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Management and Conservation Article

Effect of Approaching Boats on Nesting Black Skimmers: Using Response Distances to Establish Protective Buffer Zones

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ABSTRACT Understanding how birds respond to the activities of people is an important component of conserving wildlife. We measured responses of nesting black skimmers (*Rynchops niger*) to an approaching boat in Barnegat Bay, New Jersey, USA, by examining distance to first respond, distance to flush, and time to return to the colony. Our objective was to determine if response distances of skimmers changed as a function of year, reproductive stage, direction of approach (direct or tangential), or number of birds nesting in the colony. Generally, reproductive stage had the greatest effect on all responses, followed by direction of approach, number of adults present at the colony, number of nests, and year, which also explained variation in behavioral responses. The distance at which skimmers first flew when a boat approached decreased from the pre–egg-laying period to hatching, and then increased slightly later in the season. Time ($\bar{x} \pm$ SE) for skimmers to return to the nesting colony varied seasonally, with birds taking longer to return during the pre-egg period (9.5 $\pm$ 0.6 min) than during hatching (0.7 $\pm$ 0.1 min). The decision process for determining set-back distances to protect nesting skimmers should involve selecting 1) behavioral response of highest concern, 2) reproductive stage of highest concern, and 3) an appropriate level of response at which to establish the buffer area. We recommend that managers use a set-back distance of $\geq$118 m from the perimeter of the colony for black skimmers, which is the 95% percentile of the distance that skimmers first flew in response to approaching boats. Managers can use these data to set buffer distances for skimmers and other colonial birds.

KEY WORDS boats, buffers, coastal zone, flight initiation distance, flush distance, human disturbance, response distances, seabirds, set-back distance, skimmers.

Scientists, policy makers, and the public are interested in finding ways to allow populations of animals to coexist with people even in areas that are becoming increasingly urbanized. In turn, managers are interested in reducing the effects of people on wildlife, while still allowing recreationists and ecotourists to view and photograph wildlife. In many areas, recreation and ecotourism are being used to raise awareness and money to conserve wildlife and protect habitat (Butler 1991, Yorio and Boersma 1992, Gossling 1999). However, managers may assume that increased recreational use of an area will not unduly affect wildlife, including nesting or foraging birds, or conversely that any potential disturbance must be avoided (Burger et al. 1995, Larson 1995, Boersma et al. 2001). In areas managed under the concept of multiple use (by boaters, fishermen, and other recreationalists), the desires of recreationists must be balanced against the needs of wildlife and wildlife mangers, such that wildlife populations are not adversely affected by management actions.

People can affect birds in numerous ways. Direct disturbances can adversely affect breeding, feeding, migrating, and roosting birds (Burger 1991, 2002; Burger and Gochfeld 1994, 1999; Knight and Temple 1995). Birds nesting in dense colonies are particularly vulnerable to disturbances and have been well studied (e.g., Erwin 1989, Carney and Sydeman 1999, Villiers et al. 2005). Although many authors have concentrated on examining the effect of people walking past birds in nesting colonies (Jungius and Hirsch 1979; Burger and Gochfeld 1993, 1994, 1999), less attention has been devoted to assessing the effects of passing boats.

Many studies use approach distance as a measure of the effect that people have on birds in breeding colonies and foraging sites, because approaching humans may interrupt critical bird behaviors by eliciting attention, nervousness, movement, or departure. Approach distance is how close a person comes to the nesting colony. Response distance is the distance a bird will allow a human to approach without demonstrating any behavioral effects (Gutzwiller et al. 1998, Fernandez-Juricic et al. 2005, Gonzalez et al. 2006) in breeding colonies (Burger and Gochfeld 1993, 1999; Fowler 1999; McClung et al. 2004; Holmes et al. 2005) or foraging groups (Burger and Gochfeld 1991*a*, *b*; 1998; 2001). Flush distance (also called tolerance or flight initiation distance [Blumstein et al. 2003]) can be used to establish buffer or set-back distances (i.e., the distance between humans and breeding birds that will result in no appreciable impact on the birds) to reduce adverse effects on birds (Rodgers and Schwikert 2002). These distances can be used to set limits on how close people or vehicles should come to nesting, foraging, or roosting assemblages of birds (Blumstein et al. 2003, Fernandez-Juricic et al. 2005).

Flushing distance for birds varies by species (Holmes et al. 2005), flock size (Burger and Gochfeld 1991*a*), time of year,

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type of approach (tangential vs. direct [Burger and Gochfeld 1981, 1983, 1999; Martin et al. 2004]), time of day (Delaney et al. 1999), reproductive stage (Bauwens and Thoen 1981), previous encounters with people (Swarthout and Steidl 2001), density of human activity (Swarthout and Steidl 2003), and body condition (Beale and Monaghan 2004*b*). A major factor affecting responses is the type of human activity (Burger and Gochfeld 1991*a*, *b*; Burger 1991; Rodgers and Smith 2005), although this is not always the case (Thomas et al. 2003).

One of the main management tools for reducing the effects of people is to impose set-back distances or buffer zones where people or vehicles are excluded, which can be maintained by education, monitoring, fencing, buoys, or law enforcement (Ikuta and Blumstein 2003). Set-back distances are effective for breeding birds that are limited to a fixed location, although buffer zones do not work well with some seabird colonies because of variation in types and levels of human activity (Beale and Monaghan 2004*a*). Although others have used flushing responses to make management recommendations (see McGarigal 1991, Swarthout and Steidl 2001, Fernandez-Juricic et al. 2004), these authors did not examine ground-nesting colonial birds that are more vulnerable than those nesting in trees.

Recreation and tourism are increasing in coastal areas, making wildlife increasingly vulnerable to human disturbance (Miller 1993). Black skimmers (*Rynchops niger*) are endangered in New Jersey, USA, and declining populations have made them a species of conservation concern throughout their range (Kushlan et al. 2002), partly because of loss of habitat and human disturbance (Burger and Gochfeld 1990, 1994). It is imperative, therefore, to determine ways to protect breeding populations. This is particularly true where sandy beaches are not available and birds resort to small, low-lying islands that are vulnerable to flooding and attractive to recreationists. Determining responses of black skimmers to approaching boats in New Jersey is critical because skimmer populations have become concentrated among a few remaining colonies (Burger et al. 2001), the largest of which are on islands with sand beaches that appeal to boaters, making protection even more important. Black skimmers are particularly vulnerable because adults do not directly protect young by dive-bombing or being aggressive toward predators or people, as do many species of gulls and terns (Burger and Gochfeld 1990). Instead they swirl around in a tight mass, and eventually fly away, landing in a nearby marsh or on a sandbar, waiting for the disturbance to end.

Our objectives were to examine the effect of small boats on behavior of nesting black skimmers in Barnegat Bay and to examine response patterns as a function of stage in the reproductive cycle. We investigated the effect of small boats because they can more easily approach nesting islands, which are usually surrounded by shallow water. We were particularly interested in the timing of first responses (attentiveness and vocalizations) of black skimmers to an approaching boat, timing of initial flight and the flight of all birds in the colony, and time to return after the disturbance. Skimmers usually nest on islands that are high enough to avoid storm tides, but low enough so that the high tides of winter sweep over the island, preventing their colonization by mammalian predators (Gochfeld and Burger 1994).

STUDY AREA

Barnegat Bay is located in New Jersey (N°39.76 W°74.15). The bay was 65 km long, with >300 small, *Spartina*-dominated salt marsh islands located between the barrier beach and mainland, some of which flood during storm high tides (Flimlin and Kennish 1997). The islands were generally so low they do not have trees.

METHODS

This study was conducted in 2005, 2006, and 2007 in Barnegat Bay, New Jersey, with observations made between 1 May and 31 August. Under Rutgers University Protocol 92-036 the overall protocol was to approach colonies either directly or indirectly with a motor boat, and record the responses of the birds. We approached colonies rather than observing passing boats opportunistically to control approach distance, direction (i.e., direct or tangential), speed of approach (8 km/hr or 16 km/hr), and boat size (6-m-long Boston whaler). We made annual observations at 2–4 colonies that each ranged from 12 pairs to >400 pairs of birds. In all 3 years, Mordecai Island had the largest colony, which comprised 540 adults in 2005, 840 adults in 2006, and 405 adults in 2007. We separated repeated approaches to the same colony by 6 hours to several days, and we alternated the direction of approach between successive approaches. On a typical summer day, several other boats approached, passed by, or lingered near the colony; hence, to insure sample independence, we allowed ≥ 1 hour between our approaches. We selected speed of approach randomly, and after approaching a colony, we continued on and did not linger near the colony.

During each approach we recorded 12 variables: 1) date, 2) time, 3) colony name, 4) number of adults present (average of 3 counts during each visit), 5) number of nests, 6) number of chicks, 7) age of chicks, 8) reproductive stage (prelaying = no eggs in colony, egg-laying, incubation = most nests with eggs, hatching = chicks present), 9) behavioral measures (hereafter, response) as distance between the approaching boat and the skimmers when they first responded (i.e., extending their neck, looking alert, standing up, calling), when the first skimmers flew, and when all birds flew from the colony, 10) percentage of the colony that flew when the first skimmers flew, 11) time for the first skimmers to return to the colony following an approach, and 12) speed of approach (hereafter, approach), which we recorded with a Global Positioning System receiver, range-finder binoculars, and visual estimates to estimate distances. Our boats approached either directly toward the nesting colony, or tangentially to it (parallel to the colony). We then computed the percentage of times that skimmers flew at different approach distances.

We used a subset of approaches to determine if birds became habituated to the approaching boat in the short term

Table 1. Factors contributing to explaining behavioral responses of black skimmers to the approach of boats. Estimates (and *P*-values) from regression models assessing factors affecting variation in distance to first respond, distance to first fly, percent first fly, distance all fly, and time to return to the colony after disturbance in Barnegat Bay, New Jersey, USA, 2005, 2006, and 2007.

Factor	Distance to first respond (m)		Distance to first fly (m)		% first fly		Distance all fly (m)		Time to return	
	Estimate	*P*-value	Estimate	*P*-value	Estimate	*P*-value	Estimate	*P*-value	Estimate	*P*-value
Reproductive stage	70.00	<0.001	228.00	<0.001	22.10	<0.001	48.90	<0.001	81.40	<0.001
No. of ad	9.62	0.002	19.70	<0.001	18.30	<0.001	13.00	<0.001	38.70	<0.001
No. of nests	9.78	0.002	0.34	0.56	4.07	0.05	2.35	0.13	13.20	<0.001
Direction of travel	71.10	<0.001	31.70	<0.001	13.80	<0.001	6.29	0.01	3.10	0.08
Yr	5.36	0.006	2.62	0.08	34.30	<0.001	0.67	0.52	16.90	<0.001
Time of day	32.10	<0.001	0.43	0.51	3.40	0.07	0.00	0.99	19.10	<0.001
Approach	2.97	0.01	0.52	0.80	1.97	0.07	0.72	0.63	1.73	0.12
r^2	0.87		0.94		0.71		0.76		0.84	

(i.e., 1 day). We conducted 4 approaches at 10-minute intervals at the Mordecai colony in 2008 during pre–egg-laying period, and we alternated approach direction between successive days. We used the pre–egg-laying period because skimmers are most responsive then; thus, this period would provide the most useful data for determining buffer zones. For this analysis we compared their responses on the first approach, with the mean of the subsequent 3 approaches. Because the results from the last 3 approaches were similar, we only compared the first approach to the other approaches using an analysis of variance (ANOVA), with repeated measures. We excluded these data from other analyses.

We used regression analysis to determine if behavioral measures changed as a function of stage in the reproductive cycle (prelaying, egg-laying, incubation, hatching, chicks present), number of birds (or nests) in the colony, direction of approach, year, or time of day, and interactions of these variables (SAS 1995).

RESULTS

Depending on the stage in the nesting cycle, once birds returned to their nest site, they usually sat immediately to incubate eggs or to shield small chicks.

Reproductive stage explained most of the variation in behavioral responses of skimmers to approaching boats, followed by direction of approach, and number of adults (Table 1). Time of day and number of nests in the colony explained somewhat less variation in behavioral responses (Table 1). Overall, explanatory variables accounted for 71% to 94% of the variation in behavioral measures (Table 1). Although we initially included interactions, none had much explanatory power so we did not report these. Response measures were correlated; both the direction and extent of correlation varied among responses (Table 2). Although behavioral measures were correlated (see results below; Table 2), we report them all because correlations were not all high, direction of correlations varied, and managers may be interested most in only 1 or 2 of these measures. As response distance increased, the percentage of birds that first flew decreased (Table 2).

Distances at which birds responded varied by reproductive stage (Table 3). Birds responded when boats were at farther distances during the pre–egg-laying period for all behavioral measures, including time to return to the nesting colony site. For all measures, distance to flush decreased from pre–egg-laying until incubation or hatching, and either remained the same or increased slightly as chicks aged (Table 3). There was little variation in responses for a given reproductive stage.

Direction of approach also contributed to variation in response measures (Table 4). Direction of approach had less effect on time to return to the nest following a disturbance than it did to the other behavioral measures. In general, birds allowed boats moving tangentially to the colony to approach closer than boats approaching directly (Table 4). There were also yearly variations in responses, with birds allowing closer approach before they flew in 2006 (Table 5), when the largest number of skimmers nested in the largest colony. During the pre–egg-laying phase, 26% of the time some skimmers flew when boats were >100 m away (Table 6).

There was slight increase in responses ($\bar{x} \pm$ SE) with successive first and second approaches for distance to first fly (97 ± 3.10 m and 102 ± 1.74 m, respectively), distance to all fly (85.1 ± 2.6 m and 89.6 ± 2.4 m, respectively), and time to return (9.0 ± 1.1 min and 10.3 ± 1.5 min,

Table 2. Relationship among response variables for nesting black skimmers in Barnegat Bay, New Jersey, USA, in 2005, 2006, and 2007 (Kendall tau correlations, *P*-values for all correlations were <0.001).

Behavioral endpoint	Distance to first respond (m)	Distance to first fly (m)	% first fly	Distance all fly (m)	Time to return
Distance to first respond (m)	1.00	0.83	−0.39	0.74	0.76
Distance to first fly (m)		1.00	−0.49	0.87	0.79
% first fly			1.00	−0.37	−0.30
Distance all fly (m)				1.00	0.74
Time to return					1.00

Table 3. Responses of black skimmers in nesting colonies in Barnegat Bay, New Jersey, USA, to approaching boats during different reproductive stages in 2005, 2006, and 2007.

Reproductive stage	*n*	Distance to first respond (m)		Distance to first fly (m)		% first fly		Distance all fly (m)		Time to return (min)	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Pre–egg-laying	38	110	2.05	97.4	1.87	73.2	3.37	86.3	2.22	9.50	0.58
Egg-laying	22	95.8	1.85	84.7	1.50	77.7	3.05	82.3	6.00	3.91	0.32
Egg-laying, incubation	23	82.6	1.43	66.0	0.84	93.3	0.92	62.4	0.79	4.09	0.21
Incubation	16	74.6	2.56	43.4	2.75	97.3	0.88	40.7	1.83	1.44	0.13
Hatching	6	72.1	2.80	56.4	4.15	96.7	2.11	34.0	2.86	0.67	0.11
Small chicks	32	81.4	0.91	41.2	0.50	94.3	1.01	40.0	0.54	1.00	0.12
Large chicks	8	76.6	1.67	44.2	1.50	100.0	0.00	44.2	1.50	1.50	0.19

respectively), but these slight increases were not significant (ANOVA, repeated measures, $P < 0.20$). In Table 6 we present results for the distance to first respond, and for the distance to first fly, allowing managers to see the percent of approaches that resulted in skimmers flying when the boat approached at different distances.

DISCUSSION

The results of this study indicate that skimmers respond differently to a direct versus a tangential approach, and they begin to respond when boats are 72–110 m away. These data can be used to determine set-back distance or buffer zones.

Birds nesting along coasts are exposed to a variety of threats, including increased predator numbers, tidal flooding, storms, and human disturbances, which increase as people concentrate along coasts. Today, well over half of people in the world live within 100 km of the coast, making the wise use of coastal resources essential (Burger 2001). As human populations have increased, there have been increases in the use of boats and personal watercraft (PWC). For example, the number of boats sold in the United States in 1980 was 569,700, and in 2002 was 845,200 (National Marine Manufacturers Association 2008*a*); in the mid-1990s, there were >300,000 PWCs in the United States, and by 2000 the number had risen to 1,239,000 (National Marine Manufacturers Association 2008*b*).

Table 4. Black skimmer responses during different reproductive stages by direction of travel in Barnegat Bay, New Jersey, USA, in 2005, 2006, and 2007. Small chicks are <2 weeks old, large chicks are older.

Response and reproductive stage	Tangential			Direct		
	n	$\bar{x}$	SE	*n*	$\bar{x}$	SE
Distance to first respond to approaching boats (m)						
Pre–egg-laying	13	100.0	2.85	25	115	2.13
Egg-laying	9	91.2	2.61	13	98.9	2.21
Egg-laying, incubation	3	68.1	3.66	20	84.8	0.78
Incubation	6	67.8	2.66	10	78.6	3.21
Hatching	3	66.0	1.02	3	78.2	1.02
Small chicks	11	79.4	0.85	21	82.5	1.26
Large chicks	3	74.2	2.69	5	78.0	2.07
Distance to first fly when approached by boats (m)						
Pre–egg-laying	13	90.7	3.26	25	101.0	2.00
Egg-laying	9	79.6	2.09	13	88.2	1.46
Egg-laying, incubation	3	59.4	2.64	20	67.0	0.67
Incubation	6	37.9	2.68	10	46.7	3.81
Hatching	3	49.8	3.66	3	63.0	5.38
Small chicks	11	39.9	0.78	21	42.0	0.60
Large chicks	3	43.2	3.09	5	44.8	1.78

Previous studies of the effects of motorboats and PWC on nesting common terns (*Sterna hirundo*) in these same colonies indicated that terns respond adversely to the presence of boats and PWCs by increased number of birds flying from their nests, eventually abandoning nesting habitat to move farther from the disturbance (Burger 1998, 2001, 2002).

Factors Affecting Responses

Flushing distance varied mainly by reproductive stage. Early in the season, skimmers flushed when boats were farther away than when boats were the closest. We suggest that this reflects vulnerability of hatching eggs and young chicks to heat stress and predators because they are unable to move to vegetation for protection. We believe that habituation to boats during the breeding season plays a small role as evidenced by the leveling off in tolerance as the chicks matured (Burger and Gochfeld 1983, Erwin 1989, Burger 1998, Rodgers and Smith 2005).

There was less difference between mean distance to first respond during the pre–egg-laying and hatching phases than there was for the distance to fly, which means that during most of the season birds are equally disturbed by boats at 80–110 m away, but their departure (and return) to the colony depends partly upon the vulnerability of their eggs or chicks. This suggests that the distance to first respond is a better measure of the effect of disturbance than the other measures, which are modified by the need to prevent heat stress or predation pressure to vulnerable eggs or chicks (Rodgers and Smith 2005).

Direction of boat approach affected skimmers' responses. Gulls are also capable of assessing whether a person or boat is approaching directly, and which may be a more likely threat than those approaching tangentially (which may pass by; Burger and Gochfeld 1981). Thus birds may assess relative danger by determining whether a boat or person is coming directly toward them.

Yearly variations may partly be a result of colony size because birds flushed sooner at smaller colonies. However, during the pre–egg-laying phase it is often difficult to know how large the breeding colony will be, making it essential to protect all possible colony sizes (Burger and Gochfeld 1990).

Establishing Set-Back Distances

We suggest a series of steps to determine an appropriate set-back distance for black skimmers: 1) selecting the behavioral measures of most concern (first respond, first fly, all fly), 2)

Table 5. Black skimmer responses to approaching boats during different reproductive stages and years in Barnegat Bay, New Jersey, USA, in 2005, 2006, and 2007.

Response and reproductive stage	2005			2006			2007				
	n	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	χ^2	*P*
Distance to first respond (m)											
Pre–egg-laying	9	112	6.78	2	88.4	3.05	27	111	1.48	4.85	0.09
Egg-laying	6	92.2	4.27	2	80.8	1.52	14	99.5	1.30	6.74	0.03
Egg-laying, incubation	9	80.8	3.46	0			14	83.8	0.83	0.02	0.90
Incubation				16	74.6	2.56					
Hatching	6	72.1	2.80								
Small chicks	12	77.3	0.86				20	83.9	1.02	15.1	<0.001
Large chicks	8	76.6	1.67								
Distance to first fly (m)											
Pre–egg-laying	9	93.1	5.70	2	86.6	2.27	27	99.6	1.71	5.12	0.08
Egg-laying	6	84.3	2.91	2	73.2	6.10	14	86.4	1.49	4.28	0.12
Egg-laying, incubation	9	64.8	1.58	0			14	66.7	0.93	0.5	0.49
Incubation				16	43.4	2.75	0			19.5	<0.001
Hatching	6	56.4	4.15							10.4	0.006
Small chicks	12	40.6	1.02				20	41.6	0.53	0.28	0.50
Large chicks	8	44.2	1.50								

selecting among levels of disturbance that vary by reproductive stage (prelaying, egg-laying, incubation, hatching, chicks), 3) selecting the level of responses (mean, max., or in-between), and 4) deciding whether to establish an additional buffer (as is done for human health risk assessments by adding a safety factor).

To protect the skimmers, a set-back distance should be beyond the distance that will initiate responses that could be detrimental to reproductive success. Although one can argue that merely showing awareness of a boat (distance to first respond) might affect reproduction, a flushing response clearly has reproductive implications (Swarthout and Steidl 2001). If birds are unduly disturbed and forced to fly from their nests repeatedly, eggs or young chicks are exposed to egg destruction because of trampling, potentially fatal heat or cold stress, and predation (Burger and Gochfeld 1990).

The next question is whether to vary set-back distance as a function of stage in the reproductive cycle. We suggest that this is not practical because the actual timing of the reproductive cycle varies (e.g., in Aug skimmers can be laying eggs, incubating eggs, or caring for chicks), boaters and law enforcement personnel are unable to determine the reproductive stage unless they get close enough to disturb the birds, and reproductive stage can vary among colonies in the same geographical region. For skimmers, this is the distance birds fly during the prelaying period (Table 1). Fernandez-Juricic et al. (2007) also suggested that the set-back distance should also be established at the beginning of the breeding season when colonial birds are most sensitive.

The third decision is selecting what level of disturbance to use (i.e., mean or max. distance birds first fly). To be sure birds do not fly at any time from the future colony site during the pre–egg-laying period the set-back distance should be 120 m from the colony edge (Table 6). We suggest that a reasonable procedure is to use the 95th percentile of the distance to first fly as the set-back distance (Swarthout and Steidl 2001). The 95th percentile of the distance to first fly was 118 m in the prelaying period and

Table 6. Percent of approaches that black skimmers initiated flying as a function of distance of the boat and stage in the reproductive cycle in Barnegat Bay, New Jersey, USA, in 2005, 2006, and 2007.

Response and reproductive stage	Distance (m)							
	<60	60–70	70–80	80–90	90–100	100–110	110–120	>120
Distance to first respond (%)								
Pre–egg-laying				5	12	47	18	18
Egg-laying			9	14	45	32		
Egg-laying, incubation		4	13	78	5			
Incubation		38	31	25	6			
Hatching		50	50					
Small chicks			47	44	9			
Large chicks			88	12				
Distance to first fly (%)								
Pre–egg-laying		3	3	18	39	26	8	3
Egg-laying		5	23	54	18			
Egg-laying, incubation	9	70	21					
Incubation	88	6	6					
Hatching	17	17	66					
Small chicks	100							
Large chicks	100							

99 m for the whole season. The maximum value for the distance to first respond was 136 m (same for both prelaying and entire season), which from an implementation perspective, differs little from 118 m.

MANAGEMENT IMPLICATIONS

Behavioral responses of birds, especially colonial-nesting species, can be used to understand the effect of human activities on birds and to establish set-back distances to protect these populations. Further, different types of behavioral responses can be used as the endpoint for determination of a set-back distance, suggesting that initial studies are necessary to assess the appropriate behavioral endpoint. We suggest that for nesting birds the measure that is most useful for establishing set-back distance is the distance the first birds fly because flying exposes the eggs or young to heat stress and predation, and because once the first birds fly, the remaining skimmers follow rapidly. It will be easier for conservation officers to enforce a single set-back distance that remains the same throughout the season, and for warning buoys to be set at one distance throughout the nesting season. Thus, we suggest that the set-back distance should be the same throughout the breeding season, and should reflect the period when birds are most sensitive to being approached.

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