NOTES

SNOWY PLOVER DIETS IN 1995 AT A COASTAL SOUTHERN CALIFORNIA BREEDING SITE

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The Snowy Plover (*Charadrius alexandrinus*) feeds by pecking at the ground for invertebrates and catching insects in the air while on the run. Along the Pacific Coast, Snowy Plovers feed on both marine and terrestrial invertebrates, but little more specific information is available (Reeder 1951, Page et al. 1995).

Various methods are available for studying avian diets, including stomach content, fecal analysis, and direct observation (Rosenberg and Cooper 1990). Stomach-content analysis requires sacrifice of a large number of birds or the use of stomach pumps (Ramer et al. 1991, Martin and Hockey 1993). Poulin and Lefebvre (1995) reported tartar emetic to be safe and more effective than fecal analysis for investigating avian diets, yet 70 (2.9%) of the birds they sampled died. They found some families were more sensitive to the chemical than others and did not test it on plovers. Use of these techniques on a threatened bird like the Snowy Plover would not be acceptable or appropriate (Ralph et al. 1985). Direct observation of the prey of small shorebirds is difficult because their prey are so small (Baker 1977, Rundle 1982).

Fecal analysis has been used successfully in diet studies of other shorebirds (Swarth 1983, Nicholls 1989, Le V. Dit Durrel and Kelley 1990, Shaffer and LaPorte 1994). Although there is some bias associated with fecal analysis due to the differential digestion and passage rates of prey items, there is generally good agreement between fecal and stomach-content analyses (Rosenberg and Cooper 1990). Fecal samples are relatively easy to collect, and prey fragments are easily extracted because birds lack digestive enzymes capable of breaking down chitinous exoskeletons (Swarth 1983). Soft-bodied organisms such as polychaete worms, however, break down readily and are not well represented in fecal samples (Rundle 1982, Shaffer and LaPorte 1994).

The objectives of this study were to describe the diet of the Snowy Plover during the 1995 breeding season at a single coastal southern California breeding site and to identify available invertebrate prey in the same area. We chose to use fecal samples as the least invasive method to investigate diets to minimize the impacts on this threatened species.

The Santa Margarita River mouth, in Camp Pendleton Marine Corps Base (33° 13' 57" N, 117° 24' 37" W), San Diego County, provides a variety of habitats for foraging and breeding Snowy Plovers. As part of ongoing research on Snowy Plovers in southern California, Powell et al. (1995) estimated that the population breeding at this site in 1995 was 92 males and 69 females. Sandy beach and salt flats were the major habitats used for nesting.

We collected fecal samples opportunistically between April and July of 1995 during routine nest monitoring and banding. We observed adult and young plovers first through binoculars or spotting telescopes, then searched the ground where we observed a bird defecating. We found that binoculars worked better than spotting scopes, because of better depth of field definition, especially when we worked alone. We easily distinguished fresh feces from old, dried droppings. We did not collect samples if there was any doubt whether they had been deposited by a Snowy Plover. Actively foraging plovers defecate about every eight minutes (Swarth 1983). Snowy

Plovers can forage far from their nests, so we could not assume that fecal samples collected in a particular habitat contained fragments of prey that were actually consumed there. Collected feces were labeled with the date, location, and identity of the individual plover, then preserved in 70% ethanol.

We identified fecal contents through an Olympus SZ10 research stereo dissecting microscope, and used our reference collections to help identify exoskeleton fragments (Table 1). We attempted to identify fragments to family or order by direct comparison of parts to our reference collection, combined with keys to invertebrate identification (Ricketts et al. 1985, Borror et al. 1989).

In addition to fecal samples, we sampled invertebrates to build a reference collection and obtain a qualitative inventory of prey items. The habitats at the sampling sites, all located south of the Santa Margarita River mouth, were unprotected sandy beach, protected sandy beach, salt flat, and mudflat. The unprotected sandy beach site, which was exposed to wave action, included upper (above the tideline) and lower (intertidal) beach. The mudflat consisted of a 5-cm sun-baked clay layer covered with benthic algae, and underneath the clay layer there was coarse wet sand. Salt flats were sampled during both "normal" dry conditions and after very high spring tides had inundated large sections of this area. The Santa Margarita River changed course in 1993, leaving a small tidal lagoon in its old path, and the protected sandy beach site, which was not exposed to wave action, was located in this area. We did not sample much in sand dunes to avoid disturbing the Least Terns (*Sterna antillarum*) nesting there.

We used sticky traps and sweep nets to collect flies and other flying insects and sticky traps to capture crawling insects. Subsurface invertebrates were collected with cores taken to 5 cm (the distance likely to be accessible to a probing plover) and then sifted through a 1-mm sieve. We occasionally captured by hand. Pit traps were not used since they could trap plover chicks. Invertebrates were labeled with location and date and preserved in 70% ethanol.

The prey items identified in 32 fecal samples from adult plovers included at least nine families in six orders of insects (Figure 1). Beetles (Coleoptera) occurred in 23 (72%) of the samples, and rove beetles (Staphylinidae) were the most frequent prey. Half of the fecal samples collected at the unprotected sandy beach site contained remnants of rove beetles only. Flies (Diptera) occurred in 14 (44%) of the fecal samples, and a single fecal sample from the unprotected sandy beach site contained over 35 fly heads. Long-legged flies (Dolichopodidae) and shoreflies (Ephydridae) were the primary dipteran families found in the feces (Figure 1). Insect larvae were

Table 1 Fragments Found in Snowy Plover Fecal Samples Used for Invertebrate Identification

Order	Family	Parts used for identification
Coleoptera	Staphylinidae	elytra, wings, carapace, head, mandible, antennae, legs
	Carabidae	carapace, head, mandible
	Cicindelidae	carapace, elytra
Diptera	Ephydridae	wings, head, abdominal segments
	Dolichopodidae	wings, head, legs, abdominal segments
	Anthomyiidae	wings, head
Hymenoptera	Braconidae	wings
Hemiptera	Saldidae	wings, body, head
Decapoda	Hippidae	carapace
Neogastropoda	Nassaridae	shell

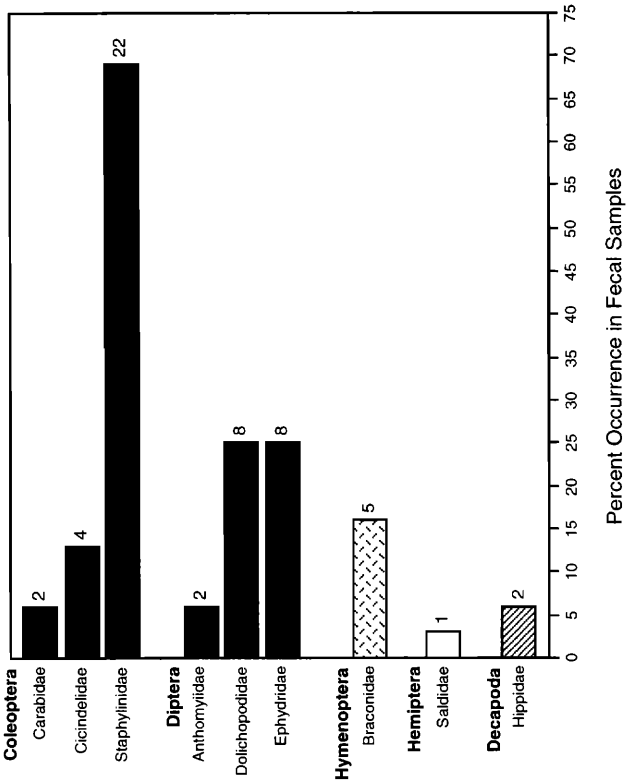

Figure 1. Frequency of various families of invertebrates in fecal samples of adult Snowy Plovers. Numbers to the right of bars indicate number of samples.

found in 16 (25%) of the fecal samples, especially in salt flat and protected sandy beach habitats. Ninety-seven percent of all feces collected from adults contained at least one of these three insect families: the Staphylinidae, Dolichopodidae, or Ephydridae.

The feces of three fledglings and one two-week-old chick were collected from sandy beach sites. All four samples included rove beetles. Long-legged flies were in two samples, Braconidae in one sample, and insect larvae in one sample. The feces of the two-week-old chick contained only rove beetles.

We identified 22 families of invertebrates in samples from all habitats. The insect families were the Ephydridae, Dolichopodidae, Anthomyidae, Coelopidae, Asilidae (Diptera); Staphylinidae, Carabidae, Cicindelidae, Curculionidae, Tenebrionidae (Coleoptera); Braconidae, Dryinidae, Formicidae (Hymenoptera), and Saldidae (Hemiptera). Non-insect families were the Hippidae (Decapoda), Conidae (Gastropoda), Halacaridae (Acarina), and five of polychaetes (Annelida): the Spionidae, Glyceridae, Arabellidae, Capitellidae, and Opheliidae. Dolichopodidae and Ephydridae were present in all habitats sampled, and Staphylinidae occurred in all but one of the habitats. Unidentified insect larvae were collected at both sandy beach sites. The greatest variety

of potential prey items available to foraging plovers occurred at the unprotected sandy beach site, mainly because of the presence of five families of polychaete worms.

Snowy Plovers appeared to concentrate their foraging effort on a few terrestrial insect families (mainly flies and beetles) at the Santa Margarita River mouth. The families most abundant in our samples were widely distributed among habitats. However, polychaete worms are digested too completely to be identified in fecal samples by our technique, so the extent to which worms contributed to the diet of Snowy Plovers in our study was unknown; they may be important. Reeder (1951) found polychaete worms in the stomachs of three Snowy Plovers collected during the breeding season along the southern California coast. We observed Snowy Plovers feeding on worms on several occasions. Polychaete worms could be important prey for Snowy Plovers foraging in intertidal areas.

Hofmann and Hoerschelmann (1969; cited in Cramp and Simmons 1983) reported that the stomach of one Kentish Plover (*Charadrius a. alexandrinus*) contained 124 beetle heads. Grover and Knopf (1982) reported rove beetles as abundant where Snowy Plovers forage in Oklahoma. We found rove beetles in the majority of fecal samples of Western Snowy Plovers at the Santa Margarita River mouth. However, because the percent occurrence of an organism in fecal samples is based on its presence or absence, the actual nutritional or volumetric contribution of rove beetles may not exceed that of other abundant prey, long-legged flies or shoreflies. Flies formed large, dense swarms, and plovers were frequently observed foraging within these swarms. Our results were consistent with the findings of diet studies of the Snowy Plover elsewhere. Swarth (1983) found beetles and shoreflies constituting the major prey of Snowy Plovers at Mono Lake, California; Grover and Knopf (1982) found them as prey on the Great Salt Plains of Oklahoma. Kentish Plovers in Europe also feed on terrestrial invertebrates, mainly flies and beetles (Cramp and Simmons 1983).

Snowy Plover chicks are highly precocial and leave the nest within a day of hatching to forage in the same habitats as their parents. Although the number of fecal samples from juveniles in our study was small, fledglings fed on the same organisms, with the exception of dipterans, as adults. Plover chicks may be unable to catch fast-moving insects such as dipterans and hymenopterans (Shaffer and LaPorte 1994).

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