Environment Agency

Evidence

Acoustic deterrents for otter management at stillwater fisheries: preliminary investigation

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Miranda Kavanagh

Director of Evidence

Executive summary

Increasing otter presence in some areas has led to conflict with inland freshwater fisheries.

The aim of this project was to assess the potential for acoustic deterrents to be used as a management tool to reduce otter predation.

There is little information on otter hearing in the literature. Two studies suggest that otter hearing in air ranges between 0.13–0.45 and 32–35 kHz (peaking at 16 kHz). It is not known how aerial hearing relates to underwater hearing.

During the first phase of the project, five Aqua*mark* 210 acoustic deterrents ('pingers') deployed in a small (~100 × 30 m) carp pond in Oxfordshire for four weeks had no apparent effect on otter visitation rates as assessed by camera capture rates. In response to these early results, it was decided not to continue with repeat field trials of the Aqua*mark* 210 acoustic deterrents.

There was some reduction in otter visitation rates during an opportunistic eight-week deployment of a Lofitech seal scarer at the same carp pond. However, the short duration of the trial and the lack of a comparable control site (otter activity at the designated control site was low) meant that it was not possible to attribute the decline to the seal scarer rather than seasonal/weather effects. Further seal scarers were not available to replicate this trial.

During the second phase of the project, a series of preliminary captive trials was carried out in an attempt to identify an underwater acoustic signal (sound) that might elicit an aversive response in otters (scare them away from stillwater fisheries, or more specifically prevent them entering the water at stillwater fisheries).

Given the current paucity of knowledge on otter hearing range, a 'chirp' of between 10 and 25 kHz, with a cycle duration of 3-4 seconds, was identified as being most appropriate for trials.

Trials 1 and 2, using a pair of 'show' otters at the New Forest Wildlife Park, tested a number of different acoustic signals (including the 10–25 kHz chirp and three potentially 'threatening' novel sounds – one predator noise and two man-made noises). Otters were not prevented from entering their pools in either trial. However, otters were clearly interested in the sound when it was played at high intensity (Trial 2) and appeared to be agitated by the presence of the equipment when the cycle duration of the chirp was reduced to one second.

Trial 3, using 'off-show' otters in two separate pens, tested the same high intensity chirp as in Trial 2 with a one-second cycle duration. The off-show otters differed from the show otters in that they were nocturnally active and were not habituated to humans. In this trial, otters entered their pools significantly fewer times, and spent significantly less time per night in the water, in the presence of the signal compared with baseline behaviour.

A preliminary literature review suggested that acoustic deterrents can be effective in reducing fish predation and damage due to seals (although habituation was rarely addressed), but evidence that they reduce bycatch of cetaceans was mixed. There were relatively few studies of the effectiveness of acoustic deterrents in deterring terrestrial or semi-aquatic mammals – most showed that they were not effective, although there was some evidence that ultrasonic devices might reduce bat activity and bat deaths at wind farms and that some (but not all) polar bears are repelled by sound. Only one study tested acoustic deterrents on otters (in this case, sea otters); that study observed no behavioural response but tested only one device and did not measure its actual acoustic output. Generalities are hard to draw due to variability in species-specific response, device tested and experimental conditions.

It appears that acoustic deterrents may offer a potential management device for otters at stillwater fisheries but further research (in captivity and in the field) is required before their use could be recommended or manufacturers could be offered guidance on an acoustic signal designed specifically for otters.

Acknowledgements

The project team is extremely grateful to Dr Paul Lepper (Bioacoustic Lab, Loughborough University) for advice, assistance with setting up, and loan of equipment required for generation of acoustic signals, Dag Hansen for loan of the Lofitech seal scarer, Ed Heap and Jason at the New Forest Wildlife Park for allowing us to carry out captive trials, landowners for allowing access to their land, Cotswold Water Park staff for their interest in the study, and Aquatec for technical advice and supply of Aqua*mark* devices.

Contents

1 Background

The recent national recovery of the otter (*Lutra lutra*) population in the UK has been a resounding conservation success. In some areas, however, this increase in otter presence has led to conflict with inland freshwater fisheries, with some fishermen calling for a cull of otters to reduce numbers. Otter predation at stillwater fisheries is a particular problem (though may be local in extent), and especially so at specimen fisheries that stock valuable carp. There is currently an urgent need to address this problem and demand for a solution to reduce the severity of the impact of otters. Although fencing provides a potential solution, it is expensive and not suitable at all sites. One alternative suggested method is the use of acoustic deterrents (‘pingers’) similar to those used to keep harbour porpoises and dolphins away from fishing nets. Although users have claimed that these deterrents have been successfully deployed to deter otters, there is currently no scientific evidence of their effectiveness as otter deterrents.

To address this evidence gap, a partnership project was developed in discussion between the Environment Agency and the Wildlife Conservation Research Unit (WildCRU) of the Department of Zoology, Oxford University. The Environment Agency’s involvement in this project stems from their statutory conservation duties, especially in relation to flora and fauna associated with the water environment, and their role as lead government agency for freshwater fisheries, and for the promotion of the social and economic benefits of fishing in England (and Wales until April 2013). This research comes under the Environment Agency’s work to address the concerns regarding otter predation on fisheries, particularly in light of their lead role for the UK otter Biodiversity Action Plan (BAP). Hampshire-based Aquatec Group Ltd, developers and manufacturers of marine mammal acoustic deterrents, were commercial partners in the project. The project steering group consisted of representatives from the Environment Agency, the WildCRU and Aquatec.

This report presents the findings of initial short-term collaborative field trial to assess the potential for acoustic deterrents to be used as a management tool to reduce otter predation problems at inland fisheries.

2 Research plan

In any field project utilising novel techniques or testing novel management methods, there is an element of unpredictability. This stage of the research was therefore necessarily preliminary. Two phases were planned initially – a captive and a field phase.

The first phase involved captive trials to address some basic biological questions, such as the ability of otters to detect the device the project intended to test, and a literature review of the effectiveness of acoustic deterrents on other species, as well as consultation with acoustic biologists and technicians developing the devices.

The second planned phase was a short-term, focused field trial designed to assess whether acoustic deterrents offer a potential management tool for otters. Logistical considerations meant that the field trial would, by necessity, be limited in scope. The research question was therefore restricted to the effectiveness of acoustic deterrents in reducing otter visitation (as an index of potential predation impact) in winter at small to medium-sized stillwater fisheries.

The original project timetable incorporated a one-month captive study and six-month field study, within the eight-month research project, to be carried out between September 2011 and April 2012 (the field trial starting November 2011). Due to unforeseen events and early results, in consultation with the Environment Agency, changes were made to the research plan (see below) that involved a shift in emphasis from field trials to captive studies.

3 Literature review: hearing range of otters

Clearly, the ability of a device to deter a species from an area depends on the species in question being able to hear the device, and to be able to hear it at a level that causes sufficient discomfort that the animal moves away or is scared away from the area. The frequency range over which sound can be heard, however, varies considerably among species (Fay 1988, Warfield 1973). Although the development of devices for many marine mammals is based on a solid body of research on the acoustic biology of these species, little appears to be known of the hearing range of otters. Obtaining a species-specific audiogram is difficult, or impossible, for many wild species. Current methods used to assess hearing range in animals include behavioural assessments with highly trained animals and physiological measurements of brainstem potentials in response to auditory stimulus; neither of these would be possible for wild otters whether in the wild or in a captive setting due to the difficulties of training a wild otter, or restrictions on handling them, respectively.

Internet searches using google.com, and googlescholar.com, as well as a literature search using Web of Science and searches of two relevant journals (*Bioacoustics Journal* and the *Journal of the Acoustic Society of America*),[1] revealed only two sources of potentially useful information.

In 1988, a master's student made behavioural measurements of hearing in air for two North American river otters, *Lutra canadensis* (Gunn 1988). More recently, researchers at the Long Marine Laboratory at the University of California undertook a preliminary investigation of sound reception in southern sea otters, *Enhydra lutris nereis* (Ghoul and Reichmuth 2011). The former study indicated a functional hearing range in air for river otters of approximately 0.45 to 35 kHz, with peak sensitivity at 16 kHz; the latter reported the maximum range of aerial hearing for sea otters as 0.125–32 kHz.

The sea otter study used behavioural methods with trained captive animals; it is not known what methods were used to measure hearing range in river otters. Two audiograms for the least weasel, *Mustela nivalis*, and the ferret, *M. putorius*, obtained by behavioural conditioned avoidance procedures and neurophysiological methods, respectively, suggest hearing ranges of 0.05–60.5 kHz (peak sensitivity at approximately16 kHz) and 0.016–48 kHz, for these species (Heffner and Heffner 1985; Kavanagh and Kelly 1988).

Sea otter ears are the most similar to those of land mammals of all marine mammal ears that have been investigated[2] and, given the similarity in results from the two otter species (as well as substantial overlap with the two terrestrial mustelid species), it seems reasonable to assume that the sea otter provides an appropriate model for the Eurasian otter in the absence of species-specific data. It is unknown, however, how aerial hearing range relates to underwater hearing sensitivity and therefore confirmation that otters can detect devices transmitting within this range underwater will be essential prior to operational deployments of acoustic deterrents at stillwater fisheries.

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[1] Search terms for google and googlescholar: 'otter hearing' and 'otter audiogram'; Web of Science: Lutra AND hearing; journals: 'otter' AND '*Lutra lutra*'

[2]From: http://www.planetpuna.com/Ketten/ketten_summary.htm (see also Evans and Raga 2001)

4 Pilot field trial

Initially, the research team had planned to test existing acoustic deterrents manufactured by Aquatec. The intention had been to follow these initial trials with further testing of otter-specific devices (adjusted to maximise detection by otters based on what was known of otter hearing range). Initially, therefore the aim was to answer the following question:

- Does the presence of the Aqua*mark* 210 acoustic deterrent reduce visitation rates by otters at small/medium carp fisheries during winter?

4.1 Methods

4.1.1 Study location

The field study was based in the Upper Thames region, where there are a number of stillwater fisheries, of various sizes and uses, many of which have experienced some level of otter predation in recent years (G. Scholey, personal communication and personal observation.). Six potential sites were selected (Figure 4.1):

- **Lechlade Trout Farm –** on the River Leach, near Lechlade, Gloucestershire. It consists of a 3.5 ha lake (stocked with rainbow and brown trout) and four small stock ponds. Two stock ponds within 4 m of the river were reported to suffer heavy predation from otters.
- **Bibury Trout Farm** – on the River Coln, Bibury, Gloucestershire. Bibury trout farm has over 35 small pools (~20 × 15 m) used to rear trout (rainbow and brown trout). The trout farm is triangular in shape and is bordered by either the river or the mill stream on all three sides. There is a small electric fence at the far end of the trout farm bordering the river, but the other end of the trout farm is unfenced. The farm reported having suffered otter predation for a number of years.
- **Horcott Lakes** – near Fairford, Gloucestershire, within 400 m of the River Coln. Horcott lakes consists of four flooded gravel pits, the largest of which is approximately 200 × 200 m (~4 ha). The lakes are stocked with coarse fish and are surrounded by a number of other lakes and active gravel pits. Fishery owners reported otter predation at one of the smaller lakes and losses of several large carp in previous winters. In summer 2011, fish were moved by the Environment Agency from the small lake, where water levels were very low, to the largest lake.
- **Vauxhall Lake** – part of a large group of flooded gravel pits, near Stanton Harcourt, Oxfordshire. Vauxhall Lake is approximately 250 m long, situated within 6 m of the River Windrush, stocked with carp and other coarse fish. Fishery owners have reported fish losses due to otter predation in past years.
- **Lower Court Lake** (see also Figure 4.2) – an isolated carp pond approximately 0.5 km from the River Evenlode, near Chadlington. The lake is approximately 100 x 30 m (depth c.2m) with a small island in the middle. The fishery owner had experienced fish losses due to otter predation over winter since 2010.

- **Ascott Lake –** an isolated pond (stocked with carp and tench) about 100 m from the River Evenlode, near Ascott-under-Wychwood in Oxfordshire. Almost identical in size to Lower Court Lake (~100 x 150 m) with a small island in the middle. No otter problems had been reported, although otters were known to be present on the river.

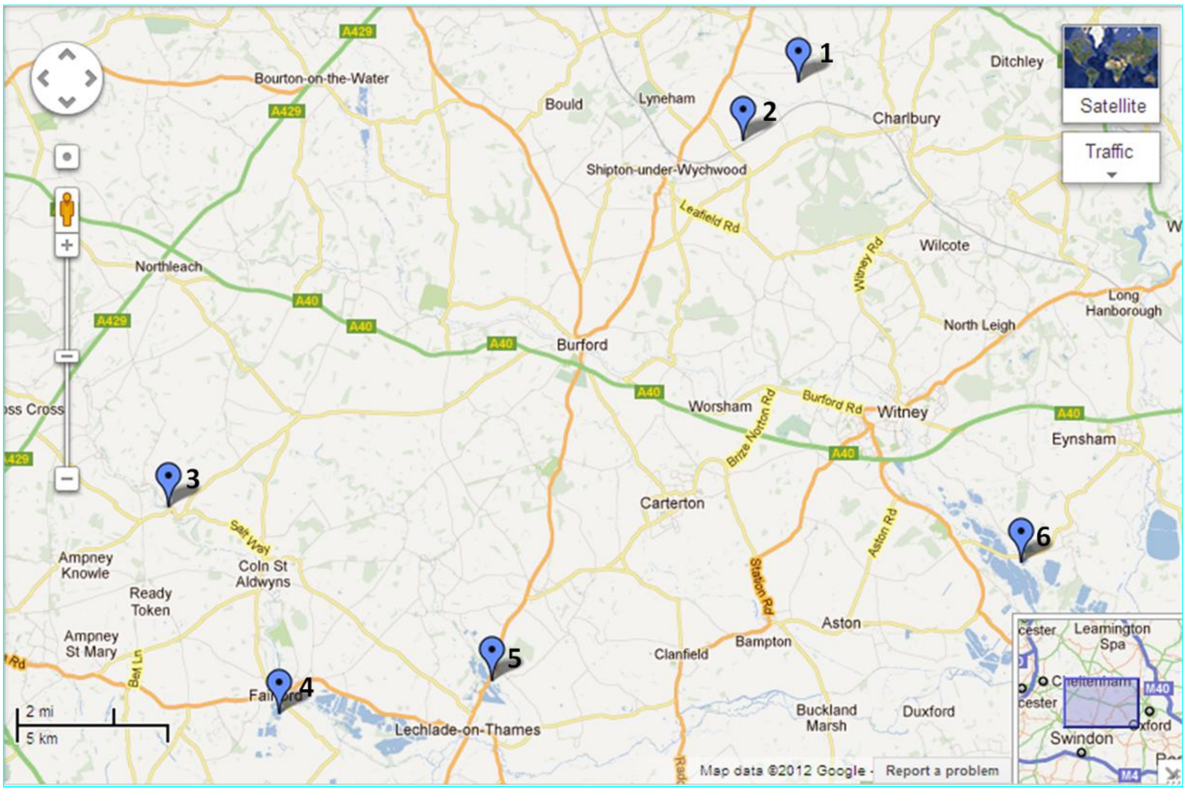

Figure 4.1 Fishery locations: (1) Lower Court Lake, (2) Ascott Lake, (3) Bibury Trout Farm, (4) Horcott Lakes, (5) Lechlade Trout Farm and (6) Vauxhall Lake

4.1.2 Acoustic devices

The Aqua*mark* 210 manufactured by Aquatec (www.aquatecgroup.com) was used in the initial trials. This device is a passive acoustic deterrent ('pinger') designed to reduce predation by dolphins in commercial trammel net, gillnet, tanglenet and driftnet fisheries (this particular model is recommended where bycatch is severe). These devices have batteries that will last 1–2 years when immersed continually (they incorporate a wet switch meaning that the device only operates, and uses power, when immersed in water). They transmit ultrasonic signals between 5 kHz and 160 kHz[3] (typically 150 dB re 1 μPa @ 1 m) and are designed to be positioned at 200 m intervals (each individual device is 164 x 58 mm in size).

At a separate time, a 'seal scarer' manufactured by Lofitech (www.lofitech.no), which is designed specifically to deter seals from fish farms, was tested (see below). The seal scarer transmits ultrasonic signals between 14 and 15 kHz (at approximately 189 dB re 1 μPa @ 1 m). The seal scarer consists of a transducer and a separate control unit that

[3] These devices are unlikely to impact on fish hearing – cyprinids (probably the most relevant fish species at sites where otter deterrents are likely to be used) have a hearing range of between 0.1 and 5 kHz, and salmon have a hearing range of 0.05–0.8 kHz (G. Peirson, personal communication).

is powered by a 12 V battery. It is designed to be used as a single unit, requiring battery recharging at 2–3 day intervals.

4.1.3 Monitoring methods

Otter visitation rates were monitored indirectly using two independent methods – spraint surveys and camera traps, supplemented by counts of large fish carcasses on the bank (recorded during spraint surveys).

All likely marking places around the entire bank of the lake at each site were searched for spraints at weekly intervals; spraints were squashed to avoid double counting but retain the scent at the location, which may otherwise alter otter marking behaviour if removed. The number of spraints was counted to provide a very simple index of otter activity.

Two remote, infra-red cameras (Bushnell trophy cam, www.bushnell.com) were placed per site – either at likely entry points, or positioned to maximise coverage of the water. Camera capture rates were recorded weekly and quantified as the 'number of events' (defined as separate visits) per day.

At Lower Court Lake, surveys for spraints and fish remains were also carried out on the island within the lake, and an additional camera was set on the island.

4.1.4 Study design

Our original experimental design was based on a 'before-after-control-impact-paired' approach, with five replicate treatment/control paired sites with each being monitored for a period of time before 'treatment' (deployment of pingers). Four of the study sites included treatment and control lakes within the same site; Ascott Lake was designated as the control site for Lower Court Lake.

Unforeseen events meant that the project was initiated in November 2011 (two months later than the original scheduled start date). Due to the late start pingers were installed at one site (Lower Court Lake, Chadlington) before all the others; all sites had been monitored for six weeks at this point. Because it was clear quite quickly that the pingers had no effect on otter visitation (see section 4.2, it was decided not to proceed with the replicate sites. Subsequently, the opportunity arose to borrow a different acoustic device (the Lofitech seal scarer) but only one of these was available for loan. Although use of a single site is problematic in terms of interpreting results (treatment effects cannot be separated from random chance events), the project team considered that a trial deployment of the seal scarer would be useful to help assess whether the use of acoustic deterrents was worth pursuing further.

From here on, the report refers unless otherwise stated only to Lower Court Lake (treatment) (Figure 4.2) and Ascott Lake (control).

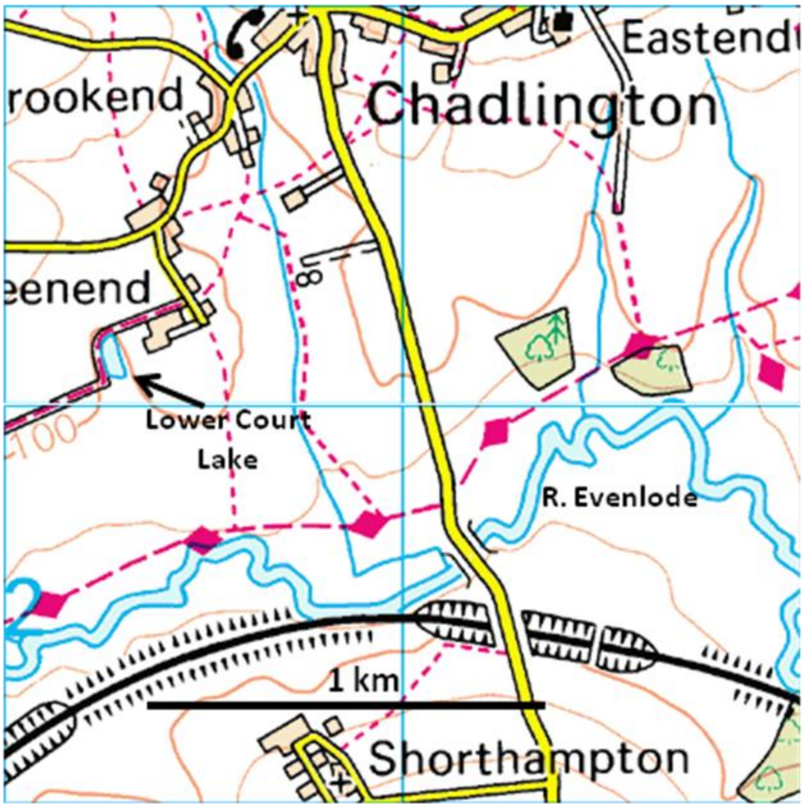

Figure 4.2 Lower Court Lake, Chadlington, showing proximity to the River Evenlode

4.1.5 Licensing

Acoustic deterrents were installed under licence (number 20114719) from Natural England (under section 16(3)(a) of the Wildlife and Countryside act 1981 (as amended) and Regulation 53(2)(a) of the Conservation of Habitats and Species Regulations 2010).

4.2 Results

4.2.1 Treatment and control sites

Otter visits were monitored at Lower Court Lake and Ascott Lake for six weeks before deployment of the pingers. Camera traps on the island in the lake were particularly effective and it was possible to photograph otters eating fish (that is, direct evidence of otters taking fish from the lake) (Figure 4.3) and sleeping in front of the camera. Pre-treatment visitation averaged 11 camera events per week at Lower Court Lake (mean number of spraints counted per week = 9.6) (Figure 4.4). At least one large carp was taken during this period (Figure 4.5).

Five pingers were suspended at a depth of ~30 cm around the island for the following four weeks. During this period, there was an average of 16.8 camera events per week (mean number of spraints counted per week = 5.8) (Figure 4.4). At least six large carp were taken during the time that the pingers were deployed.

A single seal scarer was deployed for eight weeks following the removal of the pingers. During this period, there was an average of 5.5 camera events per week (mean number of spraints counted per week = 1.6) (Figure 4.4). At least one large carp was taken during the time that the seal scarer was deployed. However, the lake was frozen for three weeks during this period, which meant that spraint counts could have been underestimated because surveys of the island were not possible and otters were prevented from diving to catch fish. Note that camera captures provided evidence that otters continued to cross the lake – presumably across the surface of the frozen lake – and to use the island.

Differences in the body size of otters observed on cameras suggested that two otters were visiting Lower Court Lake regularly. Otter presence on the River Evenlode was confirmed (by the presence of spraint) throughout the trial. Only spraint surveys were possible at Ascott Lake – a single spraint was observed most weeks over the duration of the trial but otters were clearly less active at Ascott Lake than at Lower Court Lake. No signs of otters were found on the island at Ascott Lake suggesting that they didn't use the lake extensively.

Figure 4.3 Camera trap photo of an otter with a fish on the island at Lower Court Lake, Chadlington

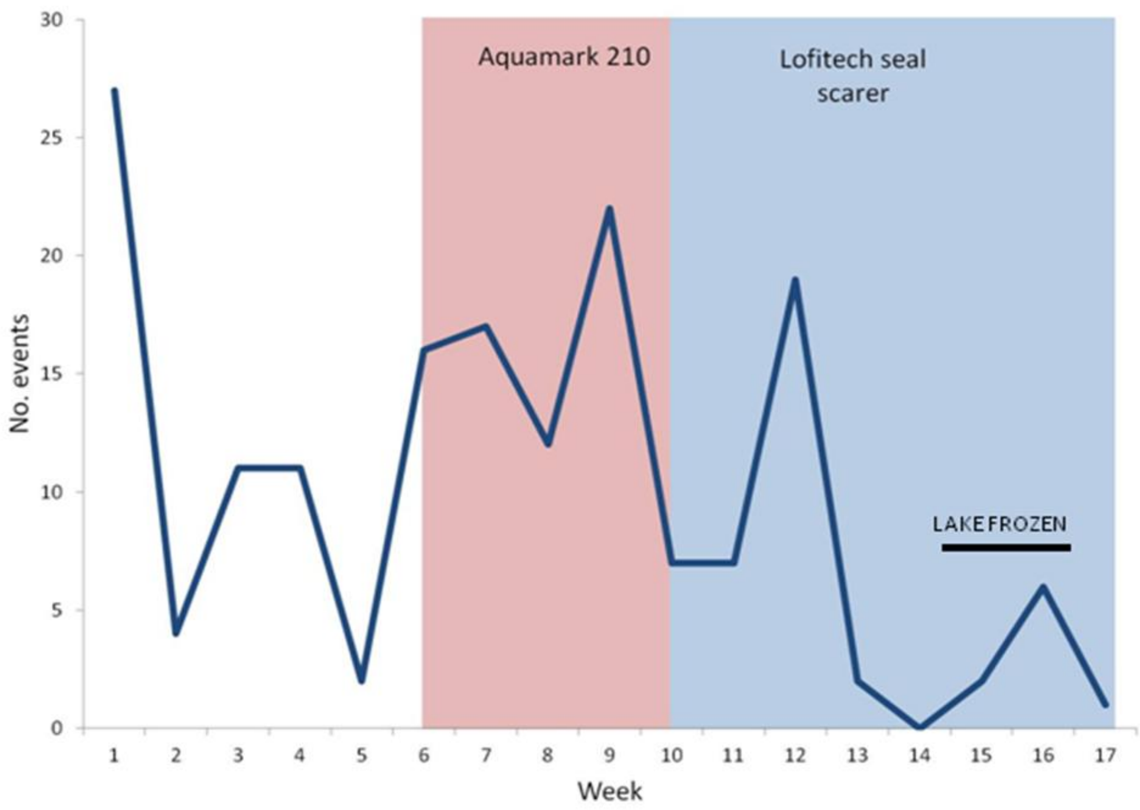

Figure 4.4 Weekly camera events before and during deployment of acoustic deterrents at Lower Court Lake, Chadlington

Figure 4.5 Carp carcasses at Horcott Lakes (left) and Lower Court Lake (right)

4.2.2 Other sites

For completeness, an overview of the monitoring at the other sites is provided here. All sites were monitored for five weeks unless otherwise stated:

- Lechlade Trout Farm. Although spraint was found regularly on the river within 6 m or less of the ponds, no otters were caught on camera on or near the stock ponds and no records of depredation were reported by the owners during the monitoring.
- Bibury Trout Farm. Opportunistic snow tracking by farm staff suggested that otters visited the farm at least twice a week. The project team obtained

photos of an otter in one of the stock ponds on one occasion but otherwise the otters appeared to avoid the camera traps (perhaps using other ponds). Photos of otters walking by the side of the pond provided evidence that one male as well as a female with three cubs were visiting the farm during the monitoring period. Additional monitoring problems were encountered because cameras were triggered by light reflections from the surface at the water. Evidence of trout taken was reported every few weeks by farm staff.

- Horcott Lakes. This site was monitored for five months. Camera trap photos suggested that one male otter was present for most of this time, and that a female visited the lake for two weeks in early March. No fish losses were reported by fishery owners during the monitoring (the photo shown in Figure 4.3 was taken prior to the monitoring).
- Vauxhall Lake. Only spraint surveys were carried out here. The presence of fresh spraint suggested that otters were continually present on the nearby river, but no spraint was found on the banks of the lake (possibly due to a lack of potential marking sites). No fish losses were reported by fishery owners during the monitoring.

4.3 Discussion

4.3.1 Comments on methodology

Spraint surveys and camera trap photos provided evidence of otter visits to the lake but not specifically whether the otter went in the water, or more importantly whether otters actually caught a fish. Monitoring was improved where there was an accessible island: any otter on the island had to have swum across the lake, although not necessarily have caught a fish.

Fish remains provided supplementary evidence of actual fish predation by otters but likely underestimated predation because carcasses on the banks of the lake could be removed by other animals (camera trap photos on the lake island at Lower Court Lake showed herons removing smaller fish carcasses).

Otter ‘rafts’ positioned in the lake and monitored for spraint activity are a possibility for the future (otters often leave spraint on mink rafts on the river).

4.3.2 Effects of acoustic deterrents

The high number of fish taken at Lower Court Lake during the pinger deployment demonstrated quite clearly that pingers did not deter otters from diving and catching fish in the lake. An apparent decline in otter visitation (number of camera events) during the deployment of the seal scarer suggests that the seal scarer might have had some effect. However, the trend in the data is heavily influenced by a single high number of camera events at the beginning of the pre-deployment monitoring, and the low number of camera events recorded when the lake was frozen. Furthermore, the paucity of comparative data from Ascott Lake means that it is not possible to disentangle chance and seasonal/weather effects. Deployments at additional sites (compared with suitable control sites) would be required to confirm the effectiveness of the seal scarer. However, the $8,000 cost of the seal scarer meant that this was not possible in the current project.

It is perhaps noteworthy that the fishery owner at Lower Court Lake was much happier when the seal scarer was installed – even in the absence of robust evidence of a reduction in fish predation at the lake.

A second deployment of the seal scarer at Lower Court Lake was monitored on a voluntary basis over the winter of 2012-2013. Although otters continued to visit the lake site (evidenced by spraint surveys around the bank) and swim in the lake (evidenced by camera captures on the island), no fish were taken during this deployment (with the exception of one period when the device's batteries temporarily ran out).

5 Changes to the project plan

Given the complete lack of effect of the presence of the pingers on otter visits and numbers of fish carcasses seen at Lower Court Lake, it was decided not to proceed with repeat trials of the pingers at the other field sites. Further seal scarers were, unfortunately, not available for repeat or longer-term testing.

In consultation with the Environment Agency, it was concluded that there was currently insufficient knowledge about the response of otters to acoustic stimuli to be able to specify the requirements for an otter specific device. It was therefore also decided not to proceed with development of otter-specific acoustic devices until further captive work had been completed.

On the basis of these preliminary field results and given the general lack of knowledge about otter hearing underwater, it was agreed that the most efficient way forward would be to shift emphasis for the remainder of the project to the captive trials.

These changes to the project plan were agreed by all parties at a meeting on 11 January 2012.

6 Preliminary captive trials

6.1 Background

6.1.1 Rationale and objectives

Our original research proposal included tests of the Aqua*mark* 210 acoustic deterrents (‘pingers’) in captivity. However, given the results of the pilot field trials indicating that ‘pingers’ are likely to have a negligible effect on otters, it was agreed with the Environment Agency that it was not worth pursuing the effect of the pingers in captivity.

Nevertheless, the initial pilot work and literature research was useful in identifying the questions that need to be addressed before an otter-specific acoustic deterrent device could be developed. The following questions were identified as potentially important:

1. Over what range of frequencies can otters hear?
2. How sensitive is otter hearing?
3. How does otter hearing differ underwater from in-air?
4. What intensity and/or frequency of noise ‘scares’ otters or causes them some discomfort? (most important)
5. What intensity of noise would damage otter hearing?

These questions could not be fully answered within the current project because:

- it is extremely difficult to obtain audiograms for animals (existing methods that utilise either behaviourally trained animals, such as sea otters, or neurophysiological methods, are not possible or suitable for otters)
- ‘experimental’ conditions are not perfect in the wildlife parks where the work would have to be based

The questions nevertheless form the basis of the current work, as well as being the basis of any plans for further work.

An effective deterrent device needs to fall between questions (4) and (5), that is, it needs to scare or cause some discomfort to the animal (sufficient to prevent it from feeding), but also not damage the otter’s hearing

During the remainder of this project, the focus was on exploring the possible effects on otter behaviour of a range of acoustic signals. The general aim was to identify a signal (sound), or range of signals that meet these criteria and which would be worth testing further with a view to developing an otter-specific deterrent device. The specific objective was to identify an acoustic signal that elicits an aversive response in otters.

6.1.2 Identification of ‘sounds’ to test

Because the project team do not have precise information on the underwater hearing range of otters, the best strategy is to use a ‘chirp’ which cycles repeatedly through a predetermined range of frequencies at a predetermined speed. Based on what is known of the sea otter’s in-air hearing (see above), a range between 10 and 25 kHz with a cycle duration of between 3 and 4 seconds was selected (that is, the signal increases from 10 to 25 kHz over 3 or 4 seconds). Given the absence of information on the sensitivity of the otters hearing underwater, the signal was turned on initially at a very low level and then the signal intensity was gradually increased over the treatment duration up to a predetermined maximum.

Additional ‘novel sounds’ were identified based on their potential to scare an otter. Many species have an innate fear of unfamiliar predators and avoid, or otherwise respond, to their scent (and it is presumed their calls). The call of a killer whale was selected as a ‘predator noise’. Two recordings of a two-stroke engine (a strimmer and a chainsaw) were also selected as a man-made ‘scary noise’ (the latter because the otter keeper at the New Forest reported that the off-show otters do not emerge when the trees outside are being cut).

6.2 Methods

All trials were carried out at the New Forest Wildlife Park where both show and off-show otters have free access to small pools. Trials were carried out on a pair of show otters housed in a single enclosure and on off-show otters in two enclosures (one of which housed a single otter, the other a pair of otters). Both pairs were a mother and her female offspring. The show otters were diurnally active, kept in an enclosure that was partly indoors, and were habituated to people; the off-show otters were nocturnally active and kept in enclosures in a woodland area away from visitors.

A transducer was used to generate an acoustic signal at specified frequencies and intensities, and the signal transmitted underwater in the otter’s pool via a hydrophone placed within a plastic tube (to protect it from the otters). Additional sounds were recorded (or recordings obtained from the internet) and replayed via a laptop connected to the underwater hydrophone.

To detect a response by the otters, baseline behaviour was recorded in the absence of the acoustic signal. To allow the response to the sound to be distinguished from a general response to the presence of novel items in the pool, control trials were also carried out in which the plastic tubes and hydrophones were placed in the pool but no sound generated. Baseline, control and treatment trials were filmed and behaviours quantified later from video.

Prior to the trials, all otters at the wildlife park were observed (Eurasian and American otters) over several days to determine activity times (and thus the optimum time of day for the trials) and to decide on appropriate behaviours to record.

For the show otters, baseline behaviours were recorded for one 15-minute block immediately before the treatment. One or more treatments were then given for 15-minutes each. All trials were carried out within the otter’s normal activity times (approximately 8am to 10am).

For the off-show otters, baseline behaviours were recorded using infra-red camera traps for 3–4 full nights each. Because off-show otters were only active at night, treatments were run remotely overnight; direct observations were not possible because the team did not have access to the park at night. Treatments were run over a whole night.

Behaviours were quantified as number of visits to the pool and total time spent in the pool. For the off-show otters these parameters provided an index of actual time in the pool because the camera used was limited to 30-second bursts of filming when triggered by the presence of an otter and so it was not possible to quantify total time spent in the pool. However, because several pool visits observed during the baseline phase were <30 s, it was considered that this index would be sufficient to detect a change in behaviour. All trials were filmed so that additional, and more detailed, behaviours could be quantified at a later date if this were deemed worthwhile (for example, time lag between approaching and entering the water, or time between first and second visit to the pool).

6.3 Results

6.3.1 Trial 1: Response to medium intensity 'chirp' (show otters)

Eurasian show otters were recorded for eight consecutive 15-minute blocks and exposed to three different treatments in the following order:

1. Pipe in water – no sound
2. 3 s chirp, 10–25 kHz
3. Pipe in water – no sound
4. 3 s chirp, 10–25 kHz
5. 4 s chirp, 5–30 kHz
6. 4 s chirp, 10–25 kHz
7. Pipe in water – no sound
8. 4 s chirp, 10–25 kHz (hydrophone deeper in the water)

For each 15-minute treatment, signal intensity was gradually increased over the 15 minutes up to a predetermined maximum level. For this trial maximum intensity was limited by the capability of the equipment.

No response was observed. Otters remained in the pool during the trials and showed no aversive reaction to the sound generated.

6.3.2 Trial 2: Response to high intensity 'chirp' and novel sounds (show otters)

For this trial, equipment was obtained that was capable of generating a higher intensity acoustic signal than in trial 1 (in this case, limited in line with existing guidelines for marine mammals to ensure no damage was caused to the otters hearing).

Eurasian show otters were recorded for eight consecutive 15-minute blocks and exposed to the following treatments:

1. Pipe in water – no sound
2. 4 s chirp, 10–25 kHz (increasing intensity)
3. 4 s chirp, 10–25 kHz (continuing to increase intensity up to the maximum)
4. 4 s chirp, 10–25 kHz (continuous maximum intensity)
5. 1 s chirp, 10–25 kHz
6. Novel sounds: killer whale (treatment stopped because otters left the observation area)
7. Novel sounds: 4 minutes of each of killer whale, strimmer, chainsaw, strimmer (repeat)

Otters did not stop using the pool in response to any of the sounds played, but their curiosity of the pipe appeared to increase quite drastically as the intensity of the signal was increased. The short 1 s chirp appeared to promote the greatest response. During the 1 s chirp, the otters were quite intently attacking the pipe, appeared agitated, and it seemed that they were trying to remove the plastic pipe (that covered the transducer) from their pool.

The recordings and transmission of the novel sounds probably need to be improved because the laptop used to play the sounds appeared to limit the volume of the recordings and underwater transmission might have been very low intensity. Sound in the pool was not recorded during the treatments so actual signal intensity could be quantified and used to generate improved novel sounds for use in future research.

At the end of this trial, as a brief pilot test, the recordings of the killer whale and the strimmer were played direct from the laptop as ‘in-air’ sounds from outside the otter’s enclosure. The otters appeared to be curious of the killer whale calls (they stood by the side of the pool and adopted an alert posture) and to dislike the sound of the strimmer (both otters were out of the water, appeared slightly agitated and eventually left the indoor part of the enclosure where the signal was being transmitted). The transmission of these latter sounds was far from ideal (poor quality recordings, transmitted only through the laptop internal speakers from outside the otters enclosure), nevertheless, the otters’ response to these sounds suggest that the inclusion of in-air sounds should be considered in further trials.

6.3.3 Trial 3: Response to high intensity ‘chirp’ (off-show otters)

The baseline behaviour of otters in each of two enclosures (n = 1 and n = 2 otters respectively) was recorded for 3–4 nights prior to treatment. Because it was only possible to test one treatment in the time available, the one-second high intensity chirp was selected. Treatment (underwater sound) was presented for one night over the whole night.

During the baseline behavioural observations, all otters made full use of their ponds, visiting them up to 50 or more times in a night; some visits were short (only 5 s) in duration, but most were 30 seconds or longer (see details above on maximum camera recording time).

Both the number of events and total time spent in the pool were significantly reduced in the presence of the sound (Figure 6.1). Although mean time in the water per event in pen 2 appeared unchanged in the presence of the sound, this was due to a small number of events towards the end of the night that probably occurred after the battery powering the transducer had died (since the batteries were often dead by the morning, this apparent lack of response was more likely due to lack of power and absence of the sound than to habituation).

Videos of the otters during the treatments revealed high levels of motivation to get into the pond, but an apparently inability or unwillingness to get into or to stay in the water, particularly with their heads underwater. Otters frequently approached the pool and investigated from the edge; they put their heads in the water before entering but then did not enter. If they did get in the pool (or fell from the edge) they jumped out quickly, and one of the otters could be seen attempting to get into the pool hindquarters first.

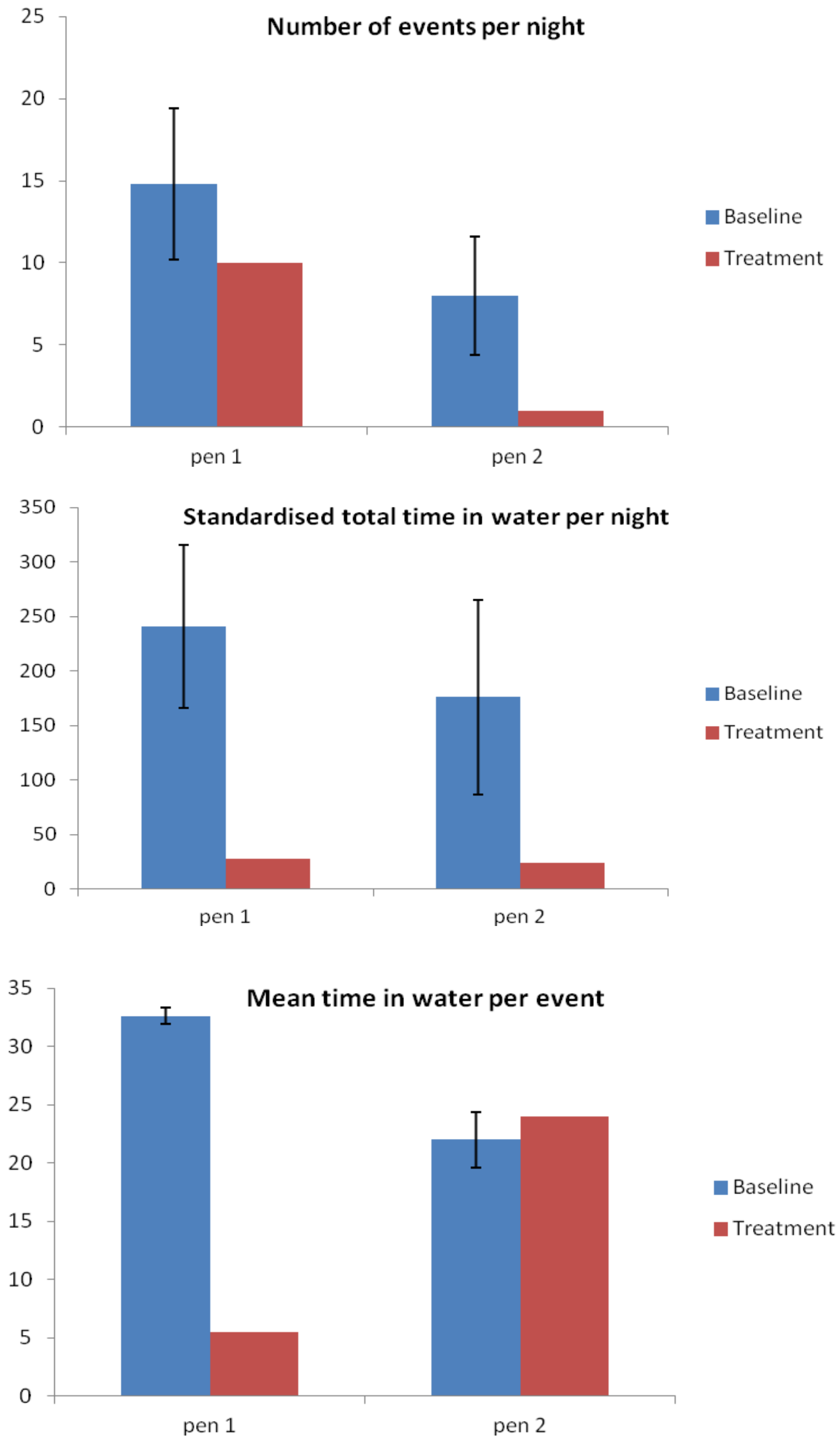

Figure 6.1 Response of off-show otters to a one-second, high intensity 'chirp'

Notes: An event = each time the camera was triggered.
Total time in water = total time in water recorded within each of the events summed over the whole night (note that this variable may underestimate time in water because each individual event has a maximum time of 30 s until the camera is triggered again). For pen 1 the time spent by both otters was recorded and the total divided by two to standardise the value
Data are mean per night ± standard error *(n* = 3 or 4 nights).
The treatment phase has no error bars because it was only presented for one night.

7 Review of the effectiveness of acoustic deterrents on other mammals

To assess the effectiveness of acoustic deterrents on other mammals, a systematic review of the literature (including both scientific published and grey literature) was carried out. Reports of the use of acoustic deterrents to reduce wildlife predation/damage problems were obtained from two scientific databases (Scopus and Web of Knowledge), and two internet search engines (google and google scholar). Title searches were run and, for internet search engine searches, the search was limited to the first 100 hits.

The following search terms were used to locate articles: acoustic AND deter*, acoustic AND repel*, acoustic AND haras*, ultrasonic AND deter*, ultrasonic AND repel*, ultrasonic AND haras*, noise AND deter*, noise AND repel*, sound AND deter*, sound AND repel* (noise AND haras* or sound AND haras* were not included because they generated too many irrelevant articles on the impact of noise or sound on wildlife rather than specifically its use as a control measure), acoustic AND scaring device, noise AND scaring device.

The inclusion criteria were that articles must report on primary studies that actually tested the effectiveness of acoustic deterrents for deterring mammals; the use of acoustic deterrents for fish or birds was not included.

The preliminary literature search produced >600 potentially relevant articles. Time constraints meant that it was not possible to review all articles located and so a random selection of 161 articles were reviewed of which 34 met the inclusion criteria (n = 63 were not primary studies, n = 2 were not available, n = 13 were repeat references, n = 17 and 31 used acoustic deterrents to deter birds or fish respectively). A list of all articles reviewed is given in the Appendix.

Most articles were on the use of acoustic deterrents to deter marine mammals, to reduce bycatch of cetaceans (9) or to reduce fish predation in nets by seals (7) (with one article on marine mammals generally). Four articles addressed the use of acoustic deterrents to keep bats away from wind farms where high numbers of bats can be killed; 12 addressed the use of acoustic deterrents to keep other terrestrial mammals (badgers, cats, rats, rabbits, deer, dingos, kangaroos, polar bears) away from agricultural areas, crops, gardens, cars (for example, to reduce human–deer vehicle collisions) or to reduce potentially dangerous interactions with humans (for example, for polar bears). Only one article tested the use of acoustic deterrents on a semi-aquatic species – the sea otter – in this case, in an attempt to keep otters away from important shellfish harvesting areas.

Less than half (12) of the articles reviewed found that acoustic deterrents were effective and a number (13) reported mixed results or were inconclusive. Results tended to be species-specific, with the greatest number of articles reporting acoustic deterrents to be effective being on seals (4 of 7 articles on seals reported positive results), while studies on cetaceans tended more often to be inconclusive (5 of 9 articles on cetaceans reported mixed or inconclusive results). There was some evidence that acoustic deterrents might reduce bat activity (or bat deaths) at wind turbines, and that some (but not all) polar bears could be repelled by sound. There was little evidence of the effectiveness of acoustic deterrents on other terrestrial mammals (5 of 9 articles reported acoustic deterrents to be ineffective); the use of deterrents to deter cats from gardens and rats from buildings produced mixed results. An ultrasonic device tested on five individual sea otters produced no startle behaviour or directional response (the idea being that sea otters would be startled by the sound and swim away from the device) and the authors of the study concluded that the device may not have any real potential use.

Generalities are hard to draw because the results clearly depend on the device or the specific sound tested (as well as the actual acoustic output of the device in the field – one commercial product marketed as a kangaroo deterrent, for example, had a signal range that was considerably less than advertised; Bender 2003) and on a number of other external conditions such as the availability of alternative food sources. The quality of each of these studies has not been rated but all included an experimental control and most were replicated to some extent. Importantly, none of the studies reviewed tested experimentally for habituation effects, although one found that rats became habituated within two weeks, and habituation was often recognised as a potential issue regarding operational use of devices. It is perhaps noteworthy, however, that in one study the deterrent effect of an acoustic device used on cats (to deter them from gardens) tended to increase over time suggesting that cats were learning to avoid those gardens rather than becoming habituated to them (Nelson et al. 2006).

8 Practical recommendations

The results of Trial 3 suggest that an underwater acoustic device may deter otters from the water in a small pool. Questions that will need to be addressed before such devices are adopted for operational use are:

- whether these results can be replicated in a larger pool and over the longer term
- whether they can deter otters from entering a pool with food in it (that is, when motivation to get into the water is higher)

The initial field trials suggest that existing devices are unlikely to be suitable for otters, although the seal scarer offered some promise. However, it is not yet possible to specify precisely what acoustic signal would be most likely to be an effective otter deterrent. It is suggested that further captive trials incorporate tests of a range of frequencies and intensities with a view to identifying the optimal acoustic signal for field trials.

Depending on the success of further captive tests, a replicated, controlled field experiment would be the next step in this research. Lessons from the systematic review highlight the importance of adequate replication and quantification of appropriate variables that allow assessment of the effect of the device on actual damage reduction (for example, fish taken) to ensure clear interpretation of the results. It will be crucial to measure actual acoustic output of any device tested in the field, and may also be useful to quantify ambient noise in the natural environment of the otter, as well as in managed fisheries. Importantly, future field experiments should be of sufficient duration (probably over two or more years) to test for habituation effects.

In summary, the project team suggest that acoustic deterrents may offer a potential management device for otters at stillwater fisheries but further research (in captivity and in the field) is required before it would recommend their use, or could offer guidance to manufacturers on an acoustic signal designed specifically for otters.

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