Beetles (Coleoptera) in the diet of Piping Plovers in the Iles de la Madeleine, Québec, Canada

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Coleoptera remains from droppings collected for a fecal analysis study of the diet of Piping Plovers (*Charadrius melodus*) in the Iles de la Madeleine, Québec, Canada were examined and identified to species level. Beetles found in the bird's droppings included *Bledius opaculus* LeConte (Staphylinidae), *Philopedon plagiatum* (Schaller), *Dryocoetes autographus* (Ratzeburg) (Curculionidae), *Baeckmanniolus dimidiatipennis* (LeConte) (Histeridae), *Negastrius delumbis* (Horn) (Elateridae), *Dyschiriodes sellatus* (LeConte), *Harpalus affinis* (Schrank), and *Cicindela* species (Carabidae). *Bledius opaculus*, an algae-feeding rove beetle that inhabits sand- and mud-flats, was two orders of magnitude more abundant than any other species.

These results allow for insights into the feeding strategy and preferences of Piping Plovers and the ecological circumstances of the environment they occupy. Piping Plovers are reliant to an important degree on the specialized algae-*Bledius*-*Dyschiriodes* ecological system; they feed in and exploit the resources of several shoreline microhabitats including sand- and mud-flats, sand dunes, beach wrack and the strand line; they appear to be diurnally- and nocturnally-active; they exploit both introduced Palearctic species that now inhabit their environment, as well as beetles that have been accidentally blown or washed into their habitat; prey sizes ranged from 3.2 mm to ~15.0 mm; and they feed on a diverse assemblage of beetles representative of the shore-line inhabiting groups. This indicates that Piping Plovers are able to exploit a diversity of potential food resources in their environment. Their diet in the Iles de la Madeleine, however, appears to be based in large measure on *Bledius opaculus*, and hence this plover is vulnerable to changes that would affect the specialized *Bledius*-based ecosystem.

INTRODUCTION

The Piping Plover *Charadrius melodus* is a small (55 g), endemic, North American shorebird. There are two subspecies, *C. m. melodus* which breeds on the Atlantic coast from Newfoundland south to North Carolina, and *C. m. circumcinctus* which breeds in the central prairie regions of Canada and the United States, with a smaller population found in the Great Lakes area. In Canada, it was upgraded in 1985 from threatened to endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Goosen *et al.* 2002). In the United States, it is listed as endangered in the Great Lakes area and threatened elsewhere by the United States Fish and Wildlife Service (Goossen *et al.* 2002). Given this concern, there has been considerable attention to the biology, habitat requirements, potential threats, and strategies to ensure the Piping Plover's survival and recovery.

However, the available information on Piping Plover diets is often qualitative, anecdotal, or lacking in taxonomic precision. Most identifications of prey have been made only to the level of family or order. Forbush (1925, pp. 473) reported that, "The food of the Piping Plover consists of insects, crustaceans, mollusks, and other small marine animals and their eggs." Howsell (1928, pp. 114) reported that, "The food of this plover, as indicated by the contents of four stomachs secured in Alabama, consist principally of marine worms, fly larvae, and beetles." The only prey items observed by Cairns (1977) were "marine worms." Gibbs (1986) found that talitrid amphipods and seaweed flies comprised the main food source of Piping Plovers in Maine, although remains of ants, beetles, and nereid polychaetes were also found in fecal samples. Crustacean remains were found in 99.7% of samples and insect remains in 14.4% of them. Loegering (1992) sampled substrate invertebrates found on Piping Plover breeding beaches in Maryland. Insects found were identified to order [Diptera, Homoptera, and Hemiptera] with Diptera comprising 91% of all arthropods collected. In connection with studies on nocturnal foraging of Piping Plovers, Staine & Burger (1994) sampled intertidal sand at sites where plovers fed, however, they identified the organisms only to family level [Donacidae (bivalves), Spionidae (polychaetes), Hippidae (sand crabs), and Gammaridae (amphipods)]. Similarly Nordstrom and Ryan (1996) sampled invertebrates, both at sites occupied by Piping Plovers [finding Diptera (four families), Hymenoptera (six families), and Orthoptera (one family)], as well as at potential reintroduction sites. Cuthbert *et al.* (1999) examined the gizzard contents of four dead Piping Plover chicks, however, they identified the invertebrates only to the level of order [Hymenoptera (32%), Coleoptera (29%), Diptera (28%), Hemiptera and Homoptera (10%), and

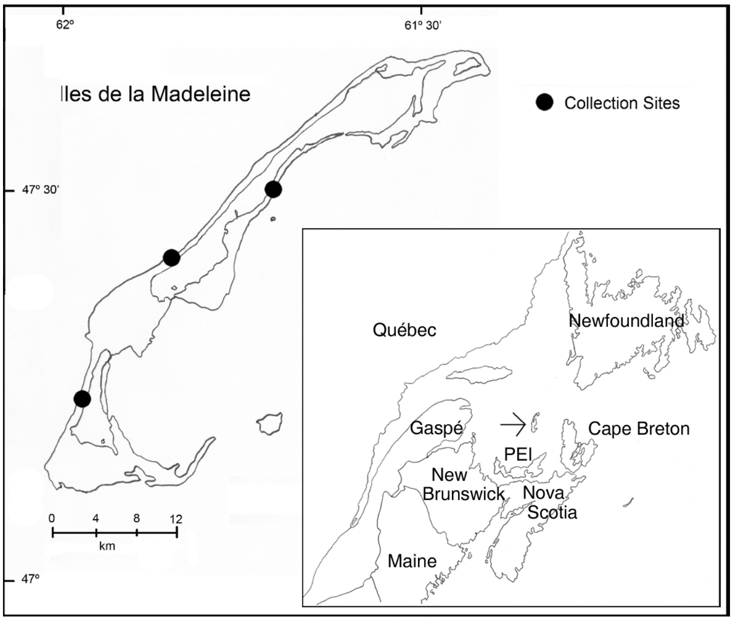

Fig. 1. Map of the Iles de la Madeleine with the collection sites indicated. Inset map shows Atlantic Canada, Québec, and Maine with the position of the Iles de la Madeleine indicated.

Ephemeroptera (1%)]. Nicholls (1989) identified fragments of eight invertebrate classes from 24 fecal samples to the level of order [Hymenoptera, Coleptera, and Diptera]. Elias *et al.* (2000) collected arthropods in areas where Piping Plovers foraged, but reported no information on them other than a relative index of arthropod abundance. Shaffer & Laporte (1994) were able to provide much more information that bears directly on the diet of Piping Plovers through an analysis of the composition of bird droppings. They reported frequencies of insect and invertebrate remains found in droppings; however, identifications were made only to the level of family, or in some cases, order.

While prey determinations to the level of family or order are useful first-order indications of the diet of birds, they obscure differences among prey species. Finer scale identification will contribute better information about the biology, range, abundance, and other components of the bionomics of the prey species that may allow for a more detailed understanding of the diet of the birds and the components of predator–prey interactions. Accordingly, the present study re-examined some of the fecal samples collected by Shaffer & Laporte (1994) for a more detailed understanding of the prey species utilized by Piping Plovers.

METHODS AND CONVENTIONS

A representative group of seven samples collected by Shaffer & Laporte (1994) from the South Dune (47°30'25"N, 61°41'47"W), West Dune (47°18'42"N, 61°57'46"W), and Hospital Beach (47°25'41"N, 61°51'34"W) sites on the Iles de la Madeleine archipelago in Québec (Fig. 1) were re-examined. Sites of feces collection were located along fine sand ocean beaches and on a sand-flat lagoon shore. Samples were gathered from 1990 to 1992 during daylight hours. The focus of the present investigation is the Coleoptera because; i) these constituted the majority of organisms found by the original study; ii) species-level determinations are possible; and iii) after passing through the digestive tract of the bird, broken Coleoptera (exoskeleton fragments such as head capsules, elytra, legs, etc.) retain sufficient physical coherence so as to allow the possibility of species-level identification. The frequency of occurrence of invertebrates was quantitatively determined by Shaffer & Laporte (1994). Consequently the aim of this study was to add species level determinations to this dataset to allow for a more detailed interpretation.

Broken fragments of Coleoptera were determined to family, subfamily, tribe, or genus level based on the first author's knowledge of the anatomy and taxonomy of beetles of the region. Thereafter species-level determinations were made by comparing fragments with reference specimens in the Coleoptera collection of the Nova Scotia Museum, through the use of various taxonomic reference works, and through consultation with colleagues. A description of the methodology of the original study is provided by Shaffer & Laporte (1994).

RESULTS

Remains of 342 individual beetles were examined, representing the four groups of Coleoptera (Carabidae, Cicindelinae, Curculionidae, and Staphylinidae) identified in Shaffer and Laporte's (1994) study. Additionally remains of three other groups (Elateridae, Histeridae, and Scolytinae) were identified amongst the Coleoptera remains. These represented eight species of beetles, seven of which were identifiable to species, the eighth to one of three species within a genus (Table 1).

DISCUSSION

Bionomics of prey species

Table 2 summarizes the bionomics of Coleoptera species that were found in Piping Plover diets. Specific details follow.

Bledius opaculus LeConte, 1863 (Staphylinidae: Oxytelinae) (Fig. 2a)

All the Staphylinidae in the samples examined were *Bledius opaculus,* a coastal marine species, previously recorded in Canada from Nova Scotia, Prince Edward Island, and insular Newfoundland, and ranging south in the United States from

Fig. 2a.

Fig. 2b.

Fig. 2c.

Fig. 2d.

Fig. 2e.

Fig. 2f.

Fig. 2. Habitus photograph of (a) *Bledius opaculus* (LeConte), (b) *Philopedon plagiatum* (Schaller) (c) *Dyschiriodes sellatus* (LeConte) (d) *Baeckmanniolus dimidiatipennis* (LeConte), (e) *Negastrius delumbis* (Horn) and (f) *Harpalus affinis* (Schrank). Photographs by C.G. Majka.

Maine to North Carolina (Herman 1976). It is herein recorded for the first time from the Iles de la Madeleine, and from the province of Québec. The only larval remains observed in the fecal samples were those of staphylinids, consistent in anatomy with those of *Bledius*.

Bledius species are found on moist, un-vegetated and algae-covered sand flats along the ocean. According to Lengerken (1929), adults are nocturnal feeders and harvest green algae such as *Oocystis solitaria* Wittr., *Oocystis parva* West., *Anchistrodesmus falcatus* Ralfs, and *Conferva minor* Klebs); blue-green algae such as *Oscilitoria amphibia* Ag. and *Anabaena* sp., and diatoms (species undetermined) from the mud or sand surface, storing it in chambers excavated in the mud where the females lay eggs and rear young. They construct complex networks of burrows and associated tumuli (or casts) on the surface of the sediments (Herman 1986, Larsen 1936). The very large proportion of *Bledius opaculus* remains in the feces of Piping Plovers is an indication that the birds are foraging extensively on sand and mud flats. Their presence in the diet of Piping Plovers may indicate nocturnal foraging as reported by Staine & Burger (1994), or the birds may be able to locate the beetles and their larvae in their burrows during the day.

Table 1. Coleoptera in the diet of Piping Plovers, Iles de la Madeleine, Québec.

Location	South Dune	West Dune			Hospital Beach	Total
	8 July 1992*	7 July 1992	8 July 1992	9 July 1992*	9 July 1992	
Bledius opaculus	70	10	18	200	24	322
Philopedon plagiatum	3	2		1	1	7
Dryocoetes autographus	5					5
Dyschiriodes sellatus					3	3
Baeckmanniolus dimidiatipennis	1	1				2
Negastrius delumbis		1				1
Harpalus affinis					1	1
Cicindela sp.			1			1

Note: numbers indicate the number of specimens found in each sample. * = two samples combined.

Table 2. Bionomics of Coleoptera species found in Piping Plover diets.

	Habitat	Trophic category	Adult habits	Length (mm)
Bledius opaculus LeConte	sand/mud flats	algophagous	nocturnal	3.6–4.7
Philopedon plagiatum (Schaller)	sand dunes	rhizophagous		4.5–8.0
Dryocoetes autographus (Ratzeburg)	beach-drift	saproxylic	N/A	3.4–5.0
Dyschiriodes sellatus (LeConte)	sand/mud flats	predaceous	nocturnal	4.3–5.0
Baeckmanniolus dimidiatipennis (LeConte)	beach-drift	predaceous		3.2–4.5
Negastrius delumbis (Horn)	sand dunes	predaceous	nocturnal	3.5–5.2
Harpalus affinis (Schrank)	open habitats	predaceous	diurnal	8.5–12.0
Cicindela sp.	sand dunes	predaceous	diurnal	10.0–15.0

Philopedon plagiatum (Schaller, 1783) (Curculionidae: Entiminae) (Fig. 2b)

All the weevils (Curculionidae) in the samples examined were *Philopedon plagiatum*, an introduced Palearctic weevil first recorded in North America in 1934 in the Iles de la Madeleine, and thereafter found in New Brunswick (1939), on Prince Edward Island (1940) (Brown 1940, 1950), and in Nova Scotia (1970) (Majka *et al.* 2007a). In North America it is restricted to Atlantic Canada.

It is a large root weevil associated with sandy, coastal, habitats where it feeds on the roots of marram grass, *Ammophila breviligulata* Fern. (Poaceae) (Hoffman 1950). The presence of this species in the diet of Piping Plovers would appear to indicate that the birds are foraging for larger invertebrates in sand dunes.

Dryocoetes autographus (Ratzeburg, 1837) (Curculionidae: Scolytinae)

A surprising find in the feces of Piping Plovers were a number of specimens of *Dryocoetes autographus,* a bark beetle common throughout eastern and Atlantic Canada associated with conifers in the genera *Abies, Picea, Pinus*, and *Tsuga* (Pinaceae) (Bright 1976, Majka *et al.* 2007a). It is found throughout North America south to New Mexico and North Carolina (Wood 1982).

Although dune and sand-spit environments cover some 60% of the Iles de la Madeleine, there are stands of coniferous trees that support populations of these bark beetles. They disperse aerially looking for new food sources (phloem of recently dead or dying conifers) and are good fliers. C.G. Majka has found *Dryocoetes* specimens in beach drift material in both New Brunswick and Prince Edward Island (unpublished data), an indication that in the course of aerial dispersal they have been blown out to sea and have subsequently washed up on beaches. It would seem that such beetles are opportunistically consumed by Piping Plovers, an indication that Piping Plovers can utilize unconventional food sources to augment their diet and that they forage in beach-wrack areas.

Dyschiriodes sellatus (LeConte, 1857) (Carabidae: Scaritinae) (Fig. 2c)

In Canada this is a coastal Atlantic species recorded from New Brunswick, Newfoundland, Nova Scotia, Prince Edward Island, and Québec (Bousquet & Larochelle 1993). Larochelle (1973) recorded the species from Grosse Ile and Ile du Havre Aubert in the Iles de la Madeleine. In North America it is found south along the Atlantic coast to Florida, and in the interior of the continent from North Dakota south to Texas (Bousquet & Larochelle 1993).

Species of *Dyschiriodes* are almost exclusively associated with rove beetles of the genus *Bledius* on which they prey (Herman 1986). *Dyschiriodes sellatus* is found on sea beaches, saline banks of rivers, brooks, lakes, pools, and lagoons, always close to water on wet, sandy, saline, or alkaline soils. It is primarily nocturnal, sheltering during the day in burrows. The larvae burrow under the soil. Herman (1986) recorded *Dyschiriodes sellatus/Bledius opaculus* predator/prey associations. Their presence in the diet of Piping Plovers may also indicate nocturnal foraging.

Baeckmanniolus dimidiatipennis (LeConte, 1824) (Histeridae: Saprininae) (Fig. 2d)

In Canada *Baeckmanniolus dimidiatipennis* is known solely from the Gulf of St. Lawrence, the northeastern Atlantic coast of Nova Scotia, and Sable Island (Bousquet & Laplante 2006). In the United States it is found on the Atlantic coast from Rhode Island and Connecticut south to Georgia (Downie & Arnett 1996; Sikes 2004).

It is found on ocean beaches, under seaweed, and on carrion. It is previously recorded from the Iles de la Madeleine

(Bousquet & Laplante 2006). The species is apparently predaceous on the larvae and eggs of Diptera that are found in decaying organic matter. C.G. Majka has found them almost exclusively in association with carrion and decomposing material in the beach drift zone (Klimaszewski *et al.* 2006; Klimaszewski & Majka 2007) and has observed them to be active diurnally. Hence their presence in the diet of Piping Plovers would indicate the birds are foraging in the specialized beach-wrack microhabitat.

Negastrius delumbis (Horn, 1891) (Elateridae: Negastriinae) (Fig. 2e)

Negastrius delumbis is found in coastal situations throughout the Maritime Provinces, ranging south in the United States to New York State (Majka & Johnson 2008, Stibick 1990). It is a small, flightless, predaceous, click beetle found in sand dunes associated with *Ammophila breviligulata* and sea-rocket, *Cakile edentula* (Bigelow) Hook (Brassicaceae). It is a nocturnal species found on the upper margins of beaches (Stibick 1990). Their presence in the diet of Piping Plovers might again indicate nocturnal foraging as reported by Staine & Burger (1994). Although *N. delumbis* is a common coastal species of New Brunswick, Nova Scotia, and Prince Edward Island in the Maritime Provinces (Majka & Johnson 2008), they have not previously been reported from the Iles de la Madeleine and from Québec. Hence this report newly records their presence in the province.

Harpalus affinis (Schrank, 1781) (Carabidae: Harpalinae) (Fig. 2f)

Harpalus affinis is an introduced ground beetle first recorded in North America prior to 1798 and first detected in the Maritime Provinces in Nova Scotia in 1899, in New Brunswick in 1904, and on Prince Edward Island in 1970 (Majka *et al.* 2007b). Larochelle (1973) recorded the species from Grosse Ile, Ile du Havre Aubert, Ile Brion, Ile d'Entrée, Ile de la Grand Entrée, and Ile du Cap aux Meules in the Iles de la Madeleine. It is now found throughout much of North America (Bousquet & Larochelle 1993).

Although *Harpalus affinis* is found in a wide variety of habitats including pastures, meadows, fields, gardens, sand and gravel pits, sand dunes, orchards, clearings and forests (Larochelle & Larivière 2003) in the Maritime Provinces, it is frequently encountered in open coastal environments. Adults feed on a wide variety of insects and invertebrates as well as seeds. They are primarily diurnal, macropterous, and are frequent fliers and moderate runners (Larochelle & Larivière 2003).

Cicindela species (Carabidae: Cicindelinae)

Broken fragments from the elytra of a *Cicindela* sp. were found in one fecal sample. The small fragments do not allow for a specific determination. In the Iles de la Madeleine three species in this genus are present: *Cicindela repanda repanda* Dejean, 1825, *Cicindela hirticollis rhodensis* Calder, 1916, and *Cicindela tranquebarica tranquebarica* Herbst, 1806 (Larochelle 1973). These three tiger beetles are active predators feeding on many invertebrates and frequently found in sandy, coastal, beaches (Leonard & Bell 1999). Tiger beetles are significantly larger than most of the other prey consumed by the Piping Plovers in the Iles de la Madeleine, and are also very quick runners and fliers. It is possible that Piping Plovers are able to capture these swift-moving beetles, or that they are able to opportunistically take advantage of dead or disabled individuals.

General observations

These species-level Coleoptera determinations allow for a number of insights into feeding strategy and preferences of Piping Plovers and the broader ecological circumstances of the environment they occupy. The vast majority of beetles consumed by Piping Plovers are the staphylinids, *Bledius opaculus*, found by Shaffer & Laporte (1994) in 43.8% of fecal samples (Table 3). In the present study they were two orders of magnitude more abundant than any other species (Table 1). Furthermore, it is seems almost certain that the Coleoptera larvae reported by Shaffer & Laporte (1994) in 20.0% of bird droppings are also of this species. Additionally a small proportion of beetles consumed are *Dyschiriodes sellatus*, a predatory beetle associated almost exclusively with *Bledius*.

Rove beetles of the genus *Bledius* are unique amongst the Staphylinidae in feeding on and harvesting unicellular diatoms, green and blue-green algae from sand- and mud-flats. Their abundance in the areas utilized by the Piping Plovers in the Iles de la Madeleine would appear to indicate that primary algal production is an important component of the ecological energetics of this habitat. Herman (1986, pp. 50) observed that, "The algae upon which *Bledius* feed grow in the interstices between sand grains . . . The algal cells there are single-celled or in small groups but if cultured will grow into long filaments. When *Bledius* are grown in cultures in which the algae have become filamentous, they starve; their guts are empty despite there being individuals with algal filaments hanging from the mouth." Presumably some feature of the environment (perhaps regular tidal or wave agitation?) maintain the unicellular growth forms of the algae, an important feature of the bio-physical environment for *Bledius* and consequently for Piping Plovers in the Iles de la Madeleine. Consequently this food chain is reliant on the environmental conditions that make possible this primary productivity, and hence is vulnerable to circumstances that might disrupt these conditions (i.e. repetitive passage of off-road vehicles (ORV's), pesticide runoff from agricultural use, and oceanic and tidal conditions that maintain sand- and mud-flats). ORV traffic has also been singled out as particularly destructive to beach-wrack environments (Godfrey *et al.* 1978), a microhabitat exploited by Piping Plovers.

The Coleoptera consumed by Piping Plovers are found in several distinct littoral microhabitats:

Table 3. Invertebrates found in Piping Plover droppings.

	Frequency (%)
Coleoptera: Staphylinidae	43.8
Coleoptera: species	35.4
Coleoptera: Curculionidae	31.5
Diptera: adults	31.5
Coleoptera: larvae	20.0
Amphipoda	16.9
Diptera: larvae	10.0
Gastropoda	8.5
Coleoptera: Cicindelinae	4.6
Coleoptera: Carabidae	1.5
Hymenoptera	0.8

Note: Sample N = 130; data derived from Shaffer & Laporte (1994)

a. sand- and mud-flat (*Bledius opaculus*, *Dyschiriodes sellatus*);
b. sand dune (*Philopedon plagiatum, Negastrius delumbis, Cicindela* sp.);
c. strand-line/beach wrack (*Baeckmanniolus dimidiatipennis, Dryocoetes autographus*).

This indicates that Piping Plovers are able to adapt their foraging strategy to include these microenvironments and the food resources that are available in each. This agrees with the findings of Elias *et al.* (2000) who found that Piping Plovers in New York foraged in ephemeral pools, bay tidal flats, the intertidal zone, beach wrack, open beach vegetation, and backshore habitats (in that order of precedence), mirroring the relative arthropod abundance in these microhabitats (except that open vegetation biotypes had a somewhat high relative arthropod abundance). Ephemeral pools and bay tidal flats had a much higher relative arthropod abundance than other biotypes. Unfortunately the authors did not supply any information on the taxonomic composition of the arthropods in these microhabitats. Furthermore, Elias *et al.* (2000) demonstrated that beach environments that included ephemeral pools and bay tidal flats (of the kind where *Bledius* spp. might reasonably be expected to occur) were of superior value to Piping Plovers. The birds preferred such habitats, they foraged more extensively in them, and (in at least one year of the study) chick survival rates in such areas were higher.

Prey species in the Iles de la Madeleine are composed of both nocturnally (*B. opaculus*, *D. sellatus, N. delumbis)* and diurnally active (*B. dimidiatipennis, Cicindela* sp., *Harpalus affinis*) species, an indication that Piping Plovers may be foraging both at night and during the day. Piping Plovers take advantage of food resources that may have accidentally washed into the environment (*D. autographus*) and of introduced species that now inhabit their environment (*H. affinis*, *P. plagiatum)*, indications of some degree of short-term, and long-term behavioral and dietary plasticity.

There is also variety in terms of the sizes of prey items that are taken. Although the preponderance of specimens are in the 3.2–5.0 mm size range (*B. opaculus, D. autographus, D. sellatus, B. dimidiatipennis, N. delumbis*) some larger species (*Cicindela* sp., *H. affinis, P. plagiatum*) are also consumed, potentially up to 15 mm in the case of the *Cicindela* species. Representatives of five families of Coleoptera, including both predaceous and herbivorous beetles, are found in the diet of Piping Plovers.

Not found in these fecal samples were remains of an assemblage of small, sandy-beach and beach-drift inhabiting beetles found in many beach environments in the region (Klimaszewski *et al.* 2006; Klimaszewski & Majka 2007, Majka & Ogden 2006; C.G. Majka unpublished data). These include *Brachygluta abdominalis* (Aubé) [~2.0 mm], *Atheta (Datomicra) acadiensis* Klimaszewski & Majka [2.0–2.5 mm], (Staphylinidae); *Cercyon litoralis* (Gyllenhal) [2.0–3.2 mm] (Hydrophilidae); *Monotoma producta* LeConte [2.5–3.0 mm] (Monotomidae); *Amblyderus pallens* (LeConte) [2.6–2.8 mm], *Sapintus fulvipes* (LaFerte) [2.3–2.7] (Anthicidae); and *Atomaria ochracea* Zimmerman [1.4–1.8 mm] (Cryptophagidae). It is possible (although unlikely) that none of these species are present in the Iles de la Madeleine in the sites frequented by Piping Plovers, or that remains of these were degraded and not found in the samples examined. It is, however, noteworthy that all these species are ≤3.2 mm whereas all of the species found in the fecal samples are ≥3.2 mm (Table 2). It is possible that this represents a size-threshold for prey items below which Piping Plovers do not forage, possibly because items of this size are too difficult to see or grasp, or else are too small to be energetically or nutritionally worth investing the time or energy to locate and consume.

Even with data from the present study, combined with those of Shaffer & Laporte (1994), it is difficult to provide a quantitative measure of the contribution of the various invertebrates to the diet of Piping Plovers in the Iles de la Madeleine. This is so for several reasons. The frequencies of occurrence of different invertebrate groups in the droppings of Piping Plovers reported by Shaffer & Laporte (1994, our Table 2) do not reflect their proportion in the diet, but simply their frequencies in droppings. The numbers in Table 1 do provide such proportions; however, the significant variations in size between different prey species would have to be factored into a dietary analysis. Also, as Shaffer & Laporte (1994) pointed out, soft-bodied organisms (such as many worms) leave few or no identifiable remains in bird droppings. Hence an approach based on fecal analysis will miss this component of the bird's diet.

Our analyses show that Piping Plovers exploit a variety of food resources both diurnally and nocturnally in a spectrum of shoreline microhabitats. Other studies at other sites (*i.e.* Cairns 1977, Cuthbert *et al.* 1999, Forbush 1925, Gibbs 1986, Howsell 1928) have reported other prey items. The variety of prey items (even when identified only to the level of family or order) indicate that Piping Plovers are able to accommodate their foraging strategy and diet to a variety of circumstances and potential food sources. This agrees with the findings of Elias *et al.* (2000) whose results suggested that food resources for Piping Plovers vary from biotype to biotype and that the plovers respond by altering their use of these habitats

In the Iles de la Madeleine they appear to be particularly reliant on *Bledius opaculus* and the specialized microenvironment that it both inhabits and creates. Given the frequency of *Bledius* in Piping Plovers diets, and the fragile and potentially vulnerable nature of the sand burrow/algae caches constructed by these beetles, attention should be devoted to ensuring the long-term viability of this environment. Elias *et al.* (2000) pointed out that Piping Plovers are adept at the adventitious exploitation of food in variable environments. Ephemeral pools, in particular, are created and maintained by overwash and wave scour. Many coastal management strategies (jetty construction, breach filling, dune building, etc.) are directed at preventing overwashing and scouring, and coastal mudflats have been threatened or degraded by other developments (Percy 1996, 1999). Ephemeral pools and bay mudflats have become relatively rare in many areas on the Atlantic coast, perhaps partly as a consequence of such management practices (Elias *et al.* 2000). All of these results raise important questions about the strategies that need to be followed in order to assure the successful recovery of this species.

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