Testing the Effectiveness of an Aquatic Hazing Device on Waterbirds in the San Francisco Bay Estuary of California

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Abstract.—Aquatic hazing devices recently have been developed as a possible means of deterring waterbirds from oil spills, thereby reducing casualties. However, the effectiveness of these devices has not been examined with rigorous statistical tests. We conducted a study in the San Francisco Bay estuary to develop a design for testing the effectiveness of an aquatic hazing device on waterbirds in open water. Transects marked with poles at 100-m intervals up to 800 m from the hazing device were established at two sites separated by three km in the north bay. Alternating two-day test and control periods were conducted at each site. Observers in over-water blinds counted the number, species and behavior (swimming, diving, or preening) of birds on transects each day. Aerial surveys of birds within four km of the device were conducted at the beginning of each test. For both aerial and ground surveys, a three-way mixed model analysis of variance test was used to examine trial, distance from the device, and treatment (device on or off) fixed effects, and site as a random effect on numbers of Greater and Lesser scaup (*Aythya affinis* and *A. marila*), Surf Scoter (*Melanitta perspicillata*), and all other waterbirds. We could not detect a significant deterrent effect of the hazing device in either aerial surveys of all ducks or scaup (all ducks, $F_{28,33} = 1.1$; Scaup, $F_{28,230} = 0.9$, all n.s.; 3-factor ANOVA), or ground surveys for all ducks or scaup (all ducks, $F_{28,23} = 1.0$; scaup, $F_{28,230} = 0.9$, all n.s.; 3-factor ANOVA). There was a significant trial-by-treatment interaction for Surf Scoters ($F_{4,9} = 5.4$, $P = 0.02$; 3-factor ANOVA), but Surf Scoter numbers fluctuated greatly among trials so the effect of the device on this species was not clear. Birds did not alter their behavior when the device was active. In general, although aquatic hazing devices have potential to reduce waterbird mortality in oil spills, the tested device was not effective as a deterrent for waterfowl in experimental trials on the estuary. *Received 27 September 1999, accepted 3 January 2000.*

Key words.—Bird-hazing, Breco Bird Scarer, oil spill, San Francisco Bay, Scaup, Surf Scoters, waterbirds, waterfowl, *Aythya* spp., *Melanitta perspicillata*.

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Bird hazing has long been used to repel nuisance birds from airports, aquaculture facilities, agricultural fields, and other sites (Bomford and O'Brien 1990; Salmon and Marsh 1991). Hazing 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. Although there have been numerous studies on the efficacy of hazing techniques in altering space use or damage caused by free-ranging animals, few of these have been well-designed (Bomford and O'Brien 1990). Most studies have lacked experimental controls and sufficient replication to determine if the observed effect is a result of hazing method or other factors (Bomford and O'Brien 1990). Bird hazing techniques are inherently difficult to test due to high mobility of birds, high spatial and temporal variation in numbers, seasonal variation in behavior, and potential for birds to habituate to the sound after a short time (Bomford and O'Brien 1990).

Aquatic 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). If effective, aquatic hazing devices have the potential to reduce bird mortality associated with oil spills in offshore, coastal, and estuarine locations. Chemical spills in urbanized estuaries such as the San Francisco Bay, which is a major staging and wintering area for waterbirds, have the potential to cause catastrophic bird mortality (Harvey *et al.* 1992; Carter *et al.* 1997). More than one spill of some hazardous material occurs every day within or on the shores of San Francisco Bay (Luoma and Cloern 1982), and, over the past five years, several major oil spills have occurred in open water of the Bay. Major spills include the 1996 *Cape Mohican* spill which resulted in an estimated mortality of 4,000 birds (California Department of Fish and Game, Oil Spill Prevention and Response, unpublished data), and the *Command* oil spill in 1999. The estuary is a major refuge for a diverse community of waterbirds including waterfowl species such as Greater and Lesser scaup (*Aythya affinis* and *A. marila*), Surf Scoters (*Melanitta perspicillata*), Canvasback (*Aythya valisineria*), Ruddy Ducks (*Oxyura jamaicensis*) and Northern Shovelers (*Anas clypeata*). Oil spills would likely affect the most waterbirds during the winter (October-April) when these migratory species are most abundant (Accurso 1992).

With the development of aquatic hazing devices and techniques, there is a need for replicated, statistically rigorous testing of their effectiveness. Therefore, the objective of our study was to develop a design to evaluate the effectiveness of an aquatic hazing device on deterring waterfowl, predominantly scaup and Surf Scoters, wintering in the open water of the northern San Francisco Bay estuary.

METHODS

The study was undertaken over the period 3-24 March 1997, a few weeks prior to the migration of ducks from the area. Two sites (38°6'N, 122°20'W and 38°6'N, 122°22'W) separated by a distance of approximately three km were selected in San Pablo Bay (Fig. 1). The sites were located near two floating duck blinds that had been used by hunters during the winter (October-January). The duck blinds were approximately 3 × 7 m, large enough to enclose the 4.3-m boat used to transport observers to the blinds. Each site was approximately one-km offshore. Water depth varied from approximately 30 cm at low tide to two m at high tide at the shallowest part of each site.

Transects were marked at each site with 4.5-m long, 2.5-cm diameter polyvinyl chloride (PVC) poles placed in the substrate. 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 two transects of 800 m each (Fig. 2). Transects radiated out at 90 degrees from a center point where the device would be anchored during testing. A global positioning system (GPS) accurate to five to ten m was used to mark transects. Each duck blind was approximately 400 m from the device anchoring point and 300 m from each transect.

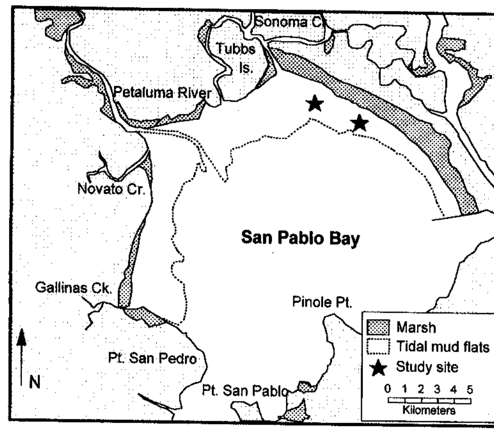

Figure 1. Map of San Pablo Bay showing the location of the study sites.

We tested the Breco Bird Scarer, a hazing device developed specifically for use in deterring birds from oil spills. The device consisted of a broadcasting system that produced a variety of high-intensity sounds (up to 130 dB at one m) played at random to minimize habituation, mounted inside a waterproof buoy. The buoy weighed 36 kg, had a diameter and height of 71 cm and 66 cm respectively, was designed to drift with the oil and to be functional over a 72-h period. Sounds broadcast by the device included a dog barking, sirens, music, human screams, gunfire and a variety of other artificial noises. The length of each sound ranged between 20 and 50 s with an emission interval of 20 s to 5 min.

Five tests of the device were undertaken at each site. Operation of the device was alternated between sites on a two-d off and two-d on cycle at each site. The device

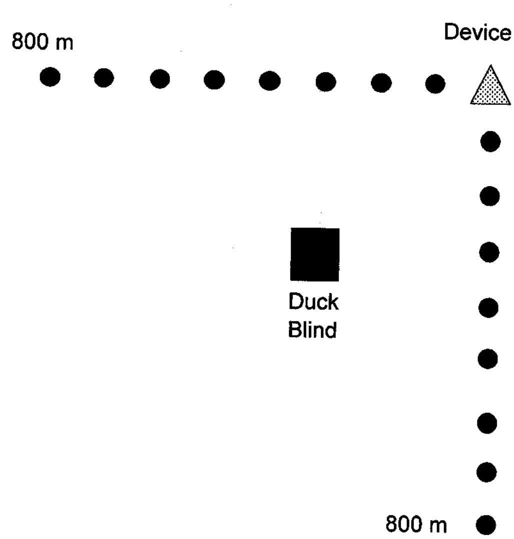

Figure 2. Layout of the study sites.

was moved between sites by boat, and batteries in the device were replaced after every other test. 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 four d of the 22-d trial. We used a decibel meter to test sound levels of the device while it was anchored at one site. Sound at one m ranged between 102 and 122 dB for four sounds tested.

Aerial surveys

Aerial surveys of birds within a four-km radius of the device were undertaken immediately prior to deployment of the device, and one h after deployment for each test. Surveys were conducted by two observers seated on either side of a Cessna 172. Each aerial survey comprised two passes at 90-degree angles that began at the device anchoring point. A GPS was used to estimate the distance traveled away from the device. The plane flew at a speed of approximately 140 km h^{-1} and at an elevation of 60 m. Each pass took about 100 s to complete. Observers used tape recorders synchronized by time to determine distance of birds from the device. Prior to the surveys, observers calibrated the 500-m wide strip by undertaking a flight at 60-m elevation down the center of a one-km wide pond. All birds seen within a 500-m wide strip on either side of the airplane were identified and counted from the device to a distance of four km.

Ground surveys

On each day of the study, an observer arrived at each blind between 0700 and 0900 h. To ensure that disturbance by the boat didn't affect counts, observers waited one h from the time of their arrival at the sites to begin counting birds. Eight counts were then undertaken at 30-min intervals. Number and species of birds were counted and their location on the transects recorded. Low visibility resulted in only two and six counts being completed on two days, while low tides reduced the period that observers could remain in the blinds on four days when only six counts could be completed. Recreational fishing boats were present near the study sites during nine trials.

Behavior of birds within each 100-m transect interval was recorded and classified as swimming (including resting), diving, preening, or flying. When large flocks were present, an estimate of the proportion of birds exhibiting each behavior was recorded.

Statistical analysis

Aerial survey data were analyzed in a mixed model three-way analysis of variance. Site was a random effect while trial, distance from the device anchoring point (8 × 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 three-way analysis of variance also was used for analysis of the ground data. Distance from the device anchoring point was divided into 8 × 100-m intervals. The mean count for each four-h period was used in analyses. Although this reduced the degrees of freedom in the analysis, taking the mean of the counts smoothed out the variation in daily number of birds on the site. Separate analyses were undertaken for scaup, Surf Scoters, and total ducks (included species such as Canvasbacks, Ruddy Ducks, and Northern Shovelers).

RESULTS

Aerial surveys

There was large variation in the number of birds counted in each trial, ranging from 1,036 to 27,571 birds. Scaup and Surf Scoters 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. Deployment of the device did not result in a significant change in number or distribution of birds (Trial × Distance × Treatment interaction) within a four-km radius of the device (Fig. 3) (Total ducks, $F_{28,33} = 1.1$; scaup, $F_{28,230} = 0.9$; all n. s.; 3-factor ANOVA).

Ground surveys

The mean number of birds present during each trial ranged from 2,601 to 17,874 birds. Scaup and Surf Scoters comprised 88.3% and 6.0% respectively of birds counted in the ground surveys. Other species included Canvasbacks (1.4%), Ruddy Ducks (0.9%), Grebes (Podicipedidae; 0.7%) and Gulls (*Larus* spp.; 0.1%). Deployment of the device did not result in a significant change in number or distribution (Trial × Distance × Treatment interaction) of total ducks ($F_{28,230} = 0.97$, n.s.; 3-factor ANOVA) or scaup ($F_{28,230} = 0.9$, n.s.; 3-factor ANOVA) (Fig. 4). There was a significant Trial × Treatment interaction for Surf Scoters ($F_{4,9} = 5.38$, $P = 0.02$) and a significant difference in the total number of ducks between trials ($F_{4,8} = 4.24$; $P = 0.04$).

Bird behavior

Bird movement on the sites appeared to be largely affected by tides. Large flocks of ducks either swam or exhibited feeding and preening behaviors with incoming tides. As they approached the device, birds did not alter their course or react visibly to any of the sounds being broadcast. Very few flying birds (0.25%) were recorded at any time during the study. Swimming was the predominant behavior observed, but birds still preened and dived near the device (Table 1).

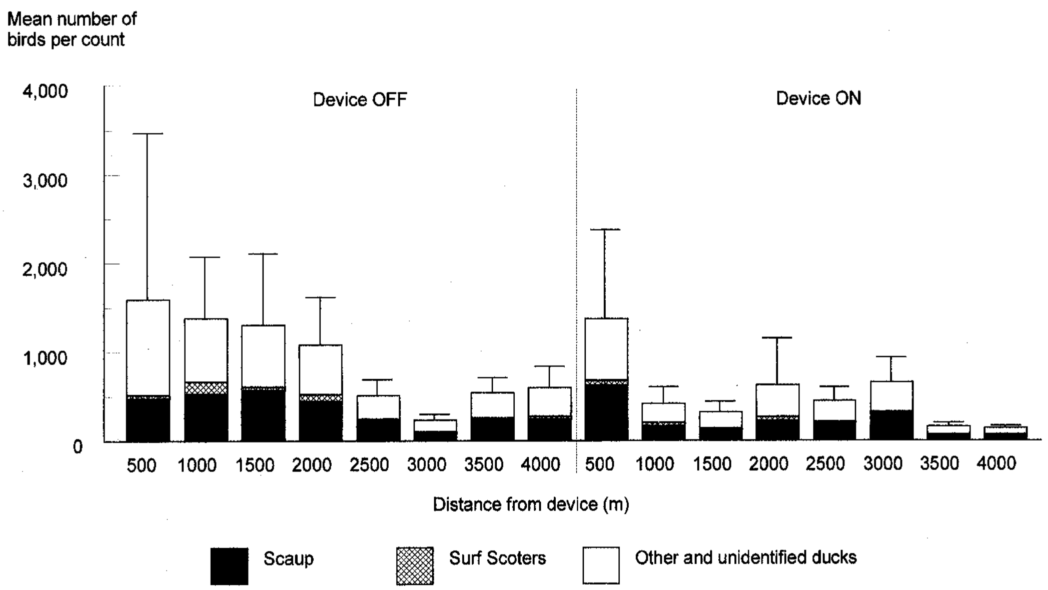

Figure 3. Mean number of scaup, Surf Scoters and other birds (with 95% C. I.) counted in aerial surveys in each 500-m interval from the device prior to and during its operation.

DISCUSSION

Lehoux and Belanger (1995) first evaluated the effectiveness of the Breco Bird Scarer on the St. Lawrence River, Quebec, Canada. In their study area, a relatively undisturbed section of the lower estuary, the main species were molting Common Eiders (*Somateria mollissima*) and scoters (*Melanitta* spp.). Their results indicated an effective scaring radius (85% reduction in birds) of 700 m and a 69% reduction in the total number of birds over a five-km long area. However, their study design did not allow for statistical testing of the results and consisted of a single test without replication.

In contrast, during our study on San Francisco Bay where we followed a rigorous study design, the same device was not effective in hazing wintering waterfowl. In aerial surveys, we did not detect a significant change in distribution of any species or total numbers within a four-km radius following deployment of the device. Ground surveys of waterbirds provided greater resolution than aerial surveys in determining the number, species composition, and distribution 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 birds. 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 within 300 m of the device while it was operating. Surf Scoters may have been present in lower numbers when the device was operating in some trials; however, Surf Scoters were present during just six trials, and their numbers exceeded 100 individuals during only three of those trials. The effect of the device on Surf Scoters therefore was not clear.

Test conditions, in terms of bird abundance, weather, and visibility were good during most of our study. Waterfowl numbers were consistent with aerial surveys undertaken in previous years in March (Accurso 1992). An aerial survey of San Pablo Bay on 27 March 1997 (Bonnell 1997), immediately following our study, estimated a total of 51,263 birds present in San Pablo Bay, comprising 51% scaup, 33% Surf Scoter and 16% other species including Canvasback, Bufflehead (*Bucephala albeola*), goldeneye (*Bucephala clangula* and *B. islandica*), Mallard (*Anas platyrhynchos*), Northern Pintail (*Anas acuta*),

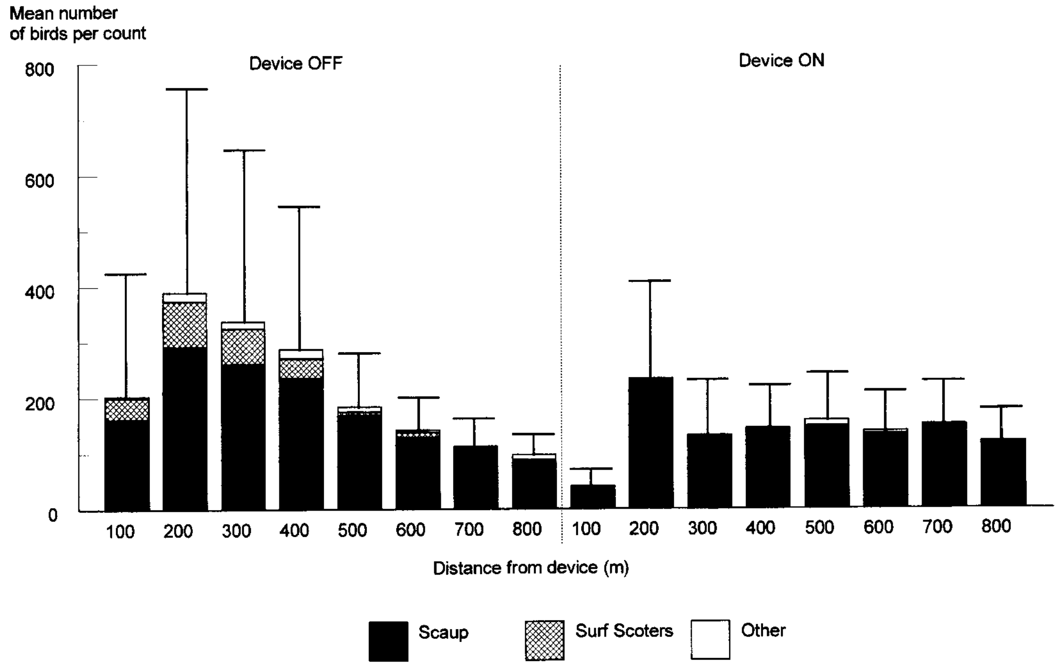

Figure 4. Mean number of scaup, Surf Scoters, and other species (with 95% C. I.) counted in ground surveys in each 100-m interval from the device prior to and during its operation.

Northern Shoveler and Ruddy Duck. Although Surf Scoters accounted for a large proportion of total waterfowl in the bay, they were not present in large numbers in the vicinity of our study sites, occurring primarily in deeper waters of the bay.

The major uncontrolled factor in our study design was the large variation in the numbers of waterbirds, ranging from 2,601 to 17,874 individuals, present at the two study sites during the tests. We attribute the variation in numbers to numerous factors including tides, weather, boating disturbance, and behavior that occurred on or near the study sites and could not be readily documented in our tests. However, we minimized the effect of variation in numbers on our results by alternating treatment and control periods at each site and by conducting repeated hourly counts of the birds. Observations of the behavior of birds encountering the device also verified our conclusions that the device was ineffective in deterring birds.

We suggest that habituation of birds to loud noise in San Francisco Bay may have limited the effectiveness of the device. San Francisco Bay is urbanized and subject to frequent disturbance along the shoreline and in open water. Bomford and O'Brien (1990) suggested that, unless sounds are reinforced by real danger, noise deterrents will have a short-term hazing effect. Birds quickly learn to ignore a repeated stimulus if it occurs regularly without reward or punishment and may habituate to noises within as little as one h (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 three d (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 (*Anas crecca*) and Mallards habituated to the sounds after only four h of continuous firing. Dabbling ducks in areas of high background noise seemed to habituate to the explosions

Table 1. Proportion of birds exhibiting various behaviors within 100 m, 100 to 300 m, and 300 to 800 m of the device prior to and during its operation.

Distance from device (m)	Device status (OFF/ON)	Bird behavior			Total number of birds observed
		Swimming	Preening	Diving	
≤100	OFF	0.88	0.05	0.07	6,838
	ON	0.87	0.04	0.09	1,395
100-300	OFF	0.93	0.03	0.04	18,714
	ON	0.92	0.03	0.05	8,798
300-800	OFF	0.81	0.03	0.15	36,289
	ON	0.81	0.06	0.13	24,525

more quickly than those in quiet areas. In contrast, Crummett (1973) did not observe ducks to habituate to the Av-alarm (broadcast of a synthetic noise) during a six-d test in a coastal area of California. The Av-alarm reduced the number of ducks over a 1.9-km^2 area by 82% and by 56% over a 3.8-km^2 area. The reason why the Av-alarm was effective for such a long period compared to other situations is not clear.

Although weather was not a major factor in our study, it may influence the effectiveness of sound-based bird hazing techniques in aquatic environments by affecting the range over which the device is audible. 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). The types of sounds broadcast also may limit the effectiveness of a bird-hazing device (Bomford and O'Brien 1990). In the device we tested, many of the sounds were derived from such sources as science fiction movies, horror movies, and special effects soundtracks (Lehoux and Belanger 1995) and had no apparent biological basis for their selection. Use of natural sounds such as bird alarm and distress calls, and predator calls may be more effective (Bomford and O'Brien 1990). 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). 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 1991). Spanier (1980) used a heron distress call to effectively repel Black-crowned Night Herons (*Nycticorax nycticorax*) from a pond. After six months, herons showed no signs of habituation to the distress call, whereas they habituated after six nights to a recording of a gas gun. Various alarm, distress and predator calls were used to effectively repel Surf Scoters from juvenile blue mussel (*Mytilus edulis*) collector lines in Miramichi Bay, New Brunswick, Canada, during a 28-d study period (Hounsell and Reilly 1995).

Although the device we tested was not effective in deterring birds in our study, hazing devices should not be dismissed as a potential tool for use in less disturbed situations and warrant further testing. Such devices may prove to be a valuable component of a hazing program that incorporates a variety of other deterrent techniques. A combination of hazing techniques based on both visual and acoustic cues may provide the maximum deterrent effect and minimize the potential for habituation to occur (Bomford and O'Brien 1990; Koski *et al.* 1993). Koski *et al.* (1993) suggested that in marine settings, birds depend more on visual than acoustic cues for communication. Consequently, effectiveness of aquatic hazing devices may be improved by incorporating visual deterrents such as lights or reflectors into the design (Greer and O'Connor 1994).

Bird mortality may be substantial in oil spills depending on the extent, location and timing of the spill (Lehoux and Belanger 1995). The success of cleaning operations in terms of collection, release and survival rates of rehabilitated birds is extremely variable, depending on the location of the spill, the product spilled, environmental conditions, species affected and their biological state, and quality and immediacy of wildlife care among other variables (Jessup 1997). The cost of cleaning and care provided to oiled birds may be quite high. Jessup (1997) reported a cost of $600 to $750 per bird in California. In contrast, the Breco Bird Scarer costs approximately $10,000, excluding deployment, and it is re-useable. Thus, the cost for such a device could be recovered if it deterred at least 17 birds that would otherwise need to be rehabilitated, from an oil spill.

Consequently, the development, testing, and acquisition of even a marginally effective aquatic hazing device or technique may be cost-effective, especially in areas such as the San Francisco Bay estuary with dense waterbird concentrations and a high potential for oil spills. However, deployment of such a device should follow carefully replicated tests to determine the range of its usefulness.

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