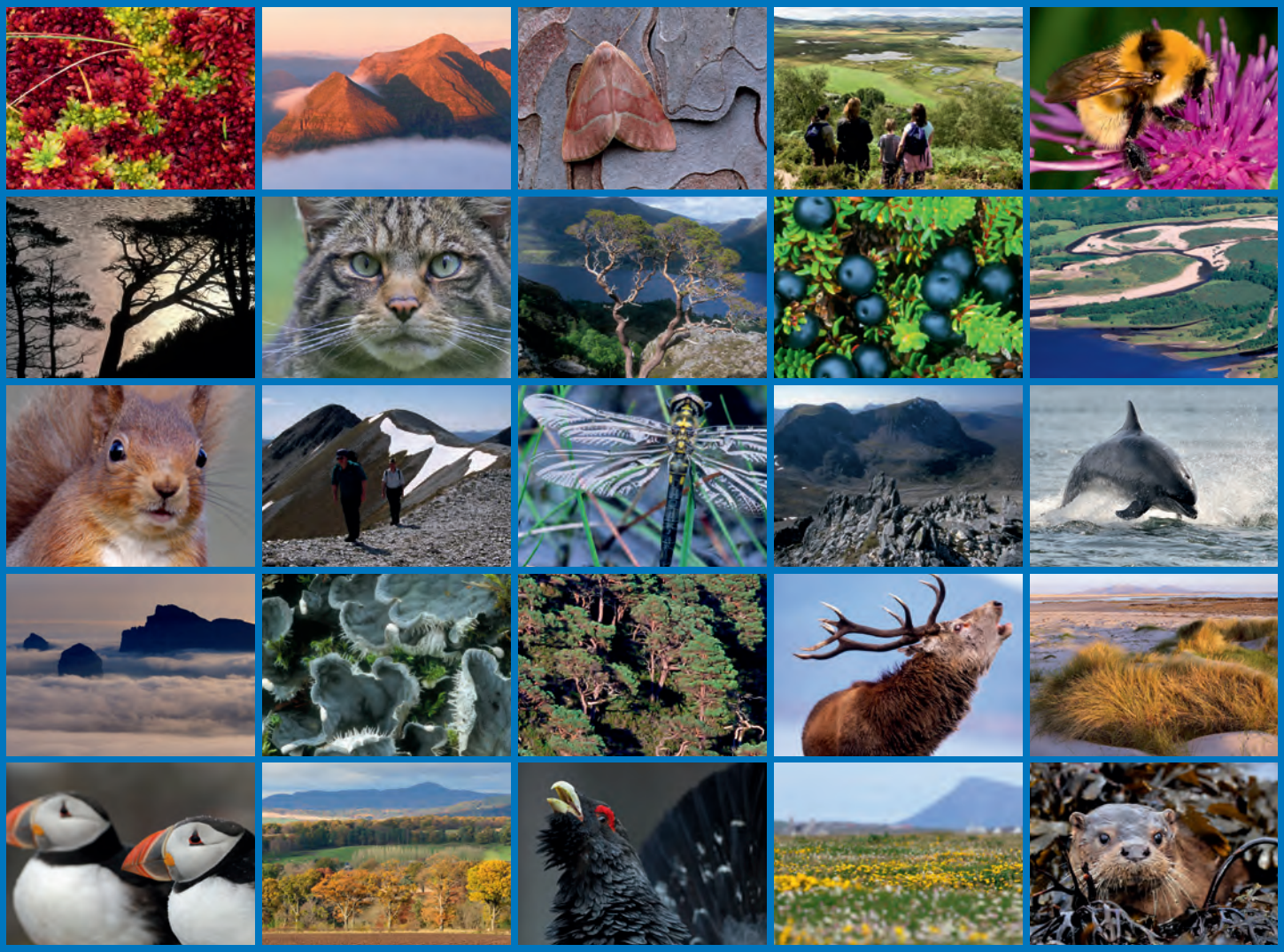
Scottish Natural Heritage
Commissioned Report No. 763

The Scottish Beaver Trial: Ecological monitoring of the European beaver *Castor fiber* and other riparian mammals – Fourth Annual Report 2013



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COMMISSIONED REPORT

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The Scottish Beaver Trial: Ecological monitoring of the European beaver *Castor fiber* and other riparian mammals Fourth Annual Report 2013

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COMMISSIONED REPORT

Summary

The Scottish Beaver Trial: Ecological monitoring of the beaver *Castor fiber* and other riparian mammals – Fourth Annual Report 2013

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Beaver; monitoring; Knapdale; Scottish Beaver Trial.

Background

In 2008, the Scottish Government approved a licence for the Scottish Wildlife Trust (SWT) and the Royal Zoological Society of Scotland (RZSS), to undertake a five-year trial reintroduction of the European beaver *Castor fiber* after an absence of over 400 years. The aims of the trial include an assessment of the ecology of the beavers, and their impacts on the Scottish environment. The success or failure of the trial will be based on a number of specific criteria, which relate to the ability of the reintroduced population to sustain itself, the effects of the beavers on biodiversity, the economic effects of the beavers, and the cost of their reintroduction and ongoing management.

In order to effectively assess the Scottish Beaver Trial (SBT), Scottish Natural Heritage (SNH) is coordinating a monitoring programme, in collaboration with a number of independent organisations. A core element of this is the monitoring of the beaver population itself. SNH is, therefore, working in partnership with the Wildlife Conservation Research Unit at the University of Oxford (WildCRU) in order to ensure the monitoring of the beavers, and other riparian mammals present at Knapdale, is suitable and appropriate. WildCRU are responsible for independent analysis of data received on the ecology of the released beavers; this is the fourth of five annual reports planned over the duration of the Scottish Beaver Trial. The aim of this report is to present and summarise the data gathered on the ecology of the beaver population and other riparian mammals, and to present analyses that address the relevant success and failure criteria of the trial, and that address key ecological questions relevant to the study of the ecology and biology of the European beaver in the Scottish environment. The current report collates ecological monitoring data to the end of the fourth year of the trial (to June 2013). A full assessment against these criteria will not take place until the end of the trial hence these are very much interim findings.

Main findings

- A total of fifteen beavers in five families or pairs were released during the first year of the trial, and one further animal during the second year of the trial. Three deaths, all males, were recorded during the first year of the trial; a total of four animals went missing over

the first two years, and a fifth in the fourth year. As of June 2013, of the 16 animals released over 2009 and 2010, eight were believed to be alive and present in the release area.

- A total of fourteen wild-born beavers have been recorded to date; two of these were predated as kits and three kits were lost. Litter size (at time of emergence) has varied between one and three kits per reproducing pair. During the fourth potential breeding season of the trial (technically Year 5 of the trial), one or two kits were observed emerging from the lodges of three of the four pairs.
- Although mortality of established animals appears to be low, reproductive success also appears to be low, and there is currently little indication that the beaver population present at Knapdale is increasing substantively. However, opportunities for breeding have been relatively limited during the trial due to the age and timing of release of the individual females.
- For those animals that survived six months or more post-release, there has been no evidence of a decline in body condition; all of these individuals have either maintained their pre-release body weight, or increased in weight.
- Beavers at Knapdale currently remain in four discrete family groups, covering a total area of 422.8 ha, at a density of approximately one beaver family per 4 km of waterway edge.
- GPS tracking and temperature-depth recorders (TDRs) were utilised as additional monitoring tools with the aim of providing further insights into the behaviour of beavers at Knapdale. Success of these deployments was low and they are not recommended for routine monitoring, however, the detailed short-term data on movements (in water as well as on land) on a subset of animals were insightful and the results were broadly in line with similar studies of beavers in Norway.
- Two sub-adults released at the start of the trial have apparently dispersed; at least one (and probably two) wild-born sub-adults also appear to have dispersed. SBT will actively seek records of beavers outside the trial area during the last year of the trial, with a view to providing information on dispersal movements and distances travelled where possible. It is anticipated that this information will be limited.
- There is no evidence that beaver reintroduction has had a negative impact on the presence of otters in the area.

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This project is supported through a partnership of Scottish Natural Heritage and the University of Oxford Wildlife Conservation Research Unit as part of the monitoring of the Scottish Beaver Trial. The authors thank the Royal Zoological Society of Scotland (RZSS), the Scottish Wildlife Trust (SWT), and Forestry Commission Scotland for their help and cooperation. RZSS and SWT have also contributed funds to the overall monitoring programme.

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1. INTRODUCTION

1.1 Background

The European, or Eurasian, beaver *Castor fiber* became extinct in Scotland around the 16th century as a result of over-hunting. Over recent years the potential for restoring this species to the natural fauna has been investigated. These investigations have resulted in a suite of information with regard to the scientific feasibility and desirability of conducting such a reintroduction. Relevant documents published by Scottish Natural Heritage (SNH) can be viewed at www.snh.gov.uk/scottishbeavertrial.

The work undertaken is in line with obligations on the UK Government, under Article 22 of the European Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Flora and Fauna (the 'Habitats Directive'), to consider the desirability of reintroducing certain species (listed on Annex IV), including European beaver.

The Species Action Framework, launched in 2007 by Ministers, and completed in 2012, set out a strategic approach to species management in Scotland. In addition, 32 species, including European beaver, were identified as the focus of new management action for five years from 2007. SNH worked with a range of partners in developing this work and further information can be found at www.snh.gov.uk/speciesactionframework.

In May 2008, the Scottish Government Minister for the Environment approved a licence to allow a trial reintroduction of up to four families of European beaver into Knapdale Forest, mid-Argyll.

The licence has been granted to the Scottish Wildlife Trust (SWT) and the Royal Zoological Society of Scotland (RZSS), who are managing the 'Scottish Beaver Trial' (SBT). The trial site, Knapdale Forest in Argyll, is owned by Forest Commission Scotland (FCS). Several families of animals were caught in Norway during 2008 and quarantined for six months. Three families were released in spring 2009, and a further two pairs[1] in May and June 2010. The release sites were Loch Coille-Bharr, Loch Linne/Loch Fidhle, Creagmhor Loch and un-named Loch (south), also known as the 'Lily Loch'. The release is being followed by a five-year period of monitoring that will run until Spring 2014. SBT have dedicated field staff in place to cover this period.

One of the objectives of the Scottish Beaver Trial, as set out in the original licence application submitted by SWT and RZSS, includes the 'study of the ecology and biology of the European beaver in the Scottish environment', which will, in part, fulfil another of the objectives, to 'generate information during the proposed trial release that will inform a potential further release of beavers at other sites with different habitat characteristics'.

The licence issued by the Scottish Government to the RZSS and SWT came with a number of conditions, a key one being that the monitoring of the project must be independently coordinated by SNH. As part of this process, SNH has, therefore, entered a partnership with the Wildlife Conservation Research Unit (WildCRU) at the University of Oxford to support, enable and report on the ecological monitoring of the beaver population and other riparian mammals[2] during the trial period.

[1] The fifth family was released, under agreement from the Scottish Government, as a replacement for the first family that failed to establish.

[2] The number of 'other riparian mammals' that we are able to monitor is limited by resources and therefore we chose to concentrate on the otter because it is a qualifying feature of the Taynish and Knapdale Woods Special Area of Conservation. We included American mink and water vole because field signs for these two species can potentially be detected while carrying out otter surveys, and thus without the requirement for additional resources. The water shrew is designated as a Species of Conservation Concern in the UK but we are not aware of any water shrew records from Knapdale so this species was not included in the monitoring programme.

This is one element of a wider monitoring programme, coordinated by SNH, which includes:

- Beaver health
- Terrestrial vegetation
- Aquatic/ semi-aquatic macrophytes
- Fish
- Odonata
- Water chemistry
- Hydrology
- Riverine geomorphology
- Socio-economics
- Public health
- Scheduled monuments

WildCRU does not have a lead role with any of the other monitoring projects listed above, but the various elements are coordinated so that data can be efficiently collected and shared by those involved with the monitoring programme.

1.2 Success and failure criteria

The licence application sets out *success criteria* for the project, some of which are specific to the ecology of the beaver (rather than the wider socio-economic and other environmental aspects of the trial), and thus are particularly relevant to the ecological monitoring work carried out. These are, that:

- **Survival of introduced animals is similar to that of successful reintroduction programmes elsewhere in Europe at a similar stage of population establishment.**
- **A stable or increasing core population is achieved within the limits of the study site.**

There are also *failure criteria.* The failure criteria specific to the ecology of the beaver are, that:

- **Mortality levels preclude establishment of a population.**
- **Significant and unsustainable damage is incurred by the ecosystem within the study site.**

1.3 Relevant objectives of the Scottish Beaver Trial

Specific *relevant objectives* of the Scottish Beaver Trial are to *'study the ecology and the biology of the European beaver in the Scottish environment'* and thus to *'generate information during the proposed trial release that will inform a potential further release of beavers at other sites with different habitat characteristics.'*

Further, although not stated explicitly initially as an objective of the ecological monitoring, for any reintroduction it is important to be able to assess post-release behaviour of animals. With both animal welfare and future success (of further releases, if the decision is made to reintroduce beavers) in mind, and given the disturbance that animals are subject to during capture, quarantine and release, it is crucial to be able to assess whether or not individual animals were negatively affected by the process, and how well they have adapted to their new environment. This question can be addressed by assessing the health of the animals and their stress levels, as well as various demographic parameters (such as survival and reproductive success), but behaviour is also key (partly because aberrant behaviours can be relatively easily detected).

An additional aim of the ecological monitoring project (Campbell *et al.* 2010 p3) is to *'ensure the methodology includes the collation of suitable data which will allow the refinement of the existing beaver population model commissioned by SNH (Rushton et al. 2002), thereby improving our ability to predict future trends in beaver populations should the trial support the case for further reintroductions.'*

1.4 Addressing relevant success/ failure criteria, and objectives of the trial

Following on from our third annual report, we have changed the format of the annual reports for the ecological monitoring, in order to more clearly address the success/failure criteria of the trial, and the stated objectives and trial aims. Early (first and second) reports were organised around the methods used, as stated in the original methodological protocols (published as Campbell *et al.* 2010). Here, we initially provide a brief overview of the animals present at Knapdale, and a very brief summary of the monitoring methods, before the three main sections of the report that address beaver demographics, morphometrics and body condition, and, ecology and behaviour. The final section covers monitoring of other riparian mammals.

The success and failure criteria of the trial are addressed by analysis of beaver demographics, with the exception of an assessment of 'significant and unsustainable damage to the ecosystem' which is primarily being addressed by other monitoring partners, but is supported by the monitoring of other riparian mammals which is reported on here. Health of the beavers at Knapdale will be reported on by the Royal (Dick) School of Veterinary Studies, but a broad assessment of body condition is included here because of the obvious link between individual body condition and population demographics, and ecology / behaviour. The broader trial objective of studying the ecology of beavers in the Scottish environment, is addressed by assessing home range size and location of beaver families, spatial organisation, activity patterns, and habitat use, all of which are covered in the section on ecological data. Although, to what extent these findings will be *relevant at other sites with different habitat characteristics* is more difficult to assess (since spacing patterns or habitat use might differ in different habitats/environments), and may require wider comparisons with similar projects elsewhere in Europe. This particular project objective is not addressed in this report but will be considered, as far as is possible, in the final report at the end of the trial. To address the additional, but important, objective of assessing the behaviour of translocated beavers (above), we have added a number of methodological protocols that will allow a more detailed insight into the behaviour of released beavers at Knapdale that are additional to the original methodological protocols but that can be carried out alongside existing monitoring and without significant increases in either workload (for SBT) or animal handling (see sections 6.3 and 6.4).

This report covers monitoring of the ecology of released beavers and other riparian mammals to the end of the fourth year of the Scottish Beaver Trial (June 2013). Note that beaver families are now referred to by their loch names for consistency with other monitoring projects (original names (numbers 1-5) are also given to allow cross-referencing to earlier ecological monitoring reports). Note that there has been some exchange of individual beavers between families over the trial period; Loch names in this report refer to beaver locations during Year 4 rather than their original site of introduction.

2. ANIMALS AT KNAPDALE

Between May 2009 and September 2010[3], 16 beavers were released. There are no plans to release more beavers in Knapdale for the duration of this trial, in accordance with amended licence conditions.

Table 1. Fate of beavers released in Knapdale, Argyll (2009 – 2013). Released animals known to be alive and present at the release site at the end of the fourth year of the trial (June 2013) are highlighted in grey.

Name	Sex	Age[a]	Family[b]	Release data	Release loch	Current loch (new family name)	Fate (as of June 2013)
Andreas Bjorn	M	5+	1	31/05/2009	Creagmhor Loch		Withdrawn from programme Dec 2009; died in captivity May 2010
Gunn Rita	F	5	1	31/05/2009	Creagmhor Loch		Missing[c]
Mary Lou	F	1	1	31/05/2009	Creagmhor Loch		Missing[c]
Frank	M	Unk	2	30/05/2009	Loch Linne	Loch Linne	Alive
Frid	F	Unk	2	30/05/2009	Loch Linne	Loch Linne	Alive
Biffa	M	2	2	30/05/2009	Loch Linne		Missing[d]
Biffa's brother	M	2	2	30/05/2009	Loch Linne		Dead (shortly after release)
Bjornar	M	Unk	3	30/05/2009	Loch Coille-Bharr	Dubh Loch	Alive
Katrina	F	Unk	3	30/05/2009	Loch Coille-Bharr	Dubh Loch	Alive
Millie	F	2	3	30/05/2009	Loch Coille-Bharr	Dubh Loch	Alive
Marlene	F	2	3	30/05/2009	Loch Coille-Bharr		Missing[e]
Tallak	M	5+	4	04/05/2010	Un-named (S) or 'Lily Loch'		Dead (approx 2 weeks post-release)
Trude	F	2	4	04/05/2010	Un-named (S) or 'Lily Loch'	Loch Buic	Alive
Eoghann	M	2	5[f]	23/06/2010	Creagmhor Loch	Loch Buic	Alive
Elaine	F	2	5[f]	23/06/2010	Creagmhor Loch	Un-named (N)	Missing[i]
Christian	M	3	4[g]	21/09/2010	Loch Buic[g]	Un-named (N)[h]	Alive

[a] Estimated age at time of release; post-mortem tooth sectioning revealed Andreas Bjorn to be > 7 years old, and Tallak to be > 13 years old (Frode Bergan, Telemark University College, unpub. data).

[3] Scottish Government granted permission for the replacement of dead or dispersed adult beavers for the period up to May 2011.

[b] Numerical 'family names' as used in previous reports.
[c] Gunn Rita disappeared in the second week post-release, her female yearling (Mary Lou) disappeared in mid-July 2009.
[d] Biffa was last seen in February 2011.
[e] Telemetry signals suggested that Marlene was on a nearby sea loch in August 2009, but this was not confirmed visually (she has not been seen since).
[f] The fifth pair of beavers was released as a replacement for the loss of Family 1 (Loch Creagmhor) with the aim of establishing a minimum of four potential breeding pairs in the release area by May 2011.
[g] Christian was released to provide a mate for Trude following the death of Tallak; he was released into Loch Buic where Trude had established a small burrow and was regularly observed feeding. Christian was released at the far end of the loch at an artificial lodge where his scent had been placed prior to release. The two beavers paired up on the night of Christian's release and remained together until the end of Year 2.
[h] Also known as Lochan Beag.
[i] Elaine was last seen in February 2013.

Table 2. Wild-born beavers in Knapdale, Argyll (2009 - 2013). Wild-born animals known to be alive and present at the release site at the time of reporting (October 2013) are highlighted in grey.

Name	Sex	Year of birth	Mother	Loch	Fate (as of June 2013)
Barney	M	2010	Frid	Loch Linne	Alive?* (3 years old)
2	?	2010	Katrina	Dubh Loch	Missing[1]
Logan	M	2011	Frid	Loch Linne	Alive?* (2 years old)
4	M	2011	Katrina	Dubh Loch	Predated as a kit
5	F	2012	Frid	Loch Linne	Predated as a kit
6	?	2012	Katrina or Millie[2]	Dubh Loch	Missing[3]
7	?	2012	Katrina or Millie[2]	Dubh Loch	Missing[3]
8	?	2012	Katrina or Millie[2]	Dubh Loch	Missing[3]
Woody	F	2012	Trude[4]	Loch Buic	Alive (1 year old)
10		2013	Millie	Dubh Loch	N/A[4]
11		2013	Millie	Dubh Loch	N/A[4]
12		2013	Trude	Loch Buic	N/A[4]
13		2013	Trude	Loch Buic	N/A[4]
14		2013	Frid	Loch Linne	N/A[4]

[1] Missing as of summer 2012; last sighting was 04/07/2012 (age 2 years old).
[2] Maternity unknown (kits were lost before being captured and thus genetic testing is not possible)
[3] Presumed dead, but bodies never found. Last seen in January 2013.
[4] Film footage suggested that this female was pregnant in 2011, but no kits were seen; Elaine (the female beaver at Un-named Loch (north)) was also thought to be pregnant last year (2012), and there were signs that she was pregnant in 2011, but no kits were observed; this female is now dead or missing (see Table 1).
* At least one sub-adult is alive on Loch Linne – identity is unconfirmed, it may be Barney or Logan. (The last confirmed observation of Barney was in February 2013, but a more recent observation of an unidentified sub-adult was also recorded in May 2013; there are no recorded observations that could be positively identified as Logan but he was captured as a yearling in summer 2012).
[4] Preliminary results from the final year of the trial.

3. SUMMARY OF ECOLOGICAL MONITORING TO DATE

3.1 Animals released

A total of fifteen beavers in five families or pairs was released during the first year of the trial, and one further animal during the second year of the trial. Three deaths, all males, were recorded during the first year (two of these deaths occurred shortly after release, the third animal was withdrawn from the trial due to ill-health approximately seven months post-release). A further three animals were also classified as 'missing' (fate unknown) by the end of the first year. No further deaths were recorded during the second year of the trial but one further animal was recorded as missing. Two of the four missing animals were sub-adults (one was two years old and disappeared in the first month post-release, the other was three years old and disappeared two years post-release). No further deaths (of released animals) or missing animals were recorded in the third year, but one adult female was recorded as missing in the fourth year (approximately 3.5 years post-release). As of June 2013, of the 16 animals released over 2009 and 2010, eight were believed to be alive and present in the release area (see Table 1 above).

3.2 Wild-born animals

In both the second and third year of the trial, two kits were recorded (one per pair for each of the two pairs that successfully reproduced). In the third and fourth year of the trial, five kits were born to three pairs. As of June 2013 (the end of the fourth year of the trial), one or two wild-born sub-adults (two or three years of age, see Table 2) and one wild-born yearling were present in the population (as of October 2013, five kits were also known to be present – this will be fully reported on in the final report). Over the course of the trial, two kits are known to have been predated (one in 2011 and one in August 2012), a further three (all from the same litter) disappeared in late autumn/winter of 2012-2013 (probably also predated, or died of other causes). The wild-born sub-adult on Dubh Loch appears to have dispersed (at two years of age); either one or both sub-adults on Loch Linne have (to date) remained in their family home range (to be confirmed). See Table 2 (above).

3.3 Methodology

Detailed methodological protocols are given in Annex 1. Here we summarise briefly the methods currently utilised and the information obtained from each. Analyses and further discussion of the data available are in the following sections.

Annual trapping

SBT aims to trap all individual beavers at least once each year, which provides data on survival and animal health[4] as well as the additional opportunity to deploy GPS tags or other remote monitoring devices whilst minimising the number of times an animal is trapped. However, the male beaver on Dubh Loch (Bjornar) appears to be particularly difficult to trap and it is not always possible to trap all individuals each year. A particular aim of the trapping is to capture and mark all wild-born animals to allow assessment of their survival and movements; to date, both wild-born animals on Loch Linne have been captured and marked with ear tags, as has the yearling on Loch Buic, but the wild-born animal on Dubh Loch was not marked and has now disappeared (probably dispersed), and none of the 2012 kits on Dubh Loch were captured before their disappearance.

[4] Animal health is reported on in detail by the relevant independent monitoring partner, the Royal (Dick) School of Veterinary Studies, but basic measures of body condition are included in the ecological monitoring.

Monthly observations

Monthly observations carried out by SBT, primarily for management purposes, also contribute information on survival and location. SBT aims to observe all beavers known to be alive, and present in the release area, at least once per month. These data are incorporated into survival and home range analyses as appropriate.

Summer lodge/den counts

Over the course of the trial different methods have been used to count the number of kits produced (including systematic and non-systematic lodge / den counts, supplemented with the additional trial use of infra-red cameras[5]). Most sightings of kits, however, have been during regular monthly observations (rather than during specified lodge watches). Nevertheless, consistency in the number of kits seen, among monthly observation periods, suggests that data on the number of kits (at emergence) are accurate and comparable across years. Observations in late summer/early autumn seem to be particularly important for detecting late-emerging kits, although observations early in the summer are also essential to detect post-emergence predation.

Field sign surveys

Seasonal field sign surveys continue to provide essential ecological information on the areas used by beavers (home range location and size) and their terrestrial habitat use, and provide continuity for the data collected thus far. The potential limitation of field sign surveys is that individual/family identity cannot be confirmed; however, in the fourth year of the trial, most field signs still occurred in four relatively distinct clusters (reflecting the current four family groups). In Years 4 and 5, camera traps were / will be deployed on an *ad hoc* basis, as necessary, to cover areas where use needs to be assigned to specific beavers.

GPS tracking

During the second year of the project, preliminary trials investigating the potential use of inexpensive route trackers to provide GPS tracking data indicated that GPS tracking would be a feasible and potentially useful monitoring tool for recording nightly movements of individual beavers and verifying home range boundaries (defined on the basis of field signs). Therefore, further amendments were made to the ecological monitoring methods to include GPS tracking. The route trackers used record for a limited duration (maximum 10 days) and therefore, given this limitation as well as the extra trapping effort required to deploy tags on animals and to retrieve the tag, the original aim was to obtain snap-shot data on all adult beavers but with effort spread over the last two to three years of the trial. At the time of reporting (October 2013), 17 tags had been deployed but tag loss and damage resulted in only nine usable datasets from five individual beavers. Further GPS tags will not be deployed in the final year of the project.

Time-depth recorders

An additional new method introduced in the third year (2012) of the project was the use of time-depth recorders (TDRs). The use of these devices was opportunistic insofar as they are small, lightweight devices (31 mm length, 8 mm diameter, weight 2.7 g in air and 1 g in water) and can be deployed attached to GPS tags so that no additional animal handling was required and no additional time required of SBT staff (the devices themselves were supplied by the Wildlife Conservation Research Unit). These devices will potentially provide

[5] Night-vision goggles were also trialled but found not to be useful because identification of individual beavers was not possible.

information on the extent to which beavers use the aquatic habitat; information that cannot be inferred from either GPS telemetry locations (fixes are not picked up in water and are too low resolution to be able to distinguish between a beaver at the edge of the loch and a beaver on the bank) or by field signs. TDRs are capable of recording depth and temperature at 1 second intervals (for approximately six days), providing very detailed dive profiles, and thus will also provide additional 'non-essential' information on the diving behaviour of beavers at Knapdale. Whilst not part of the original essential ecological monitoring protocol, data will be presented here alongside nightly movements inferred from GPS telemetry locations, and (if appropriate) observational data from the first two years of the trial, to allow a better understanding of beaver behaviour at Knapdale and with a view to assessing the general behaviour of translocated beavers. Unfortunately, loss of TDRs was high (six of 12 deployments were retrieved); no further TDRs are available for deployment in the final year of the project.

Behavioural observations

Behavioural observations (beyond the monthly observations referred to above) were not carried out beyond the second year of the study as they were judged to not add greatly to the field sign surveys and were time consuming to collect. There are currently no plans to repeat these observations during the existing trial.

Annual surveys for other riparian mammals

Annual otter surveys were carried out by SNH; these surveys are designed to detect substantial changes in otter presence or use of the site by otters. Since the literature on otter-beaver interactions suggests that a positive impact of the beaver release would be more likely than a negative impact, the surveys were not designed to provide high levels of statistical power to detect small changes in spraint density (which in any case is not related clearly to otter density) but rather to be able to detect a disappearance of otters (caused by beavers) or major decline or increase in their activity at beaver-occupied sites. Mink and water vole field signs are also recorded opportunistically.

4. DEMOGRAPHIC DATA

4.1 Survival of translocated animals

A crude estimate of minimum survival of released animals to the current time is given by the number known to be currently alive, still being monitored and present within the original release area (eight), divided by the total number of animals released (16). On this basis, minimum survival to the end of the fourth year of monitoring is 0.50. This includes only known survivors (for this analysis, missing animals are considered dead), and treats all released individuals equally, although, in reality, staggered releases over the first two years of the trial (Table 1) mean that some individuals have survived four years post-release whereas others have only, thus far, survived three years post-release.

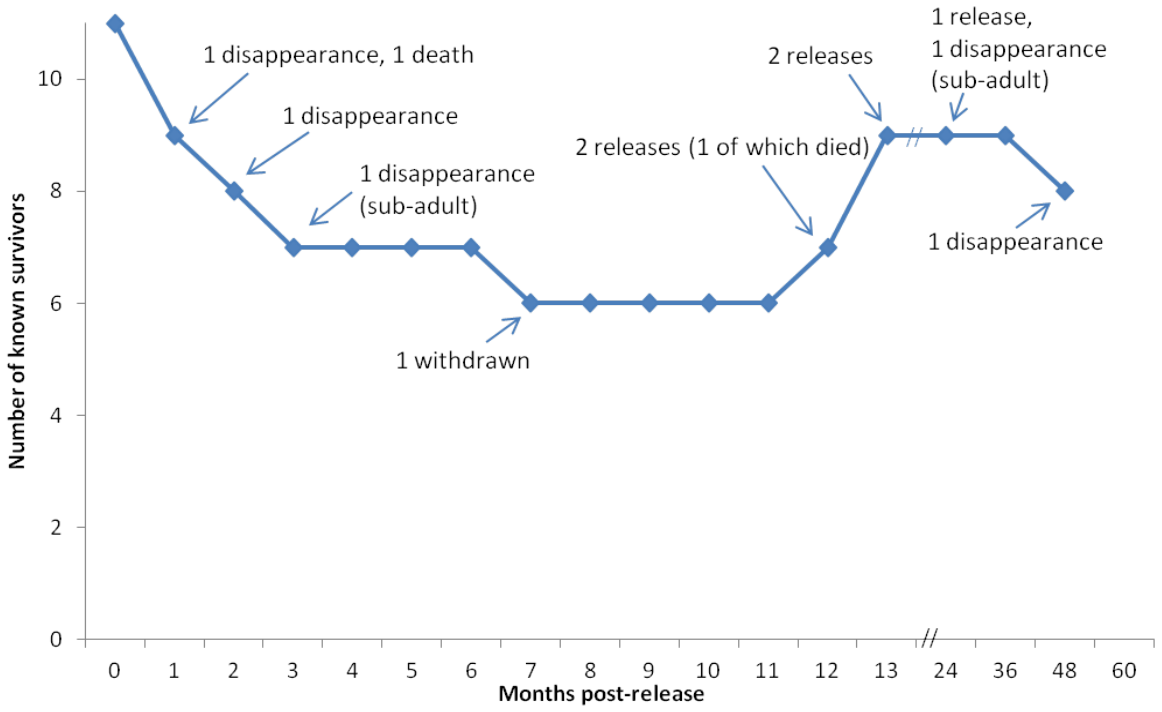


Figure 1. Number of beavers known to be surviving at Knapdale over time since initial release. Missing animals, in this case, are not counted and are presumed dead. (Note the scale change after 13 months).

Kaplan-Meier estimates of the probability of survival (*S*) take account of the different release times of individuals and the loss of animals to monitoring (i.e. those that are lost and for which fate is unknown). *S* at four years post-release[6] is estimated as 0.68 (95% confidence intervals 0.44, 1, Fig 2b), with a mean survival across all individuals of 34.7 months (± SE 6.5). However, the small size of the population being monitored mean that the variance estimate may underestimate the actual variance, and the high censoring rate (loss of animals to monitoring) means that *S* may be biased if censored (missing) animals are more or less likely to die than are the others still being monitored (i.e. if all missing animals are actually dead, survival estimates will be too high). To illustrate the effect of the unknown fate of missing animals in this population, we estimated *S* for two extreme hypothetical scenarios: one where all missing animals were assumed to be dead, and a second where all missing

[6]Analyses were run in R (version 3.0.2, R Core Team 2013), using the package "OIsurv" (Diez 2012).

animals were assumed to be alive (Fig 2a, c). Within these two extremes, *S* at four years post-release was estimated to vary between 0.38 and 0.74 (combined 95% confidence interval 0.19, 1), with mean survival times of between 23.1 and 37.2 months.

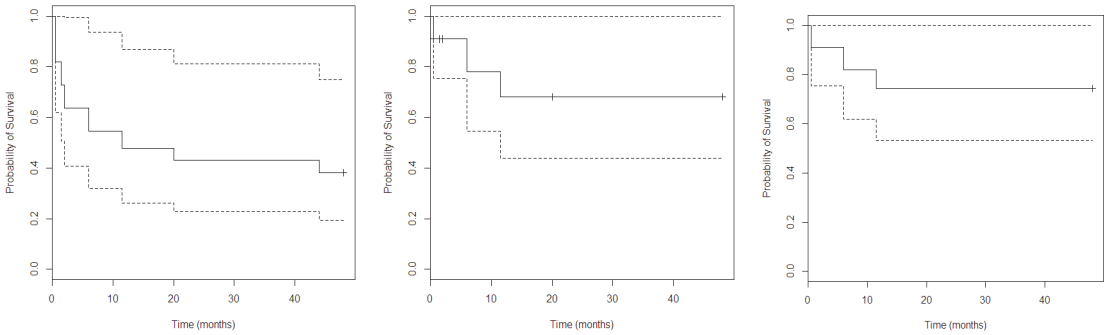


Figure 2. Kaplan-Meier estimates of the probability of survival of translocated beavers against time (in months) since release (shown with 95% confidence intervals). b) shows estimates based on actual beaver histories as in Table 1, and takes account of the loss of animals during the trial, compared with a) which shows a 'lower bound' that assumes all missing animals are dead, and c) which shows an 'upper bound' that assumes all missing animals are still alive.

Regardless of the imprecision of survival estimates, there is a clear pattern to survival over time that is common in reintroduction and translocation projects, insofar as most losses occurred within the first few months after release. Survival has tended to stabilise over time, with losses (of the original translocated animals) now being due to the occasional dispersal of animals that were released as sub-adults within their family groups, and more recently the loss (or possible death) of an older female (Fig 1, 2, Table 3).

Table 3. Kaplan-Meier estimates[1] of the probability of survival of translocated beavers at time t, where t = time in months since release.

T	*S*	SE	lower 95% CI	upper 95% CI
1	0.91	0.09	0.75	1
6	0.78	0.14	0.55	1
12	0.68	0.15	0.44	1
24	0.68	0.15	0.44	1
36	0.68	0.15	0.44	1
48	0.68	0.15	0.44	1

[1] Note that if all, or a high proportion of, the missing animals are dead, these estimates will overestimate the probability of survival.

4.2 Reproduction

No reproduction was expected in Year 1 (summer 2009) because no females were released (in May 2009) pregnant. During Year 1, females of the Loch Linne and Dubh Loch families may have become pregnant following mating in the winter of 2009/10, and thus could have produced kits at the beginning of Year 2 (summer 2010) but the Loch Buic pair and the Un-named Loch (north) pair had only just been released and so could not have reproduced. Thereafter, (from the winter of Year 2, with kits potentially produced at the beginning of Year 3 - summer 2011), four breeding pairs were present (but only two produced kits in 2011). In the third and fourth years of the trial, three of four beaver pairs successfully reproduced; litter

size (as assessed at time of emergence from the lodge) ranged between one and three kits. Throughout the trial, thus far, annual reproductive rate has ranged between 0.5 and 1.25 (defined as the proportion of pairs that successfully reproduce x the mean litter size, Table 4).

Table 4. Beaver reproduction in Knapdale (2009-2013). Data are number of pairs that could reproduce (N), proportion of pairs successful (p.pairs), mean litter size of successful pairs (ml), reproductive rate (Rr); where reproductive rate is defined as p.pairs x ml, and litter size is the number of emerging kits (as in Nolet et al. 2005).

Year	N	p.pairs	ml	Rr
2009	0	-	-	-
2010	2	1.0	1	1.0
2011	4	0.5	1	0.5
2012	4	0.75	1.67	1.25
2013	4	0.75	1.67	1.25

4.3 Survival of young wild-born animals

Of the total nine kits born at Knapdale between summer 2010 and summer 2012, only four (0.44) are known to have survived to 1 year of age. Of the three yearlings born two or more years ago, two or three (0.67 – 1.0) survived to become sub-adults, although only one appears to remain at the release site (at Loch Linne).

*Table 5. Known survival of wild-born beavers in Knapdale (2010-2013). Y = yes, survived, N = not survived (dead or missing – confirmed deaths are marked with a *). Note that missing animals ≥ 2 years probably dispersed (this behaviour is expected).*

Name	Year of birth	Loch	Survival to 1 year	Survival to 2 years	Survival to 3 years
Barney	2010	Loch Linne	Y	Y	Y?[1]
2	2010	Dubh Loch	Y	Y	N
Logan	2011	Loch Linne	Y	Y?[1]	
4	2011	Dubh Loch	N*	-	
5	2012	Loch Linne	N*		
6	2012	Dubh Loch	N		
7	2012	Dubh Loch	N		
8	2012	Dubh Loch	N		
Woody	2012	Loch Buic	Y		
10	2013	Dubh Loch			
11	2013	Dubh Loch			
12	2013	Loch Buic			
13	2013	Loch Buic			
14	2013	Loch Linne			

[1] One of these two individuals is still alive and present at Loch Linne, it is not currently clear which one.

4.4 Population structure

Beavers were released in five 'family' groups (of between two and four individuals); three families (released in 2009) included one to two sub-adults each (i.e. the breeding pair plus one or two immature offspring), the other two families (released in 2010) were released as breeding pairs. (The subsequent discussion excludes the Creagmhor family, released in 2009, which did not settle and establish a home range at the site - see Table 1, and Harrington *et al.* 2011, 2012). Of the two families with sub-adults that settled at the release

site, one sub-adult in each family – Marlene from the Dubh Loch family, and Biffa from the Loch Linne family - had dispersed by the end of the second year post-release[7] (one of the sub-adults – Biffa's brother from the Loch Linne family - also died shortly after release); only the Dubh Loch family still includes one of the released sub-adults – Millie[8] - at the end of the fourth year post-release (Table 6).

At the end of the fourth year of the trial (June 2013), and not including kits born in the summer of 2013, maximum family size was three. The Loch Linne family included at least one of their wild-born sub-adults (although it is not clear whether this was the sub-adult or the yearling from 2012), but no yearlings (the kit born in summer 2012 was predated as a kit, see Table 2)[9]. Since the disappearance of the sub-adult on Dubh Loch (during summer 2012), the Dubh Loch family (as of June 2013) consisted only of the three adults (all three kits from summer 2012 are now missing, fate unknown, Table 2, 6). Trude from the Loch Buic pair was suspected pregnant in summer 2011 (note that the male partners of each of these pairs exchanged places sometime between April and October 2011) but did not successfully produce kits. Trude produced one kit in summer 2012, that is now a yearling and remains with the adult pair at Loch Buic. There were signs that Elaine from the Un-named Loch (north) pair was pregnant in both 2011 and 2012, but no kits were ever observed and this female has now disappeared or died (see Table 1, 2), leaving only the adult male at Un-named Loch (north).

The Loch Linne, Dubh Loch and Loch Buic families continued to successfully produce 1 or 2 kits[10] in 2013 (above). As of October 2013 (including preliminary reproductive data from Year 5), the four extant beaver 'families' were composed of one to three adults (at the un-named Loch (north) there is only a single adult male), zero to one subadults or yearlings, and one to two kits (Table 6).

[7] Marlene disappeared the same summer of her release (see Table 1).
[8] Millie is now (at the end of Year 3) considered an adult; she gave birth to either some or all of the kits at Dubh Loch in the summer of 2012 (it is not known whether Katrina, the older female, also gave birth that year, Table 2, 3).
[9] It is currently unclear whether there are one or two sub-adults present, and, if only one, which individual it is (the sub-adult Barney, or the yearling from 2012, see Table 2).
[10] Note that because kits are counted as they are observed emerging from the lodge, litter size at birth may be underestimated.

Table 6. Changes in beaver family composition (post-kit emergence) at Knapdale (2009 – 2012). Non-breeding beavers that are 2 years of age or older are considered sub-adults; breeding animals are considered adults. (This summary excludes the original Creagmhor family that failed to settle).

Family	**2009**[1]	**2010**	**2011**	**2012**	**2013**
Loch Linne	Adult male Adult female 2 sub-adults	Adult male Adult female 1 sub-adult 1 kit	Adult male Adult female 0 sub-adults 1 yearling 1 kit	Adult male Adult female 1 sub-adult 1 yearling 1 kit (predated)	Adult male Adult female 1 sub-adult 1 kit
Dubh Loch	Adult male Adult female 2 sub-adults	Adult male Adult female 1 sub-adult 1 kit	Adult male Adult female 1 sub-adult 1 yearling 1 kit (predated)	Adult male 2 Adult females[2] 1 sub-adult[3] 0 yearlings 3 kits	Adult male 2 Adult females[2] 2 kits
Loch Buic	-	Adult male Adult female	Adult male Adult female[4]	Adult male[5] Adult female 1 kit	Adult male[5] Adult female 1 yearling 2 kits
Un-named Loch (north)	-	Adult male Adult female	Adult male Adult female	Adult male[5] Adult female	Adult male[5]

[1] as released.
[2] Millie (released as a sub-adult, is now a breeding female in the group; it is not clear whether Katrina is still breeding).
[3] This wild-born sub-adult (unconfirmed sex) went missing in the summer 2012.
[4] Suspected pregnant but no kits produced.
[5] Male partners exchanged places between the Loch Buic and Un-named Loch (north) pair in early summer - autumn 2011.

4.5 Population growth

The number of beaver families present at Knapdale has remained constant at four, and although the size of three of the four families appeared, in earlier years, to be increasing due to wild births, as of the beginning of the fifth year of the trial, there has been little or no net increase in family size (due to loss of kits, and disappearances of wild-born sub-adults, Table 2, 5, 6). Since 2010, a total of 14 kits have been produced but only 7 (including 4 kits born in summer 2013) are currently confirmed to remain in the population (as of October 2013).

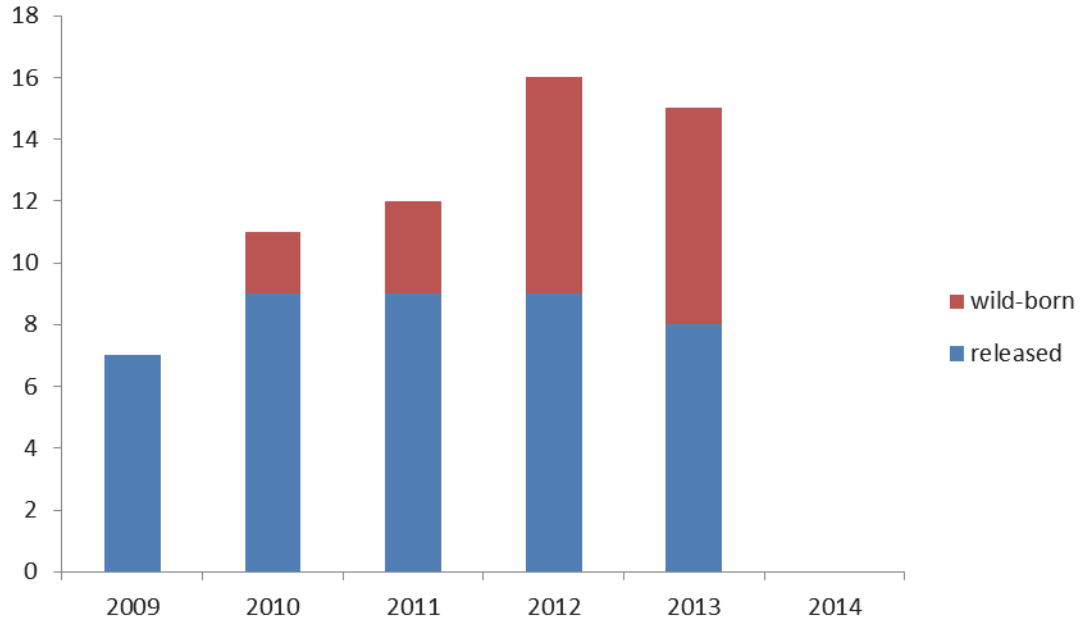


Figure 3.Total number of beavers present in Knapdale in August of each year.

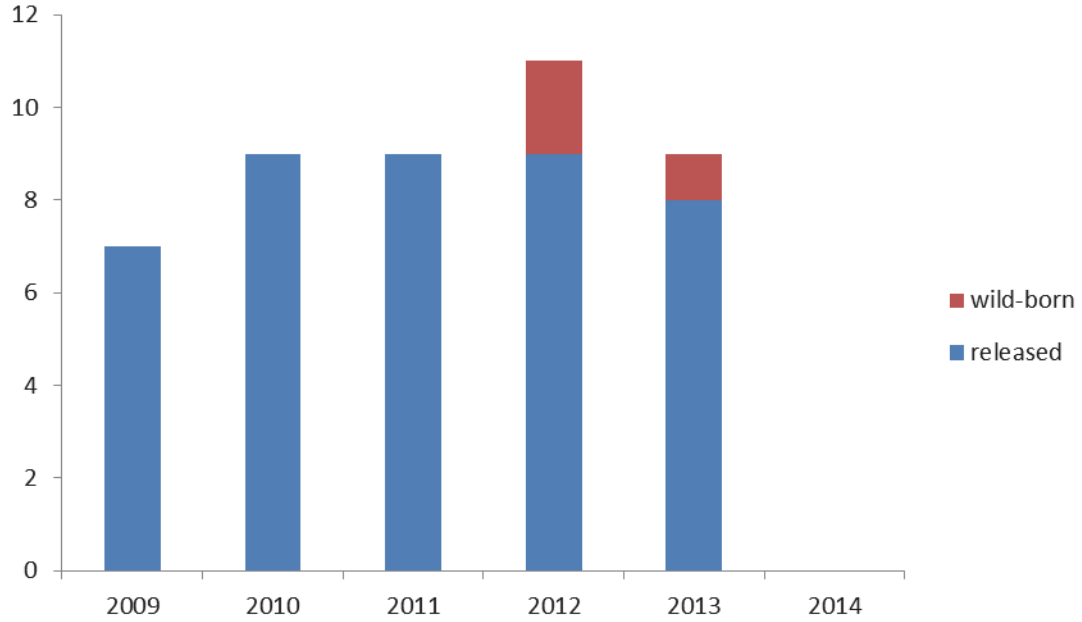


Figure 4. Total number of sub-adult and adult beavers (including all beavers two years of age or older, i.e. breeders and non-breeders in family groups) present in Knapdale in August of each year.

A total of five sub-adults (three released, two wild-born) may have dispersed, but the low numbers and the fact that they (presumably) left the occupied area in different years mean that the chances of individual beavers (of opposite sex) meeting and forming new families is low. The two most recent presumed dispersals were the wild-born two-year-old of unknown sex from the Dubh Loch (last seen in May 2012) and one of the wild-born male sub-adults from Loch Linne.

4.6 Mortality

Of the total 16 animals released, three deaths were recorded (all during the first year of the trial, and all male), equating to a post-release mortality rate of 0.19 (or approximately 20%). Andreas Bjorn was found in poor body condition and withdrawn from the programme in December 2009 (seven months post-release) and died five months later in captivity of heart failure. Tallak died a couple of weeks post-release and post mortem results suggest that he did not feed, most likely due to an individual failure to cope with the stress of change in environment (S. Girling, RZSS, pers. comm.). Andreas Bjorn and Tallak were both older males (at least 7, and at least 13, years old, respectively, Frode Bergan, Telemark University College, unpub. data[11]). The only younger (two year old) male to die post-release, died overnight on the day of release; this animal was found to have lung, liver and kidney congestion suggestive of sub-acute circulatory failure[12] (G. Goodman, pers. comm.). Beaver health is being monitored by the Royal (Dick) School of Veterinary Studies, and further details will be available in a separate report at a later date.

Of the 14 kits born at Knapdale (to date, October 2013), two were predated (one in summer 2011 and one in summer 2012). This equates to a total kit mortality rate of 0.22; and yearly kit mortality rates of 0.5 and 0.2, respectively. It is not clear, however, whether the one predation rate observed per year thus far is likely to increase proportionally with an increase in the number of kits produced, or whether they were both rare chance events. All three of last year's kits at Dubh Loch are now missing, but they were last seen in January 2013, and were over 6 months old at the time of disappearance when they would have weighed over c. 5 kg, and were presumably less susceptible to predation. It is currently unconfirmed (and unlikely that we will be able to confirm) whether or not these animals died, or, if so, what the cause of death might have been.

4.7 Population persistence

Towards the end of the trial we will carry out simple population viability modelling using VORTEX in order to make preliminary assessments of likely persistence of beavers at Knapdale, based on current population size and population growth rates observed during the trial. This will be included in next year's final report.

4.8 Comparisons with beaver reintroductions elsewhere in Europe

Although there have been a number of beaver reintroductions throughout Europe (reviewed in Halley and Rosell 2002; Dewas*et al*. 2012), few documents reveal data in sufficient detail to make comparison with the Knapdale population. The best documented reintroduction of beavers is the Biesbosch population reintroduced to the Netherlands between 1988 and 1991 (Nolet and Baveco 1996; Nolet*et al*. 2005). The beaver population in the Biesbosch experienced low reproductive rates in the initial years of establishment (due to low quality food associated with climatic changes). For comparison, annual reproductive data for the Biesbosch population were as follows: proportion of pairs that successfully bred = 0.25-0.77;

[11] Animal age was confirmed by cementum analysis of teeth taken from the carcasses; from a welfare point of view it would be ideal to know the age of the animals before the decision was made to trap them from the wild for translocation, but this was not possible in this case.
[12] There was no evidence of infection or degenerative disease (G. Goodman, pers. comm.).

mean litter size (per successful pair) = 1-3.33; reproductive rate (mean juveniles/pair – for all pairs) = 0.5-1.46. Thus far, the proportion of pairs that successfully bred at Knapdale compares favourably (0.75 pairs breeding in 2012 and 2013) but mean litter size is similar to that in the Biesbosch (current range 1-3) (see Table 4 above).

During Year 5, we will seek further comparative data, from reintroductions elsewhere in Europe and, in the final report will attempt to draw further more detailed comparisons with these, as far as possible, and with the wild source population in Norway (if comparative data are available).

4.9 Questions relevant to the success/failure criteria of the trial

Here we outline some initial thoughts on the questions posed at the beginning of the report. We will not be able to draw proper conclusions until the end of the trial and stress that these notes are preliminary and based on an incomplete dataset.

Are survival/mortality/reproductive rates similar to those of successful reintroduction programmes elsewhere in Europe at a similar stage of establishment?

Survival (of translocated animals) appears to be influenced predominantly by early post-release mortality. Early losses of animals (within seven months of release, most within two weeks) were relatively low (20%) (compared with reintroductions in general), but considerably higher than losses of 2% reported by Bajomi (2011) for the release of 234 beavers in Hungary in the late 1990s (which led to an established population of an estimated 700-900 animals over c. 16 years). Mortality of established animals, however, appears to be low.

The proportion of pairs successfully breeding compares favourably with the Biesbosch population but litter size and overall reproductive rates are similar (and reproduction at Biesbosch was known to be low). In general, beaver reproduction at Knapdale has been slow to establish, due in part to some animals not being present until 2010, as well as new pairings (see Table 1), and, possibly, inexperience (for some beaver pairs – the Loch Buic and Un-named Loch (north) pair) or even old age of the mother (which may be applicable to Katrina and Frid – the adult females released at Loch Coille-Bharr/Dubh Loch and Loch Linne, respectively).

Is the core population stable or increasing?

The beaver population present at Knapdale is currently increasing but only slightly and only very slowly. The number of adults is increasing slowly, but limited growth of the sub-adult and adult population would be expected over the duration of the trial because of the length of time required for a wild-born beaver to reach sub-adulthood and the small number of families (see Fig 2, 3, above). Since last year (2012) growth rate seems to have slowed further due to the loss of sub-adults and low survival of wild-born kits.

Are mortality levels likely to preclude establishment of a population?

Mortality of established animals appears to be relatively low thus far. All beavers appear to be in good health and body condition (Roisin Campbell-Palmer, pers. comm.), which suggests that the population could potentially grow. However, mortality of kits (presuming that all three 2012 Dubh Loch kits died) appears to be high and largely responsible for the slow growth of the population.

4.10 Data requirements

The low numbers of beavers released mean that estimation of population parameters (particularly age-specific survival of wild-born animals, and reproductive rates) at Knapdale will be imprecise and may be biased by the large influence of possible chance events (e.g. predation of kits) or demographic effects (e.g. age of the breeding females). To improve our knowledge of beaver population dynamics in a Scottish context, further study of reproductive rates in particular from the larger beaver population in the Tay catchment, would be useful to complement the SBT data. Although the Tayside population differs from the Knapdale population insofar as there was no pre-release monitoring, there are no details on the size of the founder population, and we are unable to infer anything about early population growth and population establishment on the Tay, the current Tayside population may provide very useful cross-sectional information on dynamics of an established population. Monitoring of the Tayside population is now going ahead, co-ordinated by the Tayside Beaver Study Group (taysidebeaverstudygroup.org.uk).

The trial will end in May 2014 and therefore, summer 2013 will be the last year of reproductive data from Knapdale as part of the trial. We will be unable to report on reproductive success at Knapdale in 2014.

5. BODY CONDITION

We report here basic measures of body condition for animals that survived six months or more post-release, and for wild-born animals that were captured and assessed. Detailed data on the health of the beavers at Knapdale will be reported on by the Royal (Dick) School of Veterinary Studies.

Thus far, for surviving animals, there has been no evidence of a declining body weight or condition post-release, and wild-born animals appear to be in good body condition (although data on the latter is limited).

5.1 Trap success and data availability

Pre-release data were missing for two individuals (Bjornar and Millie).

Not all animals have been trapped in all years, and the animals on Dubh Loch are particularly difficult to trap because trapping on this small loch is limited to cage trapping, which is more difficult than trapping by boat for individuals that are trap-shy (see Annex 1, and methodological protocols published in Campbell *et al.* 2010). Neither Bjornar nor Katrina (both on Dubh Loch) have been trapped since 2011, Biffa (from the Loch Linne family) was not trapped in 2010 (the year before he disappeared – presumably dispersed), and Eoghann (on Loch Buic) has not been trapped since October 2011. All of these animals (with the exception of Biffa) were, however, observed regularly through 2012 and 2013, and Bjornar, Katrina and Eoghann were deemed by field staff to be in good body condition.

5.2 Body weight of released beavers

All released beavers at Knapdale (at their last assessment, Table 7) appeared to be within the expected body weight range for Eurasian beavers, and were comparable in body weight to beavers in Norway (see Campbell *et al.* 2010, p50). Over the three-four years since release, there was no evidence that any of the beavers that had survived six months or more had been losing weight since release (Fig 5a). Two females had gained weight since release: Elaine was released as a 12.5 kg, two year old, and has gained 3.5 kg since release[13]; Trude was also released as a young adult (two years old), she was initially small for her age (8.5 kg just before release) and has since gained 8.5 kg[14] (this is normal age-related weight gain for beavers). Frank and Katrina increased substantially in body weight immediately post-release but, more recently, their weight appears to have declined (which is also probably normal for older individuals; more recent data for Katrina were not available but field observations suggest that she is in good body condition).

5.3 Tail thickness index as a measure of body condition of released beavers

Tail thickness is a standard measure of body condition in beavers (Smith & Jenkins 1997). To provide a standardised metric, tail thickness was measured at four standard points on the tail (details in Campbell *et al.*2010) and recorded as the mean of the four separate measures (Table 7). Over the three-four year release period thus far, there was no evidence of a decreasing tail thickness index in any of the beavers that had survived six months or more post-release (Fig 5b).

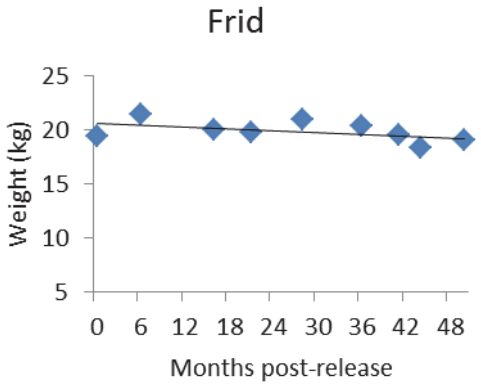
[13] The trend of increasing body weight over time (slope of the relationship = 0.12) was statistically significant ($p = 0.008$).

[14] In this case, the trend of increasing body weight over time (slope of the relationship = 0.22) only approached statistical significance ($p = 0.056$), but it is clear that there was a net gain in body weight between pre-release and approximately 18 months post-release.

Table 7. Morphometric data for 10 adult and sub-adult beavers released at Knapdale that survived ≥ six months post-release. Data are Body weight: latest body weight (kg), (date recorded), body length (measured as the distance between the nose and the base of the tail, following the spine) (cm); Tail thickness index (mean of four separate measurements, see text): latest index (cm), (date recorded – where this was not the same as for body weight).

Animal	Sex	Approx. age[†]	Latest body weight (date/length)	Tail thickness index
Frid	Female	Adult 7+	19.0, (08/2013), 79.5	1.86
Frank	Male	Adult 6+	19.0, (11/2012), -	1.68
Biffa	Male	Sub-adult 2	13.9, (12/2009), 70.5	1.62
Bjornar	Male	Adult 7+	20.4, (06/2011), 79.5	2.64
Katrina	Female	Adult 7+	18.2, (03/2011), 78.0	2.30
Millie	Female	Adult 6	20.5, (07/2013), 74.0	1.76
Trude	Female	Adult 5	17.0, (07/2013), 69.0	1.70
Eoghann	Male	Adult 5	17.0, (10/2011), 75.0	1.79
Elaine	Female	Adult 4	16.0, (12/2012), 75.0	2.43, (09/2012)
Christian	Male	Adult 6	20.5, (09/2013), 78.0	1.61

[†]Minimum age (years) at date of assessment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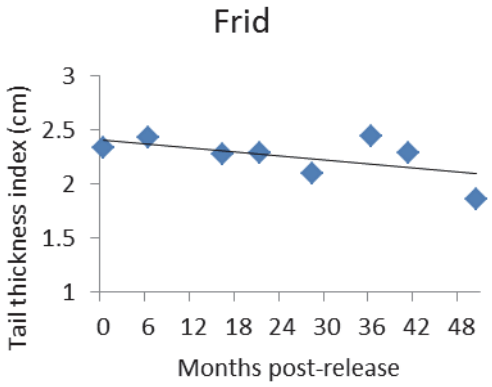
Months post-release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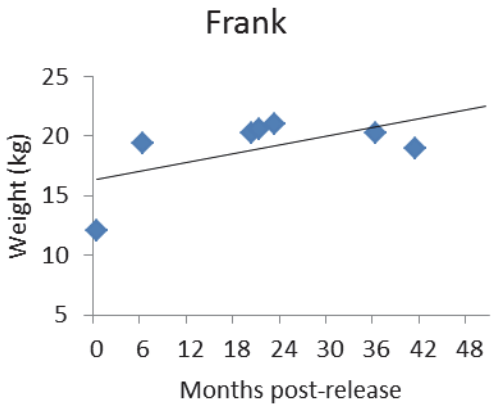
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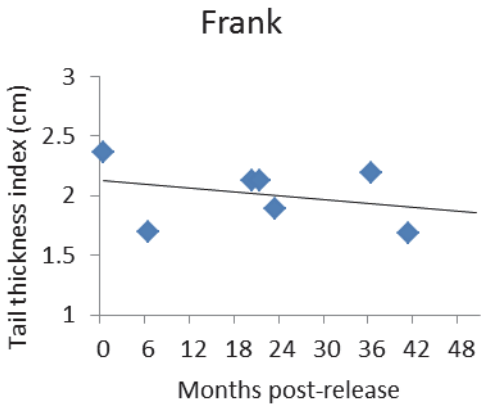
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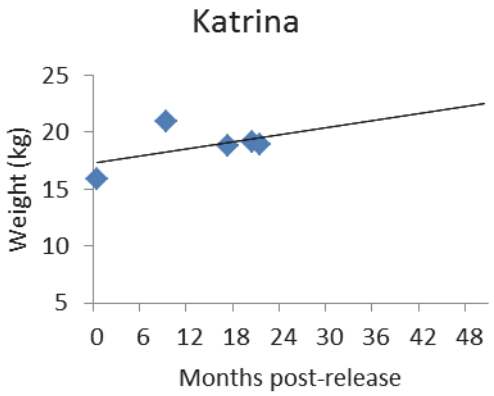
Katrina
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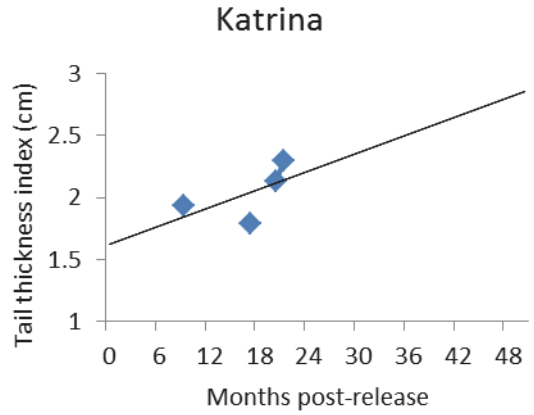
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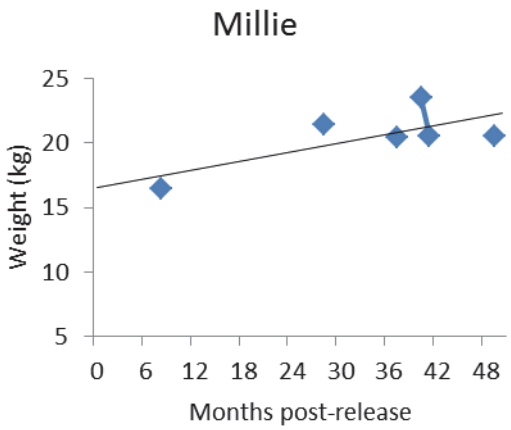
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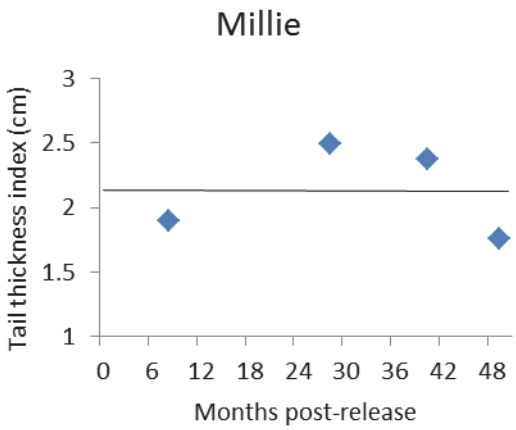
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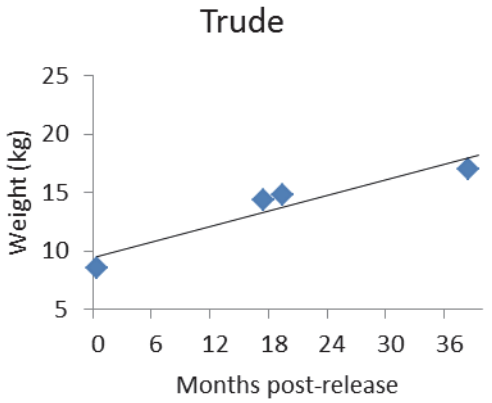
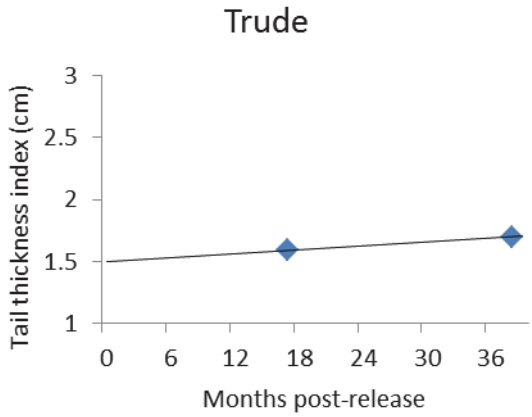
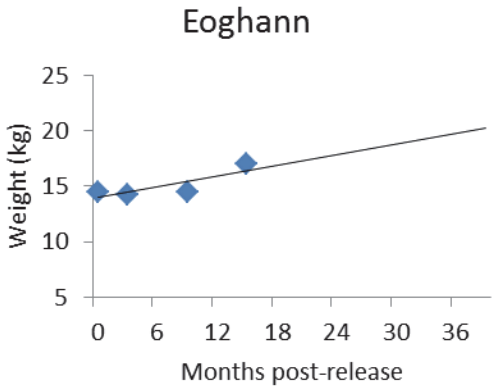
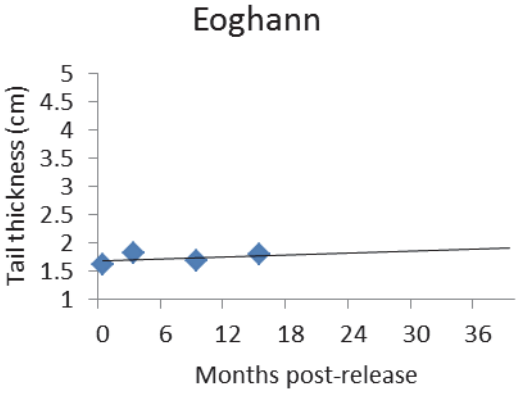
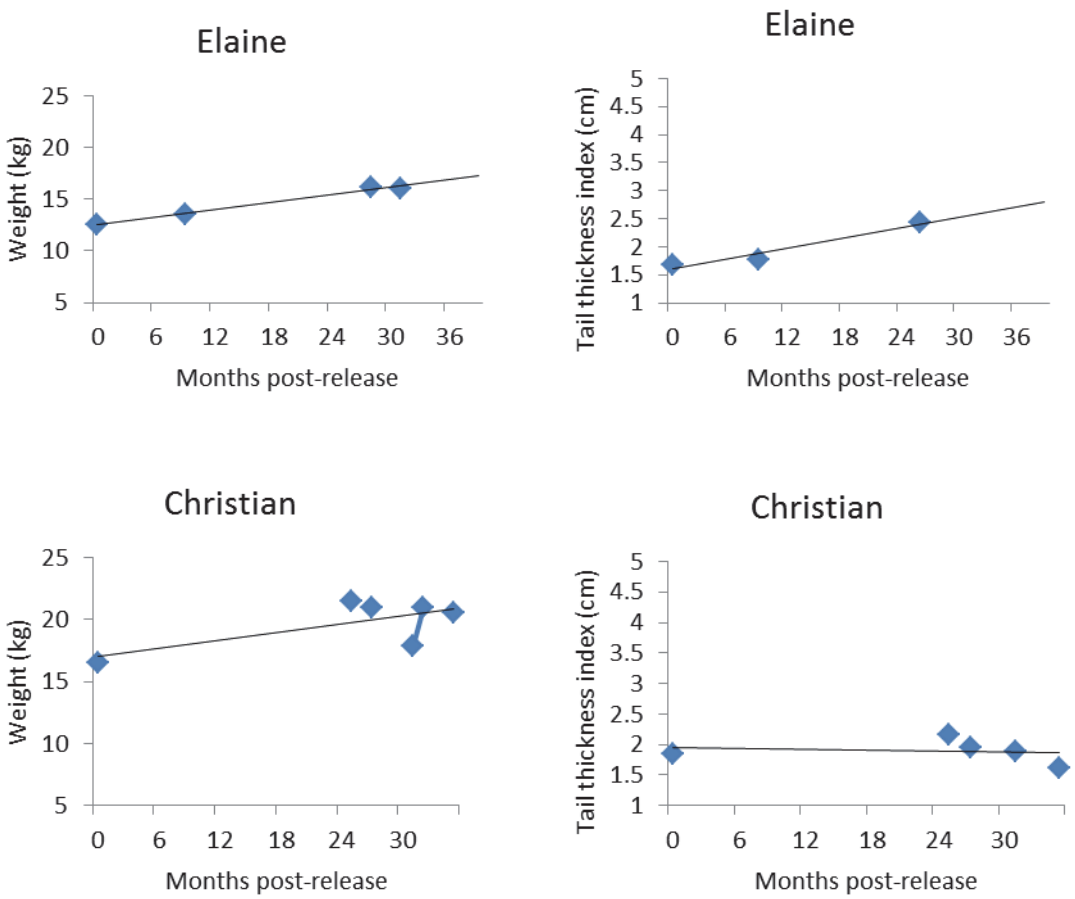
0 6 12 18 24 30 36 42 48
Months post-release


Trude
Weight (kg)
25
20
15
10
5
0 6 12 18 24 30 36
Months post-release


Trude
Tail thickness index (cm)
3
2.5
2
1.5
1
0 6 12 18 24 30 36
Months post-release


Eoghann
Weight (kg)
25
20
15
10
5
0 6 12 18 24 30 36
Months post-release


Eoghann
Tail thickness (cm)
5
4.5
4
3.5
3
2.5
2
1.5
1
0 6 12 18 24 30 36
Months post-release



a) b)

Figure 5. Body weight (a) and tail thickness index (b) of adult and sub-adult beavers released in Knapdale against time since release (in months). Note that some individuals have been monitored for four years and some for three years. Trend lines are shown only for illustrative purposes and, with the exception of trends for body weight for Trude and Elaine (see footnote 14 and 15), the slopes of the relationships were not statistically significant ($p > 0.05$). There were insufficient data to assess seasonal trends but decreases might be expected to occur in winter or towards the end of winter (in the above graphs, December occurs at 6 or 7 months [and multiples thereof] post-release).

5.4 Size and body condition of wild-born beavers

Three of the four wild-born animals at Knapdale have been captured, measured and marked (Table 8). The second wild-born beaver at Loch Linne was small as a yearling but in good body condition. The yearling female from Loch Buic (Woody) was in relatively poor body condition at first capture (at 4-5 months old), and has gained little weight during her first year; this beaver has a heavy infestation of beaver beetles (*Platypsyllus castoris*, see Duff *et al.* 2013). A fourth surviving wild-born beaver (of unknown sex) went missing from Dubh Loch (presumably dispersed) at two years old (in summer 2012) and was not captured and marked.

Table 8. Morphometric data for three wild-born beavers at Knapdale. Morphometrics are: body weight (kg), body length (cm), body condition (tail thickness index, cm).

Animal	Sex	Date	Age	Morphometrics
Barney	M	06/2011	1 year	8.4, 59, 1.48
Logan	M	06/2012	1 year	6.3, 55, 1.18
Woody	F	10/2012	4-5 months	3.6, 39, 1.03
		05/2013	c. 11 months	4.8, - , 0.95

5.5 Comments

Animals were not trapped immediately post-release so it was not possible to assess their body condition in the first few weeks/months post-release. Also, because the time of year that individual beavers were assessed varied over the years, apparent changes (or lack of change) in body weight and tail thickness must be interpreted with caution and it is difficult to disentangle seasonal effects from real health issues. However, the time of year that animals were trapped was dictated not only by logistical constraints, but also by trap success (which clearly varied considerably among individuals), and was thus (to some extent) beyond the control of the field team. Further, and arguably more importantly, animal trapping and handling, and the data that can be gathered from the process, has to be balanced against animal welfare costs and possible stress caused to the animals by repeat trapping and handling. Considering these various issues, we deemed the data sufficient to be able to report that there was no evidence of poor health at a population level, or that poor condition occurred in response to release. Unfortunately, the Knapdale population is not large enough (since poor health in some individuals may have arisen due to chance effects) to allow meaningful comparisons of beaver health in Norway or the Tayside catchment.

6. ECOLOGICAL DATA

6.1 Density of beavers within the release area

Figure 6 shows locations of beaver observations and of beaver field signs recorded during the fourth year of the trial, overlaid on the total area occupied by beavers in the previous year (the third year of the trial). There was no evidence of a change in the total area occupied by beavers at Knapdale. In the third year of the trial the four beaver families covered a total area of 422.8 ha, incorporating seven lochs (of which six were utilised; only Losgunn (the small loch north of Loch Buic) appeared to remain unused by beavers, and this remains the case in Year 4) (Figure 6). The current 'beaver range' incorporates approximately 21.5 km of loch or river bank of which all, minus 4.2 km, appears to be used by beavers. Considering all loch/river bank length available within the occupied range, this equates to a density of c. 0.22 beaver families per km of waterway edge (or, on average, one beaver family per 4 km of waterway edge).

Beaver range size, and the length of loch/river bank length, was calculated in ArcGIS 10.0 (www.esri.com). Beaver range size was estimated based on the smallest convex polygon[15] that enclosed all beaver locations (observations and field signs – field methods in Annex 1) recorded in Year 3. The length of loch/river bank length within the beaver range was measured as the length of waterway edge within that convex polygon.

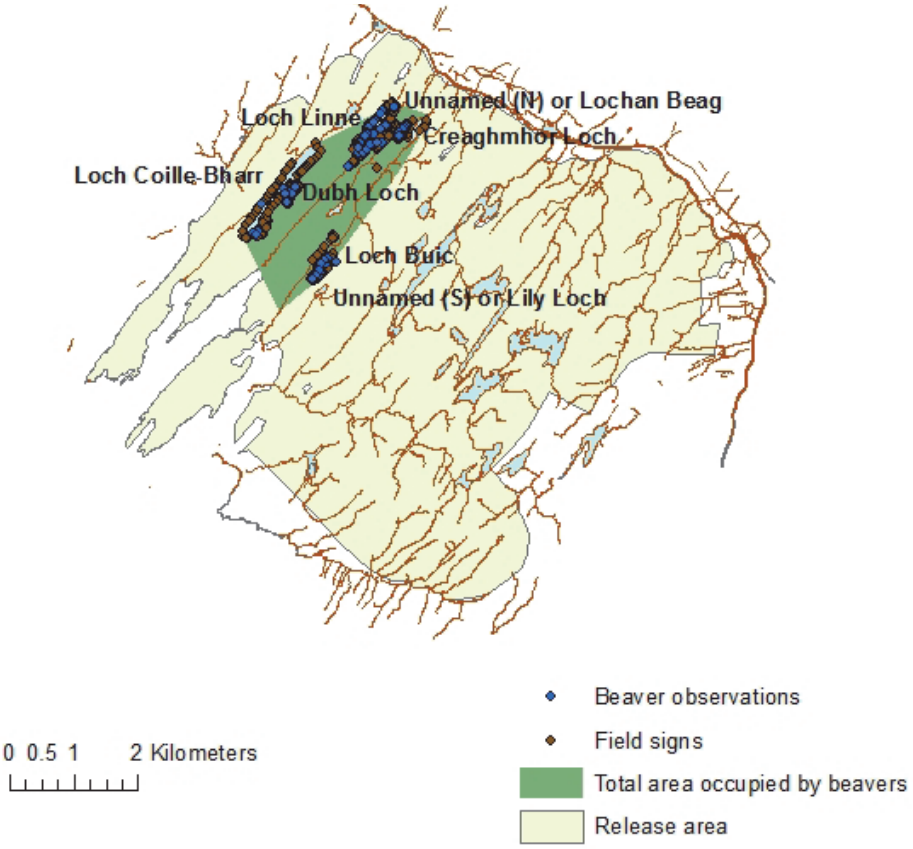


Figure 6. Area occupied by beavers at Knapdale, Argyll, in Year 3 of the trial showing no change in Year 4. Note that Un-named Loch (south) now falls outside the occupied area.

[15]Generated using the Minimum Bounding Geometry function in ArcGIS.

6.2 Number and size of territories formed

Beavers currently remain in four discrete family territories, although there have been changes in the membership of those territories over the last year (see Table 1 above). There have been some minor shifts in focus of activity (see Figures 5 - 8 below), but otherwise all families, with the exception of the Loch Buic family, continued to use their release area. Territory sizes and areas of use in Year 4 were broadly similar to those of Year 2 and 3.

To estimate territory size we used both observational locations and field sign locations (see Annex 1). Territory sizes were estimated at the family level; we did not estimate individual territories (see Harrington *et al.* 2011). At the time of writing this report, two families had been released four years previously, two other families (released as pairs) were released only three years ago (see Table 1 above).

Year 2 territory sizes were calculated in Ranges 7 (www.anatrack.com). On the basis of preliminary analyses in Year 1 (Harrington *et al.* 2011), we considered 100% restricted edge polygons (REPs)[16] (using a restriction distance of 0.2) to provide the most appropriate estimate of territory area. For comparability with other studies of beavers, and in accordance with Herr and Rosell (2004), we also calculated 100% minimum convex polygons (MCPs), and measured the length of waterway edge within the polygon defined by the MCP to provide an estimate of the length of river/loch bank used over the year. Loch/river bank lengths were calculated in ArcGIS 10.0 (www.esri.com). Year 4 locations were overlaid on Year 2 home range polygons in ArcGIS and territory sizes recalculated if there appeared to be any significant change in the area used between Year 2 and Year 4.

In all cases, field signs were inferred as belonging to a particular family on the basis of location – this is currently possible at Knapdale because the majority of field signs occur in relatively clear clusters. Outlying field signs, which were few, were not included in home range polygons. Observational locations were only used in Year 4 analyses if individual identity had been confirmed.

[16] Minimum convex polygons (MCPs) are the smallest polygon that can be drawn around a set of locations where the external angles are all greater than 180º. 100% MCPs include all locations within the polygon; they are a widely used technique and are therefore particularly useful for comparisons among studies. The area and shape of MCPs are heavily influenced by outlying locations and restricted edge polygons (or concave polygons) may provide a better method if MCPs include large areas that are not visited by the animal (e.g. a patch of unsuitable habitat). REPs are constructed by drawing lines between edge locations in the same way as for MCPs except that lines are only drawn if they are shorter than a selected fraction of the range width (the 'restriction distance'; 0.2 in this case), resulting in a concave range where linkages between edge locations are long. The restriction distance, in this analysis, was selected as the smallest distance that did not result in fragmentation of the range (as used by Harrington and Macdonald 2008).

6.2.1 Loch Linne family (previously Family 2)

This family is in their fourth year post-release.

Data available for Year 4: 540 field signs, 152 observations (of which 133 were of identified individuals).

Individual beavers present during Year 4: one adult male (Frank), one adult female (Frid), one sub-adult (Barney), and one yearling (Logan).

Territory size was estimated in Year 2 as 24.7 ha using REP (or 27.3 ha using MCP, which contained 3.7 km loch bank). There did not appear to be any significant change in territory size or location from Year 2; nor did there appear to be any significant increase in the length of waterway used (Fig. 7). Some increase in the intensity of use (as evidenced by field signs) was apparent – this was most evident in the south-west corner of the loch, and the eastern point of the loch (see Fig. 5) – but the overall spatial pattern of use remained the same as in previous years. Field signs in Year 4 were recorded 65 - 70 m outside the Year 2 REP, and 30 m outside the Year 2 MCP.

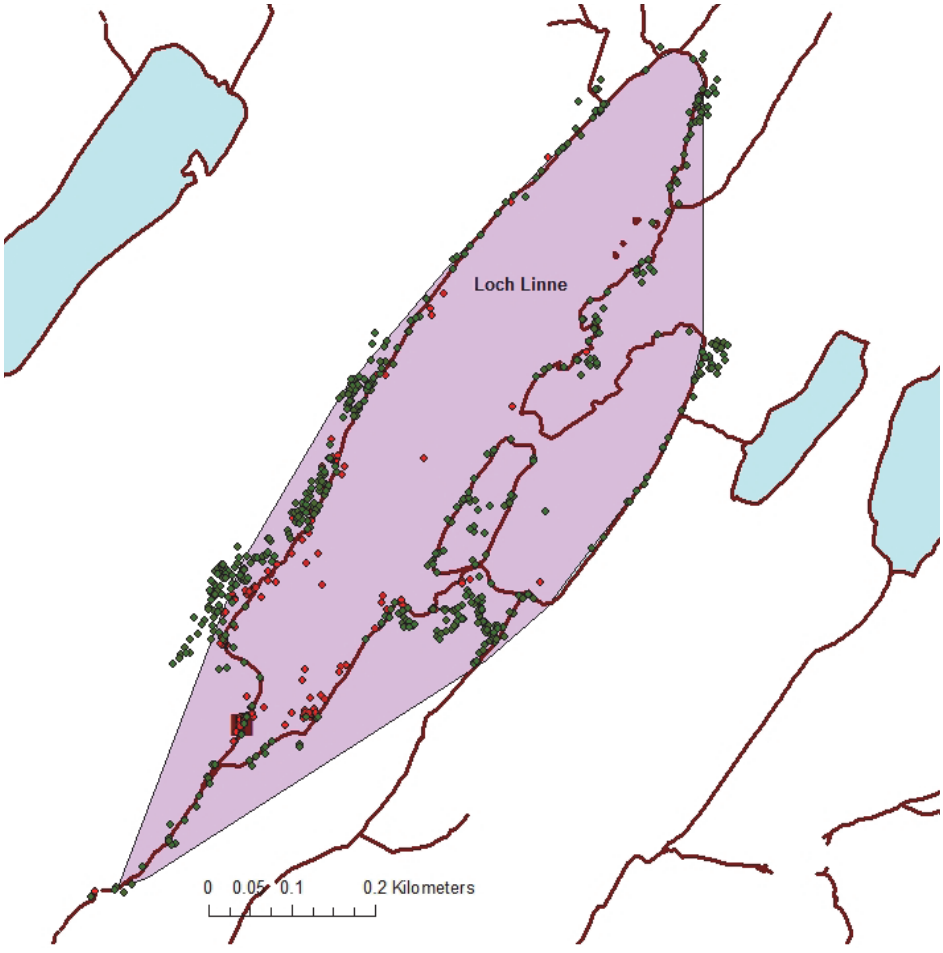


Figure 7. Schematic of the Loch Linne family territory in Year 2 and Year 4 of the trial. Year 2 home range polygon (MCP) shown in purple, Year 4 locations in red (identified and unidentified observations) and dark green (field signs). The original release area is indicated by the brown square. The pale blue areas are the lochs. This family exclusively occupies Loch Linne (the second largest loch in the release area) and a small section of the stream to the south-west of the loch.

6.2.2 Dubh Loch family (previously Family 3)

This family is in their fourth year post-release.

Data available for Year 3: 303 field signs, 149 observations (of which 119 were of identified individuals).

Individual beavers present during Year 4: one adult male (Bjornar), two adult females (Katrina and Millie), one 2 year-old sub-adult (until at least 04/07/2012[17]).

Territory size was estimated in Year 2 as 41.9 ha using REP (or 48.3 ha using MCP, which contained 4.5 km loch bank). There did not appear to be any significant change in home range size or location from Year 2 to Year 4; nor did there appear to be any increase in length of waterway used (Fig. 8). Only three field sign locations fell outside the Year 2 home range polygon, all of which were on the loch bank on short stretches of bank previously unused (or undetected); all locations were within 15 m of the Year 2 MCP.

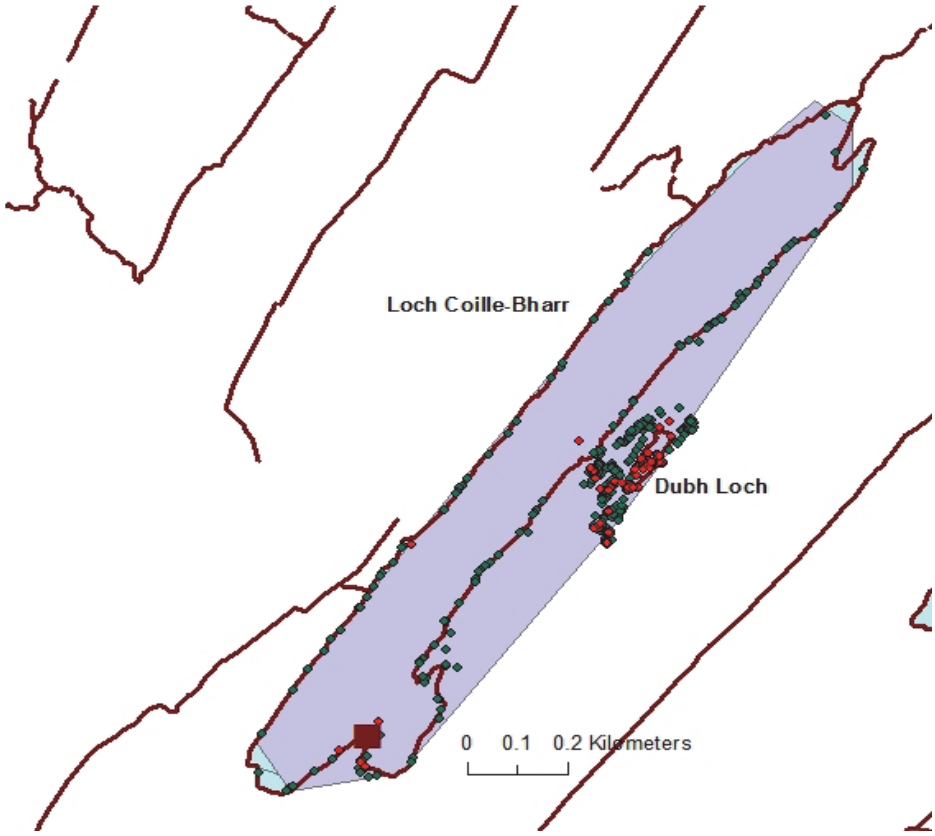


Figure 8. Schematic of the Dubh Loch family territory in Year 2 and Year 4 of the trial. Year 2 home range polygon (MCP) shown in purple, Year 4 locations in red (identified observations) and dark green (field signs). The original release area is indicated by the brown square. The pale blue areas are the lochs. As in Year 3, there was particularly intensive activity (as evidenced by field signs) around Dubh Loch, but fresh field signs were also found around the entire perimeter of the larger Loch Coille-Bharr (the largest loch in the release area) in all years, and Bjornar, Millie and the wild-born sub-adult were all observed on Loch Coille-Bharr in Year 4.

[17] Date of last identified sighting (see Table 1).

6.2.3 Loch Buic family (Trude and male partner) (previously Family 4)

This family is in their third year post-release.

Data available for Year 4: 172 field signs, 112 observations (of which 78 were of identified individuals).

Individual beavers present during Year 4: one adult male (Eoghann), one adult female (Trude) and one kit-yearling (Woody).

Territory size was estimated in Year 2 as 14.0 ha using REP (or 25.0 ha using MCP, which contained 3.0 km loch bank). There was an apparent contraction in the area used between Year 2 and 3: the Un-named Loch (south) or 'Lily Loch' appeared to no longer be used (and that remains the case in Year 4). Year 3 territory size was estimated as 10.8 ha using REP_0.3[18] (or 15.2 ha using MCP), both of which are clearly over-estimates[19] since they include a large amount of unused area between the loch and the stream (shown for MCP in the schematic below). The length of loch/river bank used in Year 3 was estimated as 2.26 km including all rivers within the MCP (evidence that the field signs on the stream to the north-west of Loch Buic belonged to this family was provided by GPS data showing the movements of the adult female, Trude, see Harrington *et al.* 2013). All Year 4 field signs occurred within 5 m of the Year 3 MCP (Fig. 9).

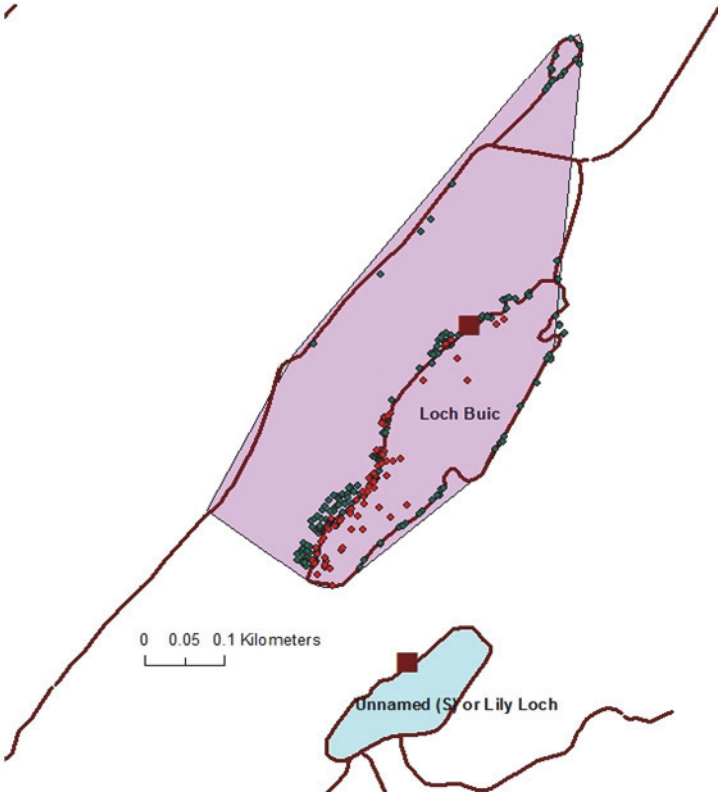


Figure 9. Schematic of the Loch Buic family territory in Year 2 and Year 3 of the trial. Year 3 home range polygon (MCP) shown in purple, observations in red, field signs in dark green. The original release area is indicated by the brown square. The pale blue areas are the lochs.

[18] REP using a restriction distance of 0.2 resulted in a fragmented range so a restriction distance of 0.3 was used in this case.
[19] Year 2 territory size estimates were also likely over-estimates for the same reasons.

6.2.4 Un-named Loch (north) family (Elaine and male partner) (previously family 5)

This family is in their third year post-release.

Data available for Year 4: 204 field signs, 81 observations (of which 72 were of identified individuals).

Individual beavers present during Year 4: one adult male (Christian), one adult female (Elaine – last seen 03/02/13). There were no wild-born young in this family.

Territory size was estimated in Year 2 as 7.8 ha using REP (or 9.5 ha using MCP, which contained 1.5 km loch bank). There was some apparent increase in the size of the territory and in the length of waterway used in Year 3 due to the extended use of Un-named Loch (north) (see Figure 8). Year 3 territory size was estimated as 10.2 ha using REP_0.2 (or 11.6 ha using MCP, which contained 1.8 km loch bank). All Year 4 field signs were within 10 m of the Year 3 MCP (Fig. 10). In Year 3, the female beaver was observed predominantly on Un-named Loch (north), and there was particularly intensive activity (as evidenced by field signs) around this lochan, but fresh field signs were also found around the entire perimeter of the larger Loch Creagmhor where the female – Elaine - was originally released. In Year 4, only limited activity was seen around Creagmhor (Fig. 10), and no fresh field signs were recorded on the eastern bank of this loch after January 2013 (since Elaine disappeared).

Figure 10. Schematic of the Un-named Loch (north) family territory in Year 2 and Year 3 of the trial. Year 3 home range polygon (MCP) in purple, observations in red, field signs in dark green. The original release area is indicated by the brown square. The pale blue areas are the lochs.

Territory sizes reported here are in line with territory sizes reported for beavers in Norway by Herr and Rosell (2004) (c. 3.5 – 4 km) and lie within the range of territory sizes (0.5–12.8 km) reviewed by Macdonald *et al.* (1995).

6.2.5 Seasonal home ranges

In our second report (see Harrington *et al.* 2012), we carried out a preliminary analysis of seasonal home ranges, and suggested that winter home ranges might be smaller than those used in other seasons. However, for all families, the presence of outlying points in winter suggested that perhaps the difference is in the intensity of use rather than the area used *per se*. Seasonality in the areas used by beaver will be explored further in the final year of the trial when data from multiple years and seasons are available.

6.3 Beaver activity and the use of GPS

The original ecological monitoring protocols (see Campbell *et al.* 2010) specified that we would provide data on nightly movements of beavers. However, the discontinuation of VHF telemetry in the first year of the project meant that this was not possible (since we are unable to describe detailed individual movements from either observations – according to current protocols - or field signs). In Year 2, in an attempt to investigate alternative affordable replacements to the discontinued radiotelemetry, SBT proposed a trial to assess the feasibility of using inexpensive GPS transmitters (i-Got-U tags) sold commercially as 'route trackers', to monitor animal movements. In consultation with SBT and SNH, we made the decision to adopt the use of i-Got-U tags to obtain further information on beaver behaviour and movements at Knapdale. Tag deployment can be combined to some extent with annual trapping of animals to minimise workload for SBT, as well as animal handling required (with animal welfare in mind) (see Annex 1). Given the short deployments possible with these tags (maximum 10 days), the data obtained provide a short but detailed insight into beaver behaviour at Knapdale[20] - whilst not of high priority, we used this novel method to compare nightly movements and activity patterns (see below) with comparable behavioural data from Norway, and thus to assess whether the translocated beaver population is behaving as would be expected (with a view to assessing how well the population has settled at Knapdale, and how the animals responded to the translocation process).

First, because this is a novel method, we assessed the accuracy and the potential usefulness of the method to provide the necessary data.

6.3.1 Usefulness and accuracy of GPS tracking with route trackers

Preliminary trials and accuracy testing in Year 2 suggested that both inter-fix intervals (>90% successive fixes were achieved within 30 minutes or less, given a programmed inter-fix interval of 15 minutes) and accuracy of locations obtained (median errors 5-19 m, maximum errors 23-75 m) were adequate for the purpose of the ecological monitoring of beavers at Knapdale. Imprecision in locations, however, meant that GPS data were not suitable for finer-scale analyses, such as habitat use (but that was not the primary aim).

Initial trial deployments on two animals revealed that GPS locations were not obtained from inside the lodge, but that was considered to be beneficial because it meant that GPS data could be used to estimate activity periods and emergence times. Trial deployments on two animals showed that beavers did not to use their entire home range over the 8-9 day deployment period, therefore GPS data will be most useful for assessing nightly movements, and temporal activity patterns (although it may be helpful in refining home range boundaries in some cases).

[20] Precision is not sufficient for habitat analysis (e.g. to distinguish between use of loch bank and use of water).

6.3.2 Success of GPS deployments

The original aim was to GPS-tag all adults over two years, with half the animals tagged in early summer and half in late autumn[21] (ensuring that there was even coverage of males and females in both seasons), each individual tracked for approximately two weeks. Ideally, all adults would be tracked in both seasons and the feasibility of this was to be reviewed as the project progresses. It was agreed that the other sub-adults or non-breeding adults would be tracked opportunistically if the opportunity arose.

In all cases, GPS were set to record over 24 hours, with 15 minute inter-fix interval; times referred to in the text are British Summer Time (BST) for April – October, Greenwich Mean Time (GMT) for November – March.

Eighteen GPS tags were deployed (including two in the initial trial), with at least one attempted deployment on each of the adult beavers, with the exception of two adults on Dubh Loch (Bjornar and Katrina) where it is difficult to trap (Table 9). Successful retrieval of tags and data was, however, low –13 tags were retrieved and six of those were damaged (resulting in either complete failure to retrieve the data or truncated datasets[22]). Nine datasets were obtained from five individuals, but only three individuals (5 datasets) were successfully tracked over more than one night.

Table 9. GPS deployments on beavers at Knapdale to date. Available datasets highlighted in grey.

Animal	Date of deployment	Trial year
Frank	22/02/11	YEAR 2
Frid	02/03/11	YEAR 2
Eoghann	24/10/11[1]	YEAR 3
Trude	25/10/11	YEAR 3
Frank	19/06/12[2]	YEAR 3
Frid	18/06/12[2]	YEAR 3
Millie	03/07/12[3]	YEAR 4
Millie	23/10/12	YEAR 4
Christian	21/11/12[2]	YEAR 4
Frank	29/11/12	YEAR 4
Frid	29/11/12	YEAR 4
Elaine	03/12/12[1]	YEAR 4
Christian	01/05/13[1]	YEAR 4
Christian	26/06/13[1]	YEAR 4
Millie	30/07/13[3]	YEAR 5
Trude	July/August 2013[3]	YEAR 5
Christian	10/09/13[3]	YEAR 5
Frank	08/10/13[1]	YEAR 5

[1] tag lost.
[2] tag damaged; limited data obtained.
[3] tag damaged; no data retrieved.

Because GPS was not priority monitoring, tagging was carried out as and when it fitted into SBT's existing field work schedule, and when it could be coordinated with annual trapping of animals. Although preliminary deployments were promising, loss rates and damage rates were too high (see Table 9) to justify continued tagging and so GPS tagging was

[21] Although the ideal situation would have been to track animals over winter, the animal welfare implications of trapping animals in winter, and the difficulties posed to fieldworkers, meant that a more feasible solution would be to limit 'cold season' tracking to late autumn. Alternative methods of inferring activity times and/or movements in winter should be considered in future.
[22] We assume that the tag stopped recording at the time that the tag was damaged.

discontinued after October 2013. Nevertheless, the data already obtained provide useful information on movements and activity patterns of a subset of animals and are presented below.

6.3.3 Quality of data

Table 10 summarises the quality of the data obtained (in terms of the number of locations recorded, and the actual inter-fix intervals achieved[23]). Data quality was generally high: although success at achieving inter-fix intervals ≤ 15 minutes ranged between 30 and 60%, for all datasets at least 80% of inter-fix intervals were ≤ 30 mins (and for all but two low sample size datasets, 90% or more were ≤ 30 mins). Data from Millie on Dubh Loch also suggests that the higher vegetative cover at this loch was not problematic in terms of obtaining locations (although further analyses on the relative precision of GPS locations in different habitats have yet to be done).

Table 10. Quality of GPS data obtained from nine successful deployments on beavers at Knapdale. Inter-fix intervals are described as the proportion of intervals that are less than, or equal to, a specified time (excluding daytime periods when the animal was clearly in the lodge). Note that the tag deployed on Frid in 2011 was set to record at approximately five minute intervals (all others were set to record at 15 minute intervals).

Animal	**Total no. locations (no. nights)**	**Inter-fix intervals**		
		≤ 15 mins	**≤ 20 mins**	**≤ 30 mins**
Frank_2011	264 (9)	0.40	0.85	0.94
Frid_2011	571 (8)	0.27 ≤ 5 mins	0.80 ≤ 10 mins	0.97 ≤ 30 mins
Trude	390 (11)	0.55	0.85	0.90
Frank_June2012	158 (4.5)	0.39	0.87	0.92
Frid_June2012[1]	37 (2)	0.29	0.74	0.86[2]
Millie	72 (<2)	0.61	0.89	0.93
Christian	22 (<2)	0.45	0.80	0.80[2]
Frank_Nov2012	72 (<2)	0.44	0.92	0.93
Frid_Nov2012	314 (7)	0.54	0.88	0.94

[1] One large 3 hour inter-fix interval between 21.24 and 00.25 suggests that the animal was probably inactive during this period.
[2] Low sample size.

6.3.4 Activity patterns

Table 11 summarises individual beaver activity patterns, in terms of time of emergence from the lodge, time of return to the lodge and the time spent active and out of the lodge. With the exception of one individual (Frid) in June, emergence times appeared to be relatively consistent among individuals (medians per individual occurring between approximately 1900 hours and 2200 hours). Time of return to the lodge appeared to be slightly more variable (medians per individual occurring between approximately 0500 hours and 1000 hours, excluding Frid in June). Neither emergence time nor return to lodge time appeared to be closely related to sunset or sunrise times. Frid returned to the lodge earlier in June (when sunrise time was earlier, 0430 hours[24]), which was probably related to the fact that she had young kits in the lodge at the time rather than sunrise time per se. However, at the same

[23] A GPS tag may fail to obtain a location when the animal is underwater or in thick vegetation – when this occurs the tag will continue to attempt to obtain a location until it is successful, thus some inter-fix intervals will be longer than 15 minutes, and the proportion of inter-fix intervals that exceeds 15 minutes (and the actual duration of the inter-fix intervals) provides an indication of the ability of the tag to record the beavers movements precisely. (Accuracy of the locations obtained is a different issue that can only be assessed using stationary tests).
[24] Sunrise and sunset times from www.timeanddate.com

time of year, Frid also emerged from the lodge early although sunset time was late (2200 hours). Frid was active for 452 minutes in June, which is comparable to activity period durations reported in Sharpe and Rosell (2003) for beavers in Norway at other times of the year (when there are no young kits), but was the shortest activity duration recorded at Knapdale. Other activity periods recorded in October and November appeared to be longer than reported in Sharpe and Rosell (2003) but these authors did not include animals in autumn when foraging and food caching might be expected to increase in preparation for winter.

Table 11. Activity patterns of four beavers at Knapdale (on eight separate occasions) as inferred from GPS data. Times are given in decimal hours (BST in June and Oct deployments, GMT in November and February); activity period is in minutes.

Animal[1]	**No. nights**[2]	**Emergence time Median (IQR)**	**Return time Median (IQR)**	**Activity period Mean ± SD**
Frank (Jun)	3	20.27 (19.69-20.63)	05.47 (04.52-07.90)	510.94 ± 65.25
Frid (Jun)	1	17.68 (17.28-18.08)	02.21 (02.11-02.30)	452.27
Trude (Oct)	9	19.31 (18.93-19.40)	06.76 (06.52-06.86)	680.11 ± 50.65
Millie (Oct)	1	20.04 (19.91-20.17)	08.07 (07.06-09.08)	616.13
Frank (Nov)	1	21.25 (21.15-21.35)	09.63 (08.49-10.76)	617.67
Frid (Nov)	6	22.10 (21.71-22.32)	10.02 (09.48-10.42)	701.01 ± 30.65
Frank (Feb)	7	21.68 (21.02-22.25)	06.78 (06.62-06.80)	530.50 ± 53.52
Frid (Feb)	6	19.87 (19.63-19.94)	06.88 (06.35-06.96)	645.88 ± 51.70

[1] Christian was not included (see Table 10) because only one full night was covered, during which < 10 locations were obtained – it is not clear whether this was a short active period, or poor ability of the GPS to obtain locations. If these data are reliable, this animal was active the previous daytime morning until approx. 12 am, but only active for 47 minutes during the 'whole' night he was tracked.

[2] This is number of full nights (to allow calculation of length of active period) and in some case differs from number of nights in Table 10 that includes some partial nights (note that single nights include emergence/return times for the previous and following nights and thus have more than one emergence/return time).

6.3.5 Nightly movements

The four beavers successfully tracked moved an average of 2406 m per night (± 918 SD, n = 34 nights in total, Table 12). This is comparable to the distances moved by female beavers in Norway (2572±1204 m) reported by Herr and Rosell (2004), although somewhat less than the movements reported for males (3756±2247 m). Unfortunately, we were only able to obtain GPS data on one male beaver (Frank) but he moved consistently shorter distances than did the females (Frank: 1847 ± 257 m; all females except Millie: 2304 ± 380 m). The longest nightly movement recorded (> 4 km, see Table 12) was made by Millie, who inhabits the largest loch (Loch Coille-Bharr). Examples of nightly movement paths are shown in Figure 11.

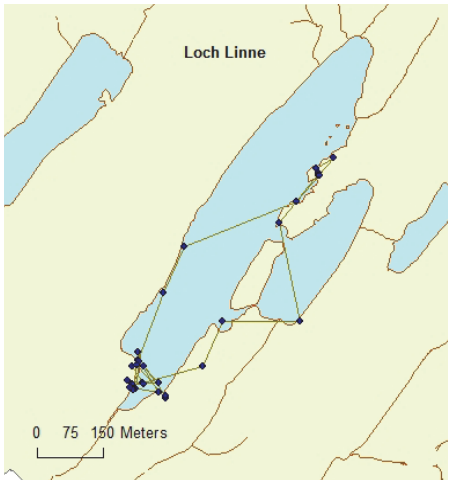
It is important to remember that these data are only short-term data on a subset of animals (for example, there was only one night of data for Millie, so it was not possible to determine whether she travelled a long distance every night, and there was only data for one male, so it was not possible to assess whether all males at Knapdale made relatively short nightly movements). It is also relevant to note the large variation in the distances moved by male beavers in Norway in Herr and Rosell (2004): movements recorded for Frank were comparable to the mean movements by Norwegian beavers minus one standard deviation (1509 m). Also, the apparently longer distances moved by male beavers as compared to female beavers suggested by Herr and Rosell (2004) was not statistically significant and so may not represent a true difference between the sexes.

Table 12. Nightly movements of four beavers at Knapdale (on eight separate occasions) at Knapdale as inferred from GPS data. Distances moved are mean distance moved per night ± standard deviation (n = no. nights).

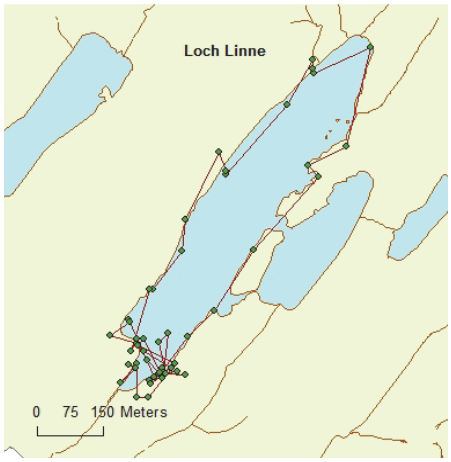
Animal[1]	**No. nights**[2]	**Total distance moved per night (m)**
Frank (Jun)	3	2059±366
Frid (Jun)	1	1770
Trude (Oct)	9	2331±663
Millie (Oct)	1	4492
Frank (Nov)	1	1562
Frid (Nov)	6	2654±497
Frank (Feb)	7	1922±464
Frid (Feb)	6	2460±723

[1] Christian was not included (see Table 10) because only one full night was covered, during which < 10 locations were obtained – it is not clear whether this represents limited movement on that night, or poor ability of the GPS to obtain locations.

[2] This is number of full nights (to allow calculation of length of nightly movements) and in some case differs from number of nights in Table 10 that includes some partial nights.



a)



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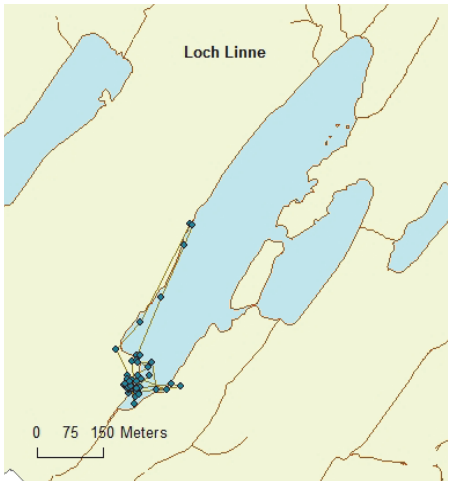

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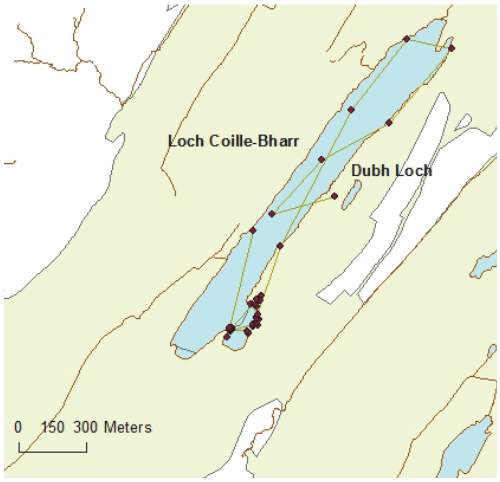

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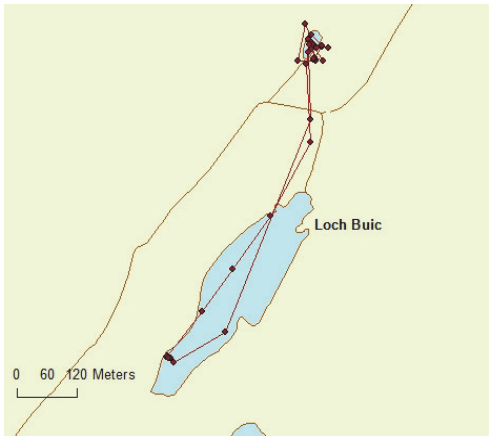


e)

Figure 11. Examples of nightly movement paths of beavers at Knapdale, as inferred from GPS locations recorded at approximately 15 minute intervals (see Table 10), for a) Frank in February 2011, b) Frid in March 2011, c) Frid in March 2011, d) Millie in October 2012, and e) Trude in October 2011. b) and c) illustrate variation among nights for a single individual; d) and e) illustrate differences in movement distances on lochs of different sizes (note the different scales).

In short, although the data were limited, there is nothing to suggest that beavers at Knapdale were behaving differently (in terms of their activity patterns and nightly movements) than beavers in Norway, although they were perhaps active for longer in autumn. Further comparative data will be sought to assess whether extended activity periods in autumn also occur in Norwegian beavers. In future, it might be insightful to investigate the energetic implications of inhabiting a large range with patchy resources (e.g. Loch Coille-Bharr) as compared with a smaller one with abundant resources (e.g. Dubh Loch and the small 'ford' pond to the north of Loch Buic that appears to be heavily used by the beavers), however, there is nothing to suggest that the Loch Coille-Bharr family are doing any worse than the Loch Buic family in terms of either body condition or reproductive success. Loch Coille-Bharr is also interesting insofar as the beavers there appear to predominantly use the smaller neighbouring Dubh Loch, yet both field signs (see Fig. 8) and Millie's movements show that they also regularly travel around the entire perimeter of Loch Coille-Bharr.

6.4 Habitat use

In last year's report we assessed terrestrial habitat use within the beaver's home range at the level of the beaver family / pair, as indicated by the location of field signs (see Harrington *et al.* 2012). We focused specifically on the use of deciduous woodland types (as defined by the dominant species present[25]). In general, preferences were hard to assess because of the small number of families and the variation in deciduous woodland habitat available within each of these four beaver home ranges.

The dominant deciduous tree species within all beaver home ranges was downy birch, *Betula pubescens*; all beaver families appeared to use woodland dominated by this species in proportion with (or slightly less than) than its availability. There was some evidence that the Loch Linne family (Family 2) preferred (insofar as proportional use was greater than proportional availability) woodland dominated by downy birch and eared willow, and avoided (proportional use less than proportional availability) sessile oak; the Dubh Loch family (Family 3), however, and in contrast, appeared to show some preference for areas dominated by sessile oak. The Un-named Loch (north) family (Family 5) occupied a less diverse deciduous woodland and appeared to use it in proportion to its availability; and, we were unable to assess deciduous woodland preferences for the Loch Buic family (Family 4) because only one dominant species, downy birch, was present within their home range.

A more detailed assessment of annual and seasonal habitat use within the home range will be included in the final report. The slight shifting of territory boundaries by some beaver families/pairs (particularly the Loch Buic family) will also allow an assessment of territory location, which will be included in the final report.

The beaver ecology monitoring no longer collects data on the size, number (or proportion), or the species of felled trees because this is covered by monitoring carried out by the James Hutton Institute (JHI) of the effect of beavers on riparian woodland (Moore *et al.* 2011). Comparisons between these two separate monitoring exercises will also be covered in the final report.

6.4.1 Use of Time-Depth Recorders (TDRs) to provide information on aquatic habitat use

One question that still remains, regarding habitat use, is: to what extent do beavers forage in the aquatic habitat? Field signs are not usually detected in the water, although macrophyte 'mats' are sometimes observed, as well as evidence of feeding on aquatic plants at the shoreline or in the material covering lodges. The resolution of GPS locations mean that it will not be possible to distinguish between a beaver on the land at the edge of the bank and a

[25] Using the Knapdale woodland deciduous 2005 dataset (Brandon-Jones *et al*. 2005) [updated in 2011].

beaver in the water at the edge of the loch. Detecting aquatic habitat use from GPS data is also complicated by the fact that a fix will only be obtained if a beaver in the water is at the surface, but not all 'surfacing events' will be recorded due to the 15 minute fix interval. Although beavers are observed foraging in the water, observational data are the most labour intensive of all monitoring methods and obtaining long duration data on focal animals is difficult and subject to bias due to observers disturbing the animal.

TDRs record depth and temperature at one second intervals (for approximately six days), and provide very detailed dive profiles, from which we are able to describe the characteristics of an animals' dives, as well as precisely when, how often and for how long they dive. Data obtained from TDRs, will provide unique, 'non-essential' data on beaver diving behaviour, as well as potentially allowing comparisons with the diving behaviour of wild beavers in Norway, and thus may allow a better understanding of beaver behaviour at Knapdale.

Twelve TDRs were deployed between June 2012 and September 2013[26]. Of these, four were lost (probably 'groomed' off by other family members, as the tags were attached to the animals' back) and two malfunctioned during data download, resulting in a potential six datasets, Table 13). Of the six datasets analysed, one contained no dives and another showed considerable fluctuations in depth data[27] meaning that dives were difficult to define precisely – data from the latter dataset are presented here but should be considered to include only a sample of dives actually made, and to represent only approximate measurements of dive parameters. One further TDR was deployed in September 2013 and is, at the time of writing, awaiting data download.

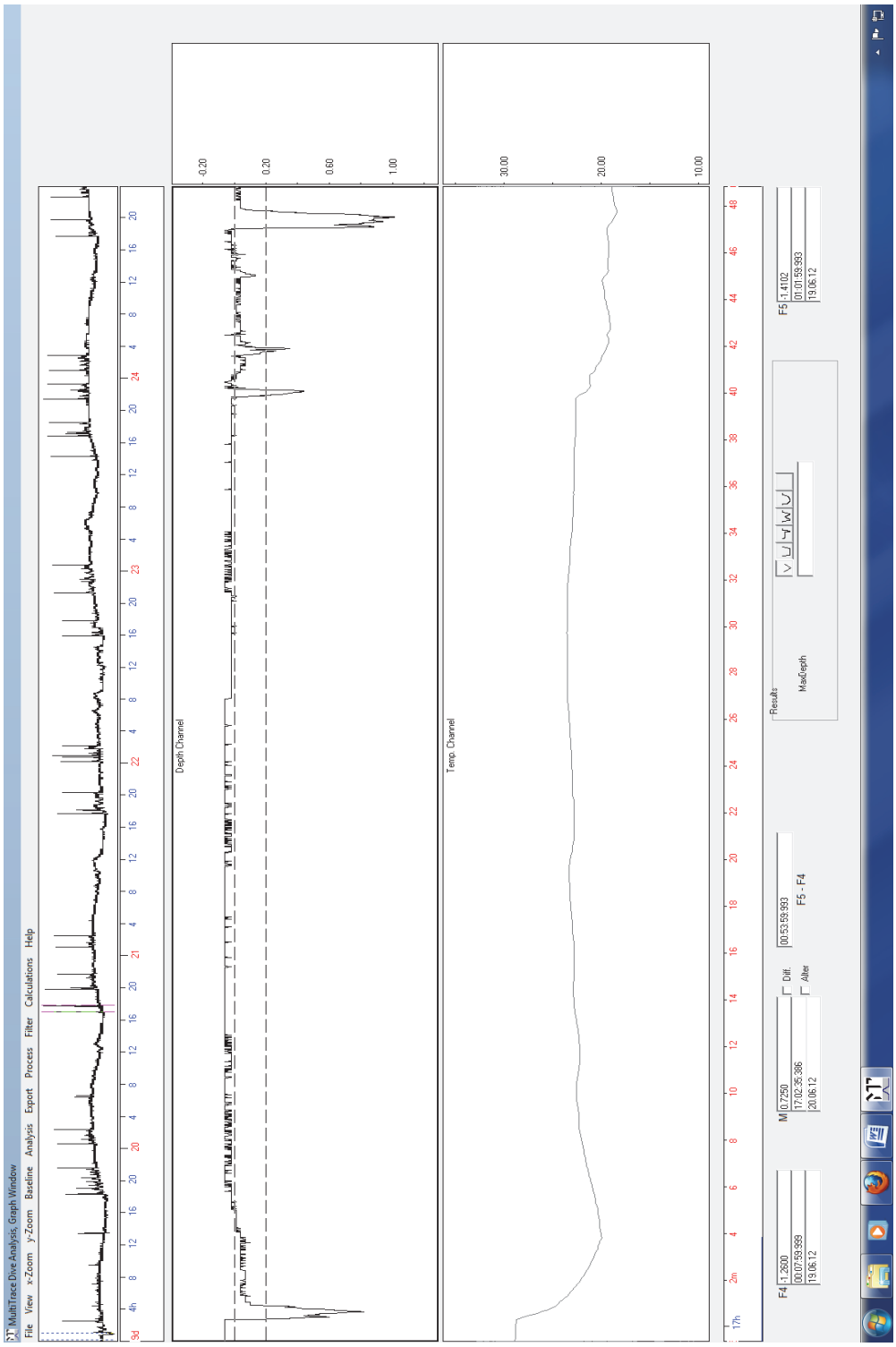
Table 13. Successful TDR deployments on beavers at Knapdale to date.

Animal	Tag no.	Loch	Date of deployment	Total dives
Frid	8230	Loch Linne	18/06/12	35
Millie	8226	Dubh Loch	03/07/12	272
Christian	8232	Un-named Loch (north)	21/11/12	0
Frid	8224	Loch Linne	29/11/12	130
Trude	8232_2	Lochan Buic	31/07/13	115
Christian	8232_3	Un-named Loch (north)	10/09/13	119[1]

[1] This is a sample of dives performed by this animal (see text).

TDRs were set to record depth at 1-s intervals and temperature at 5-s intervals, over a period of 5–6 days (the total period being limited by battery life). We used MULTITRACE (Jensen Software Systems, Laboe, Germany) to extract dive parameters, with a dive threshold of 0.2 m to exclude surface swimming and fluctuations in the water's surface due to wave action (precision of TDRs = 0.05 m, Hays et al. 2007). All dives were viewed, and the surface baseline corrected manually for each dive, before accepting parameter values. For each dive, we recorded dive depth (m) and dive duration (s). Figure 12 illustrates the type of data obtained from the TDRs.

[26] Note that this includes all data available at the time of writing (September 2013) rather than only those available at the end of the fourth year of monitoring.
[27] Possibly because the tag was approaching the end of its battery life.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MaxDepth
F4 1.2600
00:07:59.999
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M 0.7250
17:02:35.386
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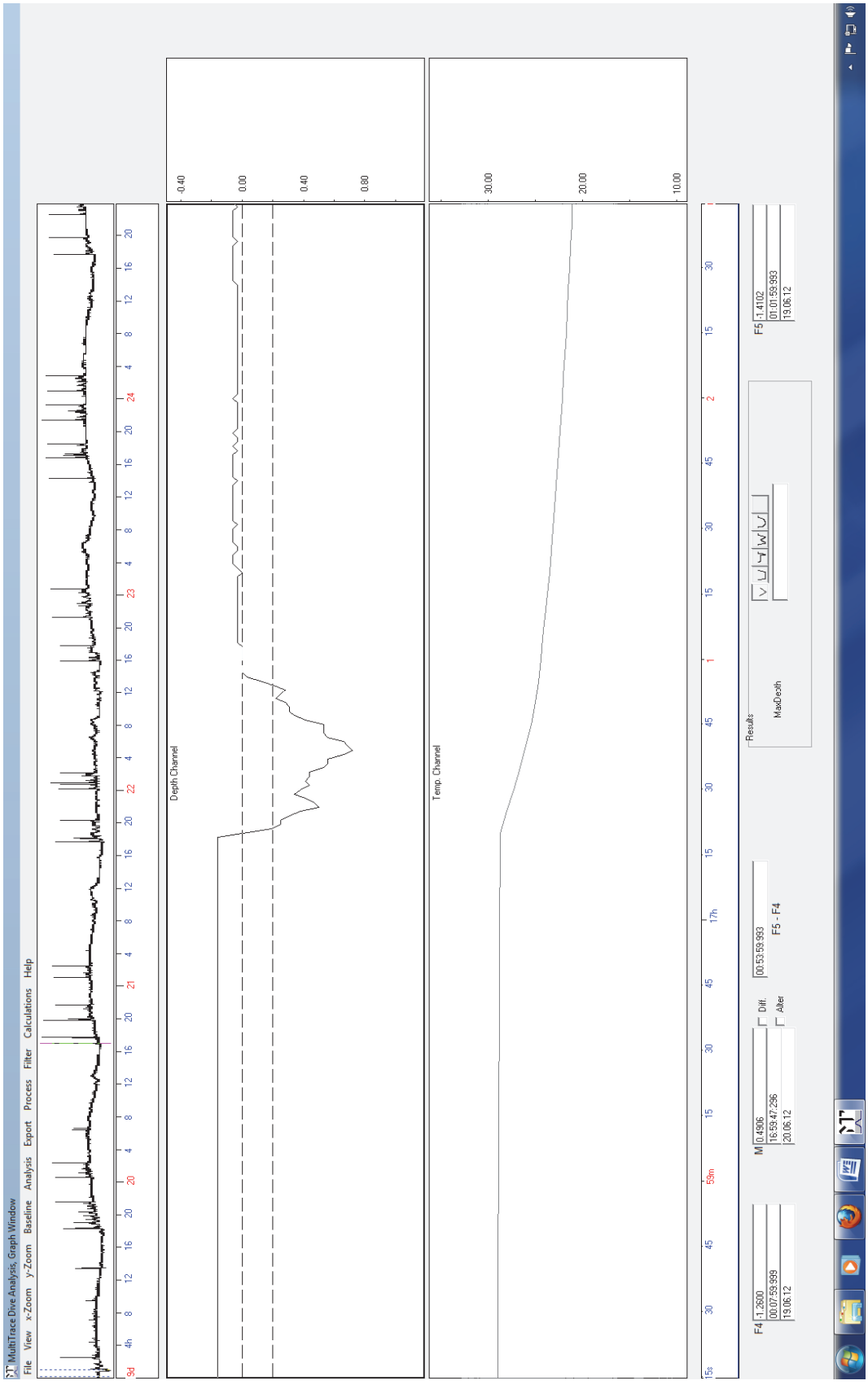
a)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F5 1.4102
01:01:59.993
19.06.12

b)

Figure 12. Screen shots illustrating TDR data viewed in MtDive[28]. The top window shows the entire 6 day dataset (depth data). The two larger windows show the depth data (middle window) and the temperature data (bottom window) zoomed in to show a series of four dives over approximately 48 minutes (a) and a detailed dive profile within a four minute series of data (b). Dives are defined, in this case, as depths of greater than 0.2 m (indicated by the two dashed lines that mark 0 depth and 0.2 m depth respectively).

Average mean dive duration was 24.2 s, average mean dive depth was 0.9 m and maximum dive duration 58.9 s (average of n = 4 individuals, number of dives recorded per individual in Table 13). Average maximum dive depth for these 4 individuals was 1.7 m, and the maximum dive depth for these four individuals was 2.4 m. However, it is likely that beavers at Knapdale can dive much deeper than this because Christian appeared to be diving up to 3.5 m. On average, Knapdale beavers performed approximately 30 dives per day and spent 17 minutes per day diving, although there was variation among individuals. Beaver dives at Knapdale appear to be somewhat limited compared with preliminary reports of beaver dives in Norway of up to 4 m in depth, and over 120 seconds in duration (Graf *et al.* 2012), but are probably a reflection of habitat differences rather than physiological differences in the animals themselves. Many species make shallower dives than the depths of which they are physiologically capable, since dive depth is a function of water depth and the depth at which prey/forage is located. Further, dive duration is usually correlated with dive depth, and thus shallower dives in shallow aquatic habitats are usually of shorter duration than deeper dives by the same animal. Further detailed comparative analysis will be presented in the final report.

6.5 Dispersal by sub-adults

In the first two years of the project, two dispersal events of a sub-adult away from the natal group were recorded. One was dispersal of a two year old female (Marlene) in the Dubh Loch/Loch Coille-Bharr family, and the other a two year old male (Biffa) in the Loch Linne family.

Marlene was tracked via VHF telemetry south-west to a watercourse in the vicinity of the Fairy Isles and then to a nearby sea loch in August 2009. She has not been seen since.

Biffa remained with the Loch Linne family for almost two years (1 year, 10 months) post-release. He was last seen in February of 2011.

During Year 3, the wild-born two year old (unknown sex) in the Dubh Loch family also appears to have dispersed. That animal has not been seen since summer 2012.

Dispersal of beavers from the release site constitutes important ecological information that will be crucial to management of the Knapdale population, and to assessing how beaver populations elsewhere might spread if the decision is made to reintroduce beavers to the rest of Scotland. However, although we are able to report the proportion of sub-adults that leave their family group and at what age this occurred (assuming that these individuals have dispersed and not died), we are currently unable to estimate dispersal distances or to otherwise describe dispersal movements (except through anecdotal information on beaver signs or sightings outside the release area). In an attempt to improve this information SBT will actively seek reports of beaver signs in Argyll outwith the trial area in the final years of the trial.

[28] A bespoke software program developed for analysis of TDR data by Jochim Lage, Jensen Software Systems.

7. OTHER MAMMAL MONITORING

One of the qualifying features of Taynish and Knapdale Woods Special Area of Conservation (SAC) is the Eurasian otter (*Lutra lutra*) (which is also a UK BAP priority species and a European Protected Species). To demonstrate that the trial reintroduction of beavers into the SAC will not negatively impact on this particular qualifying feature or on UK BAP priority species, otter presence in the area is being monitored over the duration of the project.

Thus far, there is no evidence that beaver reintroduction has had a negative impact on otters in the area.

A brief summary of the monitoring is presented here; for full details of the 2012 survey see Annex 2.

7.1 Methods

Survey methods are based on Strachan (2007) and were undertaken by SNH. Surveys were carried out within the release area and, for comparison, in a separate and independent control area (of similar habitat to the release area but located far enough outside the release area to minimise the chance of a single otter territory overlapping both the release area and the control area). Supplementary data on the presence of mink (*Neovison vison*) field signs, and water vole (*Arvicola amphibius)* field signs were also recorded. Further additional data on the presence of mink were provided by SBT from their mink control activities; SBT also provide incidental species data recorded on an *ad hoc* basis during camera trapping and other activities (including visitor sightings).

Twenty 100 m linear sites (10 in the release area, all on catchments used by beavers, and 10 in the control area) were surveyed annually in autumn (September – November) between 2009 and 2013 (the 2013 autumn survey was part of the final year of monitoring and will be presented in the final report, here we report on the first four years of the survey). Survey sites were selected amongst three broad habitat types (inland watercourse, freshwater loch outflow, coastal watercourse outflow / shoreline – see Harrington *et al.* 2011), with the additional specification that the two national otter survey sites within the release area – unnamed burn near Gariob Cottage, OS grid ref. NR781891 and the burn near Loch Barnluasgan, OS grid ref. NR789910 – were included amongst the ten sites to allow the use of survey data from earlier national otter surveys. The same sites were surveyed each year (Fig. 11).

Sites were surveyed by searching the entire length of the 100 m site and recording the following field signs: sightings (actual animals seen), total number of otter spraints[29], number of otter resting places, presence of tracks/runs etc., total number of mink scats found, presence of mink tracks, other evidence of mink (including local reports), total number of water vole latrines, presence of water vole burrows and feeding signs.

Spraint surveys are not suitable for assessing habitat use by otters but were considered sufficient to monitor for broad changes in otter presence, distribution and relative abundance.

Ten mink rafts are monitored by SBT at monthly intervals for management purposes (to inform any mink removal work required); these also provide potentially useful data on the presence and relative abundance of mink in the area.

[29] Spraint samples were only collected if species identification was uncertain. Samples were, otherwise, considered to be of limited use for further non-essential research, due to low numbers encountered and poor quality (i.e. not sufficiently fresh to allow DNA analysis).

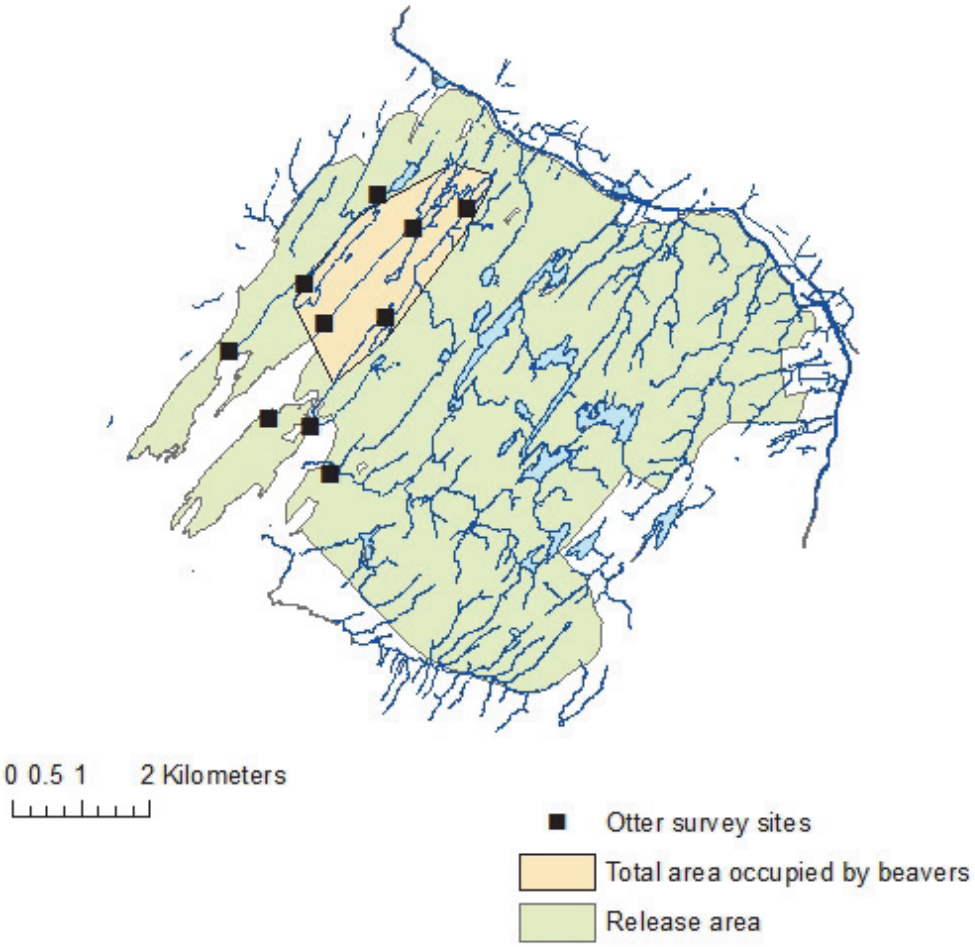


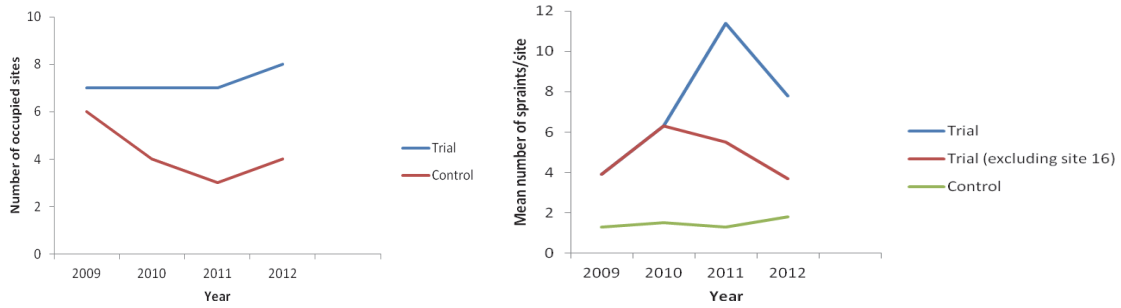
Figure 11. Otter survey sites within the release area, Knapdale, Argyll. The same sites are surveyed each year. 10 additional 'control' sites are surveyed outside the release area. See Annex 2.

7.2 Results

7.2.1 Otters

Evidence of otter activity (mostly spraints or footprints / otter paths) was recorded at eight survey sites (80%) in the trial area and six survey sites (60%) in the control area in the 2012 survey (Year 4 of the trial). This is similar to previous surveys (Fig 12) and, as in previous surveys, slightly lower than the overall mean number of positive sites recorded across the SNH Argyll & Stirling Area during the 2003/04 national survey (89.13%). It is perhaps noteworthy that weather conditions (particularly high water levels) and delays in the timing of the survey in the first three survey years meant that otter (and mink) presence may have been underestimated, but that in 2012, the survey was carried out earlier in the year (end of September) and during particularly dry conditions, which may have improved detectability (see Annex 2). Nevertheless, whilst variable weather conditions might influence trends over time, and comparisons with the earlier national survey, they will not influence the relative difference between the trial and control area (because surveys of both are carried out at the same time of year). Otter occupancy appears to be marginally higher in the trial area than

the control area, and there is no evidence of a change over time between the two areas (Fig. 12a). However, interestingly, in Year 2 and Year 3, the *quantity* of spraint found at positive survey sites within the release area was substantially greater than at positive sites in the control area (perhaps suggesting a higher level of overall otter activity within the release area, Fig. 12b). It is not currently clear whether this difference reflects habitat differences (and relative suitability for otters) between the two areas, or whether it is due to the presence of beavers.



a) b)

Figure 12. Otter survey results, Knapdale, Argyll, 2009-2012, showing a) the number of occupied survey sites (i.e. those in which otter signs were detected) out of a total of 10 sites surveyed in both trial and control areas, and b) the mean number of spraints per survey site (for all sites where spraint was found). Site 16 is a coastal site at which particularly high numbers of spraint are found. See Annex 2 for the full survey report.

SBT has reported observations of otters swimming around the lodges on Loch Linne, Dubh Loch and Loch Buic (total sightings = 4 in Year 2, 2 in Year 3, 1 in Year 4). Otters have been captured by camera traps at a beaver foraging trail and a beaver canal on Un-named Loch (north) and Loch Buic (total camera captures = 4[30]). Otter tracks have been recorded on mink rafts on nine occasions (2 in year 2, 5 in year 3, and 2 in Year 4). Only one direct interaction between beavers and otters has been recorded, during which two beavers were seen swimming towards an otter, the beavers splashed and then swam away – there was no other evidence of aggression or of close physical contact.

7.2.2 Mink

In Year 1, mink signs were recorded at one of the survey sites in the control area, and a further three sites had 'possible' mink presence (one in the release area and two in the control area). In Year 2, mink were confirmed at one site, and possibly present at one other (both in the control area). In Year 3, there were unconfirmed mink signs at three sites, and possible scats at two sites in Year 4 (Annex 2).

SBT recorded mink tracks on rafts on 12 occasions in Year 2 and one occasion in Year 3; two mink were shot as part of control operations for this non-native species in Year 2. No mink signs were recorded in Year 3 but in Year 4 tracks were recorded on one raft at Coille-Bharr, one mink scat was recorded at Coille-Bharr and a mink was caught on a camera trap at Dubh Loch (these records might all be from one mink).

7.2.3 Water voles

No evidence of water voles was found during any of the four survey years, but this is not surprising given the late autumn / winter survey dates and the heavily-shaded habitat at

[30] Camera traps were only used extensively in Year 3 and Year 4.

many of the locations. No other signs of water vole have been recorded at Knapdale before or during the trial, but a water vole was seen on Loch Linne in August 2012.

7.3 Comments on statistical power of the survey

Because the number of sites covered in these surveys is small, we will only be able to detect extreme changes in otter activity, such as the disappearance of all otter signs from the trial area (but continual high abundance in the control area). More subtle effects on otters due to the introduction of beavers in the trial area are likely to be more difficult to detect. This is appropriate for the trial, and for the survey method, since we do not know how many otters are present in either the trial or the control area, individual sites may not be independent (i.e. they may be used by the same otter), and changes in spraint marking activity do not necessarily relate directly to habitat use. Further, because we do not expect beaver presence to have a negative impact on otters (see 7.3, below), it is appropriate to test only for major impacts that may be due to an indirect effect of the beaver release (e.g. the presence of researchers). Any more subtle effects are more likely to be positive, for example, use of beaver ponds by otters (which we have not included in the current monitoring protocol due to resource limitations, but could be assessed post-trial).

A full statistical power analysis will be included in the final report.

7.4 Concluding remarks

That there is no apparent evidence of an effect of beavers on otter presence is not surprising. Indeed, given the important ecological role that beavers play in influencing the hydrology of their habitat and experience from elsewhere in their European range, negative impacts from beavers on any of these other riparian mammals are considered unlikely.

Mink abundance in the area appears to be relatively low. Although it is possible that beaver activity may influence local mink activity (mink are known to use beaver lodges as den sites, and beaver ponds for foraging, elsewhere in Europe and in North America (as are otters), e.g. Knudsen 1962; Sidorovich 2011), control methods for this non-native species are well established and are already in place at Knapdale.

It is likely that the nature of the survey sites and the timing of the survey are not suitable for providing supplementary data on water vole presence within the release area (however, this was not the main aim of the survey).

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ANNEX 1: METHODOLOGY PROTOCOLS

These protocols follow the general format as used in the original methodology protocols in Campbell *et al.* (2010), with a brief overview of each method as it applies to the trial, an outline of the work plan and the data required, as well as a summary of the key information provided by each method. These are revised protocols following amendments made during the first three years of the trial in consultation with SNH and SBT.

Note on reviewing of methods: Over the first year of the trial some changes were made to the original monitoring protocols as specified in Campbell *et al.* (2010) and these were outlined in the first annual report (see Harrington *et al.* 2011). During the second year of the project, preliminary trials investigating the potential use of inexpensive GPS transmitters indicated that GPS tracking would be a useful monitoring tool (see Harrington *et al.* 2012). Therefore, further amendments were made to the ecological monitoring methods, including a renewed emphasis on radio-telemetry (GPS) and, accordingly, decreased emphasis on observational methods (put in place in 2010 as a replacement for VHF telemetry). Field sign surveys continue to provide essential ecological information and provide continuity for the data collected thus far. In addition, in the third year of the project, we included the use of temperature-depth recorders (TDRs) to provide further information on the general behaviour of beavers, and specifically on their use of the aquatic habitat.

Trapping

Overview

The preferred technique is the Norwegian method of trapping from a boat because it allows targeted captures, and reduces individual recaptures and overall capture time. Trapping from a boat will, therefore, be used on all lochs where it is possible (current areas include Loch Linne, Loch Buic, Loch Coille-Bharr and Creagmhor). However, on some of the smaller lochs use of a boat is not feasible and, therefore, cage traps will be used at those sites (e.g. Dubh Loch, and Un-named Loch (north)). Animal welfare is paramount in terms of suitable trapping method and duration of trapping effort, and thus, cage trapping at a specific location will cease if an individual is recaptured three times within a one-month period. Trapping should resume in an attempt to capture animals not yet trapped after a period of not less than two weeks, but not more than two months. All animals should be uniquely marked with both PIT tags and ear tags (using a variety of tags depending on circumstances). Argos tags, which the SBT initially used specifically for beaver management purposes rather than the ecological monitoring will no longer be fitted. VHF telemetry is not currently part of the revised methodology but may be used for management purposes.[31]

Over the first year of the project the most important outcome of the trapping data was the health and survival of individual released animals. In future years, identification of wild-born young will also be needed to allow assessment of their survival and description of population dynamics. Therefore, capture and mark any new, unmarked young animals was a high priority. Every known animal should be trapped once per year. The weight of all animals captured should be recorded as well as standard body metrics (body length, tail length, width and thickness).

Work plan

The precise timing of the annual trapping is not critical and can be fitted in with other activities (but must be recorded so that methodology can be accurately reported). However, the earlier in the monitoring year trapping is carried out the more time is available for capturing animals not yet caught. Further, to allow

[31] ARGOS telemetry is not part of the ecological methodology protocols; VHF telemetry is not currently part of the revised methodology but may be used on 'new' animals and subadults likely to disperse for management purposes – data should still be provided to SNH and WildCRU so that its use (and potential relevance to ecological monitoring) can be further reviewed at a late date; new protocols for GPS telemetry are detailed below.

assessment of annual variation in body condition (estimated from animal weight and body metrics), the timing of trapping should be relatively consistent over consecutive years of the project (i.e. within the same season). Late February to late spring when females may be pregnant should be avoided for intensive trapping efforts with Bavarian cage traps. Trapping for kits should, ideally, be carried out as close to emergence time as possible so that early losses (mortality rates of kits in the first few months post-emergence) can be estimated. In the event that kits lose their ear tags, they should be recaptured, and new eartags fitted, as soon as possible.

Data — Data detailing the number of traps used and number of hours the traps are open (to allow calculation of trap effort) to be entered into the existing trapping spreadsheet[32]; trap locations of captured animals also to be recorded.

Key information provided

Survival of known individuals (yearly)
Body metrics for assessment of overall body condition
Reproductive rates (number of females breeding and number of kits per breeding female)
Population size and density within the release site
Age structure of the population
Dispersal (number or proportion of animals dispersing)[33]

Observations (visual checks)

Overview — Observational data offer a non-invasive alternative to repeat trapping of animals and observations can thus be considered as 'recaptures' in a capture-mark-recapture (re-sight) analysis (to determine survival and population size). Observation locations of the beaver can be used instead of radio-telemetry 'fixes' to determine territory sizes and, potentially, habitat use. It may also be possible to carry out detailed behavioural observations of focal animals[34]. The use of observations to assess survival and/or population size is dependent on the ability to identify individuals. Locations of unidentified beavers can, however, be analysed at a family level to assess family territory (home range) sizes and/or habitat use. The use of observational locations in analyses of home range size or habitat use are potentially subject to bias because animals are most often observed on the water and cannot be seen through the thick vegetation when they are ashore; biases can, however, be overcome to some extent by combining observational locations with field-sign locations (below). However, these methods are hugely resource-intensive and, therefore, given the biases inherent in these data and the fact that field signs appear to be adequate to describe home range outlines (and that additional information on animal movements will now be provided by GPS – see below), we have

[32] trap effort = total trap effort = number of traps x hours that the traps are open

[33] Whether dispersal is 'natural' dispersal of young sub-adults leaving the parental group, or 'dispersal from the release site' by newly-released adults, the proportion of animals dispersing can only realistically be estimated from the disappearance (lack of captures and observations) of animals from the site. Further, in the event of a disappearance, it will not always be possible to determine whether the disappearance was due to dispersal or to mortality. Some information on minimum distances moved will be obtained from reports of field signs outside the release area

[34] Behavioural observations of focal animals are not currently included in the monitoring protocols. Observations of beavers in Knapdale were, during the early phases of the release, somewhat problematic because newly-released beavers appeared to be disturbed by the presence of observers and/or the lights used by observers. Further, the behaviour of newly-released beavers is likely to differ in unknown ways from 'normal' behaviour of established animals.

decided that observational locations are no longer necessary for essential monitoring (see Harrington *et al.* 2011). Monthly observations of identified individuals remain important for estimates of survival, family group size and composition, dispersal of sub-adults and population size. Observations of lodges/dens to assess the number of wild-born kits are described separately below.

Spotlights should be used for observations in the dark if animals have been habituated; SBT have been habituating beavers to spotlights and should continue this with new wild-born animals.

Workplan — Observation sessions should be carried out monthly as part of the monthly visual checks carried out by SBT for management purposes. **Revised protocols require only one record of each animal per month.** Locations of all animals observed should be recorded, and, if an unidentified animal is seen, animal sex and/or approximate age class (i.e. adult or young) should be recorded.

Data — Observational records should be entered into the existing observation trial database.

Key information provided

Survival of known individuals (monthly)[35]
Population size and density within the release site
Family size and composition
Sociality of the population[36]
Dispersal (number or proportion of dispersing animals) (see footnote 5 above)
Territory locations[37]

Lodge/den counts

Overview — Observing and counting individual animals as they emerge from the lodge or den in the evening provides additional estimates of family group size (Rosell *et al.* 2006), and, most importantly, if carried out during the period when kits emerge from the den, can provide information on the presence of kits, and estimates of the number of kits. During these observation periods it is sufficient to count the number and age-class (adults, yearlings and new kits) of all animals seen as they emerge from, and return to, the lodge or den. Observation periods should be as long as possible initially to maximise the likelihood of seeing animals as they first emerge from the den in the evening – the timing of observation periods can then be refined (and potentially shortened) in future years, as necessary. A number of repeat observations of each lodge/den should be made to increase the likelihood of observing all animals present (Rosell *et al.* 2006).

Observations of lodges or dens could potentially be carried out either by observers directly or indirectly using remote video. Currently, direct observations by one or two observers are considered most reliable, and this is the method that has been used at Knapdale. The potential usefulness of remote infra-red video cameras at lodges/dens (as either a replacement or supplementary method) has also been investigated.

[35] Dependent on identification of the animal
[36] Dependent on observations of two or more animals together or of observations of multiple animals leaving the same lodge/den
[37] Recorded locations of identified individuals will provide verification that known beavers are present within home ranges mapped on the basis of field sign distribution.

Workplan Fortnightly evening observations (from 8-12 pm) of all active lodges or dens, where the presence of pregnant females is suspected, should be carried out when kits emerge (from mid-July to the end of September[38]). N.B As the trial concludes in May 2014 there will be no further breeding within the trial period.

Data Counts of animals at lodges/dens should be entered into a separate spreadsheet with columns for lodge/den location (name of loch and grid references), date, numbers of observed adults, 2-year olds, yearlings and kits, so that there is a row for each evening observation for each lodge/den.

Key Information Provided

Reproductive rates (number of breeding females and number of kits per breeding female)

Field sign surveys

Overview A lot of useful information can be gained from field-sign surveys. These surveys can be used to locate dams, lodges and dens, territory borders and areas of high foraging activity. Assessment of habitat use based only on field signs is biased towards use of woody vegetation (there are few obvious signs of foraging on herbaceous or aquatic vegetation), but field signs can be supplemented by other more difficult and/or labour intensive methods (e.g. direct observations, telemetry or other types of dataloggers – see below) to provide a more complete picture of beaver foraging-habitat use.

Field signs (and their locations) should be recorded during foot or boat surveys along loch and river banks. Surveyors should walk (or travel by boat) until a field sign is observed. If it is a single field sign, record its location (and other associated data). If it is a patch of the same type of field signs, record the location in roughly the centre of the patch (and record any other information for that patch as a whole)[39]. If there are more than one type of field sign record both with the same location. For activity and foraging signs only one location (for either a single field sign or a patch of field signs) per 10 m length of bank needs to be recorded[40]. Field signs that should be recorded include: dwellings (lodges and burrows), construction (dams and canals), feeding signs (food caches, tree/branch cutting, feeding stations, foraging trails and grazed areas), and signs of other activities (tracks, droppings, scent mound or marking) (see Table A1.1). For feeding signs, only fresh signs (i.e. those left within the last 3 months) should be recorded; for other field signs (e.g. lodges, burrows, or scent mounds), only those with evidence of recent (within the last 3 months) use should be recorded. Dams can be recorded repeatedly although additional notes on recent maintenance activity and/or deterioration should be recorded in the database, and photographs should be taken to show changes over time. To assess accurately whether a field sign is fresh or not, or been used recently,

[38] One kit was first seen emerging from the den in mid-September (in 2011 – preliminary Year 3 data), which was later than originally expected and therefore, the period for den counts has been extended from mid-July - end of August (see Harrington *et al.* 2011) to mid-July - end September.

[39] The only complication that should arise will be if field signs become so prominent that they are essentially continuous (over more than 10 m) along the loch/river bank – if that becomes the case, record locations at 10 m intervals (e.g. for a 12-15 m stretch of feeding signs, record the first point midway within the first 10 m and then the second midway in the section that extends beyond 10 m.

[40] It is not necessary to predetermine the 10 m survey sections – this can be done retrospectively at the analysis stage to monitor e.g. changes over time in the proportion of survey sections containing foraging signs.

will require a degree of expert judgement, but assessments may be assisted by using an effective marking system to mark field signs when they are first recorded[41]. During Year 1 of the project a marking system was developed using natural wool to distinguish old (previously recorded) field signs from fresh field signs – this system is currently believed to be effective and so should be continued. Search effort for all surveys should be recorded.

Any reported or observed field signs (e.g. during searches for lost animals) outside the release area should also be recorded to provide information on dispersal.

Workplan — A strip of up to 40 m away from the water's edge around each loch/river known to contain beavers, as well as surrounding riparian corridors within the trial area (as shown in Fig. A1.1), should be searched for field signs each season (Spring = Mar, Apr, May, Summer = June, Jul, Aug, Autumn = Sept, Oct, Nov, Winter = Dec, Jan, Feb).

Data — Data should be entered into the existing revised field-sign file in the beaver trial database. For field signs recorded outwith the release area, any relevant explanatory notes should be added to the comments field (for example, known or suspected animal identification, any associated trapping efforts, animal now known or believed to be dead/alive, animal now rescued and returned to the release area).

Key information provided

The number and location of dams and lodges built
Territory locations, as well as number and size of territories
Territorial marking behaviour
Terrestrial habitat selection within territories

Table A1.1. Field signs recorded (revised January 2011)

Type	Feature	Including
Dwelling	Burrow	
	Lodge	
Construction	Dam	
	Canal	
Feed Sign	Food cache	Underwater stores of cut saplings and branches outside the lodge/burrow
	Tree/branch cutting	Felled trees/saplings Cut tree stumps Gnawed trees Cut branches Stripped branches/sticks
	Feeding stations	
	Foraging trail	

[41] Markers used need to be able to persist in the environment for 1 to 2 months, but also not distract from the aesthetics of the area since Knapdale forest is located within a National Scenic Area open to visitors.

	Other	Grazed area = cropped (by beavers) ground vegetation Aquatic macrophyte mats
Activity	Tracks	
	Scent mound or marking	Single mark, or recent marking of a larger, frequently used mound etc.

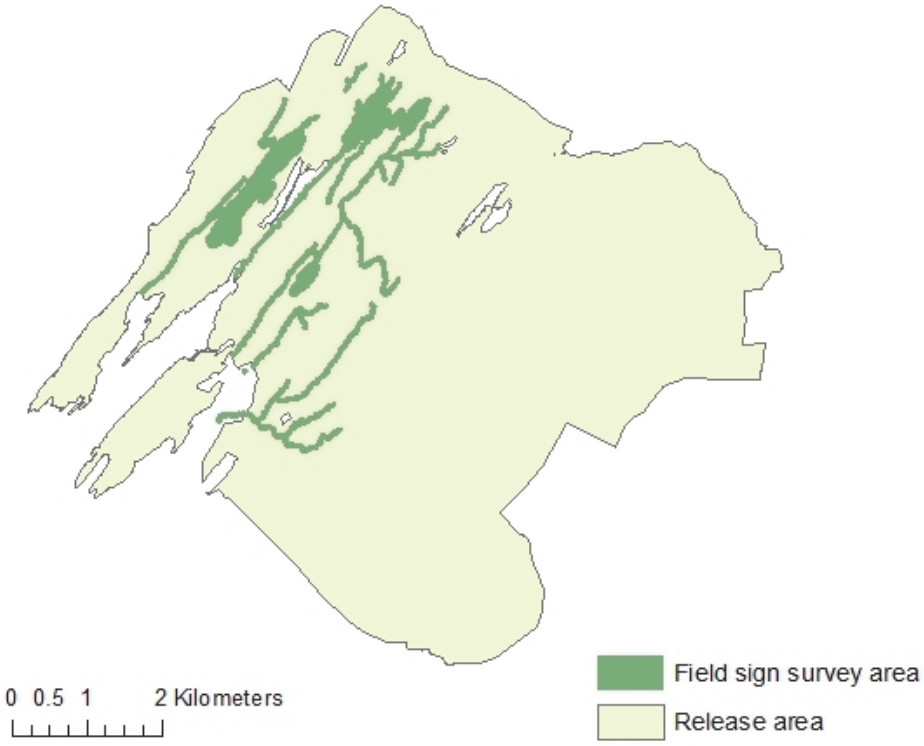

Figure A1.1. Areas surveyed for field signs within the release area (based on a 40 m buffer around each loch occupied by beavers), Knapdale, Argyll. Since January 2011, these areas have been surveyed seasonally (in Year 1, a smaller area – based on a 5 m buffer – was surveyed monthly – see text).

GPS telemetry

Overview

GPS telemetry is potentially able to provide a very detailed series of locations for beavers remotely and thus without the difficulties associated with observing beavers directly or with triangulation in VHF telemetry, and without significantly increasing the workload of the field team. Such data allow detailed analysis of (short-term) home range (and independent verification of home range boundaries as inferred from field signs) and, potentially (subject to limitations due to the precision of the data) habitat use, and could significantly help the ecological monitoring (both the quality of the data and the efficiency with which it can be gathered). GPS telemetry also provides data on nightly movements that we are otherwise unable to report on. Deployment of these tags has shown that locations are not recorded when the animal is inside the lodge but this is beneficial insofar as it, in effect, provides data on the times of emergence from, and return to, the lodge and thus, indirectly activity periods and schedules. In

theory simultaneous deployment of GPS transmitters on animals from neighbouring lochs could also provide data on home range overlap (if there is any) which would not be possible from field signs alone (however in practise tags were rarely deployed simultaneously). One disadvantage of the method is that animals have to be trapped twice, once to fit the tag and once to remove it to retrieve the tag (although one of these trap sessions can be part of the annual health monitoring trapping).

Workplan By October 2013, 17 tags had been deployed but tag loss and damage resulted in only nine usable datasets from five individual beavers. Further GPS tags will not be deployed in the final year of the project.

Data Data has been provided in its raw format in a csv file as downloaded from the tag.

Key information provided

Independent verification of home range boundaries as defined by field sign locations (and potentially, spatial overlap with neighbours)
Distance and pattern of nightly movements
Activity patterns[42]
Habitat use[43]

Temperature-depth recorders (TDRs)

Overview One unanswered question that still remains even if GPS tags are used, is to what extent beavers use the aquatic habitat. The resolution of GPS locations mean that it will not be possible to distinguish between a beaver on the land at the edge of the bank and a beaver in the water at the edge of the loch. Detecting aquatic habitat use from GPS data is also complicated by the fact that a fix will only be obtained if a beaver in the water is at the surface, but not all 'surfacing events' will be recorded due to the 15 minute fix interval. Since animals will now be trapped for GPS tag attachment, the opportunity exists to attach DTRs at the same time. DTRs are very small, lightweight devices (31 mm length, 8 mm diameter, weighs 2.7 g in air and 1 g in water) that are capable of recording depth and temperature at 1 second intervals (for approximately 6 days), providing very detailed dive profiles. Whilst it may not be possible to distinguish between foraging dives and travelling dives, or dives approaching the entrance to the lodge, dive data will provide information on the amount of time spent in the water, which, coupled with known activity periods from the GPS data, will allow us to infer the proportion of 'active time' that beavers spend in the water.

Workplan Loss of TDRs in 2012 and 2013 was high (six of 12 deployments were retrieved) and no further TDRs are available for deployment in the final year of the project.

Data Data has been provided as raw download files (both the csv and BIN[44] files).

Key information provided

Time spent using the aquatic habitat
Dive depth, duration and frequency[45]

[42] as revealed by time of emergence from, and return to, the lodge
[43] subject to limitations due to imprecision inherent in these type of data
[44] These files can only be viewed using the datalogger HOST software provided by CEFAS, but are important for diagnostics should any problems occur

Surveys of otters and other riparian mammals

Overview — One of the qualifying features of the Taynish-Knapdale Special Area of Conservation (SAC) is the Eurasian otter (*Lutra lutra*) (which is also a UK BAP priority species). To demonstrate that the trial reintroduction of beavers into the SAC will not negatively impact on the site's qualifying features or on UK BAP priority species, otter presence in the area will be monitored over the duration of the project. Surveys for the presence of otter field signs will be undertaken by SNH following standard otter-survey methodology (see Appendix B). Supplementary data on the presence of mink field signs will also be recorded, since mink field signs are easily recorded alongside otter field signs, using the same methods. Further additional data on the presence of mink will be provided by SBT from their mink control activities.

Workplan — 20 surveys sites (10 in the release area and 10 in the control area) will be surveyed annually in autumn by SNH (ideally, but should be delayed if weather conditions are unsuitable). The survey should not be undertaken immediately after a period of high-water levels and should be completed in a single four-day period of fieldwork, rather than split into two. Survey site locations are given in Appendix B; the same sites will be surveyed each year. Samples needing their identification verified should be stored in a freezer.

Data — Data will be input into the riparian mammal survey data spreadsheet using unique section IDs that link to the survey sites in the GIS database. A record should be kept of all stored samples with IDs to allow links to survey data.

Key information provided

Presence, distribution and relative abundance of otters[46]

FINAL YEAR WORK-PLAN SUMMARY

Trapping — **Annual trapping - once per year targeting all individual animals, time of year to be decided by SBT, but should be reported, and (ideally) within the same season each year**

Kit trapping – September (2013) or as soon as possible after emergence from the lodge

Observations

Data to be provided from SBT's monthly visual checks – one record per month for each individual.

Lodge/den counts

Fortnightly evening (8-12 pm) observations of active lodges or dens, counting animals present when kits emerge (from approximately mid-July, through September).

Field sign Surveys — **Surveys of known occupied areas and riparian corridors within the release area every season (Spring = March, Apr, May, Summer = June, July, Aug, Autumn = Sept, Oct, Nov, Winter = Dec, Jan, Feb) recording (and marking) all new field signs seen (within 40 m of the waters' edge of occupied areas).**

[45] Not necessarily part of the essential monitoring, but valuable biological data on beavers in loch systems

[46] It is not possible to assess habitat usage of otters from otter spraints

In ensuring that the relevant key information is collected, the aim throughout is to achieve a balance between data collection, animal welfare and maintaining natural behaviours within the population.

ANNEX 2: MONITORING OF THE OTTER *LUTRA LUTRA* AND OTHER RIPARIAN MAMMALS – REPORT ON THE 2012 SURVEY

Monitoring of the otter and other riparian mammals was carried out by Rob Raynor from SNH. The full report on this aspect of the monitoring project (authored by Rob Raynor) is provided here; a short summary is given in section 7 of the main report.

Introduction

This is the fourth in a series of annual monitoring reports on otters and other riparian mammals, undertaken by SNH, in relation to the Scottish Beaver Trial. The rationale for undertaking monitoring of these species at the release site is detailed in the WildCRU report to SNH: *Campbell, R.D., Feber, R., Macdonald, D.W., Gaywood, M.J. and Batty, D. (2010).* The Scottish Beaver Trial: Ecological monitoring of the European beaver *Castor fiber* and other riparian mammals – Initial methodological protocols 2009*. Scottish Natural Heritage Commissioned Report No. 383 (iBids No. 7062).*

One of the qualifying features of the Taynish-Knapdale Special Area of Conservation (SAC) is the Eurasian otter (*Lutra lutra*). In order to demonstrate that the trial reintroduction of beavers into the SAC will not negatively impact on the site's qualifying features, it was acknowledged that a programme of monitoring, coordinated by SNH, was required and this should necessarily include the otter. Other riparian mammals, notably American mink (*Neovison vison*) and water vole (*Arvicola amphibius*) were included, as the former, at least, can be readily surveyed using the same methodology as for the otter. Both otter and water vole are UK BAP priority species and, if information on the occurrence of the latter can be collected at the same time, this can only be beneficial, as the current distribution of water voles in Scotland is still incompletely known. Notwithstanding this, given the important ecological role that beavers play in the influencing the hydrology of their habitat and the experience from elsewhere in their European range, negative impacts from beavers on any of these other species are considered unlikely.

The fieldwork

The protocol for site selection and the fieldwork methodology are described in the first (2009) riparian mammals monitoring report (Harrington *et al.* 2011). Most sites are associated with bridges or obvious physical features such as loch outflows. Digital photographs of all the survey sections are available in the corresponding reports for 2009, 2010 and 2011. (See Objective ID B609392 for the photograph metadata).

At most sites, it was possible to conduct the survey by walking within the watercourse channel and recording any field signs observed from there. In very narrow watercourses, both banks could be inspected simultaneously, whereas at others it was necessary to survey each bank separately and/or complete part of the survey from the bank. In 2009, 2010 and 2011 two of the larger watercourses (sites 3 and 16) were surveyed along one bank only.

The length of each survey section was estimated by counting paces as the survey progressed. The following field signs were recorded: holts/dens/places of shelter,

spraints/scats, footprints/tracks and otter paths. Any evidence of prey was also recorded. The distance from the start to the first evidence of otter was recorded.

In 2012 the fieldwork was undertaken in a four day block from 25-28 September. Each 100m section was walked, noting any signs of otter, mink or water vole.

Site 11: Barnluasgan

Site 12: Fresh otter spraint

Site 6: Active otter holt

Site 5: Kaimes, by A83

Practical constraints

Conditions were favourable for survey at most sites, with predominantly dry conditions and low to moderate water levels. This, combined with the earlier timing of the survey prior to the main period of leaf-fall, may have improved the detectability of signs compared with previous years, although there is no objective measure of this.

Results

The results of the survey are summarised in Table 2. Evidence of otter activity was confirmed at eight sites (80%) in the trial area and six sites (60%) in the control area.

This level of occupancy is similar to the previous three years for the trial area and to the previous two years for the control area. As in previous years the quantity of spraint at sites in the trial area was consistently higher than in the control area. Also, as a general observation, there was more evidence of recent otter activity in the form of fresh spraint in the trial area.

Most evidence was in the form of spraints or footprints/otter paths. Of the six sites where it was not possible to confirm otter presence, two had paths considered likely to have been made/used by otter, but there were no other visible signs to confirm this. At four sites, confirmed[47] otter lie-ups were found, although *potential* lie-ups/holts were recorded at various other sites.

Once again, Site 16 (a coastal watercourse site in the trial area) had markedly more otter field signs than any other location visited. This is attributed to the entire survey length being located between the freshwater Loch Craiglin and the nearby rocky coast, forming an important thoroughfare for otters moving between freshwater and coastal habitats.

There were no sites with confirmed mink signs but two sites had possible scats from this species. No mink evidence was found on the mink rafts at the outflows of Lochs Creagmhor (Site 18), Loch Linne (Site 15) or Loch Coille-Bharr (Site 13) in the trial area.

As in previous years, no evidence of water voles was found.

Rob Raynor
Policy & Advice Officer (Mammals)
Scottish Natural Heritage

20 May 2013

[47] i.e with otter sign present.

Table 1: Location of all survey sites inside the trial area (Y) and outside (N)

Site no.	x	y	Inside_trial_area	Description	Location	National_site
1	188600	690900	N	100m downstream d/s of track	Inland	N
2	194500	692400	N	100m d/s of road bridge	Inland	Y
3	191200	694800	N	100m d/s of track	Inland	N
4	191200	690200	N	100m u/s of entrance to un-named pond/lochan	Inland	N
5	191700	689200	N	100m d/s of road bridge	Coast	Y
6	192600	691500	N	100m d/s of road bridge	Coast	Y
7	191700	686600	N	100m south of landward end of pier	Coast	N
8	192000	692700	N	100m d/s of dam	Freshwater loch	N
9	193300	695800	N	100m d/s of fish ladder	Freshwater loch	N
10	195300	697000	N	100m d/s of dam	Freshwater loch	N
11	178900	691000	Y	Burn near L. Barnluasgan - d/s from road	Inland	Y
12	176700	688700	Y	coastal burn u/s from shore	Coast	N
13	177800	689700	Y	outflow from L. Coille-Bharr	Freshwater loch	N
14	178100	689100	Y	d/s from bridge - By Gariob cottage	Inland	Y
15	179400	690500	Y	outflow from L. Linne	Freshwater loch	N
16	177300	687700	Y	100m d/s of road bridge by L. Craiglin	Coast	N
17	177900	687600	Y	up un-named coastal burn from shore	Coast	N
18	180200	690800	Y	outflow from L. Creagmhor[48]	Freshwater loch	N
19	179000	689200	Y	d/s confluence of 2 un-named burns, by ford	Inland	N
20	178200	686900	Y	d/s confluence of Barnagad Burn & AlltanGhabhar	Inland	N

[48]For practical reasons this site replaced the original site at the outflow of Loch McKay

Table 2: Riparian mammal evidence, September 2012

Date	ID	Surveyor	Osight	Ospraint	ORP	OTR	Distance to first otter sign (metres)	Msight	Mscat	MT	Mother	Wsight	Wlat	Wother	Notes
25/09/2012	1	RR	0	0	0	0		0	0	0	0	0	0	0	(Field vole signs)
25/09/2012	2	RR	1	0	0	1	80m	0	0	0	0	0	0	0	Otter disturbed during survey. Otter run in vegetation nearby
27/09/2012	3	RR	0	0	0	?		0	0	0	0	0	0	0	Possible (unconfirmed) otter run
25/09/2012	4	RR	0	1	0	1	c.35m	0	?	0	0	0	0	0	Very old otter spraint. Also (old) prey remains comprising feather, egg shell, amphibian bones (likely to be due to otter or mink, but unconfirmed). Possible (very old) mink scat at the same site. Pine marten scat (not DNA verified) on nearby forest track.
25/09/2012	5	RR	0	2	1	1	98m	0	0	0	0	0	0	0	1 old spraint and 1 recent spraint, both by the lie-up.
25/09/2012	6	RR	0	1	1	1	56m	0	0	0	0	0	0	0	Holt with fresh spraint and otter tracks
25/09/2012	7	RR	0	0	0	1	0m	0	0	0	0	0	0	0	Old spraint (x2) just outside transect, near start
27/09/2012	8	RR	0	3	1	0	10m	0	0	0	0	0	0	0	First spraint by lie-up
27/09/2012	9	RR	0	0	0	?		0	0	0	0	0	0	0	Several potential lie-ups, also probable otter runs (unconfirmed)
27/09/2012	10	RR	0	0	0	0		0	0	0	0	0	0	0	
26/09/2012	11	RR	0	6	0	0	0m	0	0	0	0	0	0	0	1 very fresh spraint at 84m. 5 old spraint. Very overgrown site. Wood mouse signs frequent.
28/09/2012	12	RR	0	4	0	1	31m	0	0	0	0	0	0	0	1st spraint at 31m (recent). Other 3 were fresh or recent
26/09/2012	13	RR	0	2	0	0	75m	0	0	0	0	0	0	0	Also 3rd (old) spraint containing crab fragments just outside the transect
26/09/2012	14	RR	0	6	0	1	29m	0	0	0	0	0	0	0	1st (fresh) spraint at 29m
28/09/2012	15	RR	0	?	0	0		0	?	0	0	0	0	0	2 unidentified scats/spraints – no scent. Retained in freezer. Very difficult site to survey due to fallen trees etc. All prominent stones, stumps etc checked for spraint
26/09/2012	16	RR	0	36	1	1	3m	0	0	0	0	0	0	0	First spraint at 3m. Most spraints not fresh. Feeding remains present (crab). Numerous obvious and well-used runs, also rolling areas. Holt/lie up @15m
26/09/2012	17	RR	0	6	0	1	20m	0	0	0	0	0	0	0	First (old) spraint at 20m. All spraints quite old. (Lots of badger latrines in adjacent fields. Brown rat dropping

															present).
27/09/2012	18	RR	0	1	0	?	17m	0	0	0	0	0	0	0	Single old spraint containing crab remains at 17m. No signs on the mink raft. Lots of mammal runs in the *Molinia* tussocks, but the origins/users are unclear. (Abundant evidence of red and/or sika deer)
26/09/2012	19	RR	0	0	0	0		0	0	0	0	0	0	0	(Field vole runs).
26/09/2012	20	RR	0	1	0	0	18m	0	0	0	0	0	0	0	Single old spraint at 18m (under bridge). Plenty of potential lie-up locations

ID = Transect identification number, Osight = otter sighting, Ospraint = otter spraint, ORP = otter resting place, OTR = otter track, Msight = mink sighting, Mscat = mink scat, MTR = mink track, Mother = mink other field sign, W = water vole sighting, Wlat = water vole latrine, Wother = water vole other field sign. Surveyor RR = Rob Raynor

Table 3: The mean number of otter spraints recorded for all sites where spraint was found

	Trial area		Control area	
	Proportion of sites with evidence of otter spraint	**Mean no. spraints per site (where spraint was found)**	**Proportion of sites with evidence of otter spraint**	**Mean no. spraints per site (where spraint was found)**
2009	7/10	3.9	6/10	1.3
2010	7/10	6.3	4/10	1.5
2011	7/10	11.4*	3/10	1.3
2012	**8/10**	**7.8****	**4/10**	**1.8**

* If Site 16 with >47 spraints is excluded, the mean of the remaining 6 positive sites is 5.5
** If Site 16 with 36 spraints is excluded, the mean of the remaining 7 positive sites is 3.7

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