ANDERSON, J. T., T. C. TACHA, G. T. MUEHL, AND D. LOBPRIES. 1996. Wetland use by waterbirds that winter in coastal Texas. Natl. Biol. Serv. Inf. Tech. Rep. 8:1–40.

ANDERSON, J. T., G. T. MUEHL, AND T. C. TACHA. 1998. Distribution and abundance of waterbirds in coastal Texas. Bird Pop. 4:1–15.

BLANKENSHIP, T. L. AND J. T. ANDERSON. 1993. A large concentration of Masked Ducks (*Oxyura dominica*) on the Welder Wildlife Refuge, San Patricio County, Texas. Bull. Tex. Ornithol. Soc. 26:19–21.

CONOVER, W. J. AND R. L. IMAN. 1981. Rank transformations as a bridge between parametric and nonparametric statistics. Am. Stat. 35:124–129.

COWARDIN, L. M., V. CARTER, F. C. GOLET, AND E. T. LAROE. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. FWS/OBS-79/31:1–103.

GOMEZ-DALLMEIER, F. AND A. CRINGAN. 1990. Biology, conservation and management of waterfowl in Venezuela. Editorial Ex Libris, Caracas, Venezuela.

JOHNSGARD, P. A. AND M. CARBONELL. 1996. Ruddy Ducks and other stifftails: their behavior and biology. Univ. of Oklahoma Press, Norman.

JOHNSGARD, P. A. AND D. HAGEMEYER. 1969. The Masked Duck in the United States. Auk 86:691–695.

LOCKWOOD, M. W. 1997. A closer look: Masked Duck. Birding 29:386–390.

MUEHL, G. T., T. C. TACHA, AND J. T. ANDERSON. 1994. Distribution and abundance of wetlands in coastal Texas. Texas J. Ag. Nat. Resour. 7:85–106.

POTVIN, C. AND D. A. ROFF. 1993. Distribution-free and robust statistical methods: viable alternatives to parametric statistics? Ecology 74:1617–1628.

SAS INSTITUTE INC. 1988. SAS/STAT user's guide, release 6.03 edition. SAS Institute Inc., Cary, North Carolina.

SOKAL, R. R. AND F. J. ROHLF. 1995. Biometry, third edition. W. H. Freeman and Company, New York.

STEWART, R. E. AND H. A. KANTRUD. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish Wildl. Serv., Resour. Publ. 92:1–23.

TODD, F. S. 1997. Natural history of the waterfowl. Ibis Publishing, Vista, California.

WELLER, M. W. 1968. Notes on some Argentine anatids. Wilson Bull. 80:189–212.

Wilson Bull., 111(1), 1999, pp. 121–123

Gizzard Contents of Piping Plover Chicks in Northern Michigan

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ABSTRACT.—The diet of Piping Plovers (*Charadrius melodus*) is not well known and information on diet requirements will enhance food resource assessment and identification of suitable habitat for this rare species. Discovery of four dead Piping Plover chicks at Grand Marais, Michigan, allowed us to examine their digestive tracts for identifiable prey. Gizzard contents represented 16 families in 6 orders of freshwater and terrestrially occurring insects confirming behavioral observations that plover chicks opportunistically capture insects in shallow water and along shorelines. The most commonly taken orders were Hymenoptera, Coleoptera, and Diptera. *Received 6 May 1998, accepted 30 Aug. 1998.*

Little is known about the diet or foraging behavior of the Piping Plover (*Charadrius melodus*) during any part of its annual cycle. Federal threatened and endangered status (U.S. Fish and Wildlife Service 1985) and sensitivity to human disturbance preclude collection of birds for stomach content analysis and require use of nondisruptive techniques to sample food while plovers are present. Because food availability is critical to shorebird reproductive success, migration, and overwinter survival (Howe 1983, Helmers 1992), assessment of food resources is an important component of conservation efforts for this species. Direct observations of food preference and foraging ecology are needed to im-

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prove assessment of food resources and allow identification of areas appropriate for critical habitat designation and for reintroduction efforts (U.S. Fish and Wildlife Service 1988).

The Piping Plover is a visual rather than tactile feeder, capturing invertebrates moving on the beach surface. Information on diet has been derived from gizzard contents (Bent 1929), direct observation of feeding (Cairns 1977), sampling of organisms present in the habitat (Whyte 1985, Nordstrom 1990, Loegering 1992, Nordstrom and Ryan 1996) and fecal analysis (Nicholls 1989, Shaffer and Laporte 1994); however, studies of prey actually consumed by Piping Plovers have been reported only for marine environments. General diet for the species is described as freshwater and marine invertebrates washed up on the shore and terrestrial invertebrates (Haig 1992). Insects appear to be a major dietary component in most or all habitats occupied by Piping Plovers throughout the year.

While monitoring plover nests in Michigan during 1996 and 1997, we salvaged carcasses of four chicks and examined gizzard contents. We believe this is the first direct information on diet reported for Piping Plovers from the Great Lakes population.

STUDY AREA AND METHODS

In 1996 three pairs of Piping Plovers nested near the mouth of the Sucker River east of Grand Marais, Michigan (46° 40′ N, 85° 56′ W) on the shore of Lake Superior. Two chicks from one of these pairs disappeared at six days of age. The carcass of one was discovered approximately 1.5 weeks later and the other 2.5 weeks later. The fresh carcass of the third chick from this brood was discovered a few hours after its disappearance at 19 days of age. In 1997, a fourth Piping Plover chick carcass was found in the same general area. This chick disappeared from its brood when it was one week old and was found three days later. The digestive tract from each chick was removed, cut open and flushed with 70% ethyl alcohol. Only gizzards yielded identifiable samples. The contents of the four gizzards were examined with a dissecting microscope and identified to family by an entomologist (Scholtens) familiar with insects of the region. Numbers of individual prey were estimated.

RESULTS AND DISCUSSION

Parts of adult and larval insects were the only prey identified in the gizzards. Prey represented 16 families in 6 orders: Hymenoptera (32%), Coleoptera (29%), Diptera (28%), Hemiptera and Homoptera (10%), and Ephemeroptera (1%). Based on the natural history of these families in northern Michigan, they can be characterized as inhabiting shoreline/wet sand (Dolichopodidae, Ephydridae), shallow water/wet sand (Corixidae, Dytiscidae, Haliplidae), beach vegetation/sand surface (Aphididae, Braconidae, Carabidae, Cicadellidae, Curculionidae, Ichneumonidae) and general shoreline habitat (Superfamily Chalcidoidea, Chironomidae, Formicidae, Muscidae, unidentified Ephemeropteran family). The only previous information related to the prey of the Great Lakes Piping Plover was found in a study of invertebrates present within National Park lands being assessed as potential reintroduction sites (Nordstrom 1990, Nordstrom and Ryan 1996). Nordstrom (1990) found 48 families of 9 orders of insects and 1 family of arachnid on the shore of Lake Superior in Pictured Rocks National Lakeshore (approximately 20 km west).

In the Great Lakes region, Piping Plovers nest on wide sandy beaches and forage along the water line of Lake Michigan and Lake Superior. Birds occasionally glean insects from beach vegetation and at some sites forage along the edges of creeks and shallow beach ponds. At the Grand Marais site, adults and chicks were observed foraging primarily along the edge of the Sucker River and in shallow pools of water and wet depressions in the sand along the river. Aquatic insects in the chick gizzards are consistent with this observation, and the presence of terrestrial, phytophagous insects indicates that chicks also gleaned insects from beach vegetation. Presence of aquatic algae-eating beetles (Haliplidae) in the gizzards suggests that chicks picked insects from algae on the river edges. While Nordstrom and Ryan (1996) reported a predominance of Dipterans in the Lake Superior habitat they sampled, we found predominantly Hymenopterans and Coleopterans in the chick gizzards. We identified two families (Corixidae and Dytiscidae) in the gizzards that were not reported by Nordstrom (1990). Members of both families inhabit streams, ponds, and stagnant pools associated with beaches.

Given the constraints on disturbance and collecting, opportunistic discovery of dead plovers and subsequent study of their diges-

tive tracts may contribute information vital to understanding the diet of this endangered species. For example, insects gleaned from vegetation, algal mats, and the water surface probably would not be revealed by traditional methods (e.g., sticky traps) used to sample invertebrates in the habitat. The information on foraging behavior and prey selection that both gizzard and fecal analyses provide is needed to increase accuracy of methods used to sample invertebrates from the habitat. It is important to note that all three methods of quantifying plover food resources (gizzard analysis, fecal analysis, and sampling from habitat) may be greatly affected by the time samples are obtained because of temporal variation in insect abundance. Fecal analysis offers the advantage that numerous samples can be collected from the same individuals to reveal temporal patterns of prey selection; however, this method underestimates soft-bodied invertebrates (Shaffer and Laporte 1994). Because gizzard contents have undergone less digestion, they are presumably less biased in this regard, but this has not been confirmed.

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LITERATURE CITED

BENT, A. C. 1929. *Charadrius melodus.* U.S. Natl. Mus. Bull. 146:236–246.

CAIRNS, W. E. 1977. Breeding biology and behavior of the Piping Plover (*Charadrius melodus*) in southern Nova Scotia. M.S. thesis, Dalhousie Univ., Halifax, Nova Scotia.

HAIG, S. M. 1992. Piping Plover (*Charadrius melodus*). *In* The birds of North America, no. 2 (A. Poole, P. Stettenheim, and F. Gill, Eds.). The Academy of Natural Sciences, Philadelphia, Pennsylvania; The American Ornithologists' Union, Washington, D.C.

HELMERS, D. L. 1992. Shorebird management manual. Western Hemisphere Shorebird Reserve Network. Manomet, Massachusetts.

HOWE, M. 1983. Breeding ecology of North American shorebirds: patterns and constraints. Proc. West. Hemisphere Waterfowl Waterbirds Symp. 1:95–100.

LOEGERING, J. P. 1992. Piping Plover breeding biology, foraging ecology and behavior on Assateague Island National Seashore, Maryland. M.S. thesis, Virginia Polytechnic Inst. and State Univ., Blacksburg.

NICHOLLS, J. L. 1989. Distribution and other ecological aspects of Piping Plovers (*Charadrius melodus*) wintering along the Atlantic and Gulf Coasts. M.S. thesis, Auburn Univ., Auburn, Alabama.

NORDSTROM, L. H. 1990. Assessment of habitat suitability for reestablishment of Piping Plovers in the Great Lakes National Lakeshores. M.S. thesis, Univ. of Missouri, Columbia.

NORDSTROM, L. H. AND M. R. RYAN. 1996. Invertebrate abundance at occupied and potential Piping Plover nesting beaches: Great Plains alkali wetlands vs. the Great Lakes. Wetlands 16:429–435.

SHAFFER, F. AND P. LAPORTE. 1994. Diet of Piping Plovers on the Magdalen Islands, Quebec. Wilson Bull. 106:531–536.

U.S. FISH AND WILDLIFE SERVICE. 1985. Determination of endangered and threatened status for the Piping Plover. Federal Register 50:50726–50734.

U.S. FISH AND WILDLIFE SERVICE. 1988. Recovery plan for Piping Plovers breeding on the Great Lakes and Northern Great Plains. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

WHYTE, A. J. 1985. Breeding ecology of the Piping Plover (*Charadrius melodus*) in central Saskatchewan. M.S. thesis, Saskatchewan Univ., Saskatoon.