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Seals and Salmon Interactions 2
Annual Report

Seals and Salmon Interactions

Sea Mammal Research Unit
Report to
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Executive Summary

The overall aim of the Seals and Salmon Interactions (SSI) project is to reduce conflict between seals and salmon fisheries. The current focus of the SSI is to reduce conflict within river systems. Project activities have been split into those with a scientific focus and those with a management focus. This annual report details progress and outputs from both scientific and management activities carried out over the last 12 months.

Scientific activities have focussed on addressing a series of questions relating to seal behaviour and ecology within river systems to inform issues raised by fisheries. Data collected during a 12-month observational study of Aberdeen Harbour and the River Dee in 2016-2017, as well as data from a movement (using telemetry) and diet study, have been processed and analysed within this reporting period with the aim of answering questions about how animals use the river system habitat. Approximately 50,000 photographic images from the observational study across the River Dee and Donmouth seal haulout site have been processed. The analysis of these images has resulted in the identification of 19 individual grey seals and 17 individual harbour seals from the River Dee. Of these 36 individual seals, 14 were categorised as salmonid specialists, 15 as regular users of the river system, and 7 as transient, based on the frequency of occurrence and their behaviour. It is believed that very few individual seals using the harbour/river were not identified during this period. Seals were seen throughout the year in the harbour but most often during winter months higher up the river. Predation events were also recorded during the observation period and it was found that predation events in the harbour peaked between December and February. A statistical model of predation events predicted the highest probability of an event occurring was during the first two quarters of the year (January-June) and increased with increasing river flow.

The presence of bottlenose dolphins and otters was also recorded during observation periods and piscivorous bird feeding events were photographed in an attempt to identify prey items. The presence of bottlenose dolphins was highest between January and June (coinciding with the period of highest probability of a salmonid predation event by seals) and otter presence was highest during the winter months (October-March). Photographs were taken of piscivorous bird predation events to provide information on the diversity of prey species available within the harbour environment.

Results of the telemetry and diet study of seals using the Donmouth haulout have previously been reported in full in an Interim Report delivered in 2018 and therefore are only summarised in this Annual Report. The scat samples were dominated by whiting and flatfish otoliths, and only one scat contained salmonid otoliths, which were of smolt size. The results from DNA metabarcoding of the scat samples require further investigation and validation. Telemetry tags were deployed on four harbour seals from the Donmouth haulout site. The tag data revealed that most of the seals spent their time travelling and foraging close to the coast. Only one seal spent time within the River Dee, and this was an individual that had already been identified and categorised as a regular user of the river. The tag data for this individual has provided further insight into the behaviour of seals that regularly use the river but that are not salmonid specialists. Skin samples from the four tagged seals were genotyped and results indicated that these seals most likely originated from more northern populations, e.g. Orkney, as opposed to populations in south east Scotland.

Management activities have focussed on the development of methods for catching river-using seals, developing monitoring methods and providing support to DSFBs for developing and evaluating management activities. A floating trap has been designed and constructed for catching seals within rivers. The deployment of this trap has been postponed due to several logistical constraints and therefore there has been no evaluation of its effectiveness. Catching at a seal haul-out at the Donmouth was however successful, resulting in the capture and tagging of four harbour seals.

It was agreed to pursue the development of a system to monitor for the presence of seals in stretches upriver of the tidal limit, and to allow for monitoring around the clock. A specification was drawn up with requirements for a video surveillance system. System components have now been purchased and will be constructed and evaluated as a seal monitoring tool.

Contents

Introduction

The Seals and Salmon Interactions (SSI) programme, funded by the Scottish Government through the Marine Mammal Scientific Support (MMSS) Research Programme, is currently focused on seal interactions with river fisheries. The main objectives have been driven by considerable changes in both predator (seals) and prey (salmonid) populations. Seals may reduce salmonid stocks, and fishery catches, potentially impacting the value of these fisheries. Conservation Orders in many areas of Scotland now prevent the killing of both salmon and harbour seals, and the changing perspective on the lethal control of seals has led to an increasing need to develop non-lethal options for mitigating the effects of seals on fisheries.

The policy objective of SSI is to undertake studies of seal interactions with river fisheries with a view to understanding potential impacts and to establish the potential value of different non-lethal measures in deterring seals from impacting on these wild salmonid fisheries. The project also provides an advisory function to assist fisheries in identifying potential impacts, as well as offering advice on the various non-lethal measures currently available.

The project can be divided into two main areas: scientific activities to understand the behaviour and ecology of seals in relation to salmonids and the river environment, and management activities that include the implementation of working agreements with District Salmon Fishery Boards (DSFBs). The overall aim is to minimise conflicts between river fisheries and seals.

The River Dee hosts important salmonid stocks and fisheries. The Dee DSFB had raised concerns about seal and dolphin predation on salmon near the mouth of the River Dee and about seals interfering with fisheries further upriver. These concerns led to the establishment of the Dee Seal Forum in 2015. The Forum was formed by the River Dee DSFB, fishery stakeholders, the Sea Mammal Research Unit (SMRU) and Scottish Government. Through the DSFB and other stakeholders were able to present information to explain their concerns and to develop a strategy to address those concerns. In part to fulfil SSI requirements, and guided by outcomes from the Dee Seal Forum, SMRU began a scientific study in April 2016 to collect 12 months of seal photo-identification (photo-ID) data to investigate the behaviour and ecology of those seals using the river and estuary. Specific questions of interest were:

- How many seals are using the River Dee system?
- How is this usage distributed in time and space?
- How much salmonid prey is likely being consumed?
- How and when are river specialist seals making use of the river?

From a management perspective, the aim has been to work with the Dee DSFB, to develop a work programme in response to seal activity, with the principle aim of developing strategies that can be applied to other river fisheries experiencing seal/fisheries conflicts.

Management activities have included:

- assisting the Dee DSFB in identifying individuals that are habitually using the river to enable management that is targeted towards individual seals;
- developing methods to catch river specialist seals where possible;
- monitoring haulout sites to determine where and when known river-users haul out and collect seal scats when resources allow.

Specific objectives over the last year have included:

- Analysis of photo-ID and behavioural observation data from the Dee river system. This has included an investigation into the number of seals using the Dee system and the factors that may have affected observed salmonid predation in Aberdeen Harbour. Other questions have been addressed to the extent that data permit and the results of the following analyses will be reported here.
- Analysis of telemetry data from Pv.030D (a harbour seal known to use Aberdeen Harbour). This included genotyping of tagged individuals to investigate their likely population of origin and DNA testing of faecal samples from those individuals to assess prey composition. The results of these analyses have been reported in an Interim Report to the Scottish Government in December 2018 (Harris & Northridge, 2018b).

- Implementation of a working agreement with DSFB, providing advice and adapting to any changes to DSFB plans. The outputs from this objective have been reported throughout the year in regular updates and will be summarised here.

In this report the achievements in relation to the first and third objectives are included under the headings of scientific activities and management activities as appropriate. The second objective reported in detail in an Interim Report (Harris & Northridge, 2018b).

Scientific Activities

Although often closely interlinked with the management activities (Section 3), those activities listed as scientific have had the primary aim of providing insight into the local seal ecology to inform on issues raised by fisheries. For example, seals hauling out at the mouth of salmon rivers are often accused of causing salmonid stock decline. Therefore, by providing information on where seals forage (tagging studies) and what they feed on (diet studies) can help alleviate fishery concern thereby helping to minimise the conflict between river fisheries and seals or highlight areas of justified concern. They may allow for a proportional response in resource allocation to refine questions or identify or mitigate an identified problem.

1.1 Introduction to the study of seals in rivers

A project was initiated in 2016 to collect 12 months of photo-ID and sightings data to record the occurrence of seals, and the frequency of prey capture events in the River Dee, and the local Donmouth harbour seal haulout site with the purpose of investigating whether seals using the River Dee were associated with the haulout. Results from the study of the Donmouth seal haulout site have been presented in full in Interim Reports (Harris & Northridge, 2017, 2018b) and so will only be summarised here.

The focus of the project (April 2016 to March 2017) was Aberdeen Harbour (see Figure 6 map). However, additional observations to investigate the occurrence and behaviour of seals were carried out at three other sites within the tidal reaches of the river (Figure 1) complemented by incidental seal sightings, by fishers, and occasional dedicated observation periods for seals from higher up the river (Harris & Northridge, 2017). The 12-month data collection period was successfully completed with over 50,000 seal images collected from the River Dee and Donmouth.

Processing of images involved the creation of a photographic identification file for each known (identifiable) seal; these files were then used to identify seals from the remaining images. Seal sightings information was entered into spreadsheets, along with presence/absence data for sightings of bottlenose dolphins and otters, and observations of piscivorous bird feeding events were also photographed to identify prey species presence in the harbour.

The photographs and sightings data have provided information on the behaviour and distribution of seals in the River Dee over the period. In particular, the sightings of seals with prey items have provided individual diet information and predation rates of salmonids by seals. Data have been used to provide an indication of the number of seals possibly specializing in the consumption of salmonids in the River Dee and the number of seals foraging higher up the river.

The remainder of this section is divided into a series of scientific questions that have been addressed using the data from the River Dee and Donmouth studies. Specific data processing/analysis methods relating to each question are included in those sections. Full details of the overall field methodology and maps are detailed in Harris and Northridge (2017).

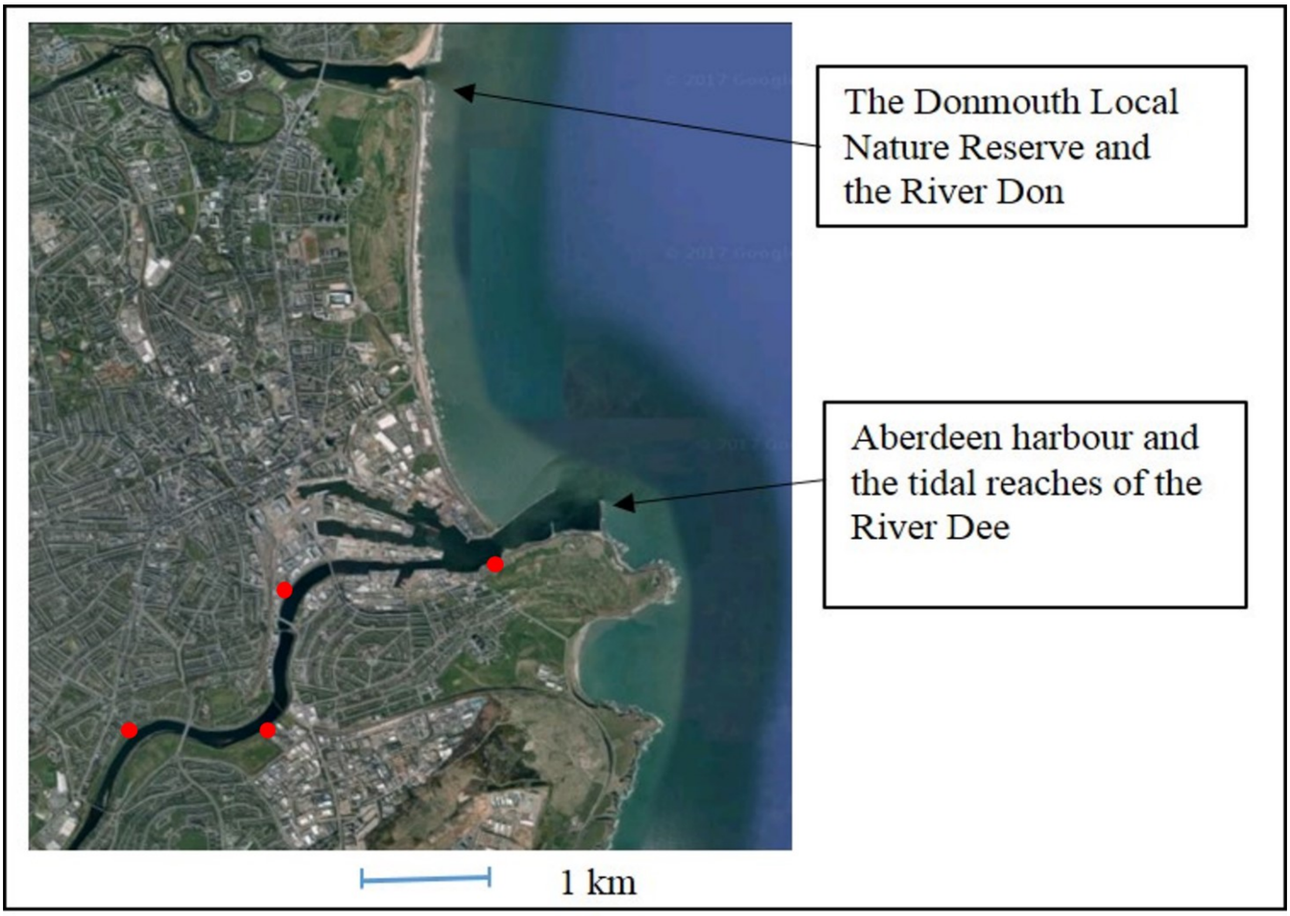


Figure 1. Map showing the location of the Donmouth, the River Dee and four observation positions (red circles) within the tidal reaches of the River Dee.

1.2 How many seals were using the River Dee system?

A total of 670 hours of observations were carried out from fixed locations within the tidal reaches of the River Dee. This resulted in over 7800 seal sightings, with associated location and time information, and ~36000 photographs. Further details of the observation protocols are reported in Harris & Northridge (2017).

Where possible seals were individually identified from photographs taken during surfacing events using their unique pelage markings or distinctive scarring. However, in some instances when photographs were not taken, it was still possible to identify individuals. This was in part due to the enclosed nature of the river where few seals were present in time and space, coupled with the high sightings rates for key individuals that allowed the identification of individuals by eye with observer experience. Furthermore, seals transiting an area on a consistent swimming trajectory were assigned to the same animal if a proportion of those surfacing events were photo-identified to an individual.

Most surfacing events resulted in many photographs, often tens of images. Therefore, rather than assign each photograph a quality grade, each surfacing/sighting event was assigned a quality grade that reflected the certainty of the observer in assigning an individual ID to the set of images associated with the sighting. The grades were defined as follows:

Grades 1 & 2 – good images with no doubt over seal ID (grade 1 was allocated to the best images, which allowed photos to be selected for use in publications and the creation of the photographic identification files of each individual).

Table 1 summarises all the surfacing events (henceforth referred to as sightings) for the entire river system. Across all sightings, almost half were identified to individuals (based on all grades), and this resulted in 20 grey seal individuals and 18 harbour seal individuals.

Table 1: The total number of seal sightings recorded in the River Dee across all observation locations, the number of these assigned an individual ID and the total number of uniquely identified seals across all grades.

Species	Total no. sightings	Sightings ID'd (grades 1-4, 0 & 6)	Sightings not ID'd (grades 5, 0 & 6)	No. unique seal ID's (all grades)
Grey (Hg.)	4907	1708	3199	20
Harbour (Pv.)	2274	1454	820	18
Unidentified species	894	-	894	-

A higher proportion of the harbour seal sightings were identified to the individual level than for grey seals as harbour seals were generally easier to identify in the water. This was due to differences in harbour seal and grey seal pelage. Harbour seal pelage is generally evenly distributed over the head as opposed to grey seals whose dorsal side is often characterised by a uniform colouration (Figure 2). This uniform colouration provides fewer opportunities for individual identification.

Figure 2. Two photo-ID images from Aberdeen Harbour. The upper image is of a grey seal and provides an example of even colouration of the dorsal surface. This can be compared with the lower image, which is of a harbour seal and shows cryptic patterning on the dorsal side of the head.

All individually identified seals were given a three-digit ID number prefixed by species abbreviation. An assessment of the number of seals using the River Dee was made using the number of uniquely identified seals at grades 1 and 2. In total 19 grey seals and 17 harbour seals were identified at grades 1 and 2. One grey seal (Hg.021D) and one harbour seal (Pv.024D) were not included here because no grade 1 or 2 record was available, both seals were only detected on one day each (Table 2). Overall more female grey seals were identified than male grey seals (6♂: 12♀: 1 unknown), the harbour seal sex ratio appeared more even (7♂: 5♀: 5 unknown) although obscured by 5 seals of unknown sex (Table 2).

Table 2: The number of uniquely identified seals (grades 1 & 2) and the number of sightings at each identification grade.

		No. sightings photographed				No. not photographed	
		Good	Ok	Poor	No ID	ID'd by eye	No ID
Species	No. unique IDs	Grades 1 & 2	Grade 3	Grade 4	Grade 5	Grades 0 & 6	Grades 0 & 6
Grey (Hg.)	19 (6♂: 12♀: 1 unknown)	774	476	330	1286	122	1913
Harbour (Pv.)	17 (7♂: 5♀: 5 unknown)	946	306	117	366	84	454
Unidentified	-	-	-	-	257	-	637

A discovery curve was fitted to the sightings data to indicate when total enumeration may have been reached, i.e., when new individuals were no longer being encountered/identified. The collection of images began in April 2016 and no new individual grey seals were identified after November 2016 and no new harbour seals were identified after January 2017 (Figure 3). Although dedicated data collection only occurred over a single year, results suggest that most seals regularly using the river may have been identified over this time period. Ideally a second year of data collection would improve confidence in this.

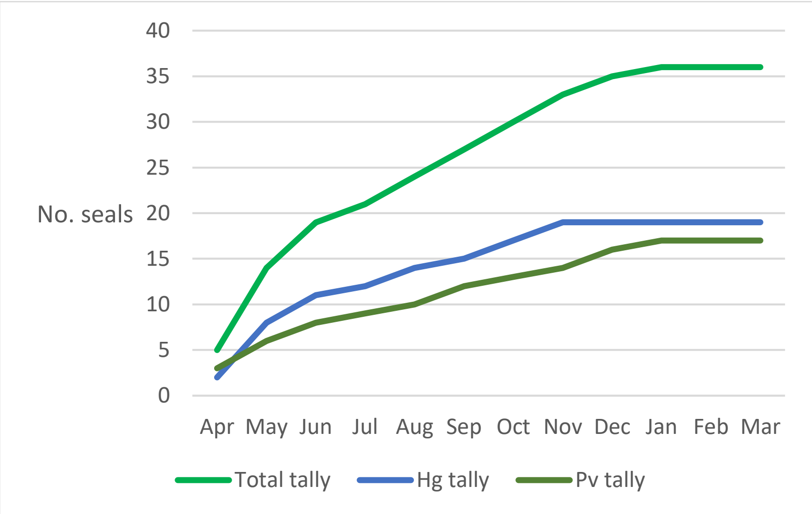


Figure 3. Discovery curve illustrating the rate at which new (previously unidentified) seals were identified in the Dee system.

1.2.1 Were any individual seals missed during observations in the River Dee?

Many sightings were not identified to the individual level (across all grades 61% of sightings were unidentified), and therefore it was important to evaluate whether these unidentified seals were likely repeat sightings of known individuals or potentially new, previously unidentified seals. Seal distance from the observation position and the effects of atmospheric distortion or lack of shutter speed (due to system capability) on images were likely primary reasons for unidentified sightings (which assumes all seals are identifiable with enough resolution). Therefore, a separate assessment of the sightings data using only the Gates harbour zone sightings was carried out to provide an indication of whether individual seals had been missed. Gates was the zone adjacent to the observation point, minimising the effect of distance between observer and seal surfacing, and was also at the entrance to the river system, meaning that all seals entering or leaving the river system must swim through Gates. Gates was approximately a 250m long channel and so it was assumed that most seals swimming through would likely surface at some point, either on their way in or out of the river system. It was felt therefore that the sightings data from Gates would provide a method to validate the minimum estimate of seals using the river system in the 12-month study period. Across all sightings in Gates, 69% were identified to the individual level based on grade 1 & 2 sightings, while this increased to 85% when "by eye" and grade 3 sightings were also included. It should be noted that there was a much higher proportion of ID's at grade 1 & 2 from this location compared with all locations combined (Tables 2 and 3). These good quality sightings resulted in the identification of 19 grey seals and 17 harbour seals (Table 3), while 20 grey seals and 17 harbour seals were identified when grade 3 sightings were included. Hg.021D was only identified using a grade 3 sighting and was only seen once, so this individual was not included in the minimum estimate. The minimum estimate of 19 grey seals and 17 harbour seals from Gates agrees with the estimate from all sighting across all zones and therefore it is believed that very few individuals were not identified.

Table 3. Sightings data for the harbour zone "Gates", showing the number of uniquely identified seals and the high proportion of sightings classified as grade 1 & 2.

		Sightings photographed				Not photographed		
		Good	Ok	Poor	No ID	Id'd by eye	No ID	
Species	No. unique IDs based on grades 1 & 2	Grade 1 & 2	Grade 3	Grade 4	Grade 5	Grade 0 & 6	Grade 0 & 6	Totals
Grey (Hg.)	19	276	96	20	23	31	38	484
Harbour (Pv.)	17	408	12	-	2	24	47	493
Unidentified	-	-	-	-	-	-	15	15

1.2.2 Characterising known River Dee seals

Foraging specialisation may be inferred where a foraging behaviour is consistently expressed by an individual that is uncommon within the population (Swan et al., 2017). It was of interest to determine how many of these River Dee seals expressed a foraging specialisation and, of these, how many individuals may be salmonid specialists.

Seals were characterised based on the number of occasions they were sighted in the River Dee, the temporal spread of those sightings and their behaviour within the river. Each individual was labelled with one of the following three categories:

- River Dee salmonid specialist

- Seals identified feeding on salmonids on more than one occasion.
- Over 50 photo-ID records per individual, spread over more than 15 different dates and were present in more than 6 different months.
- May exhibit behaviours such as 'chin up', behaviour observed in shallow rivers and deep harbour waters that may indicate a salmonid predation tactic allowing seals to surface whilst maintaining search effort for shallow swimming prey (Figure 4), foraging activity often focused on Dee Channel zones or in areas higher up the river, observed aggressive interactions between certain seals also indicates a strong desire to remain in these areas.

- Regular Dee user

- Individuals not seen feeding on more than one salmonid.
- Exhibit high numbers of photo-ID records (typically ~20-90 per seal), few prey events observed with most not seen with any prey, seen in more than 1 month, and multiple days (greater than 5).
- Seals often utilising Outer and Northern Docks zones of Aberdeen Harbour (see Figure 6 map).

- Transient seal

- Seals identified on just 1 or 2 days.

Figure 4. A grey seal identified as a "salmonid specialist" surfacing to breath in an inverted position whilst patrolling areas of the River Dee.

Of the 19 identified grey seals, 9 were categorised as salmonid specialists, 6 were regular users of the River Dee and 4 were transient. Proportionally male grey seals were more likely to be classified as salmonid specialists than female grey seals (Table 4). Females were more likely to be classified as regular users or transient seals. Of the 17 identified harbour seals, and in contrast to the grey seals, a larger proportion of the identified individuals were categorised as regular users as opposed to salmonid specialists (Table 4).

Overall, there were fewer transients compared with results from similar observational studies at coastal bagnet sites and at aquaculture sites where the majority of identified individuals have typically been characterised as transients (Harris, 2012; Harris et al., 2014; Northridge et al., 2013).

In general, it was noted that the salmonid specialists were often larger individuals (all but one was an adult) and regular users were made up of female grey seals and harbour seals, with a higher proportion of sub-adult seals.

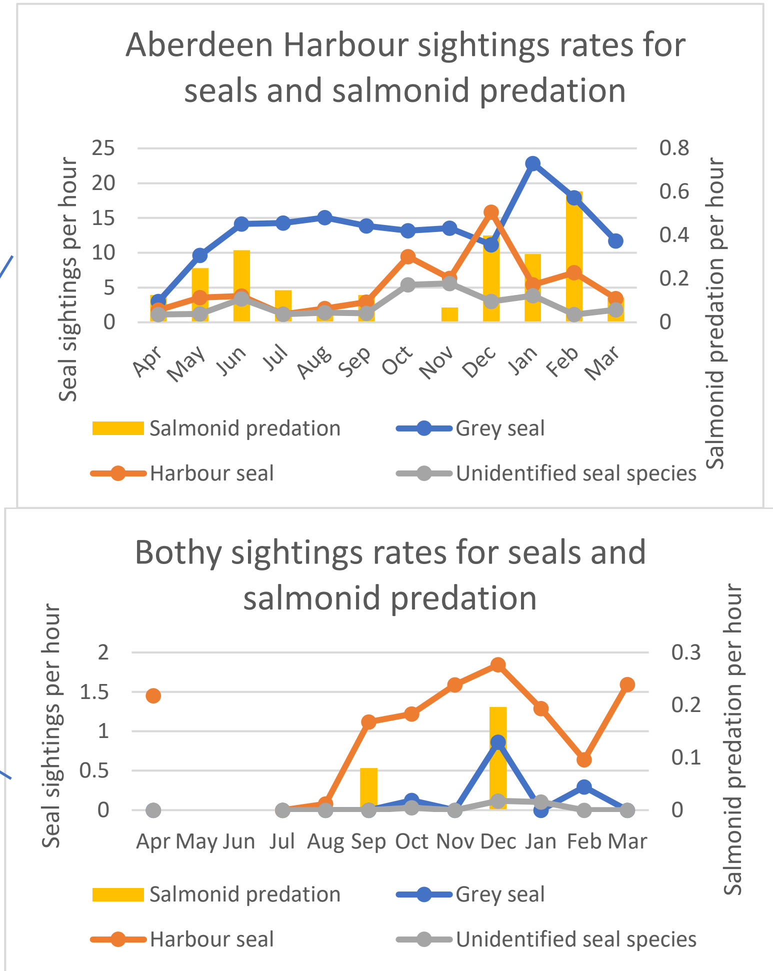
Table 4. Number of known seals using the River Dee classified as either salmonid specialist, regular user or transient seal.

	Grey seal (n=19)	**Harbour seal (n=17)**
Salmonid specialist	9 (5♂: 4♀)	5 (3♂: 2♀)
Regular user	6 (5♀: 1 unknown)	9 (4♂: 2♀: 3 unknown)
Transient	4 (1♂: 3♀)	3 (1♀: 2 unknown)

1.3 How is River Dee usage by seals distributed in time and space?

The two observation sites where most effort-related observations were available were Aberdeen Harbour and the Bothy sites, however, effort was low in April for the Harbour (furthermore there was a period of learning and experimenting with different observation positions that may explain low seal sightings rates during April) and no observations were carried out at the Bothy during May and June (Harris & Northridge, 2017). During observation periods seals were generally always present in Aberdeen Harbour resulting in high sightings rates but were more sporadic at the Bothy where sightings rates were lower. Grey seal sightings dominated the harbour; however, the opposite was the case for the Bothy where harbour seals were the dominant species (Figure 5). Both harbour seal and grey seal sightings peaked in December at the Bothy, possibly suggesting both seal species made more use of areas upriver of the harbour at this time (Figure 5). Grey seal sightings peaked in the harbour in January and salmonid predation rates in the harbour peaked in February (Figure 5). Observed salmonid predation was lower at the Bothy than at the Harbour (Figure 5).

Figure 5. The locations of the Aberdeen Harbour and Bothy observation position, seal sightings rates by species and observed salmonid predation rates.



Within Aberdeen Harbour 60% of seal sightings occurred within the three Dee Channel zones (Upper, Mid, Lower) and grey seal sightings dominated these zones. Harbour seals made up a larger proportion of sightings within the Northern Docks and Outer zones of the harbour (Figure 6). This perhaps suggests a level of foraging separation between the two species within Aberdeen Harbour.

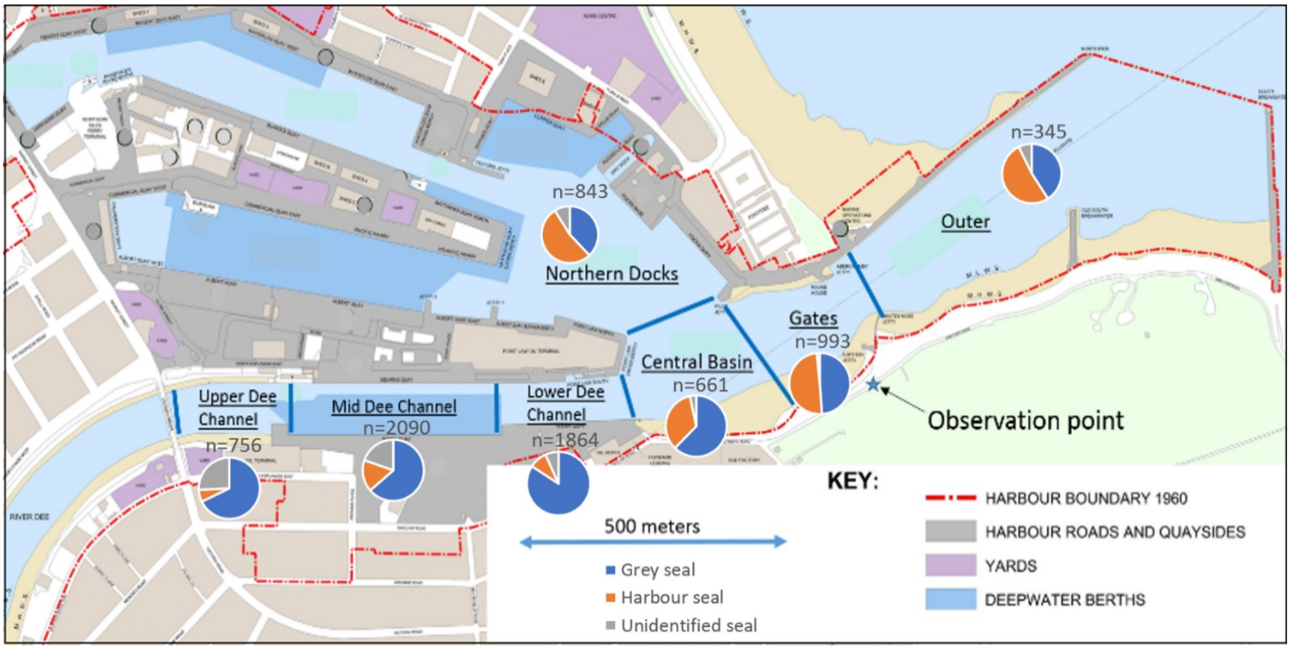


Figure 6. Aberdeen Harbour and seven zones (Upper Dee Channel; Mid Dee Channel; Lower Dee Channel; Central Basin; Gates; Outer; Northern Docks) used to record seal sighting locations. Pie charts illustrate the proportion or sightings by seal species and the number of sightings within each zone.

The Normal Tidal Limit occurs approximately 5.5 km up the river from the mouth (Figure 7). Few systematic observation periods for seals were carried out above the tidal reaches. However, there were reports from fishers of seals high up the river and attempts were made to photo-ID these seals by the fishery board and occasionally SMRU while in the area. Where multiple reports were received for the same day these were assumed to be the same seal unless seals were seen on the surface at the same time or photo-ID records were available to confirm otherwise. Of those reports coinciding with the SMRU 12-month study, there were a total of 33 seal events (29 harbour seals, 4 unidentified seal species). Reports peaked in February with eleven records of events (Figure 8). The low number of records during the summer was not surprising as seals are generally rarely seen by fishers at this time. The lack of sightings during November and December was also not surprising as the fishing season ends on the 15th October and there was less potential for seals to be seen during these months. During January there was an increased effort by fishery staff to monitor for seals and prepare for the start of the fishing season (1st February) meaning there was a greater presence on the river banks during January and through the following fishing season and thus more seal sightings (Figure 8).

Of the 33 seal reports 14 (42%) were photographed and assigned an individual seal ID. This resulted in the identification of three different individual harbour seals, although the majority of sightings were assigned to a single seal, Pv.018D (n=11).

The locations of the 33 seal reports received between April 2016 and March 2017 are shown in Figure 7.

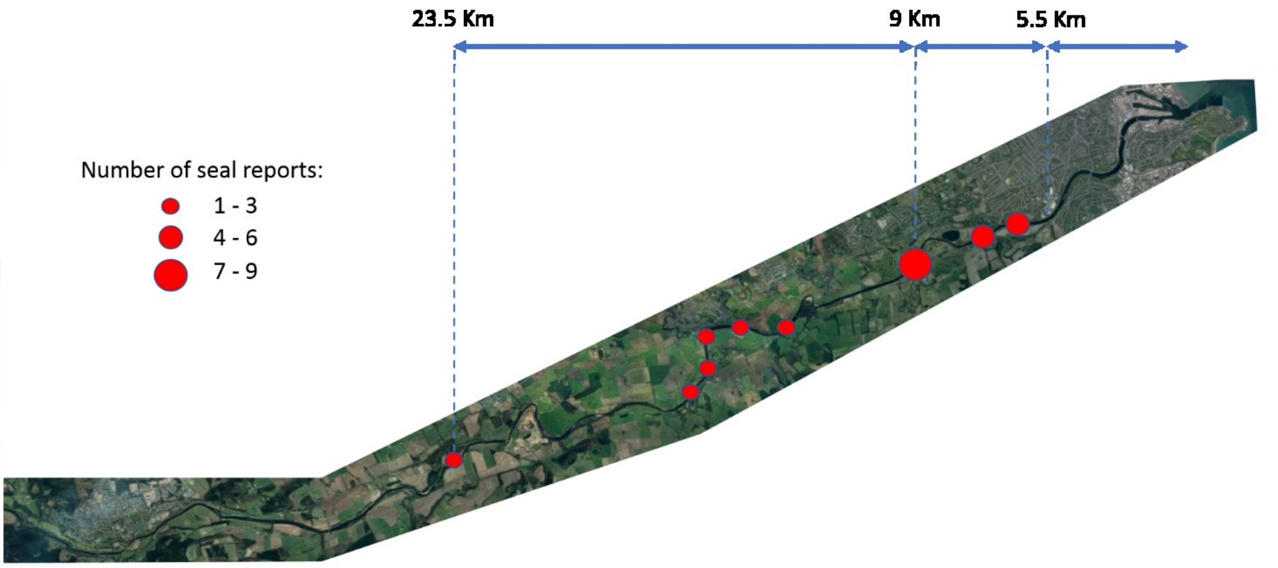


Figure 7. Seal report locations on the River Dee, Aberdeenshire, marked also are river distances from sea for the Normal Tidal Limit (5.5 km), Ardoe (9 km) and the highest report during the 12-month study (23.5 km).

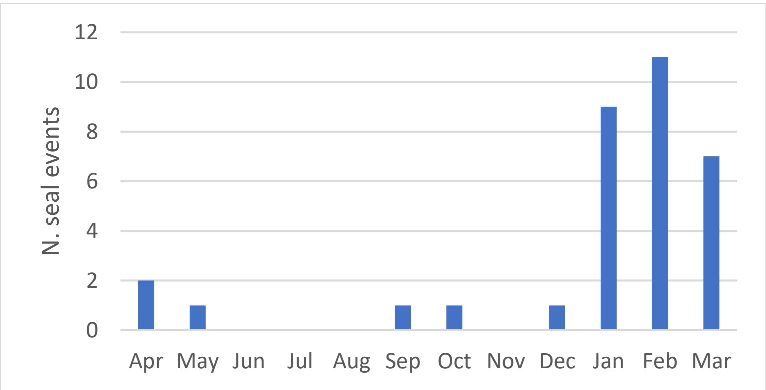


Figure 8. Number of reported seal events from fishery personnel by month.

1.3.1 How and when are "river specialist" and "regular user" seals making use of the river?

From those systematic dedicated observations for seals and the incidental reports and photo-ID images higher up the river it is possible to glean some insights into how different categories of river seals are using this habitat.

Grey seal salmonid specialists (n=9) were generally only seen feeding on salmonid prey, the exception being one individual who was also observed feeding on eels and other small unidentified prey items. These individuals appeared to primarily use the Dee Channel zones of the harbour (Figure 6). However, with the exception of the two largest male seals, they often moved out of the Dee Channel zones with their salmonid prey before starting to consume it. They often moved down river into Northern Docks or Outer before starting to feed. This behaviour may be to avoid prey stealing by other seals (known as kleptoparasitism). Although it is not possible to say how grey seals used this channel of the Aberdeen harbour to predate salmon (as underwater observations were not possible), the surfacing behaviour of these seals suggested they may have been focusing attention on the canalised side walls of the harbour or against the hulls of large docked ships. The use of multibeam sonar may allow the underwater behaviour of seals to be investigated in this area of the harbour to determine how seals are able to successfully utilise this human modified environment to predate salmonids.

Harbour seal salmonid specialists (n=5) were seen with salmonid prey less frequently than grey seals and were also seen to predate other prey items such as flatfish. These individuals were divided into those that foraged for salmonids in Aberdeen Harbour (2 adult males) and those that focused their foraging efforts upriver of the harbour (2 females and 1 male). These latter three seals were typically only ever observed traveling through the harbour.

A large proportion of the remaining seals (6 grey seals and 9 harbour seals) were identified as regular river users. These seals were rarely seen to predate salmonids and generally remained out of the Dee Channel zones. Although prey capture events were rarely observed, seals were occasionally seen with non-salmonid prey (such as eelpout and flatfish). Typically, these individuals were not observed upriver of the harbour, however there were sightings upriver on a few occasions. In particular, two small juvenile harbour seals (~1-3 years old, characterised as one regular user and one transient) were successfully identified at up to 9 km upriver. Subsequent sightings suggested these seals may also have used areas higher up the river but a lack of photo-ID studies in these areas made it difficult to confirm this.

The behaviour of one regular river user (Pv.030D) was studied in detail following the tagging of this individual (Harris & Northridge, 2018b). The telemetry study demonstrated how a regular user utilised the harbour to forage benthically in deep water areas of the harbour, potentially targeting benthic species such as eelpout, eels, flatfish and sculpin. A rectal sample taken from this individual produced DNA metabarcoding (a method for identifying the species composition of an environmental sample) reads for dab, eelpout and shorthorn sculpin, however these results need validation through further work (Harris & Northridge, 2018b). Although it spent a large proportion of time in the River Dee the harbour seal made very little use of the Dee Channel zones or the river upriver of the harbour. However, on the rare occasions when Pv.030D did move into these locations its dive behaviour changed from benthic foraging to surface foraging. Authors suggest this may represent a shift to salmonid foraging in these locations (Harris & Northridge, 2018b).

1.4 How much salmonid prey is likely being consumed in the River Dee?

Observed events of seals feeding on salmonids were recorded during the 12-month photo-ID study (Harris & Northridge, 2017). Observational effort was focused on Aberdeen Harbour primarily due to the concerns raised by the Dee DSFB of seal predation on salmonids in this area. To investigate under what conditions salmonid predation events occur in Aberdeen Harbour, observation periods were split into one hour time bins. A Generalized Estimating Equation (GEE) model was fitted to presence/absence of a predation event per observation hour, with observation day as a blocking unit to acknowledge that observation hours within a day are likely to be correlated. Explanatory variables included in the model were season (January to March; April to June; July to September; October to December), average river flow in cubic meters per second (SEPA Park gauging station) and tidal state defined as four, three-hour periods (High tide; Low tide; Ebb tide; Flood tide).

The selected model included season, river flow (fitted as a smooth term) and the interaction between season and river flow. The model was used to produce prediction plots showing the probability that a predation event may occur per hour. The model predicted the presence of predation per hour to be higher during the first two quarters of the year (January to June) and was generally found to increase with increasing river flow (Figure 9). This aligns with information from rod catches whereby catches increase with increasing flow rates and are higher in particular months. The next stage of this work is to use this information to generate a salmonid consumption estimate for seals in Aberdeen Harbour and relate this to salmonid ecology and rod catches for the river Dee. The selected model will be used to predict the probability of a predation event during each hour of a given year using hourly river flow data from SEPA. Care will be taken to not make predictions outside of the range of river flow values for which there are observation data, e.g., there are no observation data coincident with spate events (river flow values above 160 cubic meters per second).

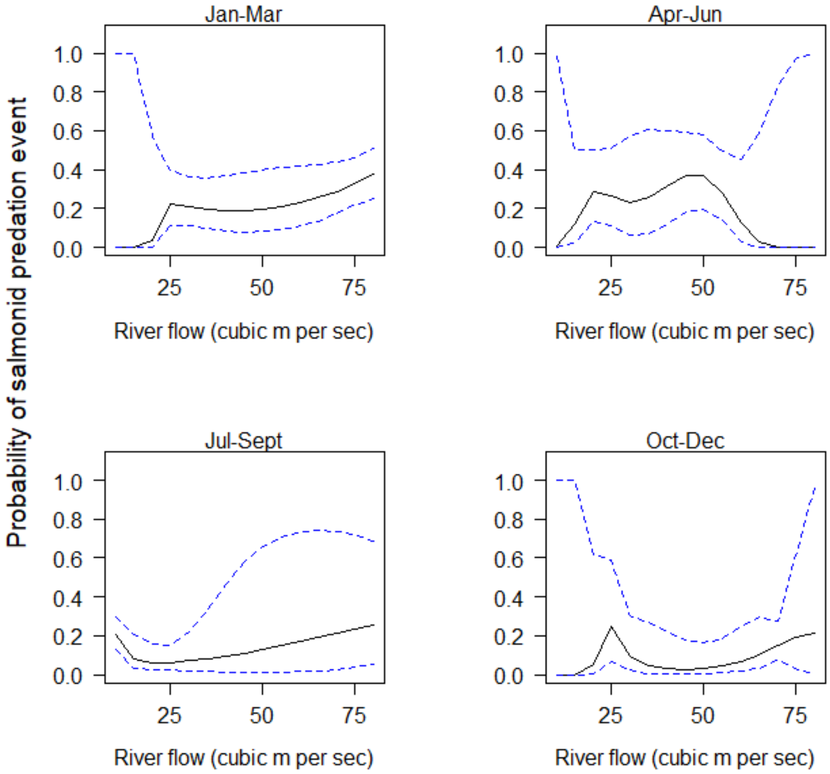


Figure 9. Predicted probability from the selected model that a salmonid predation event will occur per hour during a given season and river flow, large error bars represent areas with little observational data or where predictions relate to river flows rarely observed within a given season.

1.5 Bottlenose dolphins, otters and piscivores bird presence in Aberdeen Harbour

During systematic observation periods for seals the presence of bottlenose dolphins (*Tursiops truncatus*) in Aberdeen Harbour or immediately adjacent to the entrance of the harbour was noted. The presence of otters (*Lutra lutra*) was also recorded and the feeding events of piscivores birds were photographed to identify prey species. The motivation for the latter was to better understand the diversity of prey species available to predators within the harbour environment.

Observations were split into one-hour bins and a presence/absence value given to each hour to provide an indication of bottlenose dolphin and otter activity in Aberdeen Harbour or adjacent to the entrance. The proportion of observation periods with bottlenose dolphin or otter presence is presented as both monthly averages and quarterly averages (Figure 10 for bottlenose dolphins, and Figure 11 for otters).

The proportion of observation periods with bottlenose dolphin presence was highest during the first two quarters (January-March and April-June, Figure 10) and this coincided with those periods that seals were frequently observed predating salmon (Figure 5), and also those quarters that were predicted to have a higher probability of predation by seals (Figure 9). The proportion of hours with otter presence was lower than for bottlenose dolphins. The proportion of observation periods with otter presence was higher during the winter months compared with summer months (Figure 11).

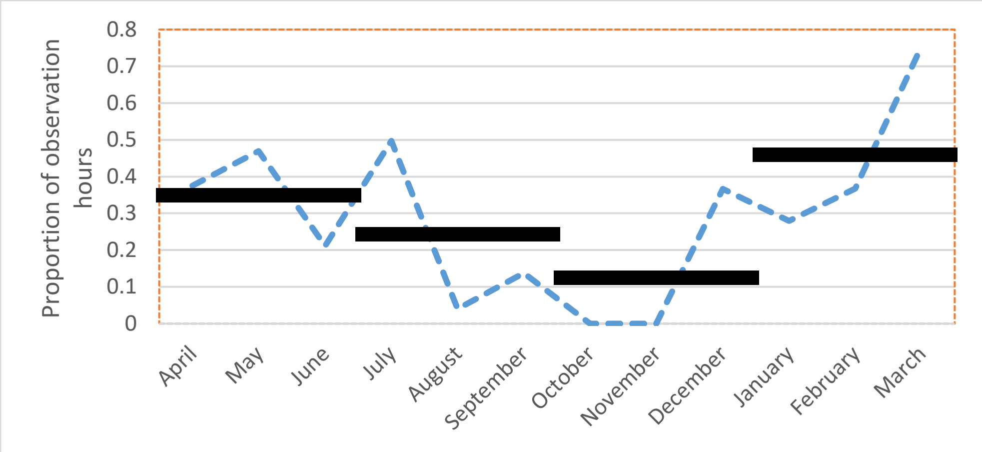


Figure 10. The proportion of one-hour bins in which bottlenose dolphins were observed from the Aberdeen Harbour observation position. Quarterly averages are presented as solid black lines.

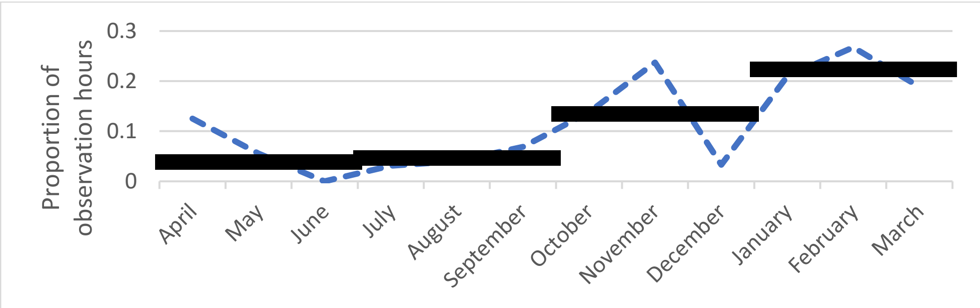


Figure 11. The proportion of one-hour bins in which otters were observed from the Aberdeen Harbour observation position. Quarterly averages are presented as solid black lines.

Piscivorous bird feeding events were photographed to provide information on prey species present in Aberdeen Harbour (Figure 12). On twenty-five occasions birds; cormorants (*Phalacrocorax* spp.) n=20, sawbills (*Mergus* spp.) n=3, guillemot (*Uria* spp.) n=2, were photographed with prey that was identified as flatfish n=9, eel (*Anguillidae* spp.) n=3, possible herrings (*clupeidae* spp.) n=3, eelpout (*Zoarcidae* spp.) n=2, white fish (*Gadidae* spp.) n=2, sculpin (*Cottidae* spp.) n=1. There were 5 events where the images were not clear enough to identify the prey item (Table 5). This list provides a minimum representation of prey diversity that may attract predators such as seals and birds.

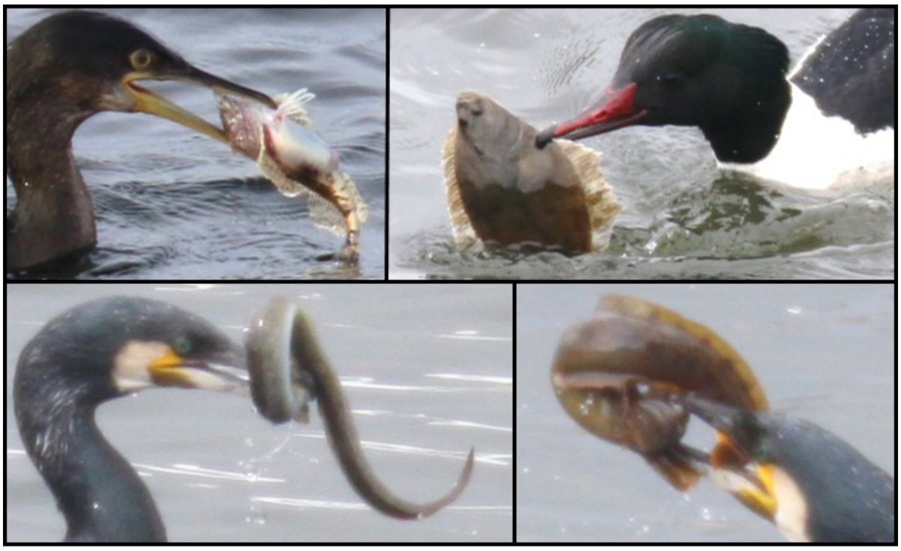


Figure 12. Prey items brought to the surface by birds were photographed to allow the identification of prey species present in Aberdeen Harbour. Clockwise from top left: sculpin (*Cottidae* spp.), flatfish (*Pleuronectidae* spp.), eel (*Anguillidae* spp.) and eelpout (*Zoarcidae* spp.).

Table 5. Identified prey items brought to the surface by piscivorous birds in Aberdeen Harbour demonstrating the variety of potential prey available to predators.

Prey item	N
Flatfish	9
Eel (Anguillidae)	3
Clupeidae	3
Eelpout (Zoarcidae)	2
Gadidae	2
Sculpin (Cottidae)	1
Unidentified	5

1.6 The Donmouth harbour seals – Diet

During seal capture fieldwork at the Donmouth seal haulout site, 27 scats were collected, and faecal samples were obtained from four seals captured for tagging purposes. Samples were subjected to prey otolith (hard-part) analysis, prey DNA metabarcoding (molecular analysis) to identify prey species and a quantitative polymerase chain reaction (qPCR) approach to assign seal species and sex to each scat. An Interim Report submitted in December 2018 (Harris & Northridge, 2018b) provided the full details of the methods and results of this work.

In summary, scat samples were processed following the methods of Wilson & Hammond (2016). Recovered otoliths were dominated by those of whiting and flatfish. Only one scat contained salmonid otoliths and these fish were of smolt size. The large number of juvenile salmonid otoliths recovered from this one scat suggests that this individual seal predated out-migrating smolts or juvenile salmonids within rivers. The overall prevalence of salmonid otoliths in harbour seal scat samples is perhaps not surprising given the low numbers of salmonid specialist identified amongst the harbour seals using the River Dee (Table 4).

DNA metabarcoding results generally confirmed the results from hard-part analysis, i.e., the high occurrence of whiting and flatfish species, however, results also reported a higher proportion of scats with salmonid DNA, particularly rainbow trout, in seal diet samples. However, it was recommended that these results be treated with caution until confirmed through further work (Harris & Northridge, 2018b). The use of DNA metabarcoding methodology to detect cryptic prey species in diet samples of seals was deemed less successful in this study than hard-part analysis as the prey DNA within scats was likely too degraded to yield results from the majority of samples. This may have been due to the degraded nature of prey DNA from scats, or specific site factors that may have played a role. The lack of wave action at the site and the potential for seals to haul out at all tidal states may allow scats to accumulate. Prey DNA within scats may degrade rapidly relative to hard-parts, such as otoliths, potentially rendering prey species detection through molecular methods less effective for samples that may be days or weeks old. A potential lack of reference barcodes and interspecific similarities between prey species may also have given rise to misclassifications of prey species and therefore results from this new approach will be treated with caution until validated through further work (Harris & Northridge, 2018b).

In March 2019 an attempt was made to carry out this validation work and confirm the high prevalence of salmonid DNA in seal scats and faecal samples suggested by the metabarcoding analysis carried out by Xelect Ltd. (Harris & Northridge, 2018b). The genomic DNA was reanalysed using qPCR to detect the presence of salmonid prey. Xelect Ltd. tested the DNA samples specifically for the presence of brown trout (*Salmo trutta*), Atlantic salmon (*Salar salar*), rainbow trout (*Oncorhynchus mykiss*) and pink salmon (*Oncorhynchus gorbuscha*). The methods used for this analysis followed those detailed by Matejusová et al. (2008) and are detailed in full, along with the results, in Appendix 1. In brief, the qPCR assays were not able to detect the presence of any of the species tested. The results suggest that the scat DNA samples were probably highly degraded or did not have enough mitochondrial copies to be detected with the assays.

Seal sex and species information were obtained from scat samples following Matejusová et al. (2013) and is summarised in the Interim Report (Harris and Northridge, 2018b). Results revealed 21 samples came from male seals and 9 from female seals. One sample failed to produce any results on seal sex. No DNA from grey seals was detected, with 27 samples testing positive for harbour seal DNA and 3 samples failing to produce any result on seal species. The failure of samples to provide specific sex and species information were likely due to very few intact DNA molecules containing the target sequence remaining in these samples. The available diet information between the sexes showed considerable crossover with high numbers of gadid otoliths recovered from both male and female samples. However, flatfish otoliths were more frequently encountered in male scats than they were in female scats (63% of male scats compared to 25% of female scats).

1.7 The Donmouth harbour seals – Telemetry data

Four individually identified harbour seals (Harris & Northridge, 2017) were captured at the Donmouth haulout site and fitted with telemetry devices to improve the understanding of individual harbour seal behaviour in the vicinity of the River Dee. Full details of the tag deployments can be found in Harris & Northridge (2018a, b) and a summary is provided here.

The telemetry data showed that seals generally did not forage in rivers but foraged close to shore, often within the intertidal zone (Figure 13). This information, coupled with the diet results from the Donmouth haulout, suggests that flatfish and gadid prey are potentially targeted close to the coast.

Individual foraging behaviour data from direct observation were linked with animal borne telemetry and diet information for one harbour seal (Pv.030D). This individual was classified as a ‘regular Dee user’ (primarily due to the number of photo-ID records within Aberdeen Harbour and general lack of observed salmonid feeding events (section 2.2.2 this report)). Combining the data from these different sources provides valuable understanding of the behaviour of this category of seal. Specifically, it shows how the mouth of the River Dee may be used by these seals (regular Dee users) to forage on species other than salmonids.

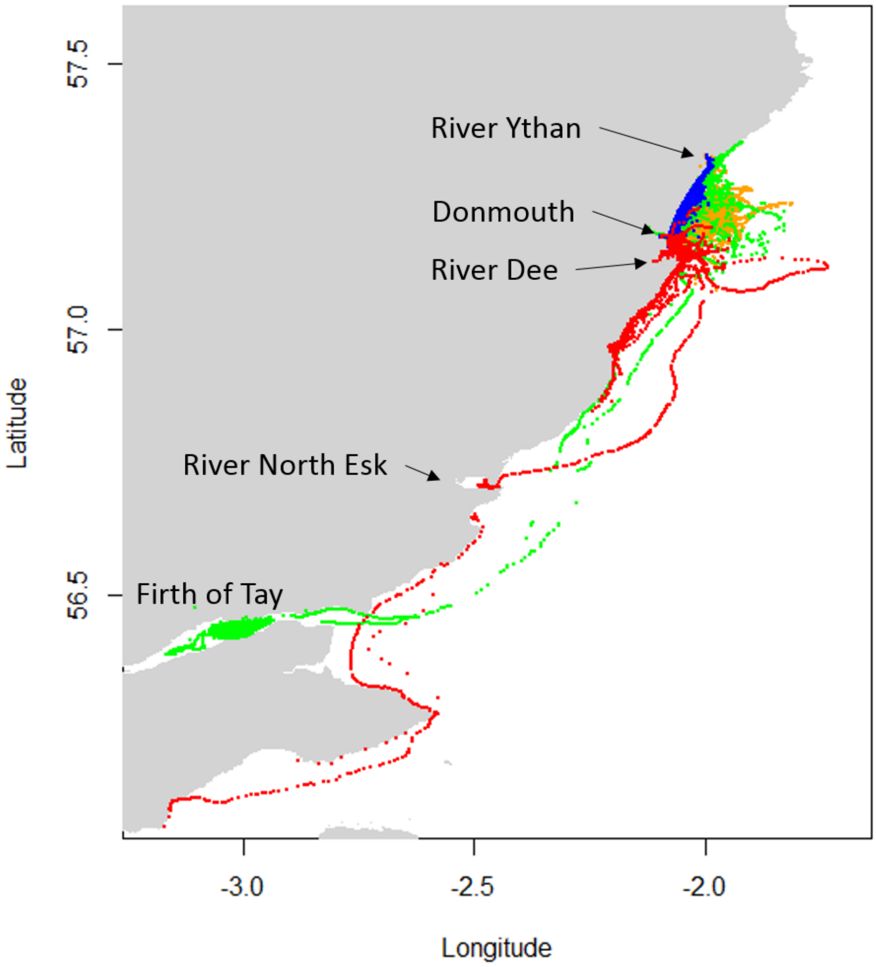


Figure 13. GPS locations for four Donmouth harbour seals across the entire tag deployment for each seal: Pv.030D in red, Pv.007D in orange, Pv.005 in blue, Pv.017D in green.

1.8 The Donmouth harbour seals – Natal origins

Harbour seal populations in Scotland have been divided into seven management areas based on the location of haulout sites, breeding sites and telemetry data from tagged individuals (SCOS, 2014). These areas were largely supported by genetic results (Olsen et al., 2017). Olsen states that an adaptive management approach should be adopted, in which the delineation of the current management areas is maintained until further genetic and ecological information has been accumulated (Olsen et al., 2017).

The four captured harbour seals from the Donmouth haulout site were genotyped to provide genetic information on the possible natal origins of seals using the site. In particular the aim was to associate these seals with a particular seal management area and help provide information on current boundaries between management areas. Full details of the methods and results from the genotyping work are provided in the Interim Report submitted in December 2018 (Harris & Northridge, 2018b). To summarise, seals were genotyped using 14 microsatellite loci alongside existing seal samples stored from previous SMRU seal capture fieldwork from five seal management areas most likely to be source populations; Shetland, Orkney, Pentland Firth, Moray Firth and SE Scotland. The analysis to assign seals to breeding colonies suggested that seals may be more closely related to northern populations, such as Orkney, as opposed to SE Scotland. This result was further supported by photo-identification records from an additional individual that utilised both the Donmouth haulout site and an Orkney breeding site over two consecutive years. However, due to the high levels of admixture among these populations and relatively small sample sizes available from the reference populations some caution is advised in the interpretation of these results.

Management Activities

A component of the SSI theme is to develop and evaluate management activities with DSFBs and to provide advice about seals in relation to river fisheries. It is important to be able to react to changing events with the overall aim of minimising conflict between river fisheries and seals. SMRU has provided Scottish Government with regular updates of its provision of advice and progress with management activities.

1.9 Development of methods to catch river-using seals

The capture of seals in the wild is important for a range of scientific and management goals. While SMRU has developed several successful techniques for capturing seals at a variety of coastal haulout locations, methods for catching seals in the more challenging river environment are less well developed.

In collaboration with the Dee DSFB, attempts were made to capture a specific harbour seal (Pv.018D) that was known to regularly travel up the River Dee, interacting with salmon fisheries on the lower river. The aim was twofold; firstly, to capture, tag and translocate this seal to another area to investigate the utility of a translocation approach to keep specific seals out of rivers, whilst keeping seal within its geographically distinct genetic cluster (Olsen et al., 2017), and secondly, allowing the exploration of new approaches for capturing seals in larger rivers (Harris & Northridge, 2018a). SMRU has successfully developed methods to capture seals in rivers where flow rates are typically low or where seals are known to actively hunt close to river banks (Graham & Harris, 2010). However, the River Dee represents a more challenging environment with high flow rates for which new methods needed to be investigated.

1.9.1 Catching at haulout

During the current project year (April 2018), one seal catching trip was organised to the Donmouth haulout site specifically aimed at capturing Pv.018D using a popup net to encircle the haulout. Unfortunately, wet and windy conditions during the week were not conducive to haulout behaviour, with seals mainly absent from the haulout during the week. Pv.018D was present on the final day of the trip, however an equipment failure prevented the full inflation of the popup net and the seals escaped the net.

The time spent at the haulout site whilst setting and retrieving the net did allow for the collection of an additional twelve seal scats. Seal scats were analysed using hard-part and molecular methods and these results are presented in summary in section 2.6 and in full in an Interim Report (Harris & Northridge, 2018b).

1.9.2 Floating trap

No further investigations have been made this project year into the potential of using a floating seal trap. A floating seal trap was designed and constructed in 2016, but there were difficulties associated with finding a suitable site in the River Dee for deployment, with sourcing suitable bait (due to perceived biosecurity issues), and with agreeing a monitoring programme during deployment periods. These issues are surmountable but have hindered the development and evaluation of this approach. In February 2018 the River Dee fishery board were able to secure a number of dead salmon kelts from the river which have been permitted for use as bait and have been stored frozen. However, there are currently no future plans to investigate the potential feasibility of this capture method for seals although it remains an option to pursue.

1.9.3 River wide net

No further investigations have been made in this current project year into the potential to deploy a river wide net across a large swift flowing river. Initial trials conducted on the River Dee in 2017 (Harris & Northridge, 2018a) found that existing SMRU seal nets were unsuitable and therefore changes were needed to both the lead line and float line to better cope with the additional forces involved. Furthermore, smaller meshes would also be required to prevent the entanglement of seals thereby removing the risk of seals becoming enmeshed and drowning.

The primary reason for continuing to pursue this approach is to develop a method for catching and tagging seals through the introduction of an escape route in the river wide net where seals can be captured as they attempt to pass through a 'cod end' type structure incorporated into the net. A secondary reason was to investigate the potential of using a river wide net for short periods of time to block the progress of incoming seals, however, the use of rivers at night by seals and the difficulty of detecting incoming seals currently limit any potential.

1.10 Development of a method to monitor seal river use

Relatively little information on seal occurrence upriver of the tidal limit is available as these infrequent events are difficult to study and night time information is absent altogether. Developing a method to monitor rivers 24 hours a day, and seven days a week would provide information on when seals are using rivers, the effectiveness of mitigation measures and potentially allow for a more targeted approach to developing further mitigation. Several potential options exist, such as sonar, underwater video and surface video monitoring (which might include thermal imaging). As a potential low-cost solution, a river surface video surveillance system to detect the head of surfacing seals is being investigated. The first requirement was to obtain funding through a Scottish Government Capital Funds bid to purchase equipment. This required the development of a specification of the monitoring requirements. The process for developing the specification has drawn on existing knowledge and information on seal behaviour and is described below.

Existing telemetry and observer data for two harbour seals in the River Dee were extracted from the SMRU telemetry database and observer fieldnotes. These data were used to provide information on the likely area of the River Dee that may need to be monitored to detect at least one surfacing event for each seal traveling upriver. Data on behaviour within the river was generally sparse as the tagged seal, an adult male (Pv.030D), generally remained within Aberdeen Harbour and rarely ventured upriver (Harris & Northridge 2018b). Information from observer fieldnotes was also limited due to observer effort being focused on Aberdeen Harbour and the infrequent nature of seal visits upriver of the tidal reaches during observation periods at those locations. Seals were occasionally observed traveling downriver in mornings but rarely observed traveling upriver, the hypothesis being that upriver travel may occur at night. Incidentally, the majority of the telemetry data upriver of Aberdeen Harbour occurred during the hours of darkness.

From Pv.030D telemetry data, 165 dive records from four separate trips upriver of Aberdeen Harbour were extracted to investigate dive behaviour in the tidal stretches of the river. Median dive duration was 112 seconds (maximum 264 seconds) and average speed between GPS locations (including both upriver and downriver passage) was 0.48 m/s (Harris & Northridge, 2018b). Therefore, median and maximum dive durations multiplied by this average speed can be used to provide an indication of distance covered during each dive. For Pv.030D the estimated median distance for underwater travel during a dive within the river was 54m (maximum 127m).

Detailed land-based observations of another seal, a juvenile female (Pv.018D) traveling upriver, were available from above the tidal reaches on one occasion. The seal was visually tracked traveling upriver against the river flow over a distance of 1840m. The observed surfacing times and locations were marked on a 1:25000 map. Seal behaviour at the time was noted as traveling, as opposed to foraging, as the seal appeared to be making relatively direct and rapid upriver progress as opposed to more tortuous movement behaviour that may imply searching or foraging. The average speed over the ground for this seal was 0.5 m/s. Median estimated distance between observed surfacing events was approximately 40m (maximum 100m).

Although harbour seal data was limited, and no suitable information for grey seals was available due to the infrequent nature of grey seal visits to this area of the river, an initial proposal was put forward to develop a surveillance system to monitor a section of river 130m long (based on calculations above). This was combined with information on the width of the lower River Dee channel to propose a minimum requirement for a system to be able to monitor an area of approximately 130m by 70m with sufficient resolution to detect the surfacing head of a seal. In reality, the actual area required to be monitored will be site specific and will partly depend on the speed of river flow in particular sections of the river. Increasing or decreasing the area to be monitored would likely require the addition or removal of cameras.

Night time monitoring of seals was agreed to be a requirement. This will require infrared illumination or thermal imaging capability. However, the relatively low resolution and high costs associated with thermal video systems led to a decision to utilise infrared lighting systems for night time recording. Furthermore, it was felt that seal detection at night using infrared illumination may be further improved by utilising the seal eyeshine reflected from infrared light sources.

These requirements were put out to tender by potential suppliers. The surveillance system that met specification requirements utilises Mobotix S16 dualflex cameras (www.mobotix.com/en/products/outdoor-cameras/s16-dualflex). The proposed system will involve four cameras, each with two 6 megapixel sensors. The total system resolution is potentially equivalent to 48 megapixels overall. Once deployed, footage will be stored on removable hard drives which will be replaced on a weekly basis. Storage space requirements will be dependent on several factors such as frame rate, video codec and image complexity. We envisage a maximum hard drive size of 8TBs each week with the aim of collecting a maximum of 4 months of video data to evaluate system performance as a seal monitoring tool.

Although the proposed system may currently offer the opportunity to study the occurrence of seals in rivers over relatively short time scales (~weeks or months), the current drawback is the labour-intensive process of manually reviewing all the footage. If the system proves successful in capturing images of seals, then the potential exists to work with collaborators to develop an automated process for detecting seals and thereby negating the need to store and review large quantities of video footage.

1.11 DSFB and salmon fishery support

During this project year support and advice in relation to seal matters has been provided to a number of DSFBs and river fisheries, including the Spey DSFB, Ness DSFB, Northern DSFB and River Ythan. Contact with the River Dee DSFB has been ongoing through the year and photo-ID images collected by DSFB staff have been processed by SMRU to catalogue and identify individuals present in the river and this information has been fed back to the DSFB.

Other relevant support:

An invitation to attend the Tees Barrage Fish Pass and Operations Steering Group meetings was received to improve information flow between work being done by the Canal and River Trust's work on seal monitoring and mitigation attempts at the River Tees barrage and SSI. The Grayling Research Trust contacted SMRU for information on seal predation on salmonids. EDP Renewables contacted SMRU for information on the use of Lofitech ADDs.

Appendix 1 – Attempt to validate the metabarcoding results indicating salmonid DNA presence.

An attempt was made to confirm the high prevalence of salmonid DNA in seal scats and faecal samples suggested by the metabarcoding analysis carried out by Xelect Ltd. (Harris & Northridge, 2018b). The genomic DNA was reanalysed using qPCR to detect the presence of salmonid prey. Xelect Ltd. tested the DNA samples specifically for the presence of brown trout (*Salmo trutta*), Atlantic salmon (*Salar salar*), rainbow trout (*Oncorhynchus mykiss*) and pink salmon (*Oncorhynchus gorbuscha*). The methods used for this analysis followed those detailed by Matejusová et al., (2008). Detailed methods and results provided by Xelect Ltd. are presented below.

Methods:

The quantification of the 31 DNA samples was performed using nanodrop 2000C Spectrophotometer and the concentration range was from 5.5ng/ul to 16.7ng/ul. The quantity and quality of DNA provided was quite low which is unsurprising given the nature of the samples. From the previous qPCR work to identify seal species and sex (Harris & Northridge, 2018b), DNA samples do not contain any PCR inhibitor, as an internal positive control (IPC) was performed on all samples.

Published qPCR primer sets and probes specific for targeting the CO1 gene for *Oncorhynchus gorbuscha* and CytB for the other three species were used. Species specific primer/probe assays for *Oncorhynchus mykiss* and *Oncorhynchus gorbuscha* were synthesized according to Andersen et al., (2018), and for *Salmo trutta* and *Salmo salar* from Matejusová et al., (2008).

Primer probe specificity tests were run using known rainbow trout, brown trout, atlantic salmon and pink salmon samples. All the assays showed positive results with cycle threshold (CT) values of around twenty. Each assay was also tested against known samples from different species tested in this study to assess the specificity of each assay because those species tested are closely related. No amplification was detected when species specific assays were used on DNA samples from different species. The assays were thus considered to be specific only to the target species.

All qPCR analysis was performed in duplicate in a 10µl reaction containing 2µl genomic DNA, species specific TaqMan® assay and Agilent Brilliant III Ultrafast Mastermix (Agilent Technologies Ltd, Stockport) following manufacturer's instructions. Each plate also contained two No Template Control (NTC) reactions which are full PCR reactions but with nuclease-free water in the place of the DNA sample.

Thermal cycling conditions for all assays were as follows; 10 minutes at 95°C, followed by 40 cycles (also repeated with 50 cycles) of 15 seconds at 95°C and 30 seconds at 60°C. FAM® and VIC® fluorescence data was collected at the end of the 1-minute step.

Results:

In this study TaqMan assays were designed to detect specific prey targets (rainbow trout, brown trout, atlantic salmon and pink salmon) in the DNA extracted from scat samples. In particular, two mitochondrial genes CO1 and CytB were chosen as target for TaqMan assays because of their high variability among closely related species. This quality makes mitochondrial genes an ideal target for species identification studies. Specific primers for CO1 gene were also designed and tested for the metabarcoding analysis (Harris & Northridge, 2018b) performed by Xelect with the same set of scat DNA samples in November 2018. In that case three different primer pairs for the CO1 gene were expected to amplify a fragment of ca 200bp, but they failed to amplify.

Due to the deterioration of prey DNA in scat samples and the high probability of DNA degradation, in the present study an attempt to increase the probability of amplification by reducing the amplicon size using TaqMan assay technology. The TaqMan assays used for the described analysis are capable of amplifying fragment sizes of 78bp to 163bp (depending on the specific assay) but none of the DNA scat samples were able to amplify successfully, even after testing various dilutions of the DNA (1/20, 1/10 and 1/5). The results suggest that the scat DNA samples were probably highly degraded or did not have enough mitochondrial copies to be detected with the assays.

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