ICES Journal of Marine Science, 58: 517–524. 2001
doi:10.1006/jmsc.2000.1025, available online at http://www.idealibrary.com on IDEAL®

# Use of underwater playback to reduce the impact of eiders on mussel farms

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Ross, B. P., Lien, J., and Furness, R. W. 2001. Use of underwater playback to reduce the impact of eiders on mussel farms. – ICES Journal of Marine Science, 58: 517–524.

One of the most commonly employed methods of reducing damage by diving ducks to mussel stocks on mussel farms in Atlantic Canada and in Scotland is chasing birds by boat. While effective in the short term, the frequency of chases is often restricted by high costs, both in time and fuel. Tests in Scotland used underwater recordings of chase-boat engines replayed at regular intervals on continuous loop tapes through an underwater loudspeaker in an attempt to reduce predation pressure by eiders on mussel farms. Trials of the underwater playback system (UPS) gave significant reductions in eider numbers of 50–80%, while a control trial with the playback of an unassociated noise gave no reduction in numbers. The mean return time of birds to the farm after chasing by boat also increased significantly. As the presence of workers on mussel farms reduces the number of eiders feeding there, the UPS is a useful deterrent when workers are not present. The long-term habituation of ducks to the system was negligible when workers are absent, providing there is occasionally reinforcement of the deterrent by boat chasing. Potential factors effecting the efficacy of the UPS are discussed.



Key words: aquaculture, *Bucephela clangula*, deterrent, eider, goldeneye, UPS, *Mytilus edulis*, pest, *Somateria mollissima*.

Received 16 October 1999; accepted 15 March 2000.

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## Introduction

The main prey of the common eider (*Somateria mollissima* (L.)) is molluscs, particularly the blue mussel (*Mytilus edulis* (L.)). Eiders usually feed at depths less than 10 m, but they have been recorded feeding over 40 m below the surface (Guillemette *et al.*, 1993). They also commonly feed on echinoderms and crustacea, and there may be changes in diet throughout the year according to availability and condition of prey (Cramp and Simmons, 1977; Ydenberg and Guillemette, 1991). The goldeneye *Bucephela clangula* (L.) is a smaller duck that breeds in fresh water, but often winters in sheltered coastal areas. A large part of goldeneyes' diet in marine habitats is also molluscs and, in particular, young *Mytilus*.

Because cultivated mussels are continually immersed in seawater, they are not limited in the time that they can spend feeding, nor are they restricted by the constraints involved with exposure to air, such as risk of desiccation. As a result, cultured mussels tend to have a higher growth rate, are thinner-shelled, and of a higher flesh content than intertidal mussels of the same size (Dunthorn, 1971; Galbraith, 1987, 1992). These features all make cultured mussels more suitable as food for eiders and goldeneyes. Large losses of stock from mussel farms as a result of diving duck predation have been documented in Scotland and also in Canada (Galbraith, 1992; Lidster *et al.*, 1994).

Problems with avian pests are reasonably well documented within both agriculture and aquaculture (Murton and Wright, 1968; Furness, 1996). Advances in farming often result in larger areas of monoculture and greater production and quality of the crop than would be found in "natural" conditions. Such areas are likely to attract species that feed on the food in the wild (VanVuren and Smallwood, 1996).

 

Relative profitability, feeding behaviour, and choice of feeding area by mussel-feeding ducks are not only dependent upon prey availability, quality, and distribution, but can vary with the degree of "danger" (generally in terms of predation risk) associated with that site (Newman and Caraco, 1987; Newman *et al.*, 1988). Deterrents should work by increasing the degree of danger, or risk, associated with the respective feeding area so that alternative feeding areas become more attractive.

Deterrents generally fall into three categories: visual, acoustic, and biological (Draulans, 1987). Biological deterrents consist of playbacks of distress and alarm calls, and various studies have produced conflicting results (see Schmidt and Johnson, 1983; Draulans, 1987). More importantly, no evidence of alarm or distress calls from eiders has been reported. Many low-cost visual deterrents, such as scarecrows or flashing lights, often result in rapid habituation (Lien and Hennebury, 1997). However, a study of the use of laser light as a deterrent to eiders (Ross, 2000) showed promising results.

Acoustic deterrents are often combined with visual scaring devices such as pyrotechnics or "wailers" producing a number of different sounds through a loudspeaker, and again have produced ambiguous results (Moerbeek *et al.*, 1987; Lidster *et al.*, 1994). A problem with many deterrent techniques is that they are not usually associated with any other deterrent and, therefore, do not allow reinforcement as a means of lessening the effects of habituation (Slater, 1980).

The presence of workers on mussel farms, harvesting or grading mussels, or carrying out maintenance work, acts as a powerful deterrent to eiders feeding on mussel farms, and can reduce the numbers of birds feeding by over 90% (Ross, 2000). However, workers cannot be on site all day, every day, and birds may adapt their feeding regime to maximise intake at times when workers are not present, e.g. early in the morning. An effective deterrent to diving duck predation may therefore have to be an automatic system that can be used independently of the presence of workers on site.

Another commonly employed method used on mussel farms in Atlantic Canada and Scotland is chasing ducks by boat. Although effective in the short term, boat-chasing is both labour intensive and expensive in terms of fuel. Work in Canada first examined the use of an underwater playback system of recorded engine noise to scare long-tailed ducks or oldsquaw (*Clangula hyemalis* (L.)), and common scoters (*Melanitta nigra* (L.)), and eiders from mussel farms. In 1996, initial harassment by a chase boat was used twice daily in set transects around mussel leases. Harassment began when ducks first appeared in the area and before feeding patterns became established. Initially, there were 200–500 eiders in the vicinity of leases. During the harassment period, flush distances from the chase boat increased dramatically and latency of ducks returning to the area following boat activity also increased. Numbers of ducks declined erratically. The following year, two leases fitted with underwater broadcast devices played recordings of the chase boat at 30-s intervals. Few ducks landed on these leases, and, when they did, dive times were very short (Lien and Hennebury, 1997).

Our main aim was to measure the efficacy of an underwater playback system (UPS) in deterring eiders from feeding on mussel farms in Scotland, and to quantify its effect on the efficacy of boat chasing and worker presence/absence. Habituation of eiders to underwater engine noises was also measured.

## Materials and methods

Underwater recordings were made using an Aiwa HD-S200 lightweight digital audio tape recorder by means of a hydrophone (Brüel & Kjær, Type 8103) through a Nexus conditioning amplifier (Brüel & Kjær, Type 2692) at 31.6 mV $ms^{-2}$.

The hydrophone was suspended 3 m below the surface from a floating platform, and recording commenced when the scare boat was 150–200 m distant with the engine being started and the boat approaching the platform at full throttle. Recordings lasted approximately 2–3 min, ending when the boat had passed the recording point. Once a satisfactory recording was made, it was repeatedly transferred onto a 15-min standard audio cassette with an interval twice the length of the recording.

The UPS consisted of a car stereo cassette deck with auto-reverse, connected to an underwater loudspeaker (Lubell labs LL964) via a 120-watt booster amplifier. The system was powered by a 12-volt car battery, replaced daily, and was contained in a watertight drum to protect the electronics. Throughout the course of each trial, the UPS was secured either on the most central raft of raft-based farms or on a moored platform in the centre of long-line farms. The loudspeaker was suspended 3 m below the surface.

Observations were made using telescopes from tents set up at least 100 m from the farms. Tents were erected prior to the onset of any deterrent trial to allow the birds to get used to their presence. Data were collected every 5 or 10 min (depending on the site and weather conditions) from dawn until dusk. The number of individual eiders in each flock (one flock being defined as a group with no individual more than 10 m from any other) was recorded, as was their position in relation to the farm. Since eiders were never observed to have moved more than 10 m between points of surfacing and diving, individuals within 10 m from the boundaries of the farm were recorded as feeding on farmed mussels, whereas individuals 10–200 m away were recorded as not feeding.

Table 1. Results of two-way ANOVA for each trial examining the effects of the UPS and time of day (hour) or worker presence/absence on numbers of eiders feeding on mussel farms and the interaction effects (*p<0.05; **p<0.01; ***p<0.001).

| Trial | Parameter | Between-factor effects $F_{df1,df2}$ value | MS | Significance |
|---|---|---|---|---|
| L. Creran 1 | UPS | $F_{2,63}=19.93$ | 4 523.0 | *** |
| (Figure 1) | Time of day | $F_{2,63}=4.02$ | 911.5 | * |
| | Interaction | $F_{4,63}=1.37$ | 311.4 | n.s. |
| L. Creran 2 | UPS | $F_{2,51}=8.37$ | 275.1 | *** |
| (Figure 1) | Time of day | $F_{2,51}=0.21$ | 6.7 | n.s. |
| | Interaction | $F_{4,51}=0.40$ | 13.1 | n.s. |
| L. Creran 3 | UPS | $F_{2,45}=5.84$ | 238.6 | ** |
| (Control) | Time of day | $F_{2,45}=4.95$ | 202.4 | * |
| (Figure 1) | Interaction | $F_{4,45}=1.58$ | 64.6 | n.s. |
| L. Creran 4 | UPS | $F_{4,48}=4.26$ | 1.5 | ** |
| (Long term) | Worker | $F_{1,48}=30.36$ | 10.8 | *** |
| (Figures 2, 3) | Interaction | $F_{4,48}=6.13$ | 2.2 | *** |
| L. Striven | UPS | $F_{2,22}=13.54$ | 13.5 | *** |
| (Figure 2) | Worker | $F_{1,22}=20.41$ | 20.4 | *** |
| | Interaction | $F_{2,22}=8.14$ | 8.1 | ** |

The mean number of birds feeding every 5 or 10 min was calculated for each hour of observations. A running mean was calculated of the hourly means for each day to reduce variation in the time-series data. Mean hourly values were then calculated for each section of each trial to describe trends in feeding pressure at different stages of each experiment. Presence or absence of workers, scare-boat activity or other disturbances were also recorded.

For trials investigating the effects of the time of day on UPS efficacy, each day was split into three parts: morning (08:00–10:55), midday (11:00–13:55) and afternoon (14:00–16:55). Means of the average number of eiders feeding per hour for the three periods were calculated.

For trials investigating the effect of worker absence/presence, as well as UPS efficacy, means were calculated each day for 1 h immediately prior to workers arriving on-site ("absent"), and for 1 h after workers had arrived ("present").

The two study sites were in Loch Striven and Loch Creran, Argyll. The Loch Striven site is a long-line installation situated approximately 8 km from the mouth of the loch in the Clyde Sea. There are no other mussel leases currently in use within the loch or in the immediate area around it. The Loch Creran farm is raft based and the only one in the sea loch. The nearest mussel farms are situated in Loch Etive, over 24 km distant by sea.

Trials were broken down into blocks of 6- or 7-d observation periods; one prior to switching on the UPS, the next one with the UPS constantly on during daylight hours, and a final one with the UPS switched off. The Loch Creran trial in 1999 was of a longer duration to investigate the longer-term effects of the UPS. This trial consisted of similar length pre-and post-UPS periods, but a protracted period with the UPS switched on for 21 d. This period was split into three 7-d blocks for analysis.

Throughout the course of each trial, boat-chasing was carried out by the farmers as usual. The return times of birds after chasing were calculated as the time between a chase ending and the first time an eider returned to that site to feed.

Three UPS trials were undertaken at the mussel farm in Loch Creran in January, March, and April 1998. The first two trials used playbacks of the scare boat usually used and the third was used as a control, with playback of an unassociated sound at the same interval as the other playbacks. The fourth (long term) Loch Creran trial was carried out in late March 1999, and is detailed above. One trial of the same format as the first two in Loch Creran was carried out in Loch Striven during October 1998.

## Results

Table 1 shows the results of two-way ANOVAs investigating the effects of the UPS trial stage and those of time or of worker presence/absence on numbers of eiders feeding at mussel farms for five different trials. Figure 1 shows the relative eider attendance for each of the first three Loch Creran trials during the three stages of the trial (pre, during UPS stimulus, and post) at each hour. For all hours and when workers were absent, the UPS had an effect on eider attendance for every trial except the control, where there was an effect of the UPS only for the afternoon, and the attendance was higher (33%) during the UPS stimulus period (Table 2). In the second

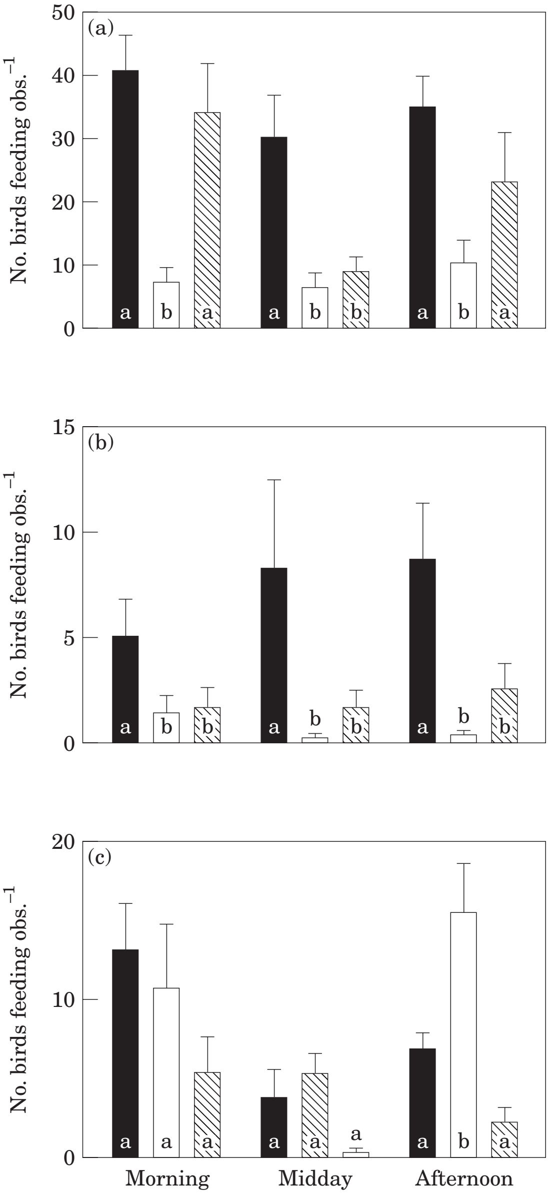


Figure 1. Loch Creran short-term UPS trial results [(a): trial 1; (b): trial 2; (c): trial 3 – control]: average number of eiders feeding at the mussel farm per observation at three different times of day, and at each stage of the trial (pre: filled bars; during UPS: open bars; post: hatched bars). Bars labelled with the same letter (within each period) are not significantly different from each other (p>0.05).

Loch Creran trial, there was no effect of hour on attendance across all treatments. After pooling the hour data for each trial stage, there was a strong effect of the UPS ($p<0.0001$, $F=8.96$). Dunn's multiple comparisons tests showed differences between the pre- and during UPS stages ($p<0.001$) and between pre- and post-UPS stages ($p<0.01$).

Table 2. Mean numbers of ducks observed feeding at mussel farms per 5 min during three periods (pre-, during, and post-UPS) for four trials and the percentage change in numbers while UPS is switched on (pre- to during) and after UPS has been switched off (pre- to post-). For the last two trials, the figures given are for periods of worker absence only.

| Trial | No. eiders feeding Pre | During | Post | % change During | Post |
|---|---|---|---|---|---|
| L. Creran 1 | 36.2 | 7.4 | 14.7 | − 80 | − 59 |
| L. Creran 2 | 6.7 | 1.8 | 2.8 | − 73 | − 58 |
| L. Creran 4 (L-term) | 2.4 | 0.7 | 0.7 | − 71 | − 72 |
| L. Striven | 36.5 | 19.3 | 1.2 | − 47 | − 97 |

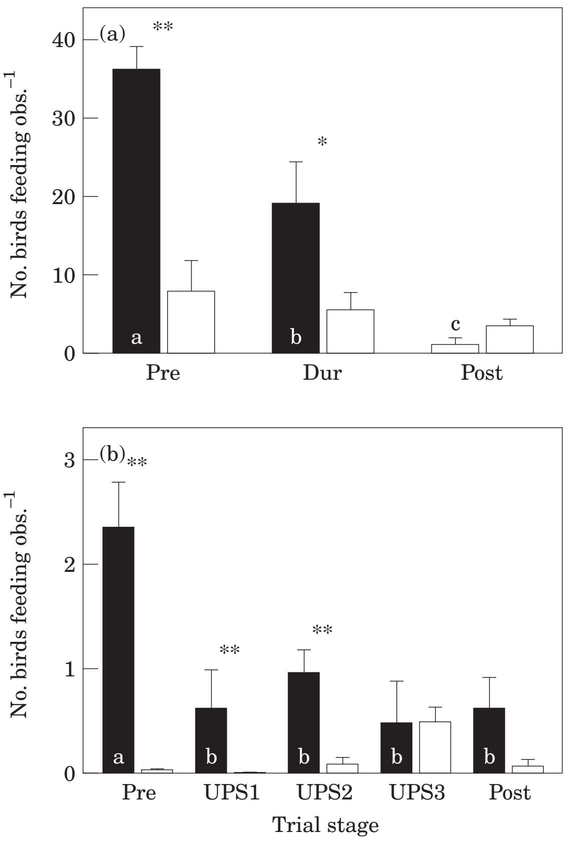


Figure 2. Results of UPS trials in (a) Loch Striven and (b) Loch Creran (long term; see the text): average number of eiders feeding at the mussel farm per observation when workers were absent (filled bars) and when workers were present (open bars) at different stages of each trial. Asterisks (*$p<0.05$; **$p<0.01$) indicate significant differences between worker presence/absence. Differences between bars of the same colour throughout each trial are indicated by different letters at the base of each bar ($p<0.05$); bars with no letters are not significantly different from each other.

Results from the two trials investigating the effect of the UPS and its association with the presence or absence of workers are shown in Figure 2. When workers were

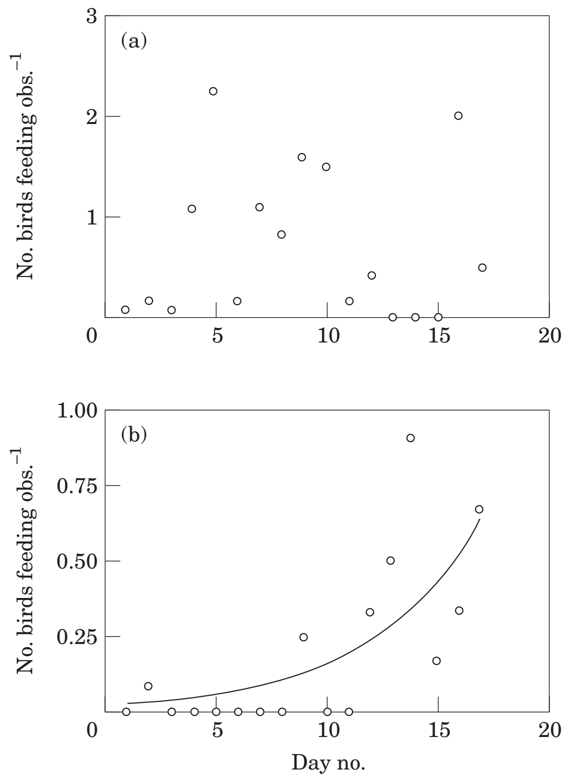


Figure 3. Relationship between number of eiders feeding per observation at the Loch Creran mussel farm and day number after the UPS is switched on, when workers are (a) absent ($r^2=0.00$, n=17) and (b) present ($r^2=0.52$, n=17). In the latter case, the best fit is presented by an exponential increase.

absent, for both trials a reduction in the numbers of eiders feeding was observed when the UPS was used. In Loch Striven, there was also a reduction in numbers between the UPS being on and the post-UPS period. When workers were present, there was no difference in eider attendance at any stage of the trial at both sites. However, when daily means for attendance in the long-term Loch Creran trial were examined with respect to day number since first switching on the apparatus, a strong positive relationship was found, although no such relationship was found when workers were absent (Figure 3).

The presence of workers had a large effect upon numbers of birds feeding at any one time, particularly at the start of each trial (Table 3). However, the extent of this effect decreased when the UPS was switched on (Figure 3), and the effect was reversed after the use of the UPS in Loch Striven, hence the interaction effect observed for both trials.

Figure 4 shows the effect of UPS treatment on the return times of birds to the mussel farm after being chased by the scare boat. For the first two Loch Creran trials, there are differences between groups ($p<0.001$, $F=13.8$, and $p<0.01$, $F=5.1$, respectively). Multiple comparisons between treatments for each trial showed that return times prior to the onset of the UPS were lower than when the UPS was in operation and after it had been switched off ($p<0.05$ and $p<0.01$, respectively). There was no effect on return time for the control treatment or for the Loch Striven trial ($p>0.05$, $F=0.3$, and $p>0.05$, $F=0.9$).

A one-way ANOVA across all five treatment blocks for the long-term study at Loch Creran revealed an effect of the UPS on return time of eiders ($p<0.05$, $F=2.5$), although Tukey tests revealed that there were no differences between groups. When all three treatment blocks were pooled, the effect of the UPS became more evident ($p<0.05$, $F=4.4$), and multiple comparisons showed that return times were lower pre-UPS than during the UPS trial or post-UPS ($p<0.05$). There was no relationship between day number and average return time while the UPS was switched on ($r^2=0.006$, n=15).

## Discussion

In general, trials of the UPS worked well in alleviating predation pressure by eiders on mussel farms, reducing the numbers of feeding birds by between 50% and 80% in all experimental trials. The control trial did not reduce feeding on the farm and numbers of birds feeding actually increased.

In all trials in Loch Creran, use of the UPS was associated with an increase in the mean return time of birds to the mussel farm. When tested in Canada, it was noted that birds became much more wary of the chase boat when the UPS was in place, and that birds would

Table 3. The effect of worker presence (+w) or absence (−w) on the numbers of eiders feeding per observation period during the long-term UPS trial on Loch Creran and on Loch Striven before, during, and after implementation of the UPS system, and the percentage change in numbers attributed to the presence of workers.

| | Pre-UPS | | | During-UPS | | | Post-UPS | | |
|---|---|---|---|---|---|---|---|---|---|
| Trial | −w | +w | % | −w | +w | % | −w | +w | % |
| L. Creran | 2.37 | 0.04 | −98 | 0.69 | 0.21 | −70 | 0.65 | 0.08 | −87 |
| L. Striven | 36.50 | 8.05 | −78 | 19.30 | 5.50 | −72 | 1.20 | 3.60 | +200 |

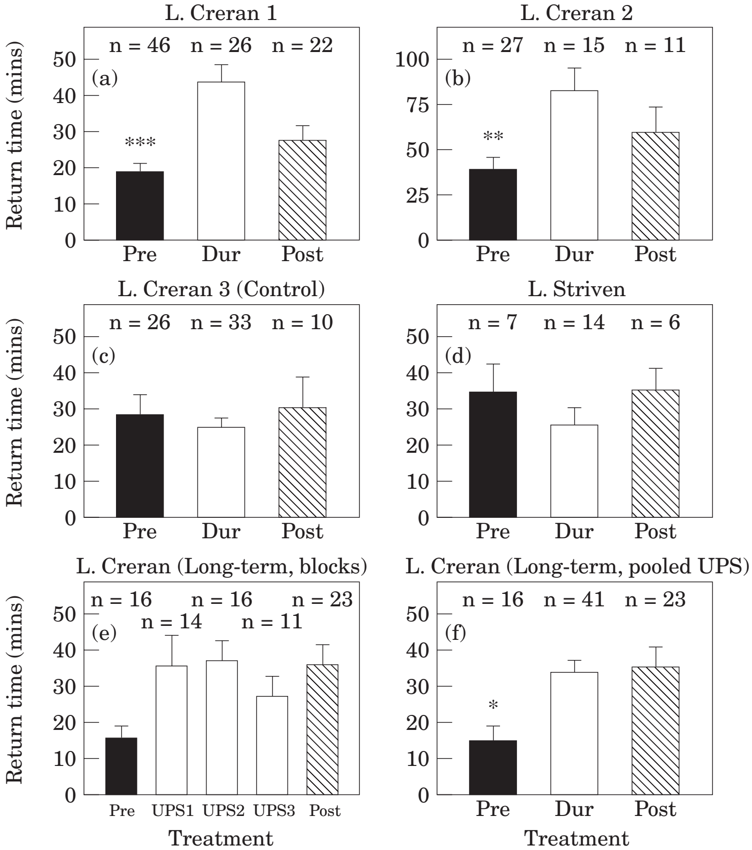


Figure 4. Mean time (and SE) for eiders to return to the mussel farm to feed after scare-boat runs during different stages of each trial (pre, during, and post): (a) Loch Creran trial 1; (b) Loch Creran trial 2; (c) Loch Creran 3 (control); (d) Loch Striven; (e) Loch Creran 4 (UPS by block of 7 d); and (f) idem but weekly blocks pooled. Asterisks (***p<0.001; **p<0.01; *p<0.05) indicate significant differences from other treatments within the same trial.

tend to fly from the boat at a greater distance than without the UPS. Both results suggest that the deterrent stimulus of the scare boat is actually strengthened by the presence of the UPS.

The results of the Loch Striven trial are ambiguous. Although the number of birds feeding dropped when the UPS was switched on, the numbers also decreased significantly between the UPS being used and it being switched off. In all other trials, the numbers of birds feeding post-UPS were either higher than during the UPS period or not significantly different. Also the return times of birds on Loch Striven, as with the control, showed no changes throughout the UPS trial.

Although the Loch Striven trial may not clearly demonstrate any constraints with the UPS, some factors are likely to affect its efficacy:

- Pre-exposure to original deterrent – If birds have previously been chased by boat only infrequently, then the UPS may provide a stimulus to them that has no association with a "real-life" deterrent.
- Frequency of reinforcement – Without reinforcement of the UPS with the scare boat it is likely that habituation to the stimulus will be much more apparent.
- Availability of alternative resources – A lack of alternative food sources (either cultivated or occurring in the wild) in the surrounding area is likely to increase dependence of birds on a particular mussel farm, and therefore makes it less easy to deter them (Draulans, 1987).
- Numbers of birds – The ease of deterrence of a species can decrease if birds become established on a particular site, and thus begin to attract conspecifics (Lidster *et al.*, 1994). Guillemette *et al.* (1993) also showed that larger flocks of eiders facilitated feeding, which in turn would increase the relative profitability of the site.
- Stage in breeding cycle – Energetic needs of eiders and other bird species will change throughout the year according to factors such as breeding, chick rearing, and moulting (Gorman and Milne, 1972).

- Mussel quality – Temporal variation in relative profitability of different size classes of mussels between wild and cultivated sites may increase or decrease dependence of populations on farms.

Several of these factors might account for the anomalous results of the Loch Striven trial. The number of birds initially feeding on the farm was similar to that observed in the first Loch Creran trial, in which the UPS worked well, and both sites are the only mussel farms in the immediate area. One difference is that these trials were carried out at different times of the year. However, one could hypothesize that the motivational state of the birds to feed would be higher in the spring (in preparation for the breeding season), which would predict that the UPS should work better in the Loch Striven trial (September) than in the Creran trials (late winter/early spring). A more likely explanation for the differences could be that the Loch Striven birds have not been pre-exposed to boat-chasing to the same degree as the Loch Creran birds. The reason for this difference in exposure may be that the mussel farm in Loch Creran is situated in very close proximity to the owner's home, and feeding birds can be quickly detected and chased. The farm in Loch Striven is much more isolated, and although chases are frequent, they are carried out in a more opportunistic fashion, with no prior knowledge of the number of ducks actually feeding on the farm.

Worker presence on site has a great effect on reducing predation pressure at mussel farms (Ross and Furness, 2000). However, with use of the UPS, the difference between the numbers of birds feeding when workers are absent and when they are present diminishes over time. It seems unlikely that numbers would ever rise above those seen when workers are absent and the UPS is switched on. The number of birds did not show any signs of increasing as the long-term trial progressed, suggesting that birds do not habituate to the UPS *per se*, but that, while applied, the effect of worker presence will become negligible over time. This effect again suggests that the UPS is (or can be) a stronger deterrent stimulus than the scare boat itself.

The UPS, with reinforcement, may be a stronger deterrent stimulus than the scare boat itself because, in theory, the birds notice it only while they are swimming or diving. The UPS is an acoustic deterrent, whereas the chase boat itself combines acoustic and visual cues. However, of these two cues, the acoustic component may be of more importance, because it is present continuously, whereas during diving the visual cue is lost. Birds may be more easily startled when underwater, as the whereabouts of the chase boat will be unknown. The presentation of deterrent stimuli only when the birds are feeding also means that they are not continually exposed to the stimulus, even when they are some distance from the farm and not feeding, as is the case with most above-water acoustic deterrents, such as propane cannons or wailers. Continuous exposure to a stimulus, irrespective of whether the target species is causing damage, is more likely to favour rapid habituation.

The savings that could arise from use of the UPS can be roughly indicated. For a site with 100 eiders regularly feeding on the farm (a not uncommon situation), UPS may reduce numbers by about 65 birds. Since eiders may remove about 2.5 kg of mussels per bird each day (Milne and Galbraith, 1986), this represents a saving of 162 kg per day. For a typical situation in west Scotland, with eiders feeding for around 100 d of the year, this represents a saving of over 16 t of mussels per year.

## Acknowledgements

The study was funded by NERC and the LINK-aquaculture programme. We thank Roger and Judy Thwaites of Shian Fisheries, and David Scott for allowing access to mussel leases and help with installation of the equipment. We also thank Mr Nosrat Mirzai for help with the electronics, and Paul Burton and Rob Malsom for data collection.

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