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# A CASE FOR ESOPHAGEAL ANALYSIS IN SHOREBIRD FOOD STUDIES

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Various methods have been used to determine shorebird foods. Indirect techniques included examination of digested foods in the form of cast pellets (Hibbert-Ware and Rutledge 1944, Goss-Custard and Jones 1976, Stenzel et al. 1976, Harris 1979) or droppings (Feare 1966, Goss-Custard et al. 1977), and remote visual identification of foods as they are procured (Goss-Custard and Jones 1976, Stenzel et al. 1976, Goss-Custard et al. 1977, Evans et al. 1979). Indirect methods are especially useful when prey are large or hard, investigators have prior knowledge of principal prey species, or where prey diversity is low.

Most food studies have involved the collection of birds and examination of contents of their digestive tracts (Sperry 1940, Spawn 1941, Reeder 1951, Couch 1966, White and Harris 1966, Brooks 1967, Bengston and Svensson 1968, Holmes and Pitelka 1968, Goss-Custard 1969, Thomas and Dartnall 1971, Prater 1972, Baker 1977, Fritzell et al. 1979, Strauch and Abele 1979). With one exception (Fritzell et al. 1979), these studies relied at least partially on gizzard contents. Biases caused by postmortem digestion and long-term retention of hard foods (Hartley 1948, Van Koersveld 1950, Dillery 1965, Swanson and Bartonek 1970) are inherent with traditional gizzard analyses, and investigators routinely qualify their results because of these problems.

Procedures used in recent studies of waterfowl feeding ecology (Swanson et al. 1974b, Krapu 1974, Drobney and Fredrickson 1979, Reinecke and Owen 1980) include: (1) collecting only birds known to have been feeding for a specified minimum time; (2) field removal of upper digestive tract contents; and (3) restricting quantitative analyses to contenst of the esophagus and proventriculus. These procedures reduce the above biases, however, they have not been used in shorebird research. Here, I present data on the foods of 4 species of inland migrants, and discuss suitability of techniques for determining shorebird prey for future research.

## METHODS

Pectoral Sandpipers (*Calidris melanotos*), Lesser Yellowlegs (*Tringa flavipes*), Killdeers (*Charadrius vociferus*), and Common Snipes (*Gallinago gallinago*) were collected from July through November, 1978–1979, at 2 man-made seasonally flooded impoundments of Mingo National Wildlife Refuge, in southeastern Missouri. The impoundments are in Mingo Swamp which lies in an abandoned valley of the Mississippi River. Swamp soils are weathered alluvium of the Waverly series. The acidic gray silt-loam topsoil reaches a depth of 12.3 cm over a gray clay subsoil (Fredrickson et al. 1977).

Collection procedures followed Swanson and Bartonek (1970). Birds were shot from a portable blind after a minimum observed feeding period of 10 min. Upper digestive tracts were removed immediately in the field and contents of the esophagus (including proventriculus and buccal cavity) and gizzard were preserved separately in 70% ethanol.

Laboratory analysis followed Drobney and Fredrickson (1979). Ingesta were soaked overnight in distilled water to restore near-live sizes to invertebrates shrunken by preservation in ethanol (Stanford 1973). Ingesta were hand-sorted under a dissecting microscope, towel dried, and volumes measured by displacement of distilled water. Measurements were made to the nearest 0.01 ml with a microsyringe.

All invertebrate foods were identified to Order, and more specifically when possible. Data were tabulated using aggregate percent and percent occurrence methods to reduce distortion caused by variability of total sample volume among individual birds (Martin et al. 1946, Swanson et al. 1974a). Esophageal and gizzard contents were analyzed separately using identical procedures. The sign test (Hamburg 1979) was used to test for equivalence between esophageal and gizzard contents.

Within 2 h after the collection of each feeding shorebird, a core sample, 9.6 cm in diameter and 5.0 cm deep, was taken at the collection site. Samples were washed through a 0.8 mm mesh screen in the field, placed in plastic bags and frozen. Before analysis, samples were thawed and soaked for 12 h in a solution of Rose Bengal to aid in recognition of invertebrates tangled in root masses (Frey et al. 1973). Four grams of technical grade Rose Bengal were dissolved in 250 ml of 95% ethanol as a stock solution. Six to 20 drops of solution were required depending on sample volume. Invertebrates and seeds were handpicked from samples and preserved in 70% ethanol. Further handling procedures were identical to those used for gut contents.

## RESULTS

Forty-six shorebirds were collected. All but 5 were shot before 1100 or after 1600. Four birds had empty esophagi, and 8 others had only trace (<0.01 ml) amounts of esophageal food. Individual esophageal food volumes of the remaining birds ranged from 0.05–1.25 ml.

Insects were the primary foods of all 4 shorebird species (Table 1). Adult and larval beetles occurred in at least 25% of the individuals of each species, and comprised over 50% of the aggregate volume in all species except Common Snipes (29%). The most commonly encountered coleopteran families were: Dytiscidae, Halipidae, Carabidae, Hydrophilidae, Staphylinidae, and Curculionidae. Dipteran larvae, mostly Tabanidae and Chironomidae, occurred in at least 25% of the individuals of all species, but were volumetrically important only in Killdeers. Ephemeropteran larvae were the primary food in the small Lesser Yellowlegs sample, and also were taken by Pectoral Sandpipers and snipes. Physid snails were taken by a few individuals of all species except yellowlegs. Oligochaetes were volumetrically important only in snipes.

TABLE 1. Percent occurrence and volumetric aggregate percent of esophageal contents (proventriculus included) of 46 migrating shorebirds collected during summer/fall 1978–79 on Mingo National Wildlife Refuge, Missouri.

| | Pectoral Sandpiper (N = 14) | | Killdeer (N = 15) | | Lesser Yellowlegs (N = 5) | | Common Snipe (N = 12) | |
|---|---|---|---|---|---|---|---|---|
| Principal ingesta[a] | % occ | Agg % | % occ | Agg % | % occ | Agg % | % occ | Agg % |
| Animal | | | | | | | | |
| Oligochaeta | | | | | | | 33.3 | 20.7 |
| Physidae | 7.1 | 10.0 | 13.3 | 0.9 | | | 16.7 | 12.5 |
| Ephemeroptera (larvae) | 7.1 | 6.0 | | | 60.0 | 40.0 | 8.3 | 6.3 |
| Plecoptera | | | | | | | 8.3 | 6.3 |
| Odonata (larvae) | | | 6.7 | 1.3 | | | | |
| Corixidae (adult) | 14.3 | 10.0 | 6.7 | 1.3 | | | | |
| Homoptera (adult) | 21.4 | 8.3 | | | | | 8.3 | 2.5 |
| Coleoptera (adult) | 50.0 | 35.3 | 40.0 | 25.5 | 40.0 | 30.0 | | |
| Coleoptera (larvae) | 21.4 | 15.3 | 20.0 | 21.2 | 20.0 | 20.0 | 25.0 | 29.1 |
| Coleoptera (adult pieces) | 7.1 | tr | 26.7 | 17.0 | | | | |
| Diptera (larvae) | 28.6 | 6.8 | 40.0 | 18.3 | 40.0 | 10.0 | 25.0 | 6.6 |
| Hymenoptera (adult) | | | 6.7 | 6.1 | | | | |
| Unidentified | 35.7 | 2.5 | 20.0 | 2.6 | | | | |
| Plant | | | | | | | | |
| *Eleocharis obtusa* | | | | | | | 25.0 | 1.2 |
| Plant fibers | 50.5 | tr | 53.3 | 1.3 | 80.0 | tr | 75.0 | 3.0 |
| Grit | 21.4 | 5.8 | 13.3 | 4.5 | | | 25.0 | 11.8 |

[a] Includes foods with ≥10% occurrence and/or aggregate percent (volume) of ≥1% for at least 1 shorebird species. See Rundle (1980) for details of occurrence.

Plant foods were unimportant in shorebird diets in Missouri. Seeds of blunt spikerush (*Eleocharis obtusa*) occurred in 25% of snipe esophagi, but were volumetrically unimportant. Small vegetative fibers were found in most esophagi, but comprised not more than 3% aggregate volume.

There were marked differences between esophageal (including proventricular) and gizzard contents (Fig. 1); foods volumetrically dominant in esophagi were different from those dominating gizzards of the same birds. Earthworms accounted for 20.7% of snipe esophageal contents, but only a trace volume was found in snipe gizzards. Insects, the principal foods of all species, were found in smaller volumes in gizzards than in esophagi (sign test, $P < .005$). Excepting dipteran larvae in snipes, all identifiable invertebrates that occurred in both esophagi and gizzards were reduced in gizzards. The volume of unidentifiable animal material in gizzards ranged from 20.6% in Killdeers to 48.6% in Lesser Yellowlegs. In the tactile feeding species, snipes and Pectoral Sandpipers, seeds comprised 14.6% and 2.7% of gizzard volumes, but only 1.2% and 0% of esophageal contents.

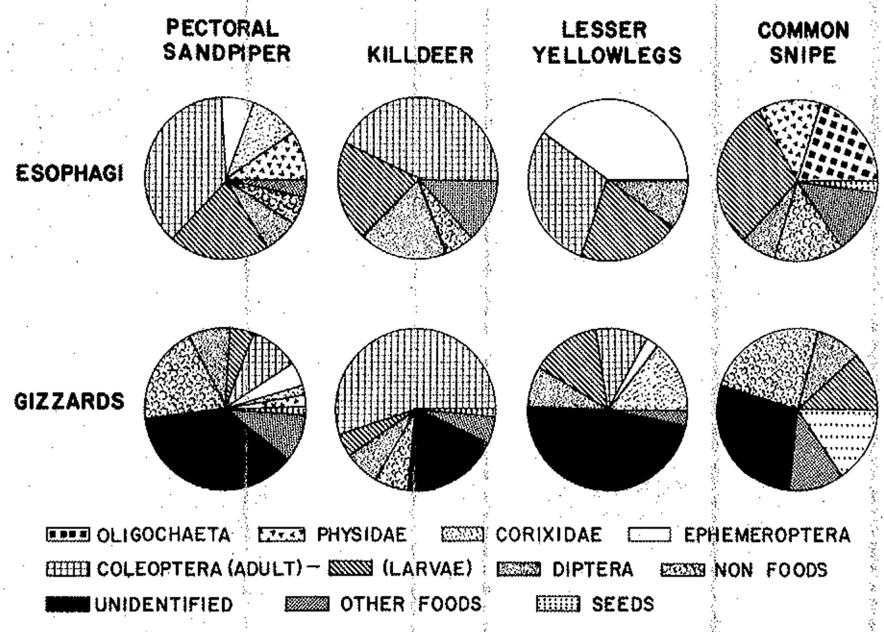


FIGURE 1. Comparison by aggregate percent volume of contents of esophagi and gizzards of migrant shorebirds.

Gizzards of all species, except Common Snipe, contained a greater diversity of invertebrate foods than did esophagi (Table 2). The majority of additional taxa were present in <10% of gizzards. Oligochaeta, Planorbidae, Odonata, and Notonectidae each occurred in 1 Pectoral Sand-

TABLE 2. Number of invertebrate taxa, by range of percent occurrence, identified from esophagi (proventriculus included) and gizzards of migrating shorebirds collected in southeastern Missouri, 1978–79.[a]

| Range Percent occurrence | Pectoral Sandpiper (N = 14) | | Killdeer (N = 15) | | Lesser Yellowlegs (N = 5) | | Common Snipe (N = 12) | |
|---|---|---|---|---|---|---|---|---|
| | E[b] | G[c] | E | G | E | G | E | G |
| 0–9 | 3 | 7 | 3 | 6 | | | 3 | 4 |
| 10–19 | 1 | 1 | 1 | | | | 1 | |
| 20–29 | | 1 | 3 | 2 | 1 | 2 | 2 | |
| 30–39 | 1 | | | | | | 1 | 2 |
| 40–49 | 1 | 1 | | 2 | 2 | 3 | | |
| ≥50 | 1 | 1 | 1 | 1 | 1 | 2 | | |
| Total | 7 | 11 | 8 | 11 | 4 | 7 | 7 | 6 |

[a] See Rundle (1980) for details of occurrence.
[b] E = No. taxa identified from esophagi.
[c] G = No. taxa identified from gizzards.

piper gizzard, and Planorbidae, Lymnaeidae, Decapoda, and Arachnidae each occurred in 1 Killdeer. All those comprised <3% aggregate volume in gizzards. In the small yellowlegs sample, corixids were absent in esophagi, but were found in 3 of 5 gizzards, comprising 15% aggregate gizzard volume. Additional seed species were also found in gizzards; these were 5, 9, 3, and 18 in Killdeers, Pectoral Sandpipers, yellowlegs, and snipe respectively.

Dipteran and coleopteran larvae occurred most frequently in core samples. Dipteran larvae had a percent occurrence of ≥77 in cores associated with each shorebird species, and comprised over 38% of invertebrate volume in all except those associated with Pectoral Sandpipers. Chironomids occurred in almost all samples, but less abundant tabanid larvae accounted for most of the dipteran volume. Coleopteran larvae occurred in ≥38% of cores in each group.

Seeds of 33 plants were found in cores. Seed volume of individual samples ranged from 0.20–4.50 ml, compared to trace—0.66 ml for invertebrates. Blunt spikerush was the most common seed occurring in 41 of 46 samples. Individual seeds were not counted, but hundreds of blunt spikerush regularly occurred in individual samples.

## DISCUSSION

When considering options for studying shorebird foods, the initial decision must determine whether individuals are to be collected. In general, indirect methodology alone cannot generate data sufficient to make sound ecological comparisons among species and across habitats, or on which decisions regarding conservation and management of habitats and populations can be based. Pellets and droppings contain no remains of totally soft-bodied prey. In marine systems, hard parts such as barnacle plates (Harris 1979) or polychaete jaws (Goss-Custard et al. 1977) may be evident. Pellets are most easily collected at roosts (Goss-Custard et al. 1977) where the origin of their contents may be in doubt, and may lack characteristics to identify the shorebird species that cast them (Below 1979). Goss-Custard et al. (1977) identified pellets from adjacent tracks, a conceivably difficult task where several similar species occur. Notwithstanding special circumstances (e.g., Harris 1979), use of pellets and droppings should be limited to rare and endangered species or small local populations (e.g., Stenzel et al. 1976).

Remote observation techniques have been used increasingly in the last decade. They have the advantages of speed, easily obtained large sample size, and reduction of time and labor requirements for tedious laboratory analysis. However, the utility of those techniques may be inconsistent among species. For example, Goss-Custard et al. (1977) reported unidentified prey in the diet ranging from 0% for Oystercatchers (*Haematopus ostralegus*) and 12.2% for Red Knots (*Calidris canutus*) to 70.5% for Dunlins (*C. alpina*) and 74% for Black-bellied Plovers (*Pluvialis squatarola*). Because prey size is usually proportional to shorebird body size (Recher 1966, Smith and Evans 1973, Baker 1977), remote observation is applied most successfully to medium and large species such as Redshank (*Tringa totanus*), Eurasian Curlew (*Numenius arquata*) (Goss-Custard and Jones 1976), Willet (*Catoptrophorus semipalmatus*), and Long-billed Curlew (*N. americanus*) (Stenzel et al. 1976). Few successful attempts have been made to identify, from a distance, the prey of small shorebirds, or prey of any species at freshwater sites where prey are small and diverse. In the course of my Missouri study (Rundle 1980), I telescopically observed over 2000 foraging attempts by the 4 species involved and was unable to identify any prey as they were taken.

Because of these remote observational problems, collection of specimens is at least a desirable supplement for determining shorebird prey. Most reports of gizzard studies acknowledge problems of post-mortem digestion of soft foods and retention of hard foods. Many investigators have dealt with post-mortem digestion by injecting preservatives into the digestive tract soon after collection (White and Harris 1966, Brooks 1967, Bengston and Svensson 1968, Holmes and Pitelka 1968, Baker 1977, Strauch and Abele 1979). Preservatives may assist in documenting soft foods, but do not address long-term retention of hard items. Controlled experiments of digestion rates in quail (Jensen and Korschgen 1947), ducks (Swanson and Bartonek 1970), blackbirds (Gartshore et al. 1979), and snipes (Tuck 1972) indicated that differential rates of gullet passage of different foods is common in birds. Despite a small sample size, Tuck's (1972) work is especially relevant. Within 10 min of ingestion, a known mass of earthworms, isopods, and beetles was reduced by 40%; and after 1 h, only 4% of insect larvae could be recognized microscopically. The present Missouri sample substantiates this problem for wild birds foraging freely on natural food resources.

In habitats where shorebird foods are not diverse and are well known by investigators, gizzard contents may be reliable. Examples include tundra breeding grounds (Holmes and Pitelka 1968) and some estuarine areas (Smith and Evans 1973, Goss-Custard et al. 1977). Results of gizzard studies from inland freshwater sites that have been studied less intensively may require reevaluation. In the present study, analysis of gizzards alone would have yielded a grossly inaccurate picture of foods actually taken. I examined 4 species, but only in Killdeer did one food comprise the greatest volume in both esophagi and gizzards.

Gizzard analyses do document occurrence of minor foods and suggest more diverse food sources than esophagi. The present data indicate that most of the additional items are ingested incidentally, having low occurrence and volume. The exception, corixids in yellowlegs, may have resulted from the very small sample or differential digestion rates of corixids and the principal esophageal food, ephemeropteran larvae.

Reliance on gizzard analyses may explain reports of seeds being important shorebird foods at inland sites. Except for Fritzell et al. (1979), data on shorebird foods from interior North America were derived solely from gizzards. Sperry (1940) reported substantial volumes (12–17%) of plant foods in the 4 species I studied. Brooks (1967) suggested that snipes, Pectoral Sandpipers, and Semipalmated Sandpipers (*Calidris* *pusillus*) sometimes selected seeds and algae over invertebrate foods in Illinois. Baker (1977) reported a high incidence of seeds in gizzards of Lesser Golden Plovers (*Pluvialis dominica*) and Short-billed Dowitchers (*Limnodromus griseus*) in northern Manitoba. Because plovers are strictly visual feeders (Evans 1979) it seems safe to assume that they intentionally consumed seeds. Tactile feeding dowitchers probably obtained seeds incidentally.

My core samples were inadquate to determine actual availability and selectivity (see Evans 1979, Myers et al. 1980). Large volume of seeds in the substrate, low occurrence and trace seed volumes in esophagi, and seed volume of 14.6% in snipe gizzards strongly suggest only incidental ingestion of seeds and long-term retention of seeds in gizzards. Unless behavioral observations dictate otherwise (e.g., Pienkowski 1979), plant materials found in shorebird gizzards should probably be disregarded in terms of energetics and nutrition.

The best methods for identifying shorebird prey vary with study goal. Indirect techniques were deemed appropriate by Goss-Custard (1973) for documentation of food occurrence in most shorebirds. Remote observations and analyses of gizzard contents sufficed to quantify numbers, volumes, or mass of prey. After finding numerous prey in the esophagi of some Redshanks and none in others, Goss-Custard (1969) developed correction factors to determine actual proportions of 2 major prey species, and (1973) suggested development of such factors for other species. I believe correction factors are unnecessary, because esophageal contents can be obtained directly by selective collection. Many workers have collected at known feeding sites, but only a few (Thomas and Dartnall 1971, Baker 1977) have selectively collected actively feeding birds. Fritzell et al. (1979) found esophageal foods in 43% of snipes collected during periods of maximum feeding activity. When snipes were actively feeding for up to 15 min before collection, 57% contained esophageal foods. In my small sample, measurable esophageal foods were obtained from 74% of birds, representing 4 genera.

Collection of actively feeding birds and subsequent analysis of esophageal contents provides accurate and minimally biased information on shorebird foods, regardless of species or habitat. Other methods can provide useful data, but have limitations that prohibit universal application. Precollection observation periods provide opportunity to study foraging behavior, and handling of intact esophageal contents is easier than sorting digested gizzard contents. Gizzard contents may be examined grossly if identification of incidental foods is desired. In some situations, remote observation techniques, pellets, or droppings can then be used to increase sample size once principal foods are known.

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