FOOD HABITS OF OLDSQUAWS WINTERING ON LAKE MICHIGAN

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Several trophic levels in Lake Michigan have been shown to be contaminated with organochlorines (Hickey et al. 1966), and contaminants that are not biodegradable are passed through the food chain from one organism to the next. Knowledge of the food habits of bird species wintering on the lake would be useful in measuring the movement of these contaminants from the aquatic environment and should help us interpret the distribution and activity of the birds on the lake. This report summarizes data on the food habits of Oldsquaws (*Clangula hyemalis*) collected during 2 periods: 1951–1954 and 1969–1972. Cottam (1939), Lagler and Wienert (1948), and Zimmerman (1953) have previously reported on the gizzard contents of a few Oldsquaws collected from commercial fishermen on Lake Michigan.

METHODS

We collected Oldsquaws from commercial fishermen who found them caught in gill nets between November and May. These nets are suspended along the bottom in water 18–46 m deep, with the leads holding the lower part of the net on the substrate and the floats keeping the mesh upright off the bottom. Presumably, since the nets are only about 1.5 m high, any birds captured would be actively feeding at or near the bottom. Even though some birds may have remained in the nets for up to 1 week before removal, the cold water prevented extensive decomposition of the esophageal material. After the specimens were removed from the nets, they were frozen until dissection and examination could be completed.

In the 1951–1954 study, 10 birds were taken from each catch of Oldsquaws and only those which had significant quantities of food were saved. Samples were collected from southeastern Lake Michigan (South Haven, Saugatuck, Holland, Muskegon), southwestern Lake Michigan (Kenosha, Racine), and northern Lake Michigan (Port Washington, Two Rivers, Gills Rock, Washington Island). From this part of the study we analyzed 192 specimens: 41 were of gizzards only and 151 were of gizzards and gullets (esophagus plus proventriculus). Food items were separated and volume to the nearest 0.1 ml and frequency of occurrence of items were recorded.

In the 1969–1972 study, we only recorded material from the esophagus because Dillon (1957), Bartonek and Hickey (1969), and Swanson and Bartonek (1970) demonstrated differences in the contents of the esophagus, proventriculus, and gizzard. Ellarson's (1956) analysis of the 1951–1954 material indicated a rapid decomposition of the material once it reached the proventriculus. In the 1969–1972 study period, specimens were obtained only from Gills Rock and Washington Island (northern Lake Michigan). We examined as many specimens as possible (956) and recorded those specimens with nothing present in the gullet as well as those having fed. Only the total volume of food present in the esophagus and the frequency of occurrence of food items were recorded.

The lipid content of specimens was determined from a 25 g sample of the homogenized carcass (head, wings, feet, feathers, and gastrointestinal tract removed). After a sample was dried in a 40°C oven for 72–96 hours, it was ground with 100 g Na_2SO_4 and extracted 8 hours on a soxhlet extractor using 70 ml ethyl ether and 170 ml petroleum ether. An aliquot of the extract was then reduced to dryness, weighed, and the amount of ether-soluble lipid determined.

RESULTS

Ingested Material

Grit content of gizzards.—The volume of grit in the 1951–1954 sample was constant among gullets. The ratio of grit to total gizzard and gullet content, for all samples, was 24.7%, and the ratio of sand (< 2 mm) to gravel (> 2 mm) was consistently about 9:1. Besides sand and gravel, grit was composed of coal cinders and ash from steamships as well as limonitic oolites. In the northern part of the lake, ¾ of the total grit content was oolite material. The constant ratios of food to grit and sand to gravel suggest some internal mechanism regulating grit retention in the gizzard. Excessive quantities of sand are possibly ingested with the food organisms and voided into the intestinal tract because the fecal material is gritty and fluoroscopic examination ($n = 2106$) indicated the lower intestinal tract was laden with sand. Sand often occurred in the esophagus when no animal or vegetable matter was present. In the 1969–1972 study, sand occurred in 83% of all esophagi examined and 90% of all esophagi with food organisms present. Gravel occurred in 28 and 30% of these samples respectively.

Crustaceans.—In the 1951–1954 sample, animal matter constituted 99% of the food volume in 151 gizzards and was present in all 192 gullets and gizzards examined (Table 1). Amphipods (*Pontoporeia affinis*) made up 82% of that volume. In the 1951–1954 sample, amphipods rated between 85 and 100% frequency of occurrence, depending on the area where taken, while in the 1969–1972 sample, they were found in 88% of all gullets examined and 95% of all gullets with some material present (Table 2). One gizzard contained 2 chelae of a small crayfish in the 1951–1954 sample.

Mollusks.—Gastropods (snails) and pelecypods (clams) constituted a relatively small proportion of the volume of gizzard contents (3.9% in 1951–1954), but their frequency of occurrence was high (51 to 79% in 1951–1954), second only to amphipods. Clams (Sphaeriidae) were present in 51 to 76% of the 1951–1954 esophagus and gizzard samples and in 61 to 65% of the 1969–1972 esophagus samples, while snails (*Cyraulus* and *Amnicola*) were present in 9 to 20% and 11 to 12% of the respective samples. The clams were generally very small; 25 average-size shells of *Pisidium* had a volume of 0.1 ml.

Insects.—Adult insects and their larvae accounted for 0.4% of the total food

TABLE 1

PERCENT FREQUENCY OF OCCURRENCE AND PERCENT VOLUME OF INGESTED MATERIAL IN OLDSQUAWS COLLECTED ON LAKE MICHIGAN, 1951–1954

Item	Northern Lake Michigan n = 35 (15)*	Southwestern Lake Michigan n =34 (34)	Southeastern Lake Michigan n = 123 (102)
Crustaceans (Amphipoda[a])	97 (52)	100 (96)	85 (82)
Mollusks	51	56	79
Gastropoda	11	9	20
Pelecypoda	51 (1)	56 (3)	76 (5)
Fish	46 (43)	24 (trace[b])	33 (12)
Skeletal remains	11 (trace)	3 (trace)	24 (7)
Eggs	40 (43)	24 (trace)	trace (trace)
Insects	51	15	28
Coleoptera	9	trace	trace
Trichoptera	31 (4)	15 (trace)	trace (trace)
Diptera	6	trace	25
Unidentified	9	trace	trace
Vegetable matter	74	59	85

* Numbers in parentheses refer to % volume.
[a] *Pontoporeia affinis*.
[b] < 0.5 %.

volume in the earlier sample, but in both this and the later sample, the frequency of occurrence was high (15 to 51% in the 1951–1954 sample). Diptera and Trichoptera larvae occurred most often but they were never abundant in any 1 specimen. Diptera larvae occurred in 6 to 25% of the earlier sample and in 15 to 17% of the later sample, while Trichoptera were recorded in 15 to 31% and 3 to 4% of these samples, respectively. Diptera consisted almost exclusively of midge larvae (Tendepedidae), but a few adult forms were found from this family as well as from the order Coleoptera.

Fish.—Fish and fish eggs were the second most important item in the 1951–1954 sample, but relatively infrequent in the 1969–1972 sample. In the earlier sample, fish remains (primarily Cottidae and Percidae) and eggs constituted an average of 13% of the food volume and the frequency ranged from 24 to 46%. In the later sample the frequency of occurrence was 3 to 4%.

The variation in fish and eggs found in Oldsquaws collected during the 2 periods appears to be related to the feeding habits of this species on Lake Michigan. In some groups of Oldsquaws, fish remains or eggs constituted the bulk of the food present, indicating that individual flocks fed on whatever food was readily available in the area. In one small sample of birds from northern Lake Michigan in the 1969–1972 period, practically all the gullets contained large chunks of decayed alewife (*Alosa pseudoharengus*), but it was

TABLE 2

PERCENT FREQUENCY OF OCCURRENCE OF INGESTED MATERIAL IN THE ESOPHAGI OF OLDSQUAWS COLLECTED ON LAKE MICHIGAN, 1969–1973

Item	% of all esophagi examined n = 956	% of all esophagi with material present n = 884
Animal matter		
Crustaceans (Amphipoda[a])	88	95
Mollusks		
Gastropoda	11	12
Pelecypoda	61	65
Fish		
Skeletal remains	4	4
Eggs	3	4
Insects		
Trichoptera	3	4
Diptera	15	17
Mysidacea	5	5
Oligochaetes	4	4
Isopods	7	8
Unidentified	3	4
Vegetable matter (detritus)	31	34
Mineral matter		
Sand (< 2 mm)	83	90
Oolites	75	81
Gravel (> 2 mm)	28	30

[a] *Pontoporeia affinis.*

found in few other samples from the area. In the 1951–1954 sample, Ellarson (1956) recorded a catch of birds from Saugatuck that had been feeding on perch (*Perca flavescens*) about 5 cm long, while other catches of birds from the area at that time were feeding on amphipods.

In northern Lake Michigan, Ellarson found 43% of the volume in 15 gizzards was composed of fish eggs (Table 2), and eggs were present in 40% of 35 birds examined from that area. One of the birds collected in this sample had ingested 35 ml of fish ova, or approximately 2600 eggs. In the 1969–1972 sample from the same area, we found 4% of 884 birds to have eaten fish eggs. No birds in the later sample contained large volumes of ingested ova. We suspect, in view of the selectivity on fish, that our earlier sample contained a few birds feeding exclusively on eggs. Since we did not find many Oldsquaws with ingested ova in the large sample from the same area in 1969–1972, the data suggest Oldsquaws will feed on fish ova when they find them, but that this occurs in isolated localities.

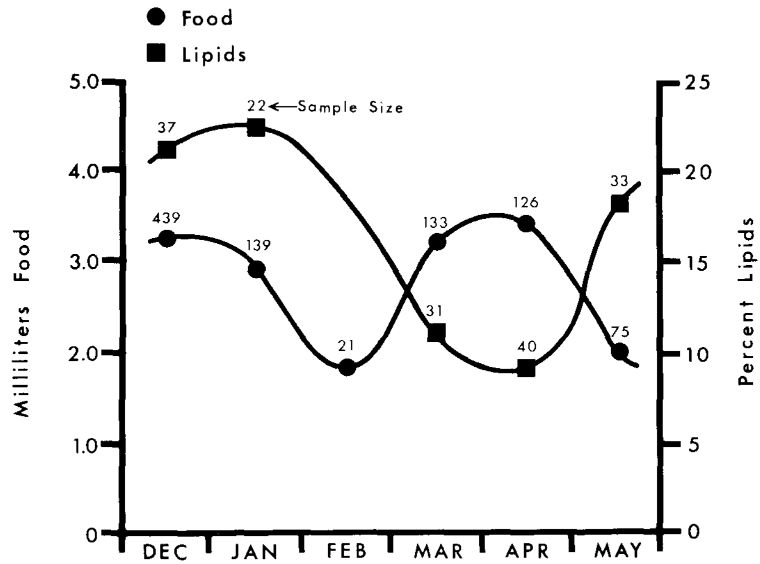

FIG. 1. Seasonal relationship between food ingested and carcass fat in Oldsquaws collected on Lake Michigan, 1969–1972. Curves are hand-fitted.

Vegetable matter.—Pieces of vegetation occurred frequently in our samples (59 to 85% in 1951–1954, and 31 to 34% in 1969–1972), but the volume was generally less than 1%. We doubt that this material is taken as food because most of the vegetation consisted of decomposed fragments characteristic of bottom debris in deep water.

Seasonal Changes in Ingested Volume

Data we have on changes in body weights of Oldsquaws suggest a seasonal rhythm in the lipid levels of this species. Changes in these lipid levels could be due to the availability of food on Lake Michigan: as the ice extends farther out from shore in the winter, Oldsquaws are forced to dive in deeper water for their food, and when either the food is deeper than their diving capability or the amount ingested per dive is less than the energy expended, the birds have to draw upon stored energy reserves. In this section we examine this relationship between food and stored energy in more detail.

Fig. 1 illustrates monthly changes in the volume of food present in Oldsquaws and the relationship to the percent lipids in carcasses. Oldsquaws are readily obtained throughout the winter except in February, when the ice is usually so thick on the northern end of the lake that fishermen cannot get out to tend their nets. The food volume data are not normally distributed about the mean: 42% of 956 esophagi had less than 1 ml present and the range was from 0 to 25 ml. We used the nonparametric Mann-Whitney U-test to check for significant differences among months. Since the sample sizes used to compute U were greater than 20, U was converted to the z distribution and the probabilities determined (Siegel 1956:116).

Our lipid data indicate a peak in deposition occurring in January, followed by a decline through April ($p < .01$), while the volume of food ingested declined from December through February ($p < .07$). In late February, the ice edge begins to retreat and larger average volumes of food ingested were recorded between February and April ($p < .01$). At the same time, lipid levels continue to decline through April, and when lipid deposits are lowest, food ingestion is at a maximum. Between April and May, there is an increase in lipid deposition ($p < .01$), especially in adults, while there is a drop in food intake ($p < .01$).

During the second week of June 1971, we collected a series of Oldsquaws on an arctic breeding ground in northwest Hudson Bay. These breeding pairs had not been on the tundra more than a few days. Lipid analyses indicated these birds had about 17% lipid content, as opposed to an average of 22% lipid content in a similar sample of birds on Lake Michigan prior to migration. However, the Lake Michigan and arctic samples may not be from the same populations.

There was no food present in the esophageal and gastrointestinal tracts in the arctic sample, and the livers as well as the intestinal tracts were much smaller than the average size on Lake Michigan prior to migration. We concluded that the birds in the arctic sample had fed little during migration, and the data in Fig. 1 suggest Lake Michigan birds had started to reduce food intake prior to spring migration.

DISCUSSION

Two important conclusions can be drawn from data on the composition of food in the diet of the Oldsquaw. First, animal matter constitutes the bulk of the ingested material. Our observations confirm what Dement'ev et al. (1952) recorded in the Soviet Union, and Polunin and Eklund (1953) found in an Oldsquaw stomach collected in Ungava. Cottam's (1939) analysis of 190 stomachs from various parts of North America and Madsen's (1954) data from the Danish coast indicate crustaceans and mollusks are the favored food items. On Lake Michigan, our data as well as that collected by Lagler and Wienert (1948) and Zimmerman (1953) indicate this animal matter is primarily amphipods and to a lesser extent clams and snails.

The second important conclusion concerning the composition of the diet is that the Oldsquaw is an opportunist that will take whatever animal matter is most abundant or most available in its feeding area. Mackay commented on this in 1892: "They [Oldsquaws] do not seem to be particular in regard to their food, eating various molluscs, fish and sandfleas." Cottam (1939:76) noted this tendency from his collections when he stated: "The [Oldsquaw], in general, do not seem to show any species preference for either small molluscs or crustaceans, if equally easily obtained;" and Madsen (1954:204) pointed out: "On the whole . . . this Diving Duck is very adaptable in its food selection. . . ."

Eggleton (1937) and Alley (1968:18) found the benthic population of Lake Michigan dominated by 4 groups: *Pontoporeia*, Tubificidae, Sphaeriidae, and Chironomidae, in order of decreasing abundance. The first 3 groups account for approximately 94% of the bottom population, with *Pontoporeia* comprising about ⅔ of the total. Alley (1968) cites Merna (1960) as stating amphipods constituted about 70% of the macrobenthos. Eggleton (1937) and Alley (1968:66) found a zone of concentration for *Pontoporeia* at 35 m, with $8420/m^2$ being recorded at 40 m. Marzolf (1962:32) found a maximum of about $14{,}221/m^2$ in Grand Traverse Bay, Lake Michigan.

Amphipods are not only the most abundant bottom organism and the most prevalent in our food samples, but also the region of concentration of this organism is the most frequent depth at which Oldsquaws are taken (Ellarson 1956). The lower limit of the thermocline in Lake Michigan is generally about 35 m, and this coincides with the junction of the sublittoral and profundal zones (Alley 1968). Environmental extremes in the sublittoral zone cause a lower density of amphipods, while cold temperatures and less food cause decreased numbers of amphipods in the profundal zone (Alley 1968).

Field tests indicated a thin detrital film (< 5 mm) was generally present on the bottom of Lake Michigan, and laboratory experiments suggested amphipod densities were positively correlated with the density of bacteria in this organic matter (Marzolf 1962). The sublittoral or inshore areas are constantly subjected to wave action which causes the organic matter to be resuspended and deposited elsewhere, thereby lowering the productivity of the area for bacteria and amphipods (Alley 1968). The decrease in the food base contributes then to less attractive and constantly changing feeding areas for Oldsquaws.

Eggleton (1937) reported Tubificidae to be abundant in the benthic zone of Lake Michigan, but we found relatively few in our samples. Oldsquaws will take members of the Tubificidae, as Rofritz (1972:57) noted: "Sludge worms were overwhelmingly the most important food source for Oldsquaw in the Milwaukee Harbor." Milwaukee Harbor has been dredged to 9 m and the bottom is a hard clay. The sewage treatment plant in the center of the harbor produces conditions suitable for an abundance of "sludge worms" (335,000/m^2 maximum, Rofritz 1972:56), and this food organism is readily available to Oldsquaws owing to the hard bottom. The substrate in Lake Michigan where Oldsquaws are most often taken is largely a mixture of sand and silt. Tubificidae can burrow into these materials and be essentially unavailable to Oldsquaws even though these worms are one of the most prevalent organisms in the benthic zone.

Other data indicate the Oldsquaw is an opportunistic feeder. Several of our samples revealed that a few small groups of birds had been feeding on fish even though the majority of the flocks taken at the same time in the same area had been feeding on amphipods. Ellarson (1956:215) and Hull (1914) have observed Oldsquaws feeding on locally abundant schools of minnows, and Oldsquaws have been seen diving for fish offal discarded by the commercial fishermen on Washington Island. Madsen (1954) noted that the high incidence of mollusks in Oldsquaws collected along the Danish coast reflected the abundance of these bivalves in the marine waters, whereas Cottam's (1939) material showed a preponderance of crustaceans from birds collected largely from freshwater habitats.

An important relationship of Oldsquaws to the gill-net fishery on Lake Michigan exists through the common amphipod food base. Our data indicate this invertebrate is the predominant food organism in Oldsquaws, and Koelz (1927:528), Rawson (1953), and Ellarson (1956) found the principal food of the whitefish (*Coregonus clupeaformis*) was amphipods. Since this bird and this fish are both largely dependent on the same food, it is understandable why both fish and ducks tend to concentrate in areas where amphipods reach maximum density, and why fishermen set their nets in these waters. Oldsquaws are also related to the gill-net fishery by their occasional predation on fish eggs.

The seasonal relationship between the volume of food ingested and the percent of lipids found in the bird is more difficult to explain. Because we do not know the energy requirements of Oldsquaws during the winter, one must interpret the data in Fig. 1 with caution. Surely the decline in lipids between January and April is caused by some stress factor, but whether or not this is due to a decrease in the volume of food ingested, as implied in Fig. 1, is questionable. Oldsquaws need a minimum winter food intake to maintain an energy balance, and when this energy demand is not met, stored energy must be used. As winter temperatures drop and shore ice forces the birds into deeper water, more energy is needed; a decrease in energy intake could cause the observed decline in lipid reserves.

King (1961) observed in White-crowned Sparrows (*Zonotrichia leucophrys*) that just prior to spring migration an increase in lipid deposition was accompanied by an increase in feeding activity that created a positive energy balance. Fig. 1 suggests this is not so for Oldsquaws wintering on Lake Michigan because lipid mobilization does not begin to level off for a month after food intake rises, and an increase in lipid reserves does not occur until about 2 months after the food intake rises. This suggests that, although the difference in the volume of food ingested between February and April may be statistically significant, there is no simple biological relationship between food intake and fat deposition during late winter and spring. As King and Farner (1966) pointed out, a change in lipid deposition is usually the result of changes in metabolism rather than changes in food availability.

The April–May decline in food intake concurrent with increased lipid deposition suggests a negative feedback relationship between the level of fat reserves and appetite, as asserted by Dolnik and Blyumental (1964) for small migratory birds. These authors state that the characteristics of this system are seasonally variable. We believe additional controlled studies are necessary before we can fully interpret the relationship between energy consumption and lipid metabolism in Oldsquaws.

SUMMARY

The food habits of Oldsquaws wintering on Lake Michigan were examined from material collected in 2 periods: 1951–1954 and 1969–1972. Grit averaged 25% of total contents in the earlier sample, and 90% of all grit was sand. Animal food constituted about 99% by volume of the food organisms present in the 1951–1954 sample. The principal food item was an amphipod, *Pontoporeia affinis*, which occurred in 52–96% of the earlier sample and in 88–95% of the 1969–1972 sample. Clams occurred frequently in both samples but the volume ingested was relatively low. The occurrence of fish and fish eggs in the diet varied with the locality and individual flocks. Oldsquaws are related to the coregonid fishery in Lake Michigan through the common food organism *Pontoporeia affinis*. Oldsquaws will also eat fish eggs when available. The decline in Oldsquaw carcass lipids during the winter may be related to a decrease in the volume of food ingested during that period, but a rise in the volume of ingested food during early spring does not appear to be associated with a premigratory increase in lipid deposition. Oldsquaws apparently decrease their feeding activity just prior to migration and do not resume heavy feeding while on spring migration.

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LITERATURE CITED

ALLEY, W. P. 1968. Ecology of the burrowing amphipod *Pontoporeia affinis* in Lake Michigan. Ph.D. thesis, Univ. Michigan, Ann Arbor.

BARTONEK, J. C. AND J. J. HICKEY. 1969. Food habits of Canvasbacks, Redheads, and Lesser Scaup in Manitoba. Condor 71:280–290.

COTTAM, C. 1939. Food habits of North American diving ducks. U.S. Dep. Agric. Tech. Bull. 643.

DEMENT'EV, G. P., N. A. GLADKOV, Y. A. ISAKOV, N. N. KARTASHEV, S. V. KIRIKOV, A. V. MIKHEEV, AND E. S. PTUCHENKO. 1952. Birds of the Soviet Union. Vol. 4. Translated 1967 Israel Prog. for Sci. Trans., Jerusalem.

DILLON, O. W., JR. 1957. Food habits of wild ducks in the rice-marsh transition area of Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 11:114–119.

DOLNIK, V. R. AND T. I. BLYUMENTAL. 1964. Bioenergetika migratsii ptits. Usp. Sovrem. Biol. 58:280–301.

EGGLETON, F. E. 1937. Productivity of the profundal benthic zone in Lake Michigan. Michigan Acad. Sci. Arts and Letters 22:593–611.

ELLARSON, R. S. 1956. A study of the Old-squaw Duck on Lake Michigan. Ph.D. thesis, Univ. Wisconsin, Madison.

HICKEY, J. J., J. A. KEITH, AND F. B. COON. 1966. An exploration of pesticides in a Lake Michigan ecosystem. J. Appl. Ecol. 3(Supp.):141–154.

HULL, E. D. 1914. Habits of the Old-squaw (*Harelda hyemalis*) in Jackson Park, Chicago. Wilson Bull. 26:116–123.

KING, J. R. 1961. On the regulation of vernal premigratory fattening in the White-crowned Sparrows. Physiol. Zool. 34:145–157.

——— AND D. S. FARNER. 1966. The adaptive role of winter fattening in the White-crowned Sparrow with comments on its regulation. Am. Nat. 100:403–418.

KOELZ, W. 1927. Coregonid fishes of the Great Lakes. Bull. U.S. Bur. Fish. 43:297–643.

LAGLER, K. F. AND C. C. WIENERT. 1948. Food of the Old-squaw in Lake Michigan. Wilson Bull. 60:118.

MACKAY, G. H. 1892. Habits of the Oldsquaw (*Clangula hyemalis*) in New England. Auk 9:330–337.

MADSEN, F. J. 1954. On the food habits of diving ducks in Denmark. Danish Rev. Game Biol. 2:157–266.

MARZOLF, G. R. 1962. Substrate relations of the burrowing amphipod *Pontoporeia affinis* Lindstrom. Ph.D. thesis, Univ. Michigan, Ann Arbor.

MERNA, J. W. 1960. A benthological investigation of Lake Michigan. M.S. thesis, Michigan State Univ., East Lansing.

POLUNIN, N. AND C. R. EKLUND. 1953. Notes on food habits of waterfowl in the interior of Ungava Peninsula. Can. Field-Nat. 67:134–137.

RAWSON, D. S. 1953. The bottom fauna of Great Slave Lake. J. Fish Res. Board Can. 10:486–520.

ROFRITZ, D. J. 1972. Ecological investigations on waterfowl wintering in the Milwaukee Embayment. M.S. thesis, Univ. Wisconsin, Milwaukee.

SIEGEL, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York.

SWANSON, G. A. AND J. C. BARTONEK. 1970. Bias associated with food analysis in gizzards of Blue-winged Teal. J. Wildl. Manage. 34:739–746.

Zimmerman, F. R. 1953. Waterfowl habitat surveys and food habit studies, 1940–43. Final Rep. Pittman-Robertson Proj. 6-R, Wisconsin Cons. Dept. (A copy has been deposited in the Van Tyne Library.)

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