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EFFECTS OF OILING ON FEEDING BEHAVIOR OF SANDERLINGS AND SEMIPALMATED PLOVERS IN NEW JERSEY[1]

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Abstract. I examined the foraging behavior of Sanderlings (*Calidris alba*) and Semipalmated Plovers (*Charadrius semipalmatus*) during their spring stopover period along the Atlantic coast of southern New Jersey following an oil spill. I used focal animal sampling to test the null hypothesis that there are no differences in foraging behavior as a function of the degree of oiling of birds. Nearly 50% of the foraging time of shorebirds was interrupted during the main period of beach oiling, primarily by clean-up personnel and vehicles that moved up and down the oiled beach, compared to less than 5% of the foraging time disruption at a control beach where birds were interrupted only by walkers and joggers. For both species, the time devoted to feeding decreased significantly, whereas the time devoted to standing about and preening increased significantly as percent of oiled plumage increased. For shorebirds that are already time-stressed in their refueling efforts before their long journey to arctic breeding grounds, these interruptions may prove fatal or might lower reproductive success once they reach the breeding grounds.

Key words: Sanderling, Calidris alba, *Semipalmated Plover,* Charadrius semipalmatus, *foraging, oiling, disturbance.*

INTRODUCTION

The demand for oil by industrialized societies has continued to increase over the past 25 years and is likely to continue increasing in the future. The uneven distribution of oil resources worldwide and the unequal demand for oil results in massive movement of both crude oil and refined products (Cutter Information Corporation 1995) with the resultant potential for oil spills. From 1978 until 1994 there were between 55 and 205 oil spills per year worldwide, each over 36 million liters, and numerous other smaller spills (Cutter Information Corporation 1995).

Birds are often the most visible casualties of oil spills because they quickly become oiled, and in the wake of large oil spills, hundreds or even thousands of birds wash ashore (Wiens et al. 1984, Fry 1992, Burger 1993, *Exxon Valdez* Oil Spill Trustee Council 1995). In general, seabirds and shorebirds are more at risk from oil spills than are most species because they spend the most time in marine environments. Birds can be harmed when they are covered with oil (Leighton 1983, Piatt et al. 1990), when they ingest it (Peakall et al. 1983), and when they bring it back on their plumage and accidentally oil their eggs (King and Lefever 1979, McGill and Richmond 1979) or offspring (Peakall et al. 1982, Boersma et al. 1988, Harfenist et al. 1990). There are no studies on the sublethal effects of oil on foraging behavior, although Sharp et al. (1996) recently examined the effects of the *Exxon Valdez* oil spill on foraging and reproductive success of Black Oystercatchers (*Haemotopus bachman*). Birds can ingest oil directly from the water, from their food, or from preening their feathers. Some estimates, based on studying oiled birds in captivity, suggest that birds ingest 50% of the oil on their feathers within 8 hr of exposure (Hartung and Hunt 1967).

Delaware Bay is one of the top three ports of the United States in terms of both oil tanker calls and amount of oil moved through the port (NRC 1991). Over 50 million metric tons of oil move through Philadelphia alone each year (NRC 1991). Given the extensive tanker traffic through the bay, it is inevitable that there will be some spills, but in the past these have been small. Delaware Bay is the major Atlantic Flyway stopover point for shorebirds in the spring (Wander and Dunne 1981, Burger 1986, Clark et al. 1993), and conservationists and biologists have been concerned about the potential for catastrophic damage to these shorebirds. On 9 May 1996, a small oil spill fouled the beaches along southern Delaware Bay and later reached the beaches

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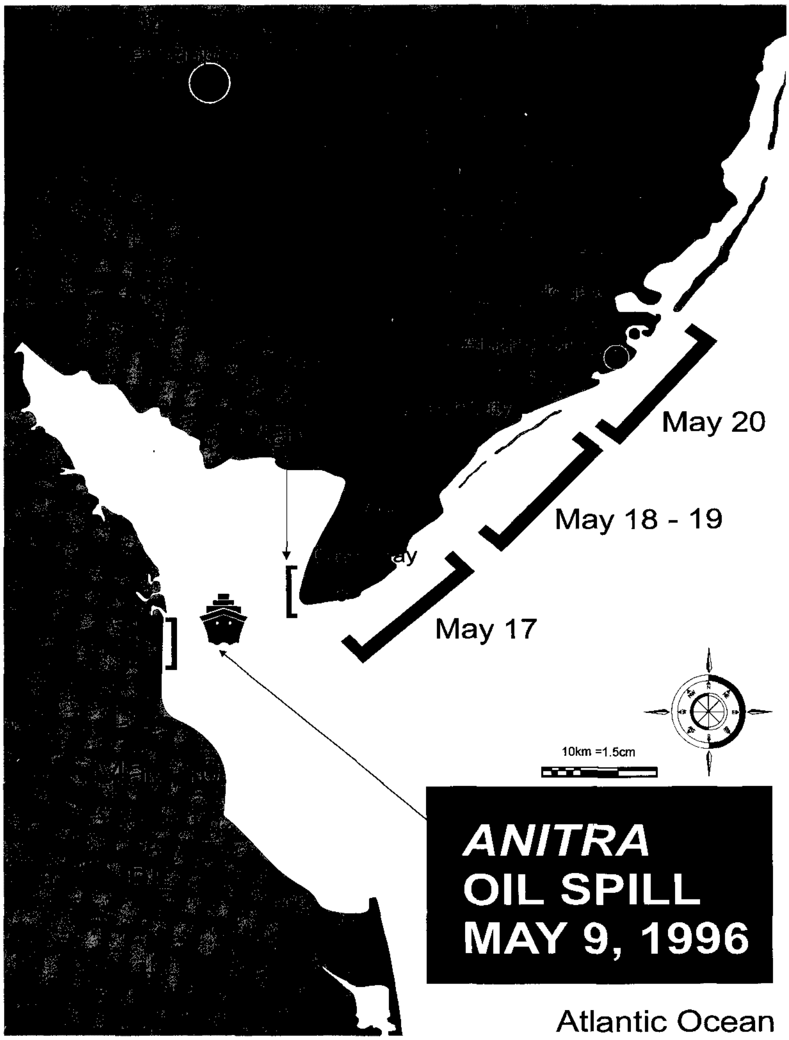

FIGURE 1. Map of *Anitra* oil spill in New Jersey. Date refers to when oiling began in that stretch of beach.

along the Atlantic coast of New Jersey. Although there were not masses of oiled and dead birds strewn along the shore, shorebirds became oiled when they fed in the surf. This provided the opportunity to examine the effect of oiling on foraging behavior of Sanderlings (*Calidris alba*) and Semipalmated Plovers (*Charadrius semipalmatus*) during their spring stopover period. I tested the null hypothesis that there were no differences in foraging behavior as a function of oiling.

THE ANITRA OIL SPILL

On 9 May 1996, the French-owned tanker *Anitra* spilled at least 150,000 liters of Nigerian light crude oil during a lightening operation (removal of oil from a tanker) at the Big Stone Anchorage at the mouth of Delaware Bay (Fig. 1). Initially the oil drifted west and hit the beaches on the Delaware side of the bay, but a shift in winds brought the oil to New Jersey beaches from Cape May Point north (Fig. 1). Small tar balls on the Delaware Bay beaches constituted a potential threat to the migrant shorebirds that were just arriving. Nearly one million migrant shorebirds move through Delaware Bay from mid-May to early June, with a peak during the last week of May (Burger 1986, Clark et al. 1993). The bayshore beaches were quickly cleaned up, however, and the threat to the shorebirds seemed minimal, largely because cold waters delayed the spawning of horseshoe crabs (*Limulus polyphemus*; R. Loveland, pers. comm.), whose eggs are a primary food for the birds.

A week after the spill, officials were ready to halt beach clean-up along the Delaware Bay shore, but suddenly oil reached the beaches along the Atlantic coast from Avalon north to Ocean City, New Jersey. For nearly another week every tide brought new oil, and clean-up crews removed the oil after each high tide. Initially the oil was in slicks about a meter wide at the high tide wrack line on the beach, but later, oil washed up largely in tar balls the size of grapes. Nearly three weeks after the initial oil spill, easterly winds continued to bring tar balls onto the beaches from Avalon as far north as Holgate (Fig. 1). There was a tar-ball line at the highest tide and at the secondary tideline.

Although the delayed horseshoe crab spawning did not concentrate the shorebirds along the Delaware Bay shore, this later proved serious because more shorebirds fed along the Atlantic coast than usual. Ultimately, there was more oil in the surf and on New Jersey beaches than along Delaware Bay. Because many of the shorebirds feed in the surf at all tide stages along the New Jersey Atlantic coast (Burger et al. 1977), they were exposed to the oil as it washed ashore. This provided the opportunity to observe foraging behavior of birds as a function of the percent of oil on their plumage.

STUDY AREA AND METHODS

I studied Sanderlings and Semipalmated Plovers foraging along a beach in Ocean City, New Jersey over a three day period when the greatest quantity of oil was coming ashore (21–23 May 1996). Observations also were made on 29 May at Ocean City when the second wave of tar balls washed ashore. The sandy beach at Ocean City is comparatively wide (about 100–140 m) with a shallow slope, and is bordered by residential and commercial tourist properties. Usually at this time of year there are few tourists and no vehicles on the beach. After Memorial Day, however, the beaches are heavily used by tourists and residents.

Observations were conducted from 09:00 to 20:00 and thus included all tide stages. Although there were Semipalmated Sandpiper, Red Knot (*Calidris canutus*) and Piping Plover (*Charadrius melodus*) on the beaches, I concentrated on Sanderlings and Semipalmated Plovers because they were the most numerous.

Four observers simultaneously walked part of the Ocean City beach, stopping to take observations on focal birds as we encountered foraging flocks. Only one transect was conducted each day to minimize sampling the same individuals. We watched birds through binoculars from a distance of 15–30 m, at which distance the birds appeared to ignore our presence; if we had an impact it would have been independent of degree of plumage oiling. When a foraging flock was encountered, we each selected a different bird for observation and recorded the following information before the start of each 1-min foraging sample: date, time, number of birds in the flock, nearest neighbor distance, and percent of body that was oiled. To avoid bias, we selected birds that were in different parts of the foraging flock and that were not already resting or preening. Oiling was graded as a percentage of body plumage stained, down to 5% staining at the base of the legs or near the vent, to 0%—no visible staining. The latter does not preclude a slight oil film. Birds were subsequently classified into zero, light (1–15%), medium (16–29%), and heavy ($\geq$ 30%) oiled. We then observed the focal bird, using stop watches to record the total time the bird foraged, preened, stood, ran (but not while foraging), flew, or was alert or aggressive. This protocol has been used extensively with Sanderlings and Piping Plovers (Burger 1991, 1994, Burger and Gochfeld 1991).

At the same time, we recorded the number of times that a shorebird either fed undisturbed for its 1-min sample, or was disturbed by the clean-up vehicles moving up or down the beach, or by tourists walking or jogging at the surf line. Similar observations were made in succeeding days at an unoiled site at Surf City beaches (Ocean County, New Jersey) to determine the number of oiled shorebirds and foraging rates at this time of the year.

Means and standard errors were obtained for the variables, and significant differences among oiling classes were determined with Kruskal-Wallis tests yielding a χ^2 statistic. A multiple regression model procedure (Proc GLM, SAS Institute 1989) was performed on the data to determine the best models explaining variations in time devoted to foraging and preening as a function of the independent variables (% oiled, time

TABLE 1. Percent and number of foraging shorebirds disturbed by clean-up personnel and tourists on oiled (Ocean City beaches) and unoiled beaches (Surf City, Long Beach Island, New Jersey).

Beach type	Date	Number birds observed	% disturbed by clean-up crews	% disturbed by tourists
Before Memorial Day weekend:				
Oiled	21 May	710	47 (336)	3 (24)
Oiled	23 May	506	48 (242)	2 (11)
Unoiled	22 May	250	0 (0)	2 (6)
After Memorial Day weekend:				
Oiled	29 May	276	17 (48)	1 (2)
Unoiled	29 May	118	0 (0)	2 (2)

of day, nearest neighbor distance, group size) for each species. Variables were selected for the model using a stepwise regression procedure that selects the factor that contributes the most to the R^2, and then selects the additional variable that increases it the most. This approach compensates for collinearity.

RESULTS

Birds on the Ocean City beaches were excessively disturbed by the clean-up crews constantly moving up and down the beaches (Table 1). This was not the case on the unoiled beach, because there were obviously no clean-up crews present. There was little disturbance by tourists and other beach-goers on oiled and unoiled beaches.

The main factor that entered as having the most significant effect on time devoted to foraging and preening for Sanderlings and Semipalmated Plovers was the percent of the bird that was oiled (Table 2). In both species, heavily (> 30%) oiled birds spent more time standing and preening, and less time foraging than birds that were less oiled (Table 3). Similarly, birds that were heavily oiled used fewer pecks while feeding than those that were lightly oiled or not oiled at all. There were significant negative correlations between the amount of oiling and foraging behaviors for both species and significant positive correlations between oiling and standing and preening for both species (Table 4, Fig. 2).

TABLE 2. Factors entering the best models (GLM) explaining variation in shorebird foraging at Ocean City, New Jersey. F is the statistic for the model, df is the degrees of freedom, and P is the probability level (** = <0.01, *** = <0.001, ns = not significant).

	Time devoted to feeding	Time devoted to preening
Model		
F	38.7	54.6
df	9, 412	9, 412
R^2	0.46	0.54
P	0.001	0.001
Factors entering (F, P)		
Percent oiled	104.6***	150.6***
Time of day	7.6**	9.2***
Flock size	ns	6.4***
Nearest neighbor distance	ns	ns

DISCUSSION

The environmental conditions and food resources that shorebirds encounter in migration at stopover areas are important for survival and later reproduction, particularly during spring migration when shorebirds must arrive on the breeding grounds with sufficient fat reserves for reproduction, and when timing is critical because of the short breeding season. Many shorebirds that migrate distances of up to 5,000 km stop only once or twice during migration, and the places they do stop must provide sufficient resources for continued flight (Morrison 1984, Myers et al. 1987). Maintaining productive foraging areas is necessary to manage migrant shorebird species that are dependent on them (Moore et al. 1990). Part of this management is to provide foraging habitat that is free from human disturbance and free from oil pollution and other contaminants.

The shorebirds that arrived on the Ocean City beaches in mid-May 1996 following the oil spill encountered both excessive disturbance from oil spill clean-up crews and vehicular traffic, as well as oiling of their plumage which had both direct and indirect effects.

TABLE 3. Behavior (mean ± SE) of Sanderling and Semipalmated Plover (1-min samples) as a function of oiling. Probability levels are * = <0.05, ** = <0.01, *** = <0.001, ns = not significant.

Characteristics	Percent oiled 0	1–15	16–29	over 30+	Kruskal Wallis χ^2
Sanderling					
Sample size	54	173	64	72	
Flock size	23 ± 2.2 (A)	25 ± 1.3 (A)	23 ± 2.4 (A)	24 ± 2.1 (A)	ns
Nearest neighbor	2.0 ± 0.2 (A)	2.6 ± 0.2 (A)	2.9 ± 0.3 (A)	3.0 ± 0.3 (A)	ns
Sec devoted to:					
Stand	0.2 ± 0.2 (A)	1.3 ± 0.4 (A,B)	5.3 ± 1.6 (B,C)	2.8 ± 0.8 (B)	19.2**
Preen	0.6 ± 0.4 (A)	2.3 ± 0.6 (A)	12.1 ± 2.0 (B)	31.1 ± 2.3 (C)	166***
Alert	0.3 ± 0.1 (A)	0.3 ± 0.2 (A)	0.3 ± 0.2 (A)	0 (A)	ns
Run/walk	1.4 ± 0.6 (A)	4.1 ± 0.6 (B)	5.9 ± 1.6 (B)	4.6 ± 0.8 (B)	9.1*
Fly	0.4 ± 0.2 (A)	1.2 ± 0.4 (A)	1.2 ± 0.4 (A)	0.7 ± 0.3 (A)	ns
Aggression	0.2 ± 0.1 (A)	0.5 ± 0.2 (A)	0.7 ± 0.3 (A)	0.2 ± 0.1 (A)	ns
Feed	57 ± 0.9 (A)	50 ± 1.0 (B)	36 ± 2.3 (C)	21 ± 2.1 (D)	143.9***
Number of pecks	25 ± 1.6 (A)	20 ± 1.1 (B)	11 ± 1.1 (C)	6 ± 0.7 (D)	136***
Semipalmated Plover					
Sample size	3	20	14	3	
Flock size	11.0 ± 5.0 (A)	29.5 ± 3.5 (A)	22.6 ± 4.6 (A)	26.7 ± 10.7 (A)	ns
Nearest neighbor	1.7 ± 0.9 (B)	4.2 ± 0.5 (A,B)	4.3 ± 0.7 (A,B)	5.7 ± 2.2 (A)	ns
Sec devoted to:					
Stand	0 (A)	1.4 ± 0.9 (A)	2.65 ± 1.2 (A)	3.3 ± 3.3 (A)	ns
Preen	0 (A)	2.1 ± 0.8 (A)	13.7 ± 4.5 (A)	31.7 ± 6.1 (B)	16.6***
Alert	0 (A)	0.2 ± 0.2 (A)	0.7 ± 0.5 (A)	0 (A)	ns
Run/walk	0 (A)	6.4 ± 1.7 (A)	6.9 ± 2.9 (A)	16.7 ± 6.7 (A)	ns
Fly	0 (A)	3.5 ± 2.6 (A)	0 (A)	0 (A)	ns
Aggression	0 (A)	0.5 ± 0.5 (A)	0 (A)	0 (A)	ns
Feed	60.0 ± 0 (A)	4.34 ± 4.0 (A,B)	33.5 ± 5.0 (B,C)	11.7 ± 1.7 (C)	13.1**
Number of pecks	24.3 ± 2.3 (A)	12.8 ± 1.6 (B)	10.5 ± 1.9 (B,C)	3.0 ± 1.7 (C)	11.0**

Values with the same letter are not significantly different from each other.

TABLE 4. Correlation of behaviors with percent oiled for Sanderling and Semipalmated Plover. Given are R^2 (probability) for Kendall tau. Probability levels are * = <0.05, ** = <0.01, *** = <0.001, ns = not significant.

Characteristic	Sanderling	Semipalmated Plover
Sample size	367	43
Flock size	ns	ns
Nearest neighbor	0.09*	ns
Sec devoted to:		
Stand	0.19***	0.33**
Preen	0.56***	0.48***
Alert	−0.09*	ns
Run/walk	0.13**	ns
Fly	ns	ns
Aggression	ns	ns
Feed	−0.52***	−0.39***
Number of pecks	−0.49***	−0.38***

EFFECTS OF PHYSICAL DISTURBANCE ON FORAGING

One obvious effect of the oil spill was the presence of personnel and vehicles engaged in removal of oil and oiled sand from the beaches. Large crews of up to 100 people were present because local officials were concerned that beaches be cleaned up for the approaching Memorial Day weekend when shore communities are inundated by tourists that contribute substantially to local economies. Thus there was a rush to remove any traces of the oil, and to remove any traces of the clean-up crews.

For most of the three-day period during the heavy arrival of oil on the beach (May 21–23), clean-up personnel and vehicles moved back and forth past any given point of beach every few minutes. In some cases crews moved along the beach more than 30 m from the water which allowed the shorebirds to continue feeding, but usually they moved along the hard sand where the surf had just receded, forcing the shorebirds to fly. Thus one cost of this oil spill was physical disturbance to shorebirds already stressed by migration and oiling, even though this may have displaced some birds away from the oiled beaches. The effects of human disturbance on shorebirds are well-described (Burger 1986, Burger and Gochfeld 1991, Pfister et al. 1992), but the excessive disturbance due to workers and vehicles cleaning up a beach has not been examined. In the present study, it severely decreased the available foraging time for birds that already forage both during the day and during the evening to obtain sufficient food resources for their northward migration.

EFFECTS OF OILING ON FORAGING RATE

Time devoted to foraging decreased with the degree of oiling for both Sanderlings and Semipalmated Plovers, and oiled birds spent more time preening and standing about than unoiled birds. These relationships were dose-dependent; the data demonstrate that there are clear sublethal effects of oiling that are experienced immediately by oiled birds. Since shorebirds feed at all tide stages during both day and night (Burger and Gochfeld 1991), the added cost of oil spills and contamination will depress their ability to acquire sufficient food reserves for a normal stopover stay. Either the shorebirds will be

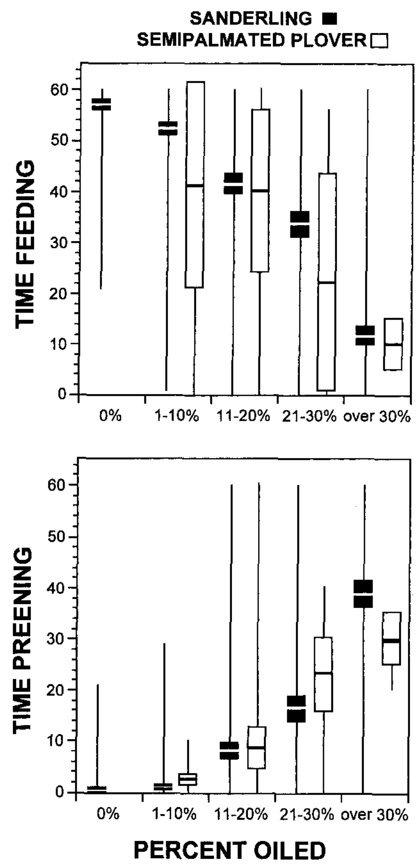

FIGURE 2. Time devoted to foraging and preening by Sanderlings and Semipalmated Plovers as a function of percent of body that was oiled. Shown are mean (horizontal bar), standard error (box) and range (vertical line).

required to stay longer to acquire the same reserves, or they will leave with less body fat.

The data point to a second problem: the ingestion of oil while preening; the amount of time spent preening increased with the degree of oiling. Hartung and Hunt (1967) found that under experimental conditions birds ingested 50% of the oil on their plumage within just 8 hr. Ingestion of oil causes a variety of problems which would compound foraging difficulties, including transient liver damage (Miller et al. 1978), impairment of osmoregulation (Peakall et al. 1982), and hypertrophy of adrenal and nasal salt gland tissue (Peakall et al. 1983). Unfortunately, some of these effects also occur with ingestion of weathered oil (Peakall et al. 1983). The adverse effects of these factors are augmented by other stressors such as cold or drinking saline water (Holmes et al. 1979).

Heavily oiled birds in New Jersey spent less time foraging than non-oiled birds elsewhere in New Jersey and in Florida (Table 5). During the winter, shorebirds foraging on beaches in Florida often encounter large numbers of people (Burger and Gochfeld 1991), and shorebirds breeding on New Jersey beaches in the early summer also encounter people, and in both cases they must devote time to vigilance and moving away from people. Thus, an oil spill in the presence of a large number of people would further decrease foraging time.

POTENTIAL COST OF OILING ON MIGRANT SHOREBIRDS

It is difficult to obtain figures on the relationship between degree of oiling and subsequent mortality, partly because it is difficult to quantify the oil on plumage, e.g., 50% of the bird can be covered with oil, but whether the layer is thick or thin influences the quantity of oil ingested. It also is difficult to find oiled carcasses in sufficiently good condition to determine oiling status when they were alive. There were no dead birds recovered in the *Anitra* spill, and no autopsies were performed. Further, some dead beached birds that have no external oiling contain oil internally (Vauk et al. 1989), presumably obtained from preening or inadvertent ingestion of floating tar or oiled prey.

The length of stay of shorebirds on a spring stopover area may depend partly on body condition (Dunn et al. 1988). Length of stay may then be a result of body fat status when they first

TABLE 5. Comparison of foraging behavior of Sanderlings and another shorebird, using a focal bird sampling for 1-minute observation periods on each bird.

Species	Location	Season & condition	Sec devoted to: Feed	Alert	Preen	Source
Sanderling	Ocean City, NJ	spring				This study
		no oiling	57	0.3	0.6	
		1–15% oil	50	0.3	2.3	
		16–30% oil	36	0.3	12.1	
		over 30% oil	21	0.0	31.1	
	Del Ray Beach, Florida	winter				Burger and Gochfeld 1991
		diurnal	41.9	9.1	<0.1	
		dusk	50.5	0.4	<0.1	
		night	51.2	0.4	<0.1	
Piping Plover	NJ Beaches:	breeding season:				
	Corson's	day	42.5	6.7	<0.1	Burger 1991
	Brigantine	day	36.6	12.2	<0.1	
	Holgate[a]	day	53.0	3.6	<0.1	
		night, prenesting	45.8	2.5	—	Staine and Burger 1994
		incubating	41.9	4.9	—	

[a] This area was restricted during the Piping Plover nesting period, and people were not allowed on the beach.

arrive on the stopover grounds, and food resources and foraging conditions on the stopover area. If food is plentiful and shorebirds can forage undisturbed, then presumably stopover time is less than if these conditions are less optimal. Heavily oiled shorebirds at Ocean City clearly altered their foraging behavior and spent less time foraging than birds that were less oiled. This may have resulted in their spending more time along the Atlantic coast and delaying their northward migration, or may have caused increased mortality during migration, or may have decreased subsequent breeding success in the Arctic.

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