J. Field Ornithol., 59(4):321–330

PIPING PLOVER STATUS IN NOVA SCOTIA RELATED TO ITS REPRODUCTIVE AND BEHAVIORAL RESPONSES TO HUMAN DISTURBANCE

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Abstract.—Piping Plover (*Charadrius melodus*) censuses and behavioral observations were made in Nova Scotia to assess the species' status and its responses to human disturbance. The population declined from 1983 (66–71 pairs) to 1987 (48–54 pairs) at a rate of 3.3–5.8 pairs/yr. Increased disturbance resulted in fewer chicks surviving to age 17 d. Disturbed chicks exhibited decreased feeding and brooding, and increased sitting and vigilance. When feeding did occur, it was at a reduced rate. By altering chick behavior, disturbance may have caused increased chick mortality and subsequently contributed to the declining numbers in Nova Scotia. Human disturbance may be an important component of the species' population decline throughout its range.

ESTATUS DE *CHARADRIUS MELODUS* EN NUEVA ESCOCIA, RELACIONADO A SU REPRODUCCIÓN Y RESPUESTAS DE CONDUCTA A LA PERTURBACIÓN HUMANA

Resumen.—Censos y observaciones de comportamiento del playero *Charadrius melodus* se llevaron a cabo en Nueva Escocia, para evaluar el estatus de la especie y sus respuestas a la perturbación humana. La población disminuyó entre el 1983 (66–71 parejas) y el 1987 (48–54 parejas) a una razón de 3.3–5.8 parejas por año. El aumento en la perturbación resultó en una cantidad menor de pichones sobrevivientes a una edad de 17 días. Los polluelos perturbados exhibieron una disminución en alimentación y en el ser cubiertos por los adultos (brooded), aumentando la vigilancia y el estar posados. Cuando los mismos se alimentaron, la alimentación se llevó a cabo a una razón más lenta. Por alterar el comportamiento de los pichones, la perturbación pudo haber causado un aumento en la mortandad de pichones, y subsecuentemente contribuir a que los números poblacionales hayan mermado en Nueva Escocia. La perturbación puede ser un componente importante en la merma poblacional de la especie a través de su ámbito geográfico.

The Piping Plover (*Charadrius melodus*) breeds on alkali skrighs or sandy beaches in central and eastern North America (Haig 1985). Its

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numbers have recently declined to the extent that only 1646–1939 pairs remain (Haig and Oring 1985). The species has been declared endangered or threatened throughout its range (Haig 1985, Sidle 1984).

Many authors have suggested that human disturbance may be an important reason for the decline (e.g., Bell 1978, Cairns and McLaren 1980, Haig and Oring 1985), but there is little evidence to show a relationship between disturbance, reproductive success, and population decline. We hypothesize that disturbance alters chick behavior, such that they spend less time feeding and more time in avoidance behavior. With increased disturbance, chicks might become weakened thereby increasing susceptibility to inclement weather and predators. This would result in higher mortality, and a subsequent population decline. Our objectives were to assess the status of the Nova Scotia population and to examine the effects of human disturbance on reproductive success and behavior.

STUDY AREA

Censuses were done at all potential Piping Plover habitats in Nova Scotia (n = 194 beaches), but behavioral observations were restricted to four sites (Fig. 1). Johnstons Pond Beach is 0.7 km long and 25–100 m wide, with white colored sand, several small beach grass (*Ammophila breviligulata*) dunes, and a tidal sandflat (13,000 m^2, mean high-low tide). It received little vehicle (<10 veh./season), and varying pedestrian disturbance (5–30 ped./d). St. Catherines River Beach is 1.4 km long and 75–200 m wide, with cobbled sand, sparsely vegetated beach grass dunes, and a tidal sandflat (Cairns 1982). It had little disturbance (<1 ped./d, <1 veh./wk). Round Bay Beach resembles Johnstons Pond in terms of size, vegetation, and sandflat. Cherry Hill Beach is a barrier beach with beach grass dunes, and a tidal mudflat. Round Bay and Cherry Hill beaches received extensive disturbance (5–50 ped. and 3–20 veh./d).

METHODS

Population assessment.—Along Nova Scotia's coastline, 795 evenly scheduled censuses were made during April–August from 1975–1987 (112 censuses were made by 45 volunteers on infrequently visited sites). Census techniques were standardized. Beaches with appropriate habitat were visited at least once. If birds were located, the beach was censused again from 3–19 times, and until the maximum count was consistent among at least three censuses (except six beaches, five of which had one pair in three consecutive census years).

Nest and fledging success.—Nests were located by observing birds returning to the nest or by following plover tracks. Chicks were counted by observing an undisturbed brood or by herding them to the shoreline (1979–1983). Nests and broods were checked 3–20 times/nest and 3–12 times/brood. An attempted nest had one or more eggs, while a successful nest hatched one or more eggs.

Assessment of human disturbance.—During censuses (1979–1983), we measured human disturbance on beaches by recording positions of people,

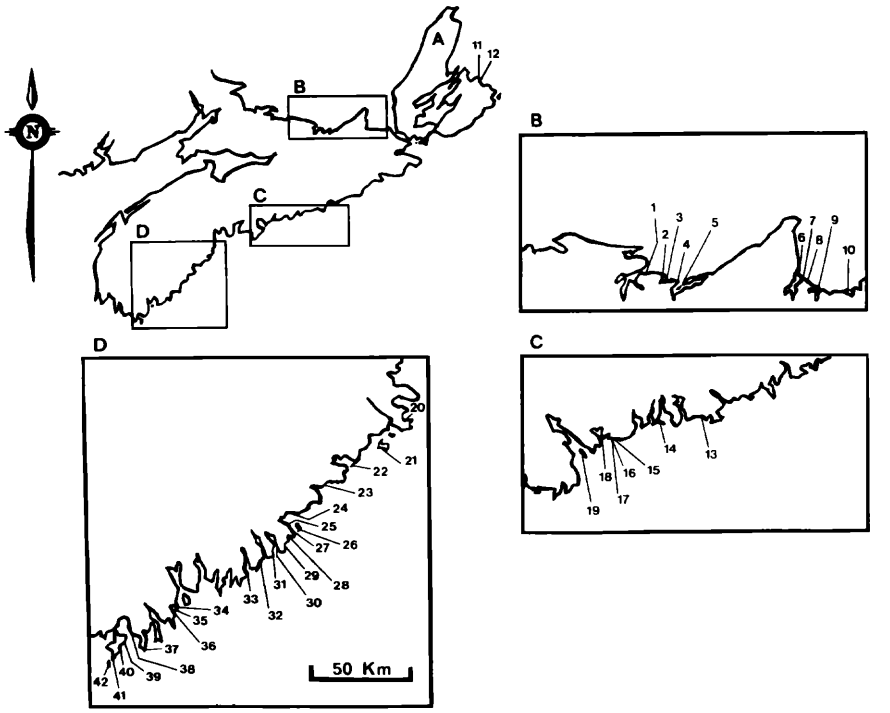

FIGURE 1. The distribution of Piping Plover breeding sites in Nova Scotia. Numbered sites correspond to those given in Table 1. Letters correspond to A, Cape Breton; B, Northumberland Strait; C, Eastern Shore; and D, South Shore. Sites 6–10 are located in St. Georges Bay.

pedestrian tracks, and vehicle tracks. On beaches visited <5 times, 3–5 local people were also questioned about disturbance in the breeding area. In all cases this latter information confirmed our assessment based on the above three measures.

To correct for track recounting bias, we used sand transects on five beaches, and found that track longevity of pedestrians and all terrain vehicles was 2–4 d (n = 43 assessments). Large vehicle tracks persisted, but this bias was eliminated by comparing tracks mapped weekly.

Disturbance to broods within an arbitrarily assigned 200 m radius was ranked by classifying vehicle and pedestrian traffic into one of four classes (0–3). Classes were defined as 0, <4 visits/wk; 1, 4–10 visits/wk; 2, 11–20 visits/wk; and 3, >20 visits/wk. Since chick mortality attributable to vehicles and pedestrians could not be separated, these were summed creating an overall disturbance index (0–6). To further increase our confidence in the disturbance assessments, low (0–2) and high (4–6) values were lumped for the analysis.

Behavioral observations and analysis.—Observations (135 h) were made

from elevated sites (50–150 m distant) with 9 × 36 binoculars and a 15–60× telescope during all daylight hours (1983). Foggy and rainy weather were avoided due to poor visibility (518 min supplemental data were collected during rain). Ten broods were observed. Most observations were directed toward 12 uniquely color banded young at Johnstons Pond Beach. Timed chick activities were: (1) feeding, which was a run/stop/peck sequence; (2) brooding; (3) sitting; and (4) vigilance, which included run/stop, occasional pecks, and "head-up" scanning behavior.

Timed behavior was converted to frequency of occurrence data. Behavior that occurred during the first three minutes of a disturbance bout was compared with randomly chosen 3 min bouts during the same hour of the day from the undisturbed condition. This matching was necessary because disturbance was not randomly distributed over time. However, it was random with respect to chick age and weather. Similarly, when raining, whether a chick was observed feeding during 1 min intervals was compared to a random sample (matched for age) from the non-raining data set.

Five aspects of chick feeding behavior were quantified, including peck number; distance traveled; number of stops; and time stopped, calculated as mean time/stop × stop number (cf. Cody 1974).

Adult response level (defined in text) and reaction distance to approaching humans, potential predators, and non-predatory species were measured during observations.

We rejected the null hypothesis at the 5% significance level.

RESULTS

Population stability.—Nova Scotia's population estimate for 1983 was 66–71 pairs, but only 48–54 pairs in 1987 (Table 1). In 1987, pairs were located along the Northumberland Strait (n = 5 pairs), Cape Breton (n = 3), Eastern Shore (n = 6), and South Shore (n = 34–40; Fig. 1). Since these estimates are based on nearly complete samples, the data demonstrate a decline of 12–23 pairs (18.2–32.4%) over a 4-yr period. Furthermore, the population was apparently declining prior to 1983 (Table 1).

The rate of decline was divided into geographical regions (Table 2). St. Georges Bay experienced a decline rate which slowed (2–2.5 to 0.5 pairs/yr) with decreasing abundance, suggesting the rate declined asymptotically. The rate of decline for the Eastern Shore was 1.5 pairs/yr, and for the South Shore was 1.9–2.6 pairs/yr. Moreover, the latter rate increased from 1.3–2.1 to 2.0–4.3 pairs/yr. The pattern extended to the provincial scale. Nova Scotia's Piping Plovers are disappearing at a rate of 3.3–5.8 pairs/yr. The species may become extirpated within 20 yrs.

Fledging success.—Fledging success (defined as survival to 17 d) was summed for 1979–1983, since no significant differences were found among years (Table 3). Fledging success was 1.2 young/pair per nest attempt and 2.3 young/pair per nest success. Table 3 shows that when considering chicks known to have survived to age 10 d, disturbance had no effect on success per nest attempt or per nest success. However, a pattern was

TABLE 1. Changes in the numbers of Piping Plovers at breeding sites in Nova Scotia (— indicates no data available).

Site no.	Beach name	Pair estimate (year)			
		Earlier date	Most recent pre-1983	1983	1987
1	Pictou Bar Spit	1 (79)	1 (82)	1	2
2	Roaring Bull Point	1 (80)	0 (82)	0	0
3	Bowen Island	2 (80)	2 (81)	1	1
4	Kings Head Beach	1 (77)	1 (80)	0	0
5	Savage Point Beach	1 (76)	0 (81)	0	0
6	Mahoneys Beach	6 (77)	3 (81)	1	1
7	Dunns Beach	1 (77)	1 (81)	2	0
8	Captains Pond Beach	1 (77)	0 (81)	0	0
9	Pomquet Beach	1 (77)	1 (81)	1	1
10	Delorey Island Beach	1 (77)	0 (81)	0	0
11	Dominion Beach	—	—	0	1
12	Glace Bay Bar	—	—	3	2
13	Clam Harbour Beach	2 (76)[a]	0 (82)	1	0
14	Martinique Beach	—	1 (75)[a]	2	2
15	Stoney Island Beach	—	1 (76)[a]	1	2
16	East Conrads Beach	2 (75)[a]	4 (82)	5	1
17	West Conrads Beach	—	1 (82)	2	1
18	Cole Harbour Beach	—	2–3 (82)	1	0
19	Maughers Beach	—	1 (79)	0	0
20	Conrad Is. Causeway	2 (76)[a]	0 (82)	0	0
21	Cape LaHave Island	—	2 (78)	[3][b]	3
22	Cherry Hill Beach	—	2–4 (82)	5	2
23	Beach Meadows	—	0 (76)[a]	1	1
24	Summerville Beach	1 (76)[a]	0 (82)	1	1
25	Wobamkek Beach	—	0 (76)[a]	0	1
26	Port Mouton Is.	—	—	[1][b]	1
27	Cranberry Pond	—	—	0	1
28	Little Port Joli	—	0 (76)[a]	1	2[c]
29	St. Catherines R.	27–29 (76)[a]	20–25 (79)[a]	11–14	7–9[c]
30	Port Joli Beach	—	0 (75)[a]	1	1
31	Sandy Cove Beach	1 (76)[a]	1 (82)	2	1–2
32	Johnstons Pond	—	1 (76)[a]	6–7	3–5
33	Louis Head Beach	—	1 (76)[a]	1	0
34	Fox Bar Beach	—	1 (75)[a]	1	1
35	Round Bay Beach	—	—	5–6	2–3
36	Red Head Beach	—	2 (76)[a]	0	0
37	Baccaro Beach	—	3 (76)[a]	2	2
38	Sebim Beach	—	—	1	3
39	Stoney Is. Beach	—	1 (76)[a]	1	0
40	Daniel Head Beach	—	1 (76)	0	0
41	The Hawk Beach	—	1 (82)	1	0
42	Cape Sable Island	1 (76)	1 (78)	1	2
	Totals	—	—	66–71	48–54

[a] Data from Cairns (1977, pers. comm.).
[b] No data available. Number taken from 1987 data for the total 1983 estimate.
[c] Collaborated data of Heilemann and Reive (1987) and authors.

TABLE 2. Rate of population change of Piping Plovers in three geographical regions of Nova Scotia.

Region	Year	No. pairs	Change in no. pairs	Rate of change per year
St. Georges Bay	1977	10	—	—
(n = 5 beaches)	1979	5–6	−4–5	−2.0–2.5
	1980	6	0	0
	1981	5	−1	−1.0
	1983	4	−1	−0.5
	1987	2	−2	−0.5
	All	—	−8	−0.8
Eastern Shore	1983	12	—	—
(n = 6 beaches)	1987	6	−6	−1.5
	All	—	−6	−1.5
South Shore	1976	42–44	—	—
(n = 10 beaches)	1983	29–33	−9–15	−1.3–2.1
	1987	16–21	−8–17	−2.0–4.3
	All	—	−21–28	−1.9–2.6
Nova Scotia	1983	62–67	—	—
(n = 40 beaches)	1987	44–49	−13–23	−3.3–5.8

found when considering chicks that survived to age 17 d. The number surviving/nest attempt decreased significantly from 1.8 young/pair in areas of low disturbance to 0.5 young/pair in areas of high disturbance. Similarly, surviving young/nest significantly decreased from 3.1 (low disturbance) to 1.6 (high) young/pair.

Disturbance effects on adult behavior.—Most adult responses to approaching humans followed the same pattern. Initially there was no apparent response (level 0), then a "head-up" posture (level 1) was assumed. If incubating or brooding, it crouched (level 2) or more commonly flushed and ran while alarm calling (level 3). Finally, an adult would feign a broken wing and emit distress calls (level 4). Responses to

TABLE 3. Effects of human disturbance on the number of Piping Plover chicks surviving to age 10 and 17 d.

Level of disturbance	No. surviving to age 10 d/nest		No. surviving to age 17 d/nest	
	Attempt[a]	Success[a]	Attempt[b]	Success[b]
Low (0–2)	1.8 (n = 24)	2.9 (n = 14)	1.8 (n = 21)	3.1 (n = 12)
Moderate (3)	1.3 (n = 26)	2.3 (n = 15)	1.0 (n = 25)	2.0 (n = 13)
High (4–6)	1.2 (n = 18)	2.6 (n = 12)	0.5 (n = 16)	1.6 (n = 10)
All levels	1.5 (n = 68)	2.6 (n = 41)	1.2 (n = 62)	2.3 (n = 35)

[a] Not a significant decrease (One-way ANOVA).
[b] Significant decrease (One-way ANOVA).

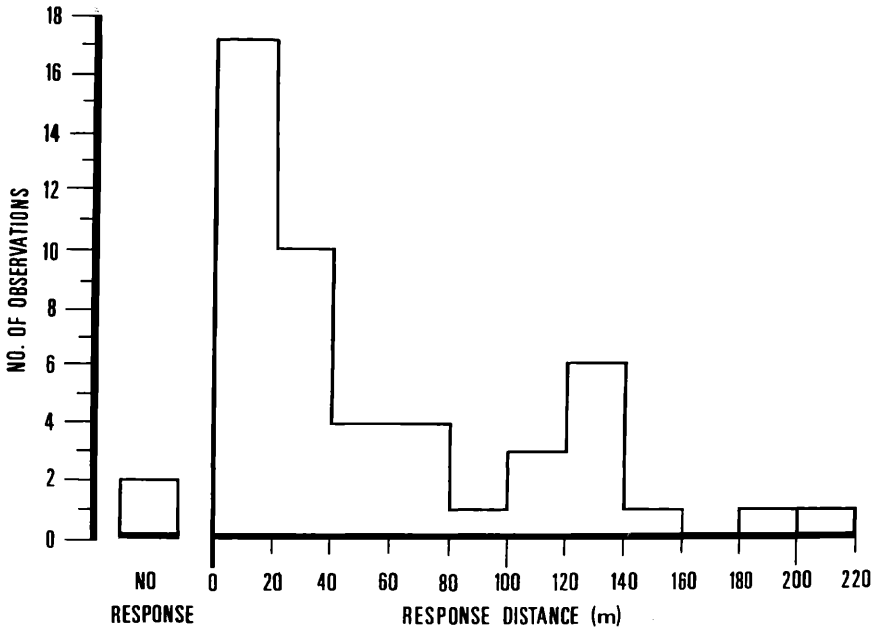

FIGURE 2. Initial response distances of a flush/run (level 3) or higher level behavior. Note that the two instances of no response occurred during hatching. Approach to birds was no closer than 2 m in these cases.

potential predators (e.g., *Larus* sp., and *Falco* sp.) were similar to those elicited by humans except that feigning was not observed, while attacks and strikes (level 5) were observed. Reactions to non-predatory species (e.g., *Phalacrocorax* sp., and *Anas* sp.) included head-up, crouch, and flush/run.

Humans elicited a significantly higher level of response (2.89, $n = 45$) than potential predators (1.54, $n = 45$) or non-predatory species (0.82, $n = 45$; Mann-Whitney U test).

Adults usually flushed from the nest/brood (level 3) at distances <40 m from approaching humans. However, great variation existed and reaction distances as far as 210 m were observed (Fig. 2). Adult behavior was not appreciably altered by vehicles. They moved slowly away, while leading their chicks.

Disturbance effects on chick behavior.—Observations of chicks indicated that their behavior did not appear to change until approaching humans were about 160 m distant. Pedestrians within 160 m of chicks affected four behavioral patterns (Table 4). Pedestrian disturbance significantly reduced the incidence of chicks feeding or brooding, and significantly increased the incidence of chicks being vigilant, or sitting. It also resulted in a significantly lower pecking rate during feeding (5.7 pecks/min, $n =$

TABLE 4. Changes in Piping Plover chick activities during disturbed (pedestrians within 160 m) and undisturbed 3 min observation bouts.

Condition	Percent occurrence of each activity[a]				
	Feeding[b]	Brooding[b]	Sitting[b]	Vigilance[b]	*n*
Disturbed	25.5	0.1	19.8	67.9	106
Undisturbed	72.2	24.5	10.4	6.6	212

[a] More than 1 behavior sometimes occurred during observation bouts.
[b] Significant (Chi-square test) using the original data.

79.8 min) than when chicks were undisturbed (12.5 pecks/min, $n = 964$ min; Mann-Whitney U-test). However, other aspects of feeding behavior including number of stops/min, distance traveled/min and proportion of time stationary were unaffected. Further, chicks responded to approaching vehicles with apparent indifference. One chick (age 5 d) was observed jumping out from the path of a vehicle's front tire, a mere 1–1.5 m distant.

Rain effects on chick behavior.—Chicks aged 6–10 d and aged 16–20 d feed significantly less frequently in rain than in fair weather (Table 5). The decreased foraging time may be partly attributed to adult brooding bouts being significantly longer during rain (16.7 min, $n = 53$ bouts) than during fair weather (9.8 min, $n = 16$ bouts). Wet weather may have contributed to chick mortality. Two (ages 3 and 16 d) of the five chicks for which we could determine exact time of mortality died during heavy rain.

DISCUSSION

The population of Piping Plovers decreased throughout Nova Scotia between 1983 and 1987 at a rate of 3.3–5.8 pairs/yr. Moreover, the population was apparently declining prior to 1983. The only apparent inconsistency with this pattern, is the observation that fledging success in our study was not notably lower than that found by other workers, despite our population decline. However, this is likely due to the different criterion used to assess a successfully fledged chick. We considered a chick fledged at age 17 d, which is conservative relative to other studies (e.g., Cairns 1982, and Haig 1985).

We hypothesize that such a decline could be caused by human disturbance altering chick behavior, thereby increasing their susceptibility to inclement weather and predators, and consequently increasing mortality. The data support this notion. Behavioral responses to disturbance were substantial. Adults responded to approaching humans at a higher level than to potential predators and non-predatory species. Further, responses occurred at various distances and did not involve attacks or strikes. Simmons (1955) found that shorebird responses are related to predator type and, in particular, to the degree of danger a predator represents. Responses to dangerous predators are elicited at greater distances and do not involve physical contact (Armstrong 1954). Adult Piping Plovers responded to

TABLE 5. Changes in Piping Plover chick feeding activity during raining and non-raining 1 min observation bouts.

Condition	Percent of time feeding			
	Age 6–10 days[a]	*n*	Age 16–20 days[a]	*n*
Raining	1.3	75	6.3	112
Not raining	68.0	75	76.8	112

[a] Significant (Chi-square test) using the original data.

humans in this manner, perhaps indicating that man is perceived as being dangerous.

This may explain why chick behavior changed when people were within 160 m. More time was devoted to vigilance or sitting and less to feeding and brooding. Moreover, when feeding did occur, it was at a reduced rate. Thus, human disturbance caused chicks to shift tactics from feeding and energy conservation to vigilance and cryptic predator avoidance. Given sufficient disturbance, chick energy reserves would be depleted making them more susceptible to inclement weather and predators.

Evidence that inclement weather plays a role in chick mortality is supported by the finding that rain leads to a decrease in feeding and an increase in brooding bout length. Thus, chicks may be expending more energy than they gain during inclement weather. Although it is unknown whether disturbance increased chick predation, it seems reasonable to suspect that if chicks are weakened by prolonged disturbance, they would become easier prey.

Disturbance affected fledging success. Chick loss apparently occurred between the ages of 10 and 17 d, since an inverse relationship between survival and amount of disturbance occurred for chicks aged 17 d, but not for chicks aged 10 d. The finding that disturbance decreases fledging success is collaborated by other studies (Cairns 1977, Lambert and Ratcliff 1981).

Our study supports the view that fledging success is adversely influenced by human disturbance. Moreover, it is plausible that disturbance, by altering chick behavior, causes increased mortality. Since Piping Plovers are fairly long-lived (Wilcox 1959) and site faithful (Haig and Oring 1988, Wilcox 1959), continual low fledging success on disturbed beaches was probably responsible for the population decline in Nova Scotia. In a similar manner, disturbance may be an important component explaining the species' range-wide population decline.

ACKNOWLEDGMENTS

This study was supported by funding from the Nova Scotia Bird Society, Nova Scotia Department of Lands and Forests, and Canadian Wildlife Service. We thank Martha Gorman and Jo-Ann Flemming for their able field assistance, and our many volunteers from the Nova Scotia Bird Society for conducting censuses.

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Received 24 Oct. 1986; accepted 22 May 1988.