

Shorebirds and stakeholders: Effects of beach closure and human activities on shorebirds at a New Jersey coastal beach

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Abstract Coastal habitats are critical for conservation of migrant shorebirds. We examined the effect of beach closure on recreationists and on shorebirds, at an important southbound stopover area for shorebirds at Brigantine, New Jersey. The study had three prongs: 1) involve stakeholders during all phases, 2) assess public use of the beach and responses to closure, and 3) assess shorebird use of the beach and response to closure. Stakeholders were involved in the design, implementation and evaluation of the project. The beach was used for fishing, walking, dog-walking, and other recreational activities. Sixty percent of recreationists were positive about the study and beach closure to protect shorebirds. The data indicate that: 1) involving a wide range of stakeholders early and often was important to our ability to conduct, design, and implement the study, 2) the beach was used by different types of recreationists 3) beach users were supportive of the closure, 4) spatial use by shorebirds depended upon whether the beach was open or closed, especially for red knot, and 5) all species of shorebirds used a small beach area behind a protective fence whether the beach was open or closed. Red knot behavior was most affected by beach closure; they spread out over the entire beach when it was closed, and concentrated at the tip when it was open. Conservation measures should take into account stakeholders views, human uses, beach physiognomy, and potential closure of refuge areas during critical migration times for shorebirds.

Keywords Closure · Conservation · Shorebirds · Human disturbance · Stakeholder involvement · Community participation

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Coastal staging and stopover sites are critical to shorebirds for both foraging and roosting in the Western Hemisphere, and preserving such habitats is an important conservation concern, particularly in the urban corridor from New York to Washington DC. Many species of shorebirds undergo long migrations from wintering grounds in South America to Arctic breeding grounds (Harrington 2001; Conklin et al. 2010). The consequences of migration partly depend on strategies of arrival, residency, departure at stopover and wintering areas, and the degree that shorebirds are free from human disturbance on those areas (Piersma and Baker 2000; Burger et al. 2004; Stillman et al. 2007). Disruptions and loss of either stopover or wintering areas can have severe consequences on breeding, breeding success, and population levels (Dolman and Sutherland 1995; Morrison and Hobson 2004). Several species of shorebirds have declined significantly over the past several decades, which has been attributed to habitat loss at migratory stopovers, declining food resources during migration, or problems on the wintering grounds (Warnock et al. 2002; Morrison et al. 2004, 2007; Niles et al. 2008; Burger et al. 2011).

At each stopover area, body condition and weight at departure affect survival during migration, breeding for northbound migrants, and wintering (Harrington 2001; Conklin et al. 2010). Little is known of the factors that adversely impact breeding behavior or success in some species, although resource availability at migratory stopover sites influences condition at arrival on the breeding grounds (Baker et al. 2004; Morrison et al. 2007), and global change will clearly affect habitat availability (Galbraith et al. 2002).

There are many papers that examine the effect of the presence of people and vehicles on birds, particularly during the breeding season (Carney and Sydeman 1999; Pearce-Higgins et al. 2007; Weston and Elgar 2007; Sabine et al. 2008), largely because direct effects on reproductive success can be monitored. The effects of human activities on migrating and foraging shorebirds have also been examined (Burger et al. 2004; Thomas et al. 2003). In general, disturbance has been implicated in the long-term declines of shorebirds because of frequent movement away from people, decreased foraging time, and reduction of suitable foraging or roosting habitat (Pfister et al. 1992; Thomas et al. 2003; Stillman et al. 2007). There have been few studies that have censused shorebirds, examined effects of human presence and activity, and experimentally reduced human activity, although Tarr et al. (2010) assessed the effect of vehicle disturbance on migratory shorebirds with beach closures. Further, no study has examined community or stakeholder involvement in experimentation and developing conservation and management measures (Burger 2011).

In this paper we describe the results of an experiment at Brigantine Natural Area in New Jersey to examine the effects of beach closure on southbound migrating shorebirds, and on the public using the beach for recreation. This is part of a larger study to understand factors affecting roosting and foraging of shorebirds during migration and while overwintering, and to use this information for managing habitats to maximize human and shorebird use. In this report we address the following questions: 1) Who are the primary managers and beach users, 2) What are the viewpoints of different stakeholders in this urban environment, 3) Why and how do recreationists use the beach, 4) What is the response of beach-goers to closure, 5) What is the general use of the beach by shorebirds, and 6) Do shorebirds use the beach differently when the beach is open or closed?. We examined the hypothesis that when managers and recreationists are involved in research and management decisions, they are more likely to approve of the measures, which will then allow for protection of the needs of both recreationists and shorebirds (Burger 2011).

While resource agencies generally manage species, communities and ecosystems, there is increasing awareness that involvement of user groups and others interested in the resource will result in better decisions (PCCRAM 1997; Chase et al. 2004; Burger 2011). In many

urban and suburban environments, there is a conflict between development and the preservation of species within natural environments. Resolution of conflicts between these two goals is essential to continue protection of natural resources. Managers often rely on adaptive management, with an emphasis on decision-making based on experience, and shifting strategies when necessary (Lyons et al. 2008; O'Donnell and Galat 2008). This management style, however, needs to be balanced with community involvement, and interactions between scientists, managers, and the public.

The value of community participation in wildlife management, exposure assessment, and human health assessment is receiving considerable attention (Allen et al. 2010; Ramsden et al. 2010; Dulin et al. 2010; Munoz and Fox 2011; NIEHS 2011). Dialogue between managers, public policy makers, and the public can lead to consensus about contentious issues such as restrictions on human activities in vulnerable or critical wildlife habitats. One of the important aspects of this study was that involving a wide range of stakeholders early in the process can lead to better and more cost-effective science and management (Burger 2011). For the purposes of this report, we define stakeholders as an agency, group, or individual that has legal or regulatory resource responsibility, landowners, conservationists, scientists, land and resource users, and anyone else having an interest in decisions. Frequent and open communication between people was a key aspect of the study. Communication should involve all levels, including local, county, state and federal agencies within the urban landscape. Communication, dialogue, and wise-management are critical within an urban landscape where natural environments are already limited.

Methods

Our overall protocol was to conduct the study when the northern tip of Brigantine Natural Area beach (Brigantine, NJ) was closed from 16 to 21 October, and was open from 22 to 27. During both periods we interviewed beach-goers, censused shorebirds, and recorded presence of other people, predators, and physical features. While the original design was developed by the investigators, the experiment was conducted only after open stakeholder meetings, with appropriate modification of protocols, sequencing, and timing of the experiment. All interviewers and observers were trained and able to identify all shorebirds, and protocols were approved by Rutgers University Review boards.

Study region

The study was conducted on the northern tip of Brigantine Natural Area, a segment of beach and salt marsh that is used extensively by recreationists for walking, jogging, sun-bathing and fishing, and by shorebirds for roosting at high tide, and foraging during spring and fall migration (Fig. 1). The Natural Area extends out from the city of Brigantine, and is thus a popular and well-used area. The width of the beach varies with tidal state and storms, and during excessively high tides very little sandy beach is exposed. Beach closures are familiar here because a small section of the beach is closed during the nesting season of the endangered piping plover (*Charadrius melodus*), and the fences remained at the tip (keeping people and trucks from segments 17–19). Thus, while the whole beach was either open or closed to human activity, even when the beach was open, trucks could not enter segments 17–19 because the fence remained from protective management for the piping plover.

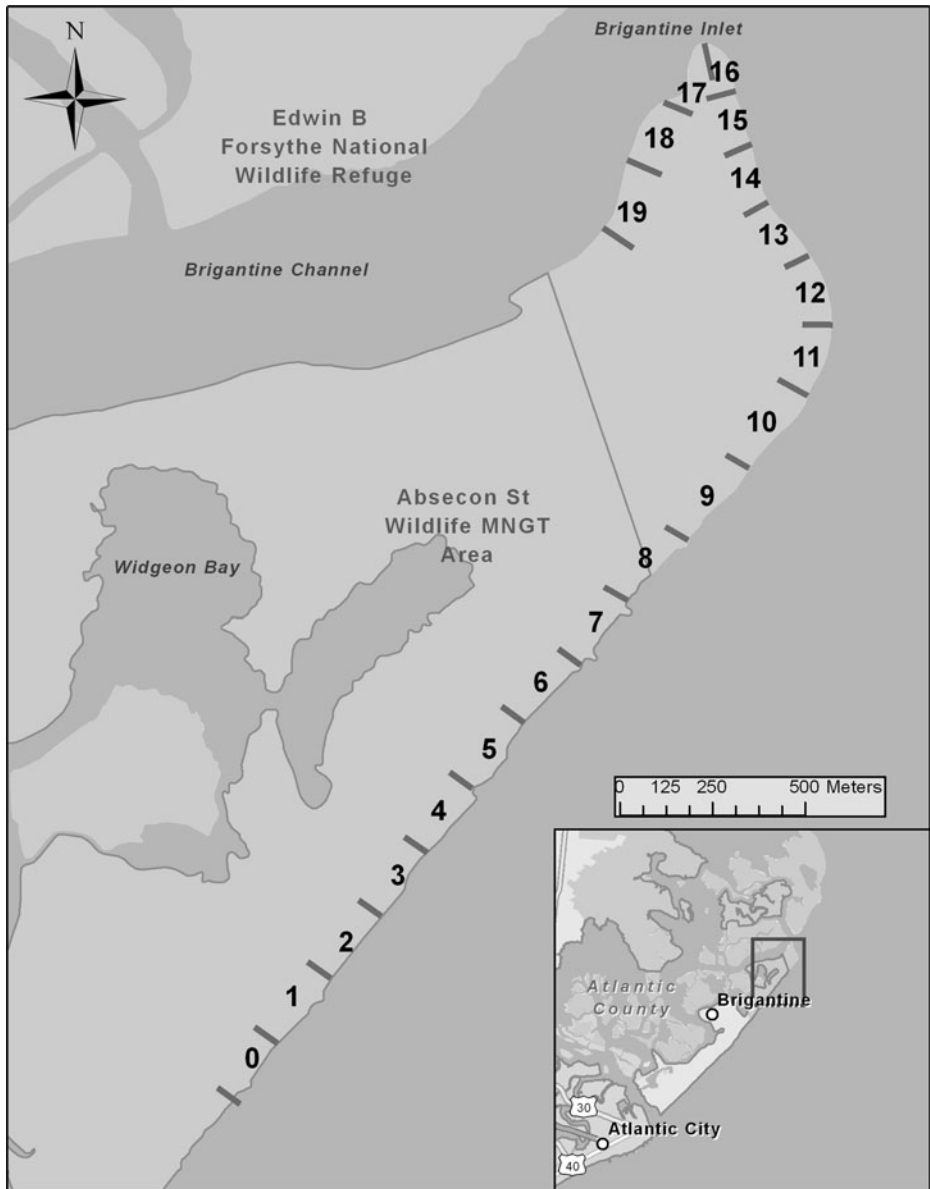


Fig. 1 Map of Brigantine Natural Area, showing the segments

Human use and perceptions

Under appropriate University protocols, we interviewed everyone who approached within 200 m of the closure location, asking questions relating to their use of the beach, their response to closure, and any other comments they wished to make. Data collected included time, type of activity, number of people in group, highest education, ethnicity, age, target

fish, other activity, months they come to this beach, times/month, response to closure, and why they liked the place (an open-ended question).

Shorebird use and responses

The beach was divided into 100 m segments that ran parallel to the beach (Fig. 1). Regular censuses were conducted between 7AM and 6PM, although shorebirds were not always present (depending upon tidal state and available exposed beach). The census-taker walked from one end of the beach to the other, recording data. During each census the observer recorded the segment, date, time, total number of shorebirds in the flock, number of people, raptors, trucks and dogs, and number of each species present. This yielded use of particular segments of the beach, species composition, and number of shorebirds present.

We used ANOVA (Kruskal Wallis tests) to determine significant differences among variables, and Contingency Chi Square tests for small samples sizes. Levels of <0.05 were considered significant (SAS 2005).

Results

Stakeholder or community involvement

One of the key factors in adaptive management is involvement of appropriate stakeholders in the conception, design, and implementation of the management. Table 1 indicates the involvement of a range of stakeholders in the project. The different resource agencies had the goal of protecting migrating shorebirds, but they differed in their responsibility for closure or police patrols. Further, the city was very interested in preserving recreational and fishing rights, as well as protecting the birds. Meeting with stakeholders clarified the importance of both recreation (especially fishing) and protection of shorebirds for all the stakeholders.

Human use and perceptions

Most people using the beach were Caucasians, with an average age of about 50 years, and with a high school education (Table 2). People came to the beach about eight times a month, alone or with another person, and about 60 % came to fish. Because of the timing of our experiment, 96 % of the anglers were there to catch striped bass (*Morone saxatilis*), although at other times of the year, target species vary.

Overall, 60 % of the 403 people interviewed said they approved of the beach closure for shorebird protection, and this percent was the same whether the people were interviewed when the beach was closed or open (Table 2). However, there were significant difference in the response to closure depending upon how people were using the beach; fewer anglers were in favor of closure compared to others. Even so, more than half of anglers were positive toward closure (Table 2). On an open-ended question asking for general comments on the beach, our study, or closure, many expressed concerns for the birds and approval of the beach closure (about 60 %), confirming the earlier question about closure (Table 3). Views differed slightly when the beach was closed versus open, but mainly with respect to people not knowing it had ever been closed (Table 3).

General comments about the study and closure are shown in Table 3 for anglers and all others combined. As expected, attitudes and perceptions differed significantly, with anglers being more concerned about fishing issues, and a little less

Table 1 Involvement of primary stakeholders was critical to performing the experiment, and to its success. Below the major stakeholders are listed, with primary responsibilities and viewpoints. All were involved in stakeholder meetings to refine study design

Agency, Organization or Interest	Responsibilities, Viewpoints, and Effects of their Input
U.S. Fish & Wildlife Service	<ul style="list-style-type: none"> -Responsible for endangered and nongame wildlife, including shorebirds. -Interested in conservation and habitat protection generally. -Currently considering adding Red Knot to the Endangered Species List (it is currently a candidate species).
NJ Department of Environmental Protection, Endangered and Nongame Species Program	<ul style="list-style-type: none"> -Responsible for endangered and nongame wildlife species, including shorebirds. -Responsible and interested in conservation and management of species and habitats -Approval of length of closure and timing, as well as appropriate NJDEP personnel and stakeholder involvement -Participated in data collecting and analysis
NJ Department of Environmental Protection, Division of Parks and Forestry	<ul style="list-style-type: none"> -Responsible for parks within New Jersey, including recreational uses, management, and protection of associated wildlife and ecosystems. -Interested in ecosystem conservation and management. -Issued permit to conduct the experiment, with appropriate park superintendent coordination -Involved coordination with park police -Participated in data analysis
Brigantine City	<ul style="list-style-type: none"> -Interested in providing opportunities for their citizens and in protecting the beach, shorebirds, and other birds. -Brigantine Police Patrol interested in keeping the peace and protecting human life
NOAA, Sea Grant	<ul style="list-style-type: none"> -Responsible for marine resources -Interested in educational development and coastal resource use and conservation.
Conserve Wildlife of New Jersey	<ul style="list-style-type: none"> -Non-governmental foundation with significant interest in shorebird management and conservation -Interested in fostering both shorebird conservation and recreational use of resources. -Participated in data collection and analysis.
Rutgers University	<ul style="list-style-type: none"> -State University of New Jersey with usual breadth of academic education, research and outreach. -Interested in basic biology, conservation, management, and stakeholder involvement in management decisions. -Participated in data collection and analysis.
Atlantic Audubon Society	<ul style="list-style-type: none"> -Interested in preserving birds and other species within natural ecosystem. -Interested in shorebird conservation and preserving human uses of beaches -Participated in data collection and analysis.
Bird-watchers	<ul style="list-style-type: none"> -Interested in opportunities to watch birds, watch the spectacle of large groups of migrants. -Interested in shorebird conservation. -Participated in data collection.
Jersey Cost Anglers Association (Fishermen)	<ul style="list-style-type: none"> -Interested in fishing and fishing opportunities -Interested in fish conservation
New Jersey Beach Buggy Association	<ul style="list-style-type: none"> -Preserving the right to drive on beaches, and to reach fishing places. -Interested in preserving natural habitat and species on the beaches.

Table 2 Age, education, number of people in a group, and number of times people use the beach each month by activity type. Given are means \pm standard error (range is given below) and Kruskal-Wallis X² (p). N=403

	Activity Type							X ²
	All Activities (n=403)	Bird Watch (n=11)	Dog Walking (n=29)	Drive on beach (n=28)	Fishing (n=239)	Walking (n=73)	Other (n=23)	
Frequency								
% Caucasian ^a	98.5 %	2.7 %	7.2 %	7.0 %	59.3 %	18.1% ^a	5.7 %	
% Positive response to beach closure	60.4 %	100.0 %	100.0 %	100.0 %	97.9 %	98.6 %	100.0 %	
Age (years)								
	49.6 \pm 0.7	81.8 %	82.1 %	60.7 %	55.1 %	68.5 %	50.0 %	26.5 (0.003)
	14–84	50.0 \pm 6.2	51.8 \pm 1.9	46.1 \pm 3.0	49.4 \pm 0.9	50.2 \pm 1.8	50.4 \pm 3.4	2.1 (NS)
Education (years) ^b								
	14.4 \pm 0.1	14–80	23–67	19–65	17–84	19–82	21–84	
	12–20	16.2 \pm 0.5	15.0 \pm 0.4	14.2 \pm 0.4	14.0 \pm 0.1	15.0 \pm 0.3	14.9 \pm 0.5	22.3 (0.0005)
Number of people in group								
	1.6 \pm 0.04	12–18	12–18	12–18	12–18	12–20	12–20	
	1–5	1.9 \pm 0.3	1.4 \pm 0.1	2.0 \pm 0.2	1.5 \pm 0.1	1.7 \pm 0.1	1.5 \pm 0.2	9.4 (0.09)
Times per month								
	8.2 \pm 0.5	1–4	1–2	1–5	1–4	1–4	1–4	
	0.5–30	2.9 \pm 0.7	11.0 \pm 2.3	10.9 \pm 2.2	8.3 \pm 0.6	6.8 \pm 0.9	7.3 \pm 2.3	10.5 (0.06)
		1–8	0.5–30	1–30	1–30	1–30	1–30	

^a other ethnicities include Hispanic (n=6) and African American (n=3)^b 12 years of education = high school diploma^c Includes people who were surfing, swimming, shell collecting and bike riding

supportive of the closure, although they were generally concerned about the birds. The most important reasons for coming to Brigantine beach included easy access, good fishing, beautiful, and solitude (Table 4). The reasons for coming to Brigantine beach differed significantly between anglers and others, with anglers appreciating easy access and good fishing, and others appreciating easy access, beauty, and the quiet of the beach.

Shorebird use

Field observations indicated that the number of birds varied by segment (Table 5). The total number of segments used by each shorebird did not differ between open and closed for black-bellied plover and sanderling (all segments used both periods), and did not vary markedly for the other species (except that in all cases, more segments were used when the beach was closed, Table 5).

However, the number of shorebirds per segment did differ, especially for red knot. For red knot, when the beach was closed there was no difference in mean flock size as a function of

Table 3 Comments of beach-goings given to an open-ended question—“Do you have any comments or concerns about the closure?” Question asked of all people visiting Brigantine Beach with (16 October 2011 through 21 October 2011) and without (22 October 2011 through 27 October 2011) the closure. People were interviewed well before they reached the closure point

Response	Beach Status		Type of Recreationist	
	Beach Closed	Beach Open	Anglers	Other
Good or great idea to close	32 %	26 %	24 %	35 %
More research is needed	3 %	3 %	1 %	11 %
Concern for birds				
Birds need protection	9 %	15 %	2 %	11 %
Foxes are the problem	5 %	3 %	3 %	5 %
Dogs are the problem	5 %	2 %	4 %	2 %
Vehicles are the problem	5 %	4 %	1 %	9 %
Need stronger restrictions to preserve area	6 %	6 %	1 %	0 %
Fishing concerns				
Fish have declined	1 %	0 %	1 %	0 %
Closed area has best fishing	6 %	3 %	4 %	0 %
Fishing doesn't affect birds	0 %	1 %	1 %	0 %
Need advance notice	0 %	2 %	3 %	0 %
Other concerns				
Fear closure time will increase	5 %	7 %	8 %	2 %
Closure not long enough		2 %		5 %
People are not the problem	2 %	2 %	7 %	0 %
People and birds should share beach	3 %	4 %	10 %	4 %
Didn't know it was close, am indifferent	0 %	5 %	3 %	2 %
Do not like closure	14 %	14 %	21 %	2 %
Birds are not important	0 %	2 %	1 %	10 %
Did not want to participate in survey	6 %	1 %	4 %	1 %
X ²	31.8 (0.03)		83.6 (<0.0001)	

Table 4 Responses to why interviewees use the beach. This questions was open ended. Chi-square = 84.2 (<0.0001)

	Overall	Anglers	Walkers	Other
Easy Access	37.5 %	40.7 %	25.0 %	39.0 %
Good Fishing	17.6 %	26.4 %	1.5 %	6.1 %
Beautiful	15.0 %	12.1 %	22.1 %	17.1 %
Quiet	13.9 %	10.8 %	26.5 %	12.2 %
Beach	7.6 %	4.8 %	14.7 %	9.8 %
Clean	2.6 %	1.7 %	2.9 %	4.9 %
Nature	1.8 %		2.9 %	6.1 %
Vehicles are permitted	1.6 %	2.6 %		
Exercise	0.8 %		2.9 %	1.2 %
Family	0.5 %	0.4 %		1.2 %
Walk Dog	0.5 %		1.5 %	1.2 %
Safe	0.3 %	0.4 %		
Surf	0.3 %			1.2 %

segment along the beach (Table 5). However, when the beach was open, knots concentrated on the beach segments that were the greatest distance from where people could enter the beach. Thus, red knot use much of the beach when there were no people, but were forced to the tip when people were around.

As with most beaches, there were differences in the beach physiognomy (Fig. 1). Most of the segments were linear and narrow, but the last segments were at the tip of Brigantine Natural Area, and thus the beach wrapped around the point, into an area closed off by fencing. The differences in segment use as a function of whether the beach was open or closed were clearer in this analysis (Table 6). For all species there was a significant difference in the mean flock size depending upon whether the beach was open or closed (Table 6, Fig. 2). Except for semipalmated plover, significantly more shorebirds moved to the last segments when the beach was open, and were more spread out when the beach was closed (Fig. 2). Fewer semipalmated plover used the last segments when the beach was open than when it was closed. Overall, however, all species used the last segments more often regardless of whether the beach was open or closed to human activity.

Discussion

Stakeholder involvement

It is becoming increasingly clear that the involvement of a full range of stakeholders improves governmental and local support, as well as leading to more cost-effective and sound decisions (Chase et al. 2004; Burger 2011). This is especially true in situations, such as described in this paper, where people are denied the use of an area previously open, and where different managers usually make the decisions about human use. In this study, both permission and acceptance of government officials at the federal, state and local level were essential to obtaining permission to conduct the

Table 5 Characteristics for shorebirds at Brigantine Beach, NJ, during study (October 16–27, 2010). Data based on a total of 1,014 observations (segments), with 20 segments. There were 515 open and 499 closed observations NS = Not significant

	Red Knot	Blackbellied Plover	Dunlin	Sanderling	Semipalmated Plover
Overall					
Total Number of Observations	96	308	167	443	166
(%)	10 %	30 %	17 %	44 %	16 %
Number of Segments Used	17	20	18	20	20
(%)	85 %	100 %	90 %	100 %	100 %
Mean Flock Size (\pm SE) (only where present)	78.3 \pm 13.3	60.0 \pm 13.4	370 \pm 60	33.8 \pm 3.3	41.7 \pm 10.0
Flock Size Maximum	720	3500	4845	1000	950
Experiment (open/closed) ^a					
Total Number of Observations	47 / 46	153 / 155	86 / 82	239 / 204	82 / 70
(%)	9 % / 9 %	30 % / 31 %	17 % / 17 %	46 % / 41 %	16 % / 14 %
Number of Segments Used	14 / 17	20 / 20	16 / 17	20 / 20	15 / 18
(%)	70 % / 85 %	100 % / 100 %	80 % / 85 %	100 % / 100 %	75 % / 90 %
Mean Flock Size (\pm SE)	96.3 \pm 23.6 /	71.3 \pm 24.5 /	441.6 \pm 97.4 /	28.4 \pm 4.9 /	25.2 \pm 5.2 /
(only where present)	59.4 \pm 11.2	48.8 \pm 11.0	296.0 \pm 67.7	40.2 \pm 4.2	63.3 \pm 20.6
Flock Size Range	719 / 309	3499 / 959	4844 / 3549	999 / 459	299 / 949
X ² Comparing mean Flock Size Among Segments When Open	24.6 (0.03)	72.9 (<0.0001)	53.1 (<0.0001)	47.3 (0.0005)	42.7 (0.0002)
X ² Comparing mean Flock Size Among Segments When Closed	14.4 (NS)	54.7 (<0.0001)	43.7 (<0.0004)	49.3 (0.0003)	37.2 (0.0005)

^a Data from when the beach was open/when the beach was closed to the public

Table 6 Use of North Brigantine beach by bird species while the beach is closed to the public use (October 16–21, 2010) versus open to the public use (October 22–27, 2010). Given are the frequency of use per segment and mean flock size \pm standard error, and Kendall' Tau correlations (p-values). There were 476 observations when the beach was closed and 489 when it was open

	Segments 0–3	Segments 4–7	Segments 8–11	Segments 12–15	Segments 16–19	X ²	Overall X ²
# of observations for all shorebirds							
Closed	92	92	100	98	94		
Open	91	88	94	110	106		
Red Knot							
Closed	43.5 \pm 20.0	15.0 \pm 0.0	48.0 \pm 20.5	56.7 \pm 14.3	81.5 \pm 23.5	4.6 (NS)	1336.8 (<.0001)
Open	10.1 \pm 4.2	30.5 \pm 29.5	10.7 \pm 5.2	32.7 \pm 9.1	199.3 \pm 46.4	21.9 (0.0002)	
Blackbellied Plover							
Closed	10.3 \pm 1.9	3.9 \pm 0.8	6.6 \pm 1.5	72.6 \pm 30.0	134.3 \pm 36.5	34.3 (<.0001)	981.6 (<.0001)
Open	7.7 \pm 1.5	3.4 \pm 1.0	4.5 \pm 0.8	47.4 \pm 18.3	284.9 \pm 115.8	56.3 (<.0001)	
Dunlin							
Closed	29.3 \pm 5.2	3.0 \pm 2.0	16.0 \pm 5.3	289.9 \pm 129.6	615.2 \pm 154.3	31.4 (<.0001)	1586.4 (<.0001)
Open	52.5 \pm 20.6	2.6 \pm 0.9	11.3 \pm 4.9	258.3 \pm 109.2	1031.1 \pm 222.2	(46.9<.0001)	
Sanderling							
Closed	68.9 \pm 11.3	25.9 \pm 4.0	29.3 \pm 4.6	29.0 \pm 8.3	32.9 \pm 10.2	24.4 (<.0001)	1434.8 (<.0001)
Open	27.7 \pm 3.9	17.5 \pm 2.0	14.8 \pm 1.8	28.0 \pm 9.0	132.5 \pm 73.4	10.2 (0.04)	
Semipalmated Plover							
Closed	21.1 \pm 3.8	5.9 \pm 1.7	29.4 \pm 12.5	27.3 \pm 14.7	588.0 \pm 157.2	16.6 (0.002)	1742.9 (<.0001)
Open	12.0 \pm 2.1	5.1 \pm 1.2	44.3 \pm 11.8	42.0 \pm 17.3	300.0 \pm 0.0	23.4 (0.0001)	

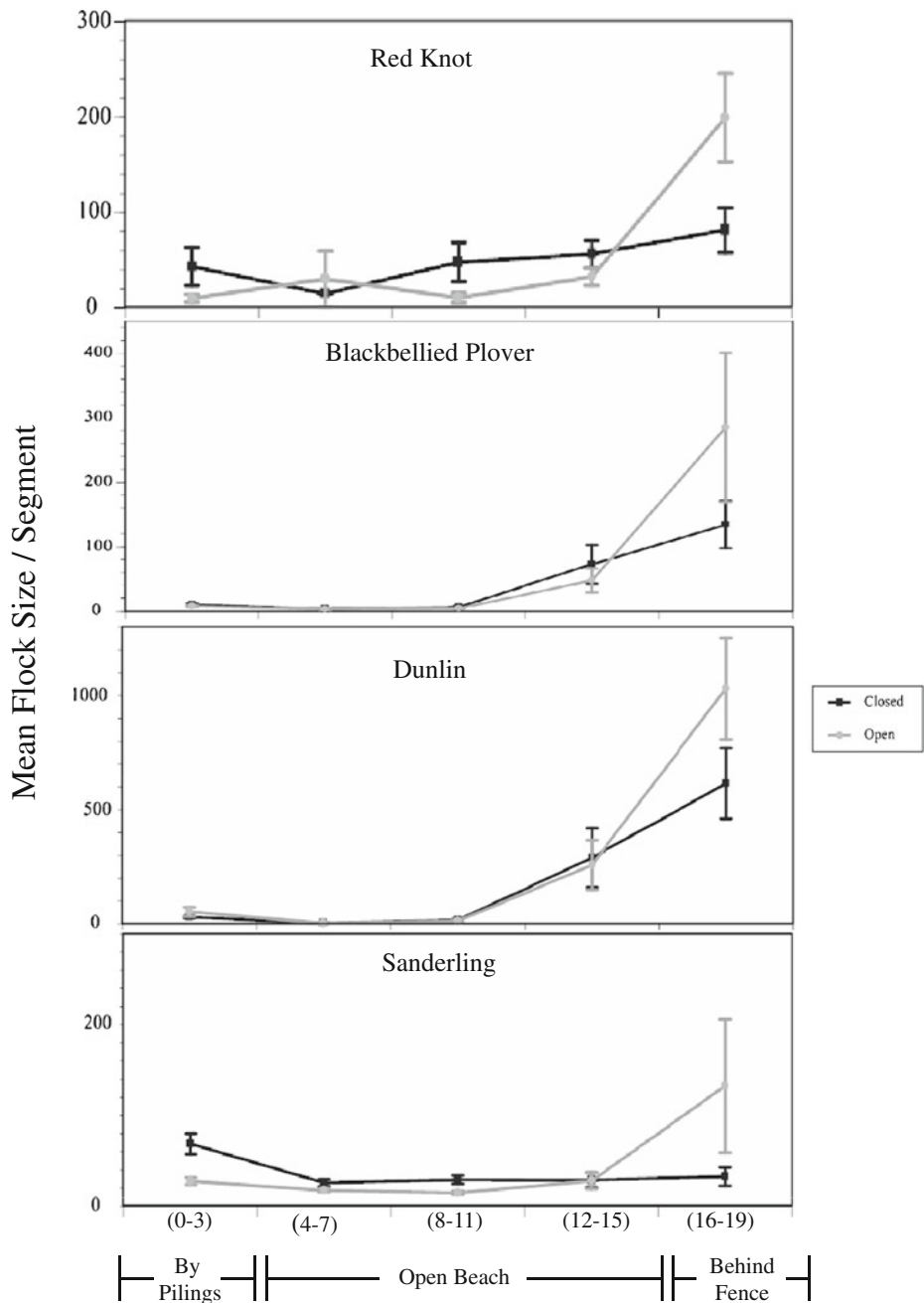


Fig. 2 Mean flock size (+ SE) for four species of shorebirds when the beach was closed or open to recreationists

study, to enlisting the aid of local monitors and park police to enforce the closure, and to involve personnel in the study, as well as to ensure success. More importantly, however, involvement of the user groups was key to support for the study, as well as

compliance and interest in the study. Stakeholder involvement also improved the study in that it helped refine the closure period (to accommodate park police, conservation officers, and recreationists), questions to be asked of recreationists (to be maximally useful to park managers), interviewer approach (best location for interviews), and shorebird data (additional data to help managers and provide justification to recreationists) for future management actions.

While stakeholder involvement requires additional time and energy, at Brigantine it resulted in a more balanced and approved study that clearly showed both the importance of closure during critical migration periods, and of having small refuge areas where shorebirds can always retreat, depending upon the level of human use. Management in areas of high human density, such as much of the coastal Northeast of the United States, requires compromises between human uses (recreational and commercial) and wildlife uses, particularly for threatened or endangered species, and for species of species concern, such as migrant shorebirds whose populations are declining.

Human use and perceptions

While involvement of governmental personnel, as well as others, was critical to development and execution of the study at all levels, it was equally important to assess how recreationists used the beach at this time, as well as their responses to closure. For closure to be implemented generally during shorebird migration as a conservation measure, it is essential to know how the recreationists use the beach during the relevant migration period, and how they react to closure, both to allow managers to maximize human use and shorebird use, and to ensure public buy-in.

The closure of Brigantine beach for this experiment was for a limited period, involved only half the beach, and occurred in October, well past the sun-bathing and swimming season when there is maximum use of New Jersey beaches. However, this is the relevant time period when migrant shorebirds are using these beaches to refuel, often for long-distance migrations of hundreds of miles (Niles et al. 2008, 2010). The data thus provide site-specific relevant data on both human use and shorebird use that will be used by land managers.

Over half of the recreationists were anglers, and another 7 % simply liked to drive their trucks on the beach, suggesting that off-road vehicle (ORV) users are a critical component in terms of use, perceptions of users, and support for a closure. Although anglers and ORV drivers had the lowest approval for closure, still over 55 % were positive about closure. Their main concerns were that the closure time would increase, which relates directly to their ability to continue to drive and use the beach. However, they did express considerable concern for the shorebirds. This suggests that management options that maximize shorebird use while minimizing restrictions to anglers should be a high management priority (see below).

Shorebird use and human activities

Studies of the effect of human activity on foraging and roosting migrant shorebirds usually involve observing the effects of people, dogs, or trucks on shorebirds, either haphazardly when such disturbances occur, or by directly approaching shorebird flocks (Yasue 2006). Much less often, scientists observed shorebird behavior under open versus closed conditions (Tarr et al. 2010). Overall, in their study, shorebird use and relative use of microhabitat zones

was reduced with increased use by vehicles, providing a direct link between level of disturbance and habitat use (Tarr et al. 2010). They used controlled levels of vehicle disturbances to show measurable reductions in use during a migratory stopover

The results of the present study indicated that the abundance and distribution of shorebirds on Brigantine Beach was affected by whether the beach was open or closed, and by segment. Shorebirds preferred to use the northern tip, where there was a fence that prevented access by trucks during all periods, but that they spread out more into other parts of the beach when it was closed. The spatial variability in both beach structure and human use suggests that having even a small refuge (behind the fence) where shorebirds could always roost or feed was critical to keeping them at Brigantine (rather than flying to another, more distant beach to roost or forage). However, the results also suggest that such a small area could be enlarged to provide more protection and range in foraging habitats.

Determining the effect of human activities on shorebird populations, however, is more difficult. Simply showing that birds move when disturbed may not be equivalent to showing population effects because birds that move may have alternative foraging or roosting sites to use (Gill et al. 2001; Stillman et al. 2007). West et al. (2002) used models to show that several short disturbances are more damaging than larger, longer disturbances, and that preventing disturbances practically eliminated population consequences. In models developed for oystercatchers (*Haematopus ostralegus*), Goss-Custard et al. (2006) showed that disturbance flight rates of 1.5 times/hr or more reduced fitness in good feeding conditions, but fitness was affected when such flights were only 0.2 to 0.5 times/hr under poor foraging conditions. Their model is based on individuals, and tracks diet, foraging location and body condition of each individual within the population; it then determines whether or not each individual would starve before the end of winter. Disturbance (e.g. flight rates) influenced foraging rates. Such disturbance models need to be developed for other species, particularly those experiencing population declines, such as the red knot. Several other factors also affect the degree of response (and effects) from human activities on foraging or roosting shorebirds, including time of day, prey availability (birds took longer to resume feeding in low prey availability), and the presence of predators (Yasue 2006; Piersma et al. 2006; Dekker et al. 2011).

Our results demonstrate that shorebirds on Brigantine Beach foraged or roosted on particular segments as a function of whether the beach was open or closed; thus the presence of people affected how shorebirds used the beach. Further, we had about 150 h afield by each of two teams, and recorded 403 incidences where people came (or were about to come) onto the beach, for a possible disturbance rate of 2.69 disturbances per hr by only people. Raptors were also present, which provided an additional disturbance stress. Using the Goss-Custard et al. (2006) model, these data suggest that the shorebirds have reached a disturbance threshold that affects fitness. Another possible effect is that when the beach is closed, shorebirds are spaced out, making it difficult for predators to approach easily and reducing their effectiveness. When open, the shorebirds concentrate, making them vulnerable because predators often key in on a bird that lags behind.

Conservation in urban environments

Our research suggests that closure of some area of a beach can have positive benefits on shorebirds in that it provides a place for roosting and foraging without disturbances. When a large section of Brigantine Beach was closed, the shorebirds spread out, and used the entire area. When the beach was open for human use, leaving only a small enclosure at the far end

of the point (area protected because of piping plover management), then all species of shorebirds concentrated in the protected area (sections 16–19) for both roosting and foraging. This was particularly clear for red knot and sanderling (refer to Fig. 2).

We suggest that an optimum management strategy might well be to enlarge the “piping plover” closure area to encompass more space at the end of Brigantine Beach, providing the shorebirds with a large area for roosting and foraging that would allow some spacing out. Thus, it would not be necessary to close as much of the beach as was closed in the present experiment. While several authors have dealt with set-back distances from breeding colonies, it is much harder to deal with ephemeral feeding or roosting associations (Rodgers and Schwikert 2002). Finding solutions to allow recreational use of beaches, while protecting shorebirds, will surely become more important with global change and sea level rise (Hannah 2011), when some beach and mud-flat areas will no longer be available.

Management in urban areas, such as in the corridor from Boston to Washington, is a complex process whereby responsible resource agencies assess and monitor species, communities or ecosystems, develop and conduct management actions, evaluate the options, and move forward with additional (or different) management measures. But they must do so within the complex urban landscape where few natural or undisturbed habitats remain. Four categories are essential to the success of adaptive management in urban environments: dealing with spatial and temporal scales, describing and acknowledging uncertainty, evaluating costs and benefits, and obtaining support from institutions and stakeholders (Gregory et al. 2006; Burger 2011). Developing effective methods of communication and interacting with human populations is an additional, critical aspect, particularly in highly developed urban and suburban landscapes.

Three other aspects are important in the context of the present research: 1) the efficacy of management practices are often untested (Macnab 1985), 2) scientific data is often ignored by research agencies or decision-makers because of the manner of presentation or its general availability (McCleery et al. 2007), and 3) a wide range of stakeholders are usually not consulted. In our study we interacted with a wide range of stakeholders, and adapted our research schedule and protocol according to their views. Thus, the agencies were invested in the project, and interested in the results because they had been partially tailored to their needs. Adaptive management, in our view, will move forward only when scientists listen with the same attention and openness as managers listen to data from scientists. However, it should be noted that adaptive management will not be effective unless both managers and scientists are willing to change their views, methods, and protocols (McCleery et al. 2007).

While it is intuitively obvious that closure of an area to human activities should improve resource use by birds, this assumption is usually not tested. In this study we experimentally closed a section of beach, recorded shorebird use and behavior during and after the closure, and found that spatial use of the beach depended upon whether it was open or closed (shorebirds often moved to a small fenced off area when the beach was open). Transmitting such information to policy makers, the public and managers is thus critical to conserving these species.

Finally, adaptive management, stakeholder involvement, and community-based management are all paradigms that will allow policy makers, managers, and the broader public to participate in the wise management and conservation of our natural resources (Burger 2011; Jordan et al. 2011; Mills et al. 2011). Biologists and conservationists must find ways of working productively with a wide range of people, in a range of disciplines and approaches. These approaches are critical in urban environments where conflicts between development and natural resource protection are increasing.

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