TESTING THE EFFECTIVENESS OF AN AQUATIC HAZING DEVICE ON WATERBIRDS IN SAN FRANCISCO BAY, CALIFORNIA

Desley A. Whisson
Department of Wildlife, Fish and Conservation Biology
University of California, One Shields Ave.
Davis, CA 95616

and

John Y. Takekawa
U. S. Geological Survey, Biological Resources Division
San Francisco Bay Estuary Field Station, P. O. Box 2012
Vallejo, CA 94592

Report prepared for the California Department of Fish and Game, Office of Oil Spill Prevention and Response
May 1998

[*Suggested citation:* Whisson, D. A. and J. Y. Takekawa. 1998. Testing the effectiveness of an aquatic hazing device on waterbirds in San Francisco Bay, California. Unpubl. Rep. to the Calif. Dep. Fish and Game, Oil Spill Prevention and Response. Univ. of California, Davis. 41p.]

ACKNOWLEDGMENTS

We thank Paul Kelly (OSPR) for his role in initiating the project and his assistance with the aerial surveys, and Randy Imai (OSPR) for his technical assistance. We are also grateful to our pilot Lyle Palmer (Aggie Flying Farmers) and Jeff Cann (DFG) for their assistance with the aerial surveys, and Darryl Whitworth (USGS) for helping set up the sites. We thank Dan Anderson, Department of Wildlife, Fish and Conservation Biology, University of California at Davis for loaning us a boat and motor for the duration of the study. Richard Greer (Exxon Biomedical Sciences Inc) and Jerry Karr provided valuable comments on our study design. Richard Engeman (National Wildlife Research Center) provided advice on data analysis.

Special thanks go to Chantal Green and Rebecca Kaiser for conducting the ground surveys.

Funding for this study was provided by Exxon, Arco, and Chevron. The Breco Bird Scarer© was provided by Hyde Products. Clean Bay, Inc. provided administrative support and some logistical assistance in setting up the sites. The California Department of Fish and Game Office of Oil Spill Prevention and Response (OSPR) provided the aircraft and personnel for aerial surveys. Betsy Radtke (USFWS) assisted with permits to undertake the study in San Pablo Bay.

SUMMARY

- The Breco Bird Scarer© is a bird-hazing device that was developed specifically for use in oil spill situations. It comprises a broadcasting system that produces high-intensity sounds (up to 130 dB at 1 m) mounted inside a buoy. The buoy is designed to drift with the oil, and be functional over a 72 hour period. This report presents results of field trials of the effectiveness of the Breco Bird Scarer© undertaken in northern San Francisco Bay over the period 3 to 24 March 1997. This study represents the first replicated field testing of this device.

- A total of 10 trials using 2 sites were undertaken. Each trial comprised 2 days without the device and 2 days with the device operating. Distribution and number of birds within 800 m of the device were recorded each day by observers in duck blinds. Aerial surveys documented number and distribution of birds within 4 km of the device immediately prior to and one hour after deployment of the device in each trial.

- Bird numbers were high throughout the study period with up to 4249 birds present on the study transects at any time. Scaup (*Aythya affinis* and *A. marila*) and surf scoter (*Melanitta perspicillata*) were the predominant species present in the study area comprising 88.3% and 6.0% respectively of birds counted during ground surveys and 65.1% and 7.0% respectively of birds counted during aerial surveys.

- A mixed model analysis of variance was used to analyze data collected in aerial and ground surveys of birds. Aerial surveys did not detect a significant effect of the device on number or distribution of birds within 4 km of the device. In ground surveys, there was a significant decrease in number of scoter within 800 m of the device when the device was operating. There was not a significant decrease in the total number of birds (all species combined). These results are in contrast to results of a study undertaken in Canada which

showed the Breco Bird Scarer© to be highly effective in dispersing common eiders and scoter to a distance of 700 m.

- Because San Francisco Bay is a highly urbanized area, birds may have been habituated to loud noise and therefore not deterred by the device. Further testing of this device in both urbanized and less disturbed situations is necessary to confirm these results.

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BACKGROUND

Oil spill hazards to wildlife

Oil spills pose a serious threat to seabirds in the marine environment. Seabird mortality may be extremely high depending on the extent, location and timing of a spill (Lehoux and Belanger 1995). The Exxon Valdez oil spill in Alaska in 1989 resulted in the documented death of over 30,000 seabirds (Piatt et al. 1990). Wildlife concerns have been addressed in the United States Coast Guard Area Contingency Plan which provides for the identification of wildlife resources at risk, wildlife hazing, oiled wildlife collection and processing, veterinary services and other rehabilitation activities.

A small proportion (0.3 - 30%) of birds that are oiled in a spill are retrieved alive and taken to rehabilitation centers for cleaning and treatment (Sharp 1996). The success of rehabilitating oiled birds in terms of release and survival rates is extremely variable, depending on the species affected, the breeding or biological state of those species, the nature of the product spilled, weather and temperature, and quality and immediacy of wildlife care among other variables (Jessup 1997). Success rates of between 50% and 90% have been reported (Frink 1987). Sharp (1996) has suggested that a high percentage of rehabilitated North American seabirds die shortly after release on the basis of an analysis of banding and recovery records.

In addition to low survival of released birds, the cost of rehabilitating oiled birds may also be quite high. Jessup (1997) reported a cost of $600 to $750 per bird in California. A cost of $15,000 per bird was widely reported in the Exxon Valdez oil spill. This latter figure reflects costs associated with the building of temporary rehabilitation centers and other indirect costs, as well as veterinary care. The low recovery rate of oiled birds, and the marginal effectiveness and high cost of rehabilitation efforts emphasize the urgent need to develop strategies to minimize the number of birds contaminated in an oil spill.

Bird hazing techniques

Bird-hazing has been proposed as a preventative approach to reduce waterbird casualties during oil spills (Koski and Richardson 1976, Ward 1977, Koski *et al* 1993, Greer and O'Connor 1994). It has long been used to repel nuisance birds from airports, aquaculture facilities, agricultural fields, and other sites (Bomford and O'Brien 1990, Marsh *et al.* 1991, Salmon and Marsh 1991b). Methods or techniques used alone or in combination include acoustical repellents such as gunfire, gas-operated exploders, electronically produced noises, and bird distress calls; and visual deterrents such as scarecrows, flagging, lights, and balloons. The effectiveness of these techniques seems to vary according to the conditions, bird species and numbers present, physiological condition and age of the birds, nocturnal and diurnal activity patterns, breeding status, whether the birds are migrants or well-established residents, and availability of favorable alternative sites (Bomford and O'Brien 1990, Salmon and Marsh 1991b, Marsh *et al.* 1991).

A number of bird-hazing techniques have been tested for use in aquatic situations but there have only been a few unreplicated studies to determine their effectiveness. Techniques tested include use of propane guns (Sharp 1978, Biggs *et al.* 1978, Sharp 1987, Lehoux 1990), cracker shells (Biggs *et al.* 1978), explosive rounds (Lehoux 1990) the Av-alarm (an electronic sound generating device) (Crummett 1973, Sharp 1978 & 1987), motorboats (Lehoux 1990), and a helicopter (Lehoux 1990). As in terrestrial applications, effectiveness of these techniques in dispersing birds appears to vary according to species, the situation, and period over which birds are exposed to the sound.

Although bird-hazing devices developed for terrestrial applications have the potential to reduce waterbird casualties in oil spill situations, they generally are impractical for use in oil spills in offshore areas because of the large areas normally affected, mobility of the oil with currents and wind, and environmental conditions (Ward 1977, Koski *et al.* 1993, Greer and O'Connor 1994). The ideal bird-hazing device for oil spill situations would therefore have a wide radius of effect, move with the oil, deter birds from either flying or swimming into the spill, be effective against all species present, be functional at night as well as during daylight hours, and be functional under adverse environmental conditions.

Two electronic sound generating devices, the Marine Phoenix Wailer (MPW) and the Breco Bird Scarer© have been developed for use in offshore situations. These devices were recommended by the Marine Spill Response Committee as the top two priorities for bird deterrence research (Thomas 1994). Preliminary, unreplicated tests of these devices suggest that they may be effective in dispersing and deterring birds. The Marine Phoenix Wailer (MPW) was tested in Miramichi Bay, New Brunswick, Canada for effectiveness in keeping scoters [black scoters (*Melanitta nigra*), surf scoters (*M. perspicillata*), white-winged scoters (*M. fusca*)] away from juvenile mussel collector lines (Hounsell and Reilly 1995). The MPW was effective in excluding birds from a circular open-water area with a radius of 500 m.

The Breco Bird Scarer©

The Breco Bird Scarer© was designed specifically for hazing birds from oil spills. It comprises a broadcasting system that produces high-intensity sounds (up to 130 dB at 1 m) mounted inside a buoy. The buoy weighs 36 kg, has a diameter and height of 71 cm and 66 cm respectively, is designed to drift with the oil, and be functional over a 72-hour period. Sounds include a dog barking, sirens, music, human screams, bells, military-type noises (gunshots, bombing noises etc.) and a variety of other artificial noises. The length of each sound ranges between 20 and 50 s with an emission interval of 20 s to 5 min. Sounds are randomized to minimize the potential of birds habituating to the device.

The only field testing of this device undertaken to date was conducted by the Canadian Wildlife Service in the lower estuary of the St. Lawrence River in September 1994 (Lehoux and Belanger 1995). The study area was a staging area for molting common eiders in summer and early autumn with densities reaching 3,500 eiders and scoters per 10 km of shoreline. Two tests of the device indicated that it was highly effective in dispersing birds. In the first test, the device was anchored approximately 500 m from the shore and allowed to operate for 42 h. Birds were counted in each of 20 x 100-m intervals and a final 500-m interval either side of the device in surveys undertaken:

(i) prior to the device being positioned (6 surveys over 2 days),
(ii) with the device positioned but not operating (10 surveys over 2 days),
(iii) during operation of the device (22 surveys over 2 days),
(iv) after operation but with the device still present (3 surveys in 1 day), and
(v) following removal of the device (4 surveys in 1 day).

Prior to operation of the device, there was an average of 68 birds per 100-m interval. Bird species comprised common eider (52%), scoter (29%), gulls (13%), dabbling ducks (3%) and other species (3%). Numbers decreased to a mean 21 birds per 100-m interval over the 5-km study area as soon as the device was deployed. Common eider and scoters were most affected, decreasing by 85% and 88% respectively. The radius of effectiveness was estimated at 800 m for common eider, 700 m for scoter, 600 m for cormorant, 500 m for American black duck and 400 m for gulls. Birds did not appear to habituate to the device and actually continued to stay away from the area for one day after the device stopped broadcasting and another day after the device was removed from the site.

A second test was conducted to observe the behavior of birds when the device was moving freely. In that test, the device was positioned in the middle of a raft of approximately 4000 eiders and scoters and allowed to drift with the tides and currents for approximately 4 h. Swimming birds were observed to alter their course so as to maintain a distance of 700 to 800 m between them and the device.

Study Objectives

The objective of our study was to evaluate the effectiveness of the Breco Bird Scarer© in hazing waterbirds wintering in the northern San Francisco Bay estuary. Through a replicated field trial we aimed to determine the radius of effect of the device and document behavior exhibited by birds on encountering the device for each species present.

THE STUDY AREA

San Pablo Bay is at the northern reach of San Francisco Bay (Figure 2). It is an area that is heavily used by both recreational and commercial boats. For the most part, the bay is fairly shallow with tidal mudflats accounting for approximately 19% of the bay area (San Francisco Estuary Institute, unpubl. data).

The San Francisco Bay estuary is a major staging and wintering area for a variety of waterbirds, especially migratory waterfowl species including scaup (*Aythya affinis* and *A. marila*), surf scoter (*Melanitta perspicillata*), canvasback (*Aythya valisineria*), ruddy ducks (*Oxyura jamaicensis*) and northern shovelers (*Anas clypeata*). It supports over 300,000 birds in midwinter surveys and more than 50% of diving ducks in the Pacific Flyway. These birds are present in high numbers over the October - April period each year (Accurso 1992).

METHODS

The study was undertaken over the period 3 - 24 March 1997, a few weeks prior to the migration of ducks from the area.

The study sites

Two sites, separated by a distance of approximately 3 km, were selected at the northern end of the bay. The sites were located near floating duck blinds that had been used by hunters for several decades during the October - January hunting season (Figure 3a&b). The duck blinds were large enough to house the 14 ft Zodiac boat used in the study. Each site was approximately 1 km offshore. At low tide, water depth was about 30 cm at the shallowest part of each site.

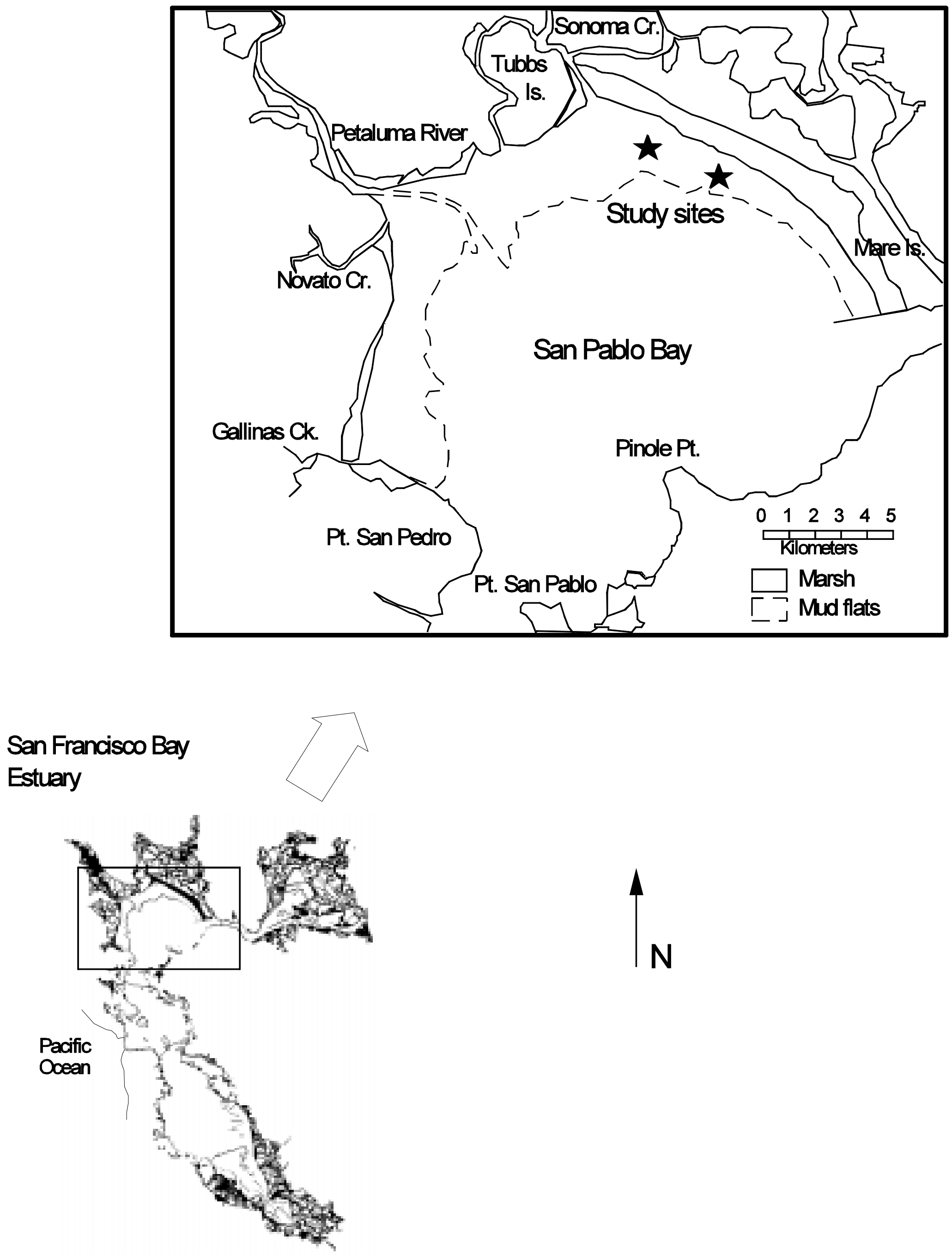

Figure 2. The study area and location of study sites

Figure 3a.

Figure 3b.
Figures 3a &b. Photos of the duck blinds from which ground surveys were conducted

Sites were marked out with 4.5-m long, 2.5-cm diameter polyvinyl chloride (PVC) poles placed in the substrate one week prior to the study (Figure 4). The tops of the poles were painted with pink and green florescent paint to make them more visible to observers. At high tide at least 30 cm of each pole was above water. Poles were placed at 100-m intervals along 3 transects of 800 m each, radiating out from a center point where the device would be anchored during testing (Figure 5). A Global Positioning System (GPS) unit was used to accurately mark the transects. The device anchoring point was marked with a pink buoy. Each duck blind was approximately 300 m from the center point and 200 m from the 2 closest transects.

Device Operation

Five tests of the device were undertaken at each site. Operation of the device was alternated between sites on a two day off and two day on cycle. The device was moved between sites in the boat (Figure 6) and batteries were replaced after every other trial (Figure 7). At the end of the study, a decibel meter was used to test noise levels of the device while anchored at one site (Table 1). Weather conditions were calm during this test. Mean ambient noise level during this test was 58.5 ± 1.2 dB. Noises from the device were inaudible at 400 m.

Table 1. Noise level of device at 1-m, 100-m, 200-m, and 300-m from device.

Distance from device (m)	Noise level (dB)	Number of tests
1	102 - 122	4
100	67.3 - 67.7	2
200	62.3 - 62.8	2
300	57.2 - 64.9	2

Visibility and conditions for observing birds were excellent over most of the study period. Strong winds and overcast or rainy conditions were recorded on only 4 d during the 22-d trial.

Figure 4. Photo of the study transects. PVC poles were used to mark the transects

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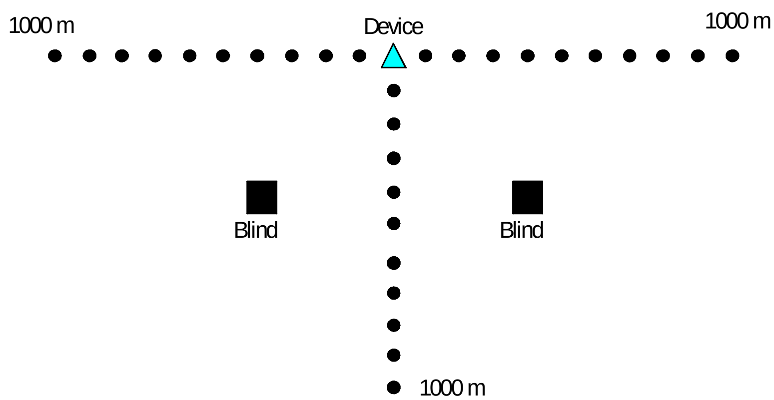

Figure 5. Layout of study sites

Figure 6. Photo of the device being moved in the 14-ft Zodiac

Figure 7. Photo showing the battery compartments inside the Breco Bird Scarer©

Aerial surveys

Aerial surveys of birds within 4 km of the device were undertaken immediately prior to deployment of the device, and one hour after deployment for each test. Surveys were conducted by 2 observers seated on either side in the rear of a Cessna 172. Each aerial survey comprised 2 passes at 90 degree angles and began at the device anchoring point. A GPS unit in the airplane was used to accurately gauge the distance traveled away from the center point. The plane flew at a speed of approximately 140 km/h and at an elevation of 60 m. Each pass took about 100 seconds to complete. Observers used tape recorders synchronized by time to the GPS to determine distance of birds from the center point of the study grid. All birds seen within a 500-m wide strip on either side of the airplane were identified and counted. Prior to the surveys, observers calibrated the 500-m viewing distance by undertaking a flight at the same elevation over the middle a 1-km wide waste water treatment pond with a consistent waterfowl population.

Ground surveys

On each day of the study, an observer arrived at each duck blind between 0700 and 0900 h depending on tides. Observers waited an hour from the time of their arrival at the sites to begin counting birds, to ensure that disturbance by the boat didn’t affect counts. Eight counts were then undertaken at 30-min intervals (Figure 8). Number and species of birds were counted and their location on the transect recorded with respect to the transect markers. Number and species of birds occurring on the study site (within 1,500 m of the device anchoring point) but not on the transects, were recorded to provide an estimate of species composition of birds in the vicinity of the device (Table 2). Only 2 and 6 counts were conducted on each of 2 days respectively because of low visibility, and 6 counts on 4 days when low tides reduced the period that observers could remain in the blinds (Table 3). The presence of recreational fishing boats on or near the study sites may have affected the distribution of birds during some of the trials and is reported (Table 3).

Hunters removed a duck blind from each site during the first trial, thus not all 3 transects could be surveyed from a similar distance. Consequently, only data from the 2 transects closest to the remaining blind at each site were used in analyses.

Bird behavior was recorded and classified as swimming, diving, preening or flying. When large flocks were present, the predominant behavior or a combination of behaviors were recorded for a flock.

Statistical analysis

Aerial survey data were analyzed in a mixed model 3-way analysis of variance (SAS Mixed Models Procedure, SAS Institute 1995). Site was considered a random effect while trial, distance from the grid center (8 x 500-m intervals), and treatment (device OFF or ON) were defined as fixed effects. Separate analyses were conducted for scaup and total ducks.

A mixed model 3-way analysis of variance also was used for analysis of the ground data. Distance from the center point was divided into 8 x 100-m intervals. Because counts during the 4-h period each day were repeated measures, we used the mean count for this period in the analysis. Although it greatly reduced the degrees of freedom in the analysis, taking the mean of counts smoothed out the variation in daily numbers of birds on the site. Analyses were undertaken for scaup, surf scoter, canvasback, ruddy duck, and all bird species (included species such as grebes, gulls, northern shovelers).

Figure 8. Photo of observers counting birds in ground surveys.

Table 2. Percentage bird species composition within 1,500 m of the device anchoring point during each test. Counts not restricted to transects.

Site:	1										2									
Trial:	1		2		3		4		5		1		2		3		4		5	
Status:	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Scaup *Aythya marila, A. affinis*	57.7	61.4	83.6	89.4	39.5	36.2	33.2	19.7	27.5	15.5	85.6	87.7	80.2	93.1	97.4	65.3	99.5	98.9	98.9	96.8
Scoter *Melanitta perspicillata*	0.2	4.4	13.8	0.3	0.01	1.1	0	0	0	0	0.8	0.5	19.0	2.0	0	0.2	0	0.1	0	0.2
Canvasback *A. valisineria*	12.3	0.5	0.5	0.01	3.2	1.3	0.7	1.5	4.0	2.4	1.5	0.1	0.2	0	0.02	1.6	0.02	0.01	0.8	1.8
Ruddy Duck *Oxyura jamaicensis*	5.8	0.3	0.01	0.02	3.7	1.3	0.1	3.5	0.8	0.6	10.9	0.9	0.2	0	0.02	0.7	0.03	0	0	0.02
Northern Shoveler *Anas clypeata*	0.03	0	0	0	0	0	0	2.0	0.5	0.5	0	0	0	0	0	0	0	0	0	0
Unidentified (duck)	7.8	0.1	0.4	0	0.4	0.4	0.7	0.1	0	1.0	0.6	10.6	0.3	4.8	2.0	31.6	0.1	0.1	0.04	0.7
Gull *Larus* spp.	0.3	1.7	0.1	0.1	0.5	0.2	1.6	0.7	0.04	0.1	0.04	0.01	0.01	0.01	0.1	0.5	0.1	0.01	0.1	0.2
Double-crested cormorant *Phalacrocorax auritus*	0	0	0	0	0	0	0	0.1	0.03	0.02	0	0	0	0	0	0	0	0.01	0	0
Grebe *Aechmophorus spp.*	0.3	0.5	0.4	0.5	0.4	0.1	0.2	0.8	0.7	0.4	0.8	0.2	0.1	0.1	0.5	0.3	0.2	0.5	0.2	0.3
Shorebirds[1]	15.4	31.1	1.1	9.6	52.3	59.4	63.5	71.5	66.4	79.4	0	0	0	0	0	0	0	0	0	0
Total number	23,635	5,527	39,192	23,803	32,660	20,131	23,517	26,961	53,275	21,319	4,950	31,802	75,637	34,189	24,162	4,444	19,623	16,799	24,455	22,315

[1]Avocets (*Recurvirostra americana*), Sandpipers (Family Scolopacidae)

Table 3. Conditions and number of counts taken for each day of the study period.

Site	Trial	Date	Device status	Weather	Wind[a]	Tide High	Tide Low	Time of first count	Counts	Number of counts when boats were present	Distance to nearest boat (m)
1	1	3/3	OFF	Sunny	Mod	0734	1451	1100	6	1	400
		3/4		Sunny	Calm	0839	1551	1000	8	0	-
		3/5	ON	Sunny	Calm	0941	1643	1000	8	0	-
		3/6		Sunny	Calm	1040	1732	1030	8	0	-
	2	3/7	OFF	Sunny	Light	1136	0540	1000	8	8	400
		3/8		Sunny	Calm	1229	0630	1000	8	1	1100[b]
		3/9	ON	Sunny	Calm	1323	0719	1000	8	0	-
		3/10		Sunny	Calm	1416	0809	1015	8	0	-
	3	3/11	OFF	Overcast	Mod	1512	0900	1130	8	1	500
		3/12		Sunny	Calm	0327	0954	0845	8	3	700
		3/13	ON	Sunny	Calm	0411	1052	1045	8	0	-
		3/14		Sunny	Calm	0500	1155	0830	8	0	-
	4	3/15	OFF	Overcast	Strong	0555	1305	1045	6	0	-
		3/16		Raining	Strong	0657	1415	0915	8	1	400
		3/17	ON	Sunny	Calm	0802	1518	1115	6	0	-
		3/18		Sunny	Light	0905	1612	1015	8	0	-
	5	3/19	OFF	Sunny	Calm	1001	1656	1100	8	2	200[b]
		3/20		Sunny	Mod	1050	0512	0945	8	0	-
		3/21	ON	Hazy	Calm	1134	0551	1015	8	1	1400
		3/22		Overcast	Strong	1215	0626	0830	2	0	-
2	1	3/5	OFF	Sunny	Calm	0941	1643	1300	3	0	-
		3/6		Sunny	Calm	1040	1732	1045	8	5	400[b]
		3/7	ON	Sunny	Light	1136	0540	1200	8	0	-
		3/8		Sunny	Calm	1229	0630	1015	8	1	1300
	2	3/9	OFF	Sunny	Calm	1323	0719	1015	8	6	500[b]
		3/10		Sunny	Calm	1416	0809	1015	8	3	200[b]
		3/11	ON	Overcast	Mod	1512	0900	1145	8	0	-
		3/12		Sunny	Calm	0327	0954	0845	8	4	300
	3	3/13	OFF	Sunny	Calm	0411	1052	1045	8	0	-
		3/14		Sunny	Calm	0500	1155	0845	8	0	-
		3/15	ON	Overcast	Strong	0555	1305	1045	6	0	-
		3/16		Raining	Strong	0657	1415	0915	8	0	-
	4	3/17	OFF	Sunny	Calm	0802	1518	1115	6	0	-
		3/18		Sunny	Light	0905	1612	1215	6	0	-
		3/19	ON	Sunny	Calm	1001	1656	1100	8	0	-
		3/20		Sunny	Mod	1050	0512	0945	8	1	1200
	5	3/21	OFF	Overcast	Calm	1134	0551	1015	8	6	700[b]
		3/22		Overcast	Strong	1215	0626	0830	2	0	
		3/23	ON	Sunny	Mod	1254	0659	1215	6	0	-
		3/24		Sunny	Calm	1333	0732	0900	8	0	-

[a] Light: <10 kph; Moderate: 10 - 15 kph; Strong: >15 kph

[c] Boat on transects

RESULTS

Aerial surveys

Scaup and surf scoter comprised 65.1% and 7.0% respectively of birds counted in the aerial surveys. Other species included canvasbacks (1.4%) and ruddy ducks (0.2%). Unidentified ducks comprised 20.1% of the total number of birds counted during the aerial surveys. There was high variation in the number of birds counted between trials (Table 4).

Table 4. Total number of ducks counted within 4000 m of the device prior to and one hour following its deployment in each trial.

		Device status	
Site	Trial	OFF	ON
1	1	664	464
1	2	840	196
1	3	1,408	2,100
1	4	1,245	500
1	5	3,560	2,473
2	1	7,218	1,440
2	2	2,026	5,698
2	3	318	781
2	4	1,419	353
2	5	19,640	7,931

Deployment of the device did not result in a significant change in number or distribution of birds within a 4 km radius of the device (Figure 9) (Table 5).

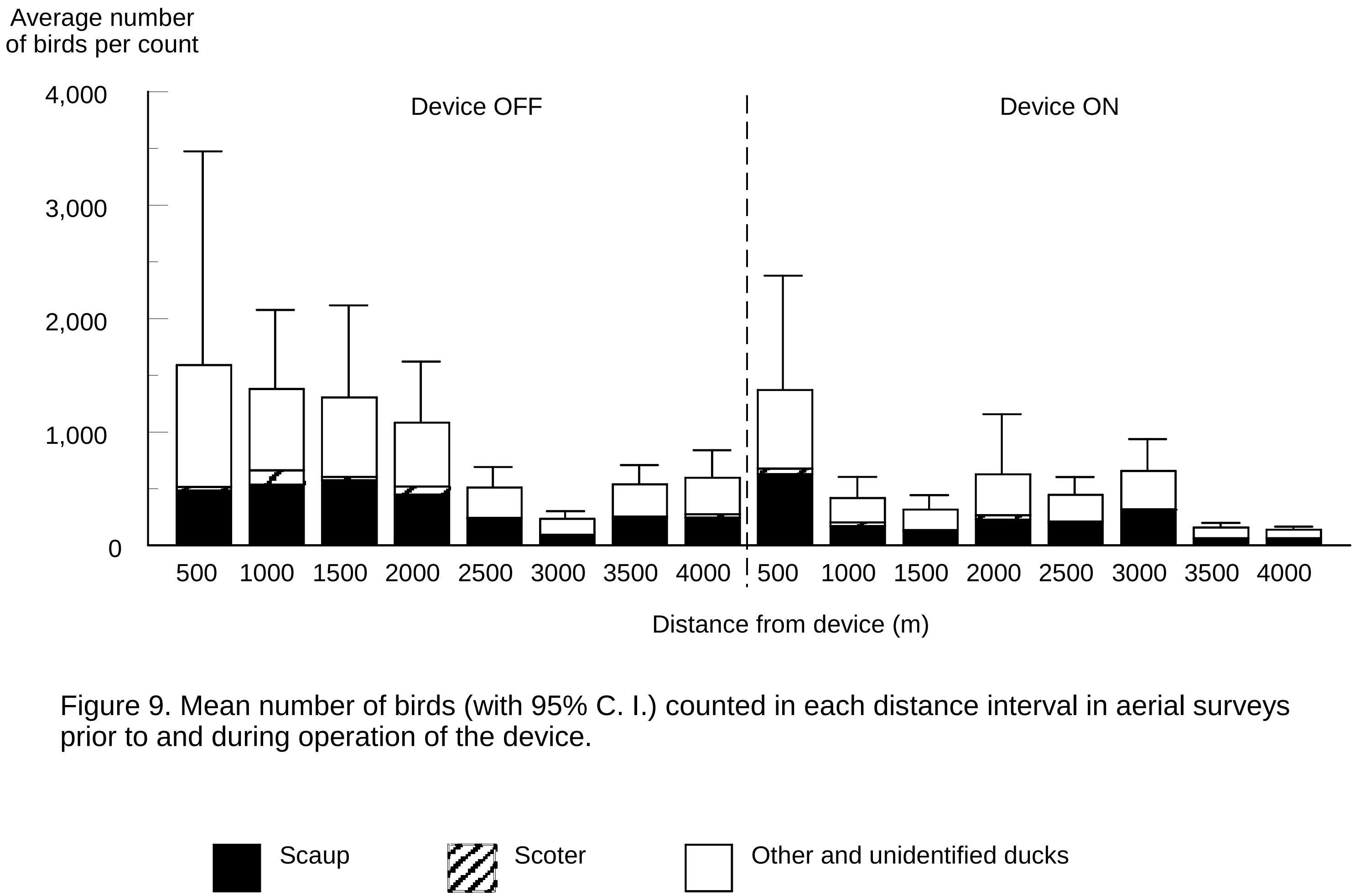

Figure 9. Mean number of birds (with 95% C. I.) counted in each distance interval in aerial surveys prior to and during operation of the device.

Table 5. Results for all species and scaup of a 3-Way Analysis of Variance of aerial survey data where Site is a random effect, and Trial, Treatment and Distance are fixed effects.

Species	Source of Variation	Degrees of Freedom	*F*	*P*
Total ducks	Trial	4, 4	1.8	0.29
	Treatment	1, 5	1.7	0.25
	Distance	7, 7	0.5	0.82
	Trial x Treatment	4, 5	1.2	0.40
	Trial x Distance	28, 30	0.9	0.60
	Distance x Treatment	7, 33	0.8	0.60
	Trial x Distance x Treatment	28, 33	1.1	0.40
Scaup	Trial	4, 8	3.8	0.05
	Treatment	1, 2	0.3	0.65
	Distance	7, 230	1.7	0.10
	Trial x Treatment	4, 8	1.7	0.25
	Trial x Distance	28, 230	0.7	0.90
	Distance x Treatment	7, 230	0.7	0.71
	Trial x Distance x Treatment	28, 230	0.9	0.62

Ground surveys

Scaup and surf scoter comprised 88.3% and 6.0% respectively of all birds counted in the ground surveys. Other species included canvasbacks (1.4%), ruddy ducks (0.9%), grebes (0.7%) and gulls (0.1%). There was high variation in the mean number of birds present during each trial, ranging from 13 to 772 when the device was not present and from 61 to 459 when the device was operating (Figure 10). In 3 trials (Site 1, Trial 1; Site 2, Trial 1; Site 2, Trial 5) an increase in number of birds from the period when the device was OFF to when the device was ON was observed over all distance intervals of the transects. In the other trials, a decrease in number of birds was observed up to 100 m (Site 2, Trial 4), 300 m (Site 1, Trial 4), 400 m (Site 2, Trial 2), 600 m (Site 1, Trial 2; Site 1, Trial 5 and Site 2, Trial 3), and 800 m (Site 1, Trial 3) from the device when it was operating.

A 3-way analysis of variance did not identify a significant difference in distribution or number of birds between treatment periods for total birds, scaup, canvasbacks, or ruddy ducks (Figure 11). There was a significant difference in number of birds between trials. A significant Trial x Treatment interaction was observed for scoter (Table 6). Scoter were present during only 6 trials, their numbers exceeding 100 individuals during 3 of those trials and on days when the device was not operating.

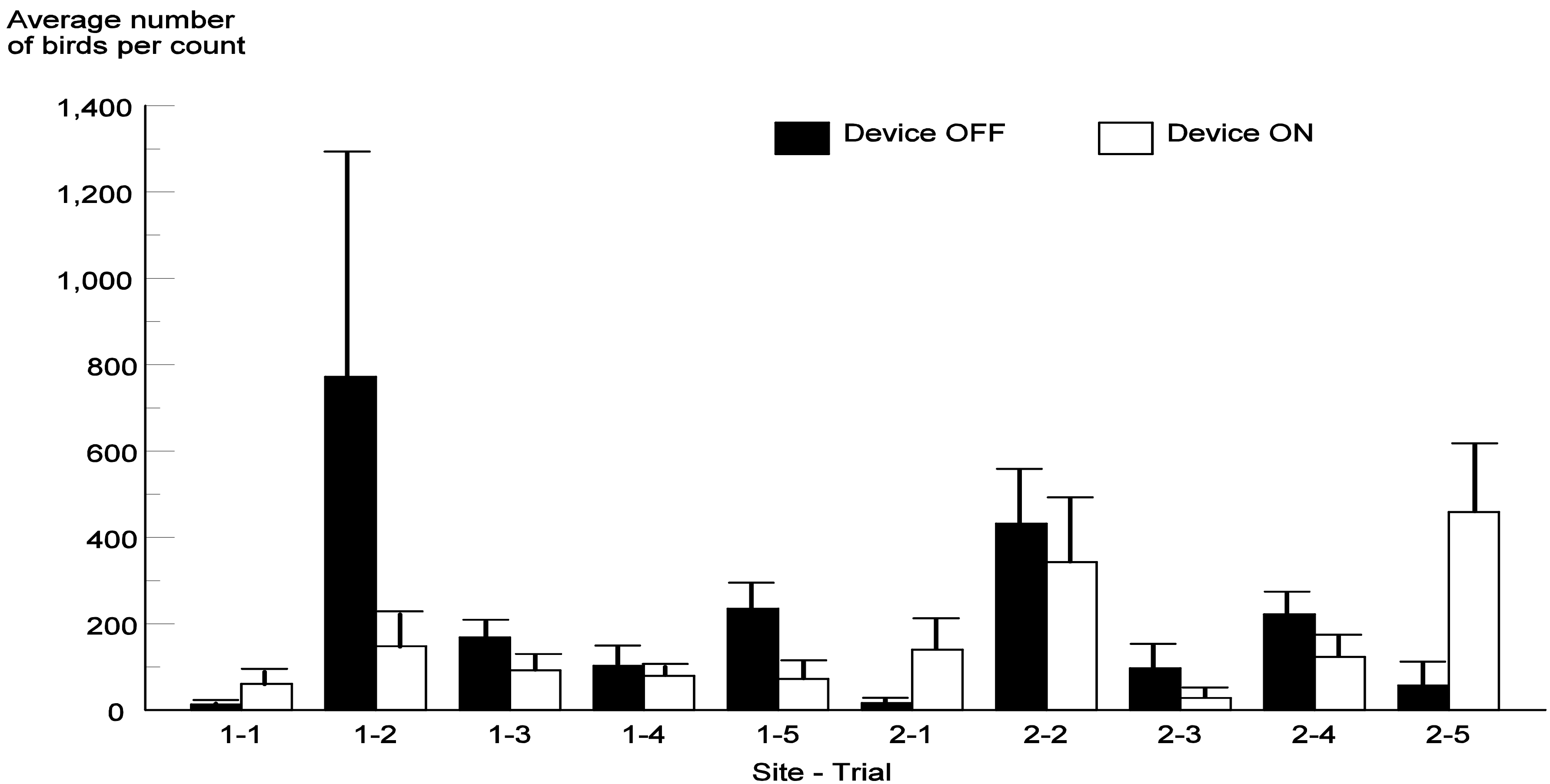

Figure 10. Mean number of birds (with 95% C.I.) counted in each trial in ground surveys prior to and during operation of the device.

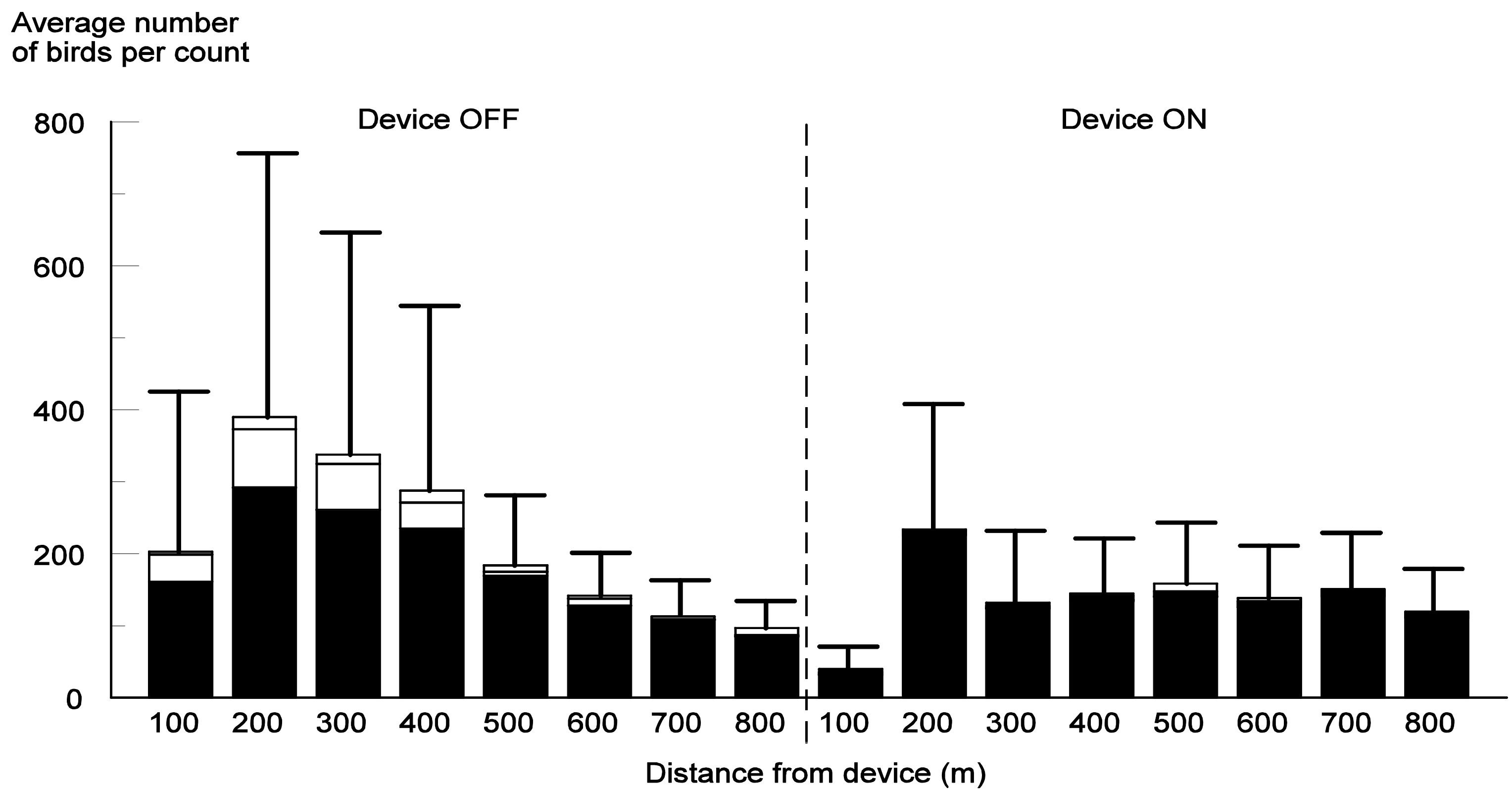

Figure 11. Mean number of birds (with 95% C.I.) counted in each distance interval in ground surveys prior to and during operation of the device.

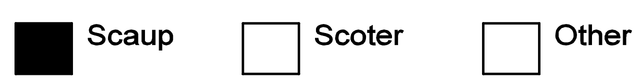

Table 6. Results for all species, scaup and scoter of a 3-Way Analysis of Variance of ground survey data with Site as a random effect, and Trial, Treatment and Distance considered as fixed effects.

Species	Source of Variation	Degrees of Freedom	*F*	*P*
Total ducks	Trial	4, 8	4.24	0.04[a]
	Treatment	1, 2	0.56	0.53
	Distance	7, 230	1.71	0.11
	Trial x Treatment	4, 8	2.22	0.16
	Trial x Distance	28, 230	0.79	0.76
	Distance x Treatment	7, 230	0.85	0.55
	Trial x Distance x Treatment	28, 230	0.97	0.51
Scaup	Trial	4, 8	3.79	0.05[a]
	Treatment	1, 2	0.28	0.65
	Distance	7, 230	1.74	0.10
	Trial x Treatment	4, 8	1.66	0.25
	Trial x Distance	28, 230	0.66	0.90
	Distance x Treatment	7, 230	0.65	0.71
	Trial x Distance x Treatment	28, 230	0.90	0.62
Scoter	Trial	4, 9	5.20	0.02
	Treatment	1, 9	4.92	0.05
	Distance	7, 230	1.21	0.30
	Trial x Treatment	4, 9	5.38	0.02[a]
	Trial x Distance	28, 230	1.20	0.23
	Distance x Treatment	7, 230	1.20	0.30
	Trial x Distance x Treatment	28, 230	1.21	0.23

[a]Significant result at 0.05 level

Bird Behavior

Bird movement on the site appeared to be largely affected by tides. Large flocks of ducks either swam or exhibited feeding and preening behaviors with incoming tides onto the sites. As they approached the device, birds did not display any visible signs of reaction to any of the sounds being broadcast, or alter their course. Very few flying birds were recorded at any time during the study (0.0025 of all birds observed). ‘Swimming’ was the predominant behavior observed. Preening behavior was observed within 100 m of the device while it was operating. The proportion of birds diving did not increase during operation of the device (Table 7).

Table 7. Proportion of birds exhibiting various behaviors within each distance interval from the device prior to and during its operation.

Device status	Distance from device (m)	Swimming	Preening	Diving	Swimming, Diving & Preening[a]	Number of birds
OFF	100	0.84	0	0.02	0.14	6,838
	200	0.91	0	0	0.09	9,862
	300	0.87	0	0.01	0.12	8,852
	400	0.85	0	0.06	0.09	8,904
	500	0.87	0	0	0.13	6,613
	600	0.78	0	0.13	0.09	7,275
	700	0.74	0	0.16	0.10	6,503
	800	0.65	0	0.27	0.08	6,994
	Total	0.75	0	0.15	0.10	92,381
ON	100	0.82	0	0.05	0.13	1,395
	200	0.89	0	0.02	0.09	5,418
	300	0.89	0	0.01	0.10	3,380
	400	0.84	0.03	0.07	0.06	4,825
	500	0.89	0.05	0.04	0.02	5,120
	600	0.85	0.05	0.08	0.02	4,775
	700	0.75	0.05	0.16	0.04	4,996
	800	0.66	0.06	0.25	0.03	4,809
	Total	0.79	0.03	0.14	0.04	53,441

[a]Large flocks often exhibited a combination of behaviors

DISCUSSION

Test conditions

This study is the only replicated field trial of the Breco Bird Scarer© to be undertaken to date. Test conditions in terms of number of birds, weather and visibility were ideal throughout most of the study. Bird numbers on the sites were high with up to 4249 birds present on the study transects at any time. This is consistent with surveys of birds undertaken in previous years, which report a high number of wintering birds in the bay in March (Accurso 1992), and results of a survey of the entire bay undertaken on 27 March, 1997, immediately following our study (Bonnell 1997). Bonnell (1997) estimated a total of 51,263 birds present in San Pablo Bay, comprising 51% scaup, 33% scoter and 16% other species including canvasback, goldeneye, mallard, pintail, northern shoveler and ruddy duck. Although scoter accounted for a large proportion of total waterfowl in Bonnell's (1997) survey, distribution maps show that unlike scaup, they were not present in large numbers in the vicinity of our study sites and tended to occur primarily in deeper waters of the bay (Figures 12 & 13).

Although the mean number of birds on the sites was high on each day of the study, there was high variation between counts. During the 4 h observation period each day, the number of birds on the sites varied from only a few birds to flocks of several thousand birds. There also was high daily variation in bird numbers. This may be attributed to numerous factors including bird behavior, tides, climatic variables, as well as boating and other activities occurring on or near the study sites and outside the bay, that could not be accounted for in our study. Tide seemed to be a major factor influencing abundance. Large flocks of birds were observed to drift with incoming tides onto the sites. On one hand, this was advantageous in that birds encountered the device gradually as would happen if the device was drifting with an oil slick, and we were able to observe birds' reactions to the device. However, high variation in numbers confounds interpretation of results and makes it difficult to detect a significant effect. This highlights the importance of replication in assessments like these.

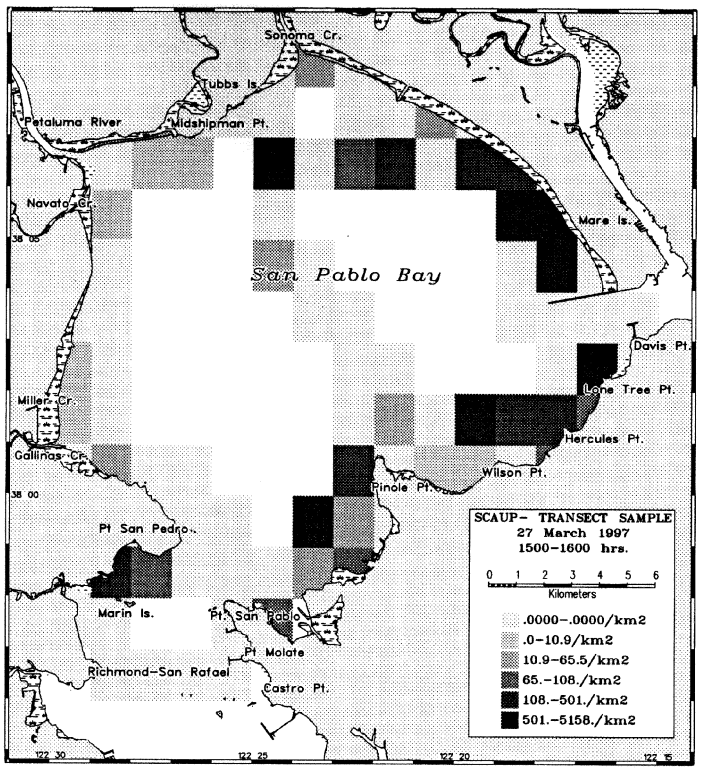

Figure 12. Distribution of scaup in San Pablo Bay, 27 March 1997 [from Bonnell (1997)].

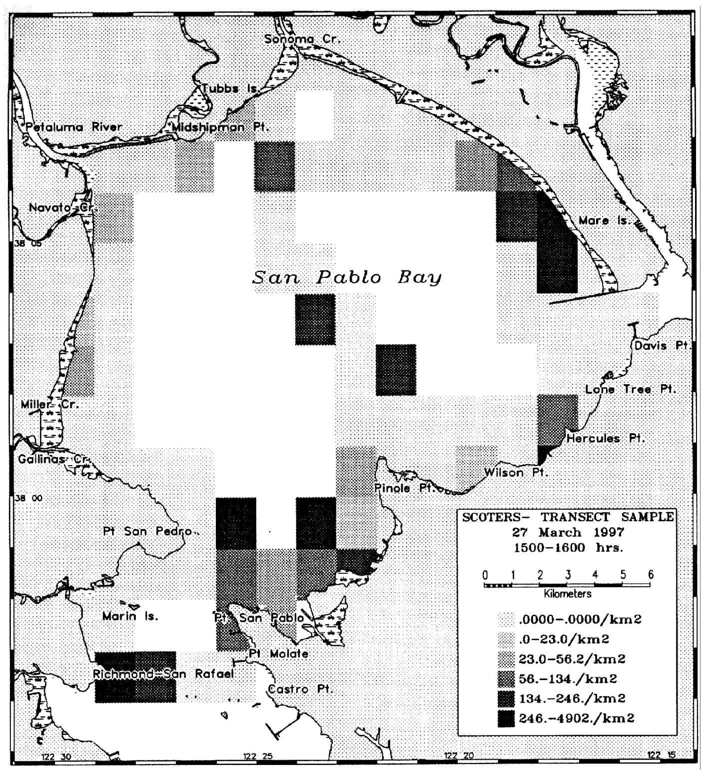

Figure 13. Distribution of scoter in San Pablo Bay, 27 March 1997 [from Bonnell (1997)].

Another factor that confounds interpretation of our results is the possibility that the device was not operating as specified during the study. Following the return of the test unit to the distributor, we were advised that 3 of the 4 speakers were not functioning such that the device was not broadcasting the noises at 130 dB. Our test of noise levels at the end of the study did not suggest a directional component to the noise broadcast, as would be expected if only one speaker was operating. Furthermore, noise levels at 1 m from the device when floating were in the range of 102 to 122 dB. Although we did not test noise levels throughout the study, this suggests that the device may have been damaged during shipment after the testing had been completed.

Effect of Breco Bird Scarer© on birds

The Breco Bird Scarer© was not effective in hazing waterbirds during our study. Aerial surveys did not detect a significant change in distribution of any species or total numbers within a 4 km radius following deployment of the device. Ground surveys of birds provided greater resolution than aerial surveys in determining the number, species composition, and distribution of waterbirds within an 800-m radius of the device, but like aerial surveys did not detect a significant effect of the device on number or distribution of ducks. Furthermore, birds did not display any signs of distress or alarm on encountering the device, and did not change their course of movement when approaching the device. In many instances, flocks of several thousand birds were observed to surround the device while it was operating. A significant result was found for surf scoter, which were present in lower numbers when the device was operating. However, scoter were present during only 6 trials, their numbers exceeding 100 individuals during 3 of those trials.

Comparison with results of previous test

Our results are in contrast to those reported by Lehoux and Belanger (1995) who recorded an effective scaring radius (85% reduction in birds) of 700 m and a 69% reduction in the total number of birds over a 5 km long area during an assessment on the St Lawrence River estuary, Canada. However, their study was unreplicated so it is questionable if the device was solely responsible for the change in number of birds from before to following its deployment. The test conditions in the Canadian study were also different. The predominant species recorded in the Canadian study were common eiders and scoters, birds were molting, and there was little disturbance by boat traffic in the study area. In contrast, the predominant species in our study were scaup that were wintering in the bay area. Our results suggest species differences in reaction to the device. Although scoter were present only in low numbers during our study, there were significantly fewer present while the device was operating. Furthermore, San Francisco Bay is an urbanized area and subject to disturbance by boat traffic. Consequently, birds may already have been accustomed to noise disturbance so were not scared by the device.

Habituation resulting in short term effectiveness of a hazing technique or device is a factor that has been frequently observed in studies of their effectiveness (see Bomford and O'Brien 1990). Birds can quickly learn to ignore a repeated stimulus if it occurs regularly without reward or punishment and may habituate to such noises within as little as 1 hour (Bomford and O'Brien 1990). The rate at which birds habituate to a noise seems to depend on species as well as the situation and environmental conditions (Bomford and O'Brien 1990, Salmon *et al.* 1991). In assessments of the effectiveness of propane exploders for dispersing waterbirds on the Beaufort Sea Coast, birds habituated to the exploders in 3 days (Sharp 1978 1987). Biggs *et al.* (1978) tested the effectiveness of propane exploders and cracker shells in coastal areas near Vancouver, Canada. Northern shovelers, green-winged teal and mallard habituated to the sounds after only
4 h of continuous firing. Dabbling ducks in areas of high background noise seemed to habituate to the explosions more quickly than those in quiet areas. In contrast, Crummett (1973) did not observe ducks to habituate to the Av-alarm during a test in a coastal area of California. The Av-alarm reduced the number of ducks in a 1.9 km^2 area by 82% and by 56% over a 3.8 km^2 area. The declines in numbers began immediately when the device was turned on and continued over the 6 day period when the Av-alarm was operating. The reason why the Av-alarm was effective for such a long period in this study compared to other situations is not clear.

Weather also has been reported as a factor influencing the effectiveness of sound-based bird-hazing techniques in aquatic environments. In a test of propane exploders in coastal areas near Vancouver, effectiveness was high with calm and clear weather and low when foggy or windy (Biggs *et al.* 1978). It is unlikely that weather conditions reduced the distance over which the sounds broadcast by the device were audible and thus effectiveness of the Breco Bird Scarer© in our study. Conditions were calm and clear on most days.

The types of sounds broadcast by the Breco Bird Scarer© also may limit the effectiveness of the device. Many of the sounds were derived from such sources as science fiction movies, special effects soundtracks and horror films (Lehoux and Belanger 1995) and do not have any biological basis for their selection. Use of natural sounds such as bird alarm and distress calls, and predator calls may be more effective. These types of sounds have been used with variable effectiveness for repelling birds from roosts, fish-rearing ponds, airport runways and agricultural settings (Salmon and Marsh 1991 for review). Effectiveness varies with bird species, depending on factors such as flocking behavior of the species, and whether the species communicates through acoustic or visual cues (Bomford and O'Brien 1990, Salmon and Marsh 1991a). Spanier (1980) used a heron distress call to effectively repel night herons (*Nycticorax nycticorax*) from a pond. After 6 months, herons showed no signs of habituation to the distress call, whereas habituated after 6 nights to a recording of a gas gun. Various alarm, distress and predator calls were used to effectively repel scoters from juvenile mussel collector lines in Miramichi Bay, New Brunswick, Canada, during a 28-day study period (Hounsell and Reilly 1995). The sounds were broadcast by a Marine Phoenix Wailer which can be programmed to broadcast specific distress, alarm or predator calls as well as artificial noises (gun shots etc) depending on its intended use.

Potential use of Breco Bird Scarer©

Although not effective in deterring birds in our study, the Breco Bird Scarer© should not be dismissed as a potential tool for use in less disturbed situations, and warrants further testing. The device may prove to be a valuable component of a hazing program that incorporates a variety of other deterrent techniques such as helicopter hazing or use of shotguns, shell-crackers, effigies, cannons, rockets and mortars. A combination of hazing techniques based on both visual and acoustic cues has long been recognized as providing the maximum deterrent effect and minimizes the potential for habituation to occur (Bomford and O'Brien 1990, Koski *et al.* 1993). A helicopter, motorboat, explosive rounds and propane exploders were used to deter birds from a coastal area in Canada for a 24-h period (Lehoux 1990). Low altitude helicopter flights and motorboat disturbance over a 1.5-h period were successful in reducing scoter numbers from 2000 to 100 but scoter numbers increased to 800 only 15 min after hazing ceased. An additional hour of hazing caused the departure of all birds. Propane exploders established on the beach for hazing during the night had an effective range of 1 km.

Koski *et al.* (1993) suggested that in open habitat such as marine settings, birds may depend more on visual than acoustic cues for communication. Consequently, effectiveness of the Breco Bird Scarer© may be improved through modification to incorporate visual deterrents such as lights or reflectors (see Greer and O'Connor 1994). Effectiveness also may be improved through inclusion of natural sounds such as bird alarm and distress calls or predator calls.

Conclusions

Despite the widespread use of bird-hazing techniques and devices, there have been few replicated studies to evaluate their effectiveness (see Bomford and O'Brien 1990). Because of their potential high value in oil spill situations, assessment of new and existing bird-hazing techniques and devices should be a priority. In oil spill situations the cost savings associated with an effective technique may be significant. The Breco Bird Scarer© (including one set of batteries which will power the device for 72 h) costs approximately $10,000 to purchase. Additional batteries cost approximately $1,000 per set. This expense may be considered minimal in comparison to the costs incurred in cleaning oiled birds, which in California have been estimated at $600 to $750 per bird (Jessup 1997). Thus a device which saves 10 to 20 birds is cost-effective, especially when success rates for rehabilitated birds are low.

The Breco Bird Scarer© is the first device to be developed specifically for use in oil spill situations and thus represents an important innovation in bird-hazing technology. Further testing of the Breco Bird Scarer© and other deterrent devices developed for aquatic situations (e.g., the Marine Phoenix Wailer) is needed. Such tests should be replicated to cater for the high spatial and temporal variation in bird numbers, and as far as possible simulate a real oil spill situation (e.g. also include an assessment of a drifting device). Sound levels should also be taken at regular intervals to ensure that the device is operating correctly.

LITERATURE CITED

Accurso, L. A. 1992. Distribution and abundance of wintering waterfowl on San Francisco Bay 1988-1990. Unpubl. Master's Thesis, Humboldt State Univ., Arcata, CA. 252pp.

Biggs, W. G., Sverre, S. F., and Boisvert, M. P. 1978. The field testing of exploding devices for use in deterring and dispersing waterbirds from oil spill sites. Pace Report No. 78, Entech Environmental Consultants Ltd., Vancouver B. C. 23p.

Bomford, M. and P. H. O'Brien. 1990. Sonic deterrents in animal damage control: A review of device tests and effectiveness. Wildlife Society Bulletin. 18:411-422.

Bonnell, M. 1997. Waterfowl and seabird survey of San Pablo Bay. Institute of Marine Sciences, University of California, Santa Cruz. Report for California Department of Fish and Game, Office of Oil Spill Prevention and Response. 14p.

Crummett, J. G. 1973. Bird dispersal techniques for use in oil spills. Report for American Petroleum Institute., Washington, DC. 120p.

Frink, L. 1987. An overview: rehabilitation of oil contaminated birds. Proceedings of the 1987 Oil Spill Conference, Maryland. pp 479-482.

Greer, R. D. and O'Connor, D. J. 1994. Waterbird deterrent techniques. Exxon Biomedical Sciences, Inc. Marine Spill Response Corporation, Washington, D.C. MSRC Technical Report Series 94-003, 38p.

Hounsell, R. and Reilly, T. J. 1995. New Brunswick bird deterrent study. Technical Report Series, 95-021, Marine Spill Response Corporation, Washington, DC. 18p.

Jessup, D. 1997. Oiled wildlife care and the myth of the $15,000 bird. Proceedings of the 5th International Conference of the Effects of Oil on Wildlife. November 3-6, 1997. Monterey, California U.S.A. pp191-193.

Koski, W. R. and Richardson, W. J. 1976. Review of waterbird deterrent and dispersal systems for oil spills. Pace Report No. 76-6, LGL Limited, Environmental Research Associates, Toronto, for Petroleum Association for Conservation of the Canadian Environment. 122p.

Koski, W. R., S. D. Kevan and W. J. Richardson. 1993. Bird dispersal and deterrent techniques for oil spills in the Beaufort Sea. Environmental Studies Research Funds Report No. 126. Calgary, 122p.

Lehoux, D. 1990. Evaluation of different deterrence techniques applicable to waterfowl during hydrocarbon spills. Environment Canada, Canadian Wildlife Service.

Lehoux, D. and L. Belanger. 1995. Evaluation of the effectiveness of the Breco Bird Scarer© in dispersing aquatic birds away from oil spills. Environment Canada and Canadian Wildlife Service. 45p.

Piatt, J. F., C. J. Lensing, W. Butler, M. Kendziorek, and D. R. Nysewander. 1990. Immediate impact of the Exxon Valdez oil spill on marine birds. Auk. 107:387-397.

Salmon, T. P. and R. E. Marsh. 1991a. Bird hazing and frightening methods and techniques. A literature review compiled for the California Department of Water Resources, under Contract No. B-57211. University of California, Davis, CA. 233p

Salmon, T. P. and R. E. Marsh. 1991b. Effectiveness and cost of minimizing bird use on agricultural evaporation ponds. Final report to California Department of Water Resources, Contract No. B-57211. University of California, Davis, CA. 118p.

Marsh, R. E., W. A. Erickson, and T. P. Salmon. 1991. Bird hazing and frightening methods and techniques (with emphasis on containment ponds). University of California, Davis, CA, pp 301-304.

SAS Institute, Inc. 1995. SAS/STAT User’s guide. Version 6.12. Cary, N. C.: SAS Inst. Inc.

Sharp, B. E. 1996. Post-release survival or oiled, cleaned seabirds in North America. IBIS. 138:222-228.

Sharp, P. L. 1978. Preliminary tests of bird-scare devices on the Beaufort Sea Coast. LGL Limited, Edmonton, Alberta, for Canadian Marine Drilling, Ltd., Calgary, Alberta.

Sharp, L. 1987. Chasing birds from oil spills- two experiments. Coastal Zone '87, pp 1-15.

Thomas, A. M. (Tech. Ed.). 1994. MSRC Workshop report: Research on waterbird deterrents for marine oil spills, November 1-2, 1994, Denver, CO. Marine Spill Response Corporation, Washington, DC. MSRC Technical Report Series 94-006, 32p.

Ward, J. G. 1977. Techniques for dispersing birds from oil spill areas. Proceedings of the 1977 Oil Spill Response Workshop. 15-17 February, 1977, Metairie, Louisiana. P. Fore (Ed.). pp 113-125.