifications to the bag-net design have chiefly focused on changes to the entrance to the fish court – the final chamber of the net where the fish end up and from which they are removed by the fishery. Traditional nets have used a rope framed flexible entrance with a circumference ~130 cm, often hung in an oval or rectangular shape, but such entrances enable seals to enter the fish court more or less at will, to remove fish that reach this chamber. Experiments in the current work have involved using steel rods to make a rigid and inflexible entrance of varying widths. It was found that seals are generally unable to enter the fish court if the width of the entrance is 7.5 inches or less (19 cm). Entrances of 6 inches (15 cm) are very effective at preventing seals from entering the fish court, but also impede the ingress of salmonids which hesitate for extended periods of time in the outer chamber (doubling), and are then subject to possible seal predation over an extended period of time. A compromise appears to be around 7.5 inches, which is narrow enough to prevent seal entry, but wide enough not to discourage salmonids from entering for too long.

Several other possible bag-net modifications have been suggested and some minor modifications (such as eliminating blind corners within the fish court) have been tested and implemented successfully. There are likely to be several other avenues for net modification that could be explored, but at present the most obvious management recommendation would be that the entrance to the fish court is made rigid and narrow enough to prevent seal access, while still enabling salmon to enter at will.

6.2 Potential options for further research and development of non-lethal options.

Coram *et al.* (2014) provided a detailed review of possible non-lethal options for limiting seal depredation, primarily in the context of aquaculture, but their results are pertinent here as well. The results presented in this paper along with the recent conclusions presented here have suggested some further options for exploration.

6.2.1 Bag-net fisheries

While it is clear that in the context of bag-net fisheries both ADDs and modifications to the fish court entrance can and do have a significant positive effect on minimising seal depredation, there are a number of existing, alternative approaches that still require investigation.

One example would be to enable easy changes to the sound characteristics of the ADD devices as this was shown to be an effective means of addressing habituation at least in one instance. Other commercially available devices that were not trialled have this feature available, and it would be useful to determine the extent to which this is a general solution to the widespread concern over habituation.

Other approaches involve taste aversion to make food from nets unattractive to seals or perhaps trapping and moving individual problem seals. Perhaps the most important method, and the one for which investigations have been started, is the removal of food rewards for seals that visit nets. The same principle may apply in rivers, where swift removal of seals (using either traps or down river sweeps of portable ADDs) may help prevent the possible foraging rewards of the river becoming apparent to the seals involved.

In the context of bag-nets, seals can be successful in depredating fish either by intercepting whole fish within the net or by attacking and damaging trapped fish through the meshes from outside the netting. Further work on the design of bag-nets might help (1) speed the passage of fish through the net and into the fish court while preventing seal entry and (2) limit or eliminate the potential for seals to be able to bite fish through the meshes of the net. Further work on the entrance to the fish court might focus on the physical ability of seal of varying sizes to squeeze through rigid openings, and on the reactions of salmon to passages of varying widths. The second approach has been tested successfully in the Baltic using a ‘double skinned’ net whereby two sets of meshes attached to a frame prevent seals from attacking fish inside the fish court. In this case the UW video system whole fish court is raised to the surface using an air pump, an elaborate design that may or may not be practicable in a Scottish context.

To date, this work has focussed on the first method described above by which seals obtain a food reward. The use of the UW video system has provided an initial insight into the methods seals are using to target salmonids held inside the fish court. Future work would include further study of these methods used by seals and the identification of any problem locations within the fish court. Improved understanding of depredation methods would lead to the design and testing of measures to reduce fish court damage. If appropriate, it may be useful to investigate the use of double-skin nets such as those deployed in the Baltic fisheries.

6.2.2 River fisheries

Many of the options for research focussed on reducing the impact of seals on river fisheries could be transferable to other fisheries or aquaculture. Non-lethal options can broadly be separated into four categories, however there are a considerable array of different delivery/deployment options available for each:

1. Physical barriers (permanent, semi-permanent or responsive):
    - Barriers to predators in the form of exclusion devices, fish refuges, fences, curtain nets or weirs
2. Deterrent techniques (continuous or responsive):
    - ADDs, electric gradients, taste aversion
3. Hazing techniques (to move seals back to the sea or prevent river foraging):
    - Human presence, seal harrying, mobile ADDs, non-lethal bullets (warning gun shots, cracker shells, beanbags)
4. Trapping (scientific or management):
    - Relocation, temporary housing, permanent housing (captivity), tagging (scientific studies or warning systems (for repeat offenders) e.g. pit tags or radio tags that enable listening stations to detect seal presence early to trigger deterrent or hazing techniques).

Effectiveness at a specific site may ultimately be determined by both the approach and the deployment method chosen (as well as site characteristics). In addition, although one method/ deployment combination may have been shown to be effective, it is likely that the best solutions will utilise a combination of methods such as the use of ADDs, fish refuges and hazing techniques, with no reliance on one single method. ADD barriers have been shown to be effective at reducing the number of seals that travel upriver. In one study photo-identification of seals at an ADD barrier suggested that relatively few individuals were prepared to pass the barrier when it was ‘on’ compared to when it was ‘off’ (Harris 2011a). However, deploying ADD barriers effectively is often difficult, and poor deployment, under-sized deployment or deployment of faulty devices may result in an increasing number of seals being prepared to ignore the barrier. This may ultimately create a more complex situation to resolve. Developing practical river deployment methods for ADD barriers is essential if they are to provide a useful tool for river managers. In addition, an understanding of the rate at which seals learn to pass correctly functioning barriers is important, not only in defining the long term effectiveness of barriers, but in allowing the development of further mitigation measures that may work in combination.

Seals quickly learn the value of a food resource, so mitigation options should include the development of systems to detect seals as soon as they arrive in a river and before they have had a chance to forage (sonar, UW video, electrical impedance - solution could incorporate fish numeration capability for added value). Early detection may allow either automated activation of deterrent systems or a proactive response from bailiff/river staff to disrupt foraging and attempt to return seals to the sea (hazing). The costs of such approaches will play a significant role in the assessment of their practicality, however many systems may provide additional services to fisheries such as fish numeration.

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9 Appendix 1

Table 6. Recorded salmon and trout landings from Gamrie Bay where effort was available, CPUE (salmonid catch per hour), No. salmon, No. trout and proportion of salmonids damage.

	Net site	No. Salmon	No. Trout	Effort (hours)	CPUE (catch per hour)	No. salmonids damaged	% damaged
April	Peter	14	1	235	0.06	0	0.0
	Wirren	3	0	227	0.01	0	0.0
	Grip	0	0	4	0.00	0	0.0
	Rock	.	.	.	.	.	.
	More Head	16	1	297	0.06	6	35.3
	Crovie	5	4	148	0.06	1	11.1
	Skate	14	4	297	0.06	8	44.4
	March	10	5	298	0.05	0	0.0
May	Peter	61	6	525	0.13	8	11.9
	Wirren	20	1	499	0.04	2	9.5
	Grip	21	5	719	0.04	8	30.8
	Rock	.	.	.	.	.	.
	More Head	20	1	720	0.03	4	19.0
	Crovie	10	1	507	0.02	2	18.2
	Skate	46	3	674	0.07	23	46.9
	March	26	2	719	0.04	6	21.4
June	Peter	68	10	478	0.16	3	3.8
	Wirren	66	7	478	0.15	2	2.7
	Grip	26	8	477	0.07	8	23.5
	Rock	8	0	334	0.02	0	0.0
	More Head	18	3	470	0.04	3	14.3
	Crovie	16	0	477	0.03	0	0.0
	Skate	41	9	477	0.10	3	6.0
	March	35	19	478	0.11	5	9.3
July	Peter	69	3	506	0.14	3	4.2
	Wirren	92	3	507	0.19	3	3.2
	Grip	20	1	514	0.04	3	14.3
	Rock	26	1	511	0.05	4	14.8
	More Head	23	1	510	0.05	3	12.5
	Crovie	14	1	486	0.03	1	6.7
	Skate	39	1	493	0.08	6	15.0
	March	34	1	512	0.07	1	2.9
Aug	Peter	25	1	365	0.07	0	0.0
	Wirren	34	0	313	0.11	2	5.9
	Grip	5	0	255	0.02	3	60.0
	Rock	10	0	436	0.02	0	0.0
	More Head	11	0	435	0.03	3	27.3
	Crovie	11	0	258	0.04	0	0.0
	Skate	24	0	312	0.08	5	20.8
	March	23	1	312	0.08	1	4.2