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FEEDING ECOLOGY OF DIVING DUCKS ON KEOKUK POOL, MISSISSIPPI RIVER

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Abstract: From 1966 through 1968, a study was conducted to investigate the relationships between diving ducks and their food resources on the Keokuk Pool of the Mississippi River. This information was needed as a baseline from which to measure the impact of channelization on food resources of diving ducks. Nearly 20 million diving duck days were recorded during each year by aerial and ground census. Night dispersal and feeding seemed particularly important to diving ducks since disturbances caused the concentration of 90 percent of the waterfowl on 28 percent of the study area during daytime. Molluscs, especially fingernail clams (*Sphaerium transversum*), were of paramount importance as food for five species of diving ducks. The analysis of duck esophageal contents collected during spring indicated that diving ducks ingested larger benthic organisms until large items became unavailable due to intensive predation. The combination of estimates of food consumption by diving ducks and benthos data indicated diving ducks possibly harvest 25 percent of the benthic standing crop during fall. The future of this important migration stopover area largely depends on the preservation of the rich molluscan fauna.

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The Keokuk Pool (Pool 19) is a 45-mile section of the Mississippi River from Keokuk to near Burlington, Iowa. The lower half (Fig. 1) is noted for the great concentrations of migrating diving ducks that rest and feed during spring and fall. Lesser scaup (*Aythya affinis*), ring-necked ducks (*A. collaris*), canvasbacks (*A. valisineria*), and common goldeneyes (*Bucephala clangula*) are the most abundant species and use the area from late September to early December and from late February until early May. Small numbers of ducks, especially common goldeneyes, remain on the pool during mild winters.

The gradual disappearance of diving ducks on the Illinois River due to pollution (Mills et al. 1966) heightened concern over increased industrialization of the Keokuk Pool. This study was established to gather baseline data about the food resources of waterfowl prior to channelization at Fort Madison, Iowa. The study began in August 1966 and continued through May 1968 under Pittman–Robertson Project W-108-R of the Iowa State Conservation Commission.

I thank F. C. Bellrose of the Illinois Natural History Survey for providing the aerial census data used in this study. Helpful suggestions were received from M. W. Weller, R. J. Muncy, and K. D. Carlander of Iowa State University, L. J. Korschgen of the Missouri Department of Conservation, A. S. Hawkins of the Bureau of Sport Fisheries and Wildlife and W. F. Gale of Ichthyological Associates.

STUDY AREA

The study area included the lower 26 miles of the Keokuk Pool from the dam at Keokuk north to Dallas City, Illinois (Fig. 1), with about 17,000 acres of open water. The average water depth at 120 randomly selected sites was 9 feet with a maximum of 36 feet. Substrate types ranged from soft clay to bedrock.

The study area was divided into three sections based upon access roads and distinguishing topographic features. The lower 11-mile section (Keokuk to Nauvoo, Illinois) lies in a north–south direction and averages 1 mile wide (Fig. 1). The mean depth is 11 feet but there is a broad, shallow area near Nauvoo that averages less than 2 feet deep and contains dense stands of emergent vegetation.

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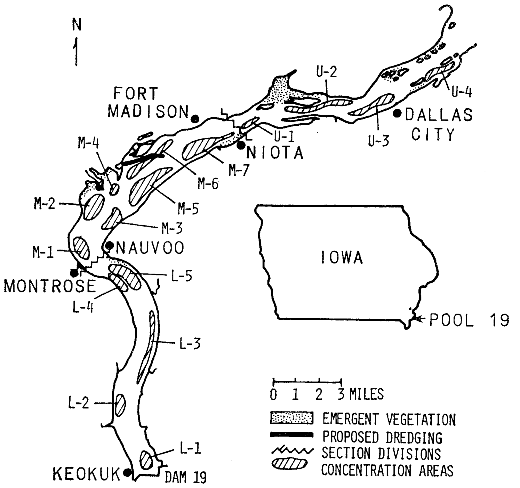

Fig. 1. Keokuk Pool study area from Keokuk, Iowa to Dallas City, Illinois. Three subdivisions are separated by jagged lines and concentration areas are indicated by section: lower (L), middle (M), and upper (U).

The 8-mile section from Nauvoo to the bridge at Fort Madison, Iowa, is up to 2 miles wide, averaging 1.4 miles (Fig. 1). Excluding the narrow navigation channel, the depth averages only 7 feet. Heavily vegetated backwater sloughs are extensive.

The 7-mile upper section from Fort Madison to Dallas City is about 1 mile wide and averages 10 feet deep (Fig. 1). An island complex with numerous vegetated backwaters dominates most of the river from Fort Madison to Burlington, Iowa.

The Keokuk Pool receives considerable commercial barge traffic from March through December. Small boat traffic due mainly to commercial fishing is generally light but continues until freeze-up.

METHODS

Aquatic Plants and Benthos

In September 1967, distribution and relative abundance of conspicuous aquatic plants were recorded by aerial survey. Beds of *Potamogeton* spp., *Sagittaria* spp., and *Nelumbo lutea* were sketched on outline maps and rated in one of five categories of relative density.

Seasonal population estimates of benthos were made near the proposed site of channel-dredging. A variety of habitats were sampled using grabs and a core sampler. Detailed bottom fauna data were presented by Gale (1969). In a cooperative effort, Gale and I estimated standing crops of fingernail clams on the entire study area in September 1967 prior to the arrival of diving ducks (Gale 1973). One hundred twenty samples were taken at randomly selected sites with a 9- × 9-inch Ponar grab over a 3-day period. To save time, samples were screened through ⅛ inch hardware cloth which retained only larger organisms. To estimate the population of smaller organisms, 3-inch core samples were collected and screened through a mesh of 30 grids per inch. From the core samples, it was possible to estimate the number of organisms being lost from the Ponar samples. This procedure introduced some bias, but it was essential to reduce sampling and sorting time. Samples were preserved in 10 percent buffered formalin. Verification of identifications were made by various authorities (Gale 1969).

Waterfowl Population Appraisal

A combination of aerial counts and ground counts was used to quantitate use of the study area by diving ducks. As part of the cooperative program, F. C. Bellrose made weekly aerial counts in the fall of 1966 and in the spring and fall of 1967. Bellrose's data were used to tabulate the number of waterfowl days of use on the upper, middle, and lower sections of the study area. To calculate seasonal use by waterfowl, the number of birds observed on each aerial count was multiplied by the number of days since the previous count.

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Waterfowl days of use for each period then were summed for the entire season.

Supplementary ground counts provided a more detailed record of the activity of large flocks. In the fall of 1966, ground counts were made only on the middle section of the study area, but all three sections were covered during the following field seasons. Counts were made on an irregular basis between aerial counts in 1966 and 1967. During the spring of 1968, ground counts were made weekly because aerial counts were not conducted.

Weather conditions affected ground counts more than aerial counts. Waves over 2 feet high and poor light conditions considerably reduced the accuracy of ground counts. Analysis of ground photographs suggested that ground counts could be used only as an index to flock size. Therefore, numbers and sizes of flocks observed from the ground were used to estimate relative use of small areas within a section of the study area.

From each observation site, flock size and location were sketched on outline maps. Besides direct counts of birds within flocks, species composition and general behavior were recorded. Since disturbances by barges, pleasure boats, and boats of commercial fishermen and hunters were common, areas were assigned a value of from one to five.

Appraisal of Foods and Feeding

To determine which foods were eaten by ducks on Keokuk Pool, the contents of 599 digestive tracts from six species of diving birds were examined. Birds were collected in several ways. In fall, hunters contributed duck gizzards. In spring and fall, diving ducks were occasionally collected from commercial fishermen who unintentionally caught ducks in trammel nets or on trotlines. I collected additional birds by using gill and trammel nets.

Gizzard contents were washed in a wire basket (40 grids per inch), dried, and stored in coin envelopes. Later, the dried foods were examined with a binocular dissecting scope and the occurrence of food items was recorded.

Of the 599 birds, 134 were collected in spring of 1968. Esophageal contents were removed from these 134 and the numbers of each food item were recorded. Numbers of the various kinds of foods were summed and expressed as percentages of the total number of items. Data were grouped according to sites at which the birds were collected.

RESULTS

Waterfowl Populations and Distribution

Bellrose's data revealed that three species of waterfowl accounted for 93–99 percent of the total use of Keokuk Pool. Lesser scaup and ring-necked ducks accounted for 84–86 percent of the waterfowl days in three seasons of aerial survey. Ring-necked ducks were considered with scaup because it was impossible to distinguish between them in my ground counts. Canvasbacks accounted for 9–13 percent, while other species such as goldeneyes, ruddy ducks, and coots accounted for less than 5 percent of the total. Approximately 3,000 goldeneyes overwintered, thereby accounting for more days of use than were indicated by spring and fall counts.

Use of the area is shown by section for six species (Table 1). In fall, the lower section had the greater percentage of waterfowl days, but in spring, the upper section received greater use. The middle section received similar percentages of use in spring and fall.

Diving ducks tended to concentrate in

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Table 1. Seasonal distribution of waterfowl on three sections of Keokuk Pool during 1966 and 1967.

Section of Pool	Fall 1966 17 Oct.–24 Dec.		Spring 1967 3 Mar.–19 Apr.		Fall 1967 17 Oct.–11 Dec.	
	Number[a]	Percent	Number	Percent	Number	Percent
Lower	7,826,150	69.9	2,413,540	21.6	4,446,880	46.8
Middle	3,228,670	28.8	4,196,200	37.5	3,340,090	35.2
Upper	142,000	1.3	4,573,175	40.9	1,711,360	18.0
Total	11,196,820	100.0	11,182,915	100.0	9,498,330	100.0

[a] Estimated number of waterfowl days from aerial census data of F. C. Bellrose.

16 areas which composed 28 percent of the open water of the entire study area and ranged in size from 50 to 700 acres with a mean of 290 acres (Fig. 1). Based upon ground counts, about 85 percent of flocks over 500 birds and 98 percent of flocks over 15,000 birds occurred on these 16 areas.

Through indices derived from ground counts, distinct seasonal changes in occurrences of flocks on the concentration areas were noted. When waterfowl use (Table 1) was compared with levels of human disturbance (Table 2) it was obvious that sections with greater human disturbance had lower use by ducks.

Benthos and Aquatic Plant Resources

The fingernail clam was widely distributed in Keokuk Pool and exceeded 100,000/m^2 in summer in favorable habitats (Gale 1969). The population of fingernail clams, however, underwent drastic seasonal changes in numbers and size classes. The overall clam population remained high in fall and early winter because of the great preponderance of small (less than 2 mm wide) clams. In December, only 3–4 percent of the individuals were over 1 mm wide. Because small clams may be as deep as 16 cm in the substrate (Gale 1973) many may have been unavailable to predators such as diving ducks.

Fingernail clams grow slowly in winter and, presumably because predation resumed early the following spring, the number of large individuals decreased in the spring. By May, fingernail clams grew rapidly and by June, 31 percent of the population exceeded 2 mm in width. The numbers of large clams continued to increase in July but dropped sharply in August and continued to decline during autumn and early winter (Gale 1969).

In September 1967, it was estimated the study area had a standing crop of 18,000 sphaeriids per square meter or 1,131 lb/acre (blotted dry weight with shells intact). The upper section had 1,841 lb/acre; the lower section had 1,026 lb/acre; and the middle section had the lowest crop with 675 lb/acre.

The mean number of snails per square meter was 71 on the lower section and 58 on the upper section. *Somatogyrus isogonus* occurred at 23/m^2, *Lioplax sulculosa* at 18/m^2, *Campeloma crassula* at 8/m^2, and several other species occurred at lesser densities. Small snails were not found in the Ponar samples but *Fontigens nickliniana* occurred at a density of 25/m^2 in core samples.

Based on Ponar sampling, mayfly (*Hexagenia* sp.) density was estimated to be 41/m^2 on the entire study area in September. Density was greatest on the upper section with a mean of 115/m^2. The middle and lower sections had means of 14/m^2 and 4/m^2 respectively.

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Chironomids (Chironomidae) and caddisflies (Trichoptera) were fairly abundant in the Pool. On the basis of seasonal samples, chironomids reached their maximum density in winter, but usually did not exceed 3,000/m^2. Caddisflies were most abundant in summer when the density of *Cheumatopsyche* spp. sometimes exceeded 20,000/m^2. *Oecetis* was usually the most abundant caddisfly genus (Gale 1969).

The lower section contained less vegetation than other sections, according to my aquatic plant inventory. Vegetation types and the density ranking for the submergent vegetation in each concentration area were presented by Thompson (1969). Beds of emergent and submergent vegetation covered less than 3 percent of the study area.

In general, the diurnal distribution of waterfowl in fall seemed unrelated to density or distribution of vegetation or benthos.

Table 2. Relative disturbance levels on 16 waterfowl concentration areas in three sections of Keokuk Pool, fall and spring, 1966–68.

Section of Pool and area	Disturbance level[a] March–April	Disturbance level[a] October–November
Lower		
L-1	4	3
L-2	3	1
L-3	2	1
L-4	4	4
L-5	4	5
Total	17	14
Average	3.4	2.8
Middle		
M-1	3	4
M-2	2	4
M-3	3	4
M-4	4	4
M-5	4	4
M-6	3	4
M-7	2.5	4
Total	21.5	28
Average	3.1	4.0
Upper		
U-1	3	3
U-2	1.5	4
U-3	3.5	5
U-4	3.5	5
Total	11.5	17
Average	2.9	4.2

[a] Relative disturbance in each section was assigned a value of from one to five according to the following criteria: little or no on-the-water disturbance, mild disturbance by fishermen or hunters, moderate disturbance by fishermen, or hunters, or barges, common disturbance by hunters, barges, or fishermen, or a combination of these, and frequent disturbance by hunters, fishermen, and barges.

FALL FOODS

Fall food habits of diving ducks on the Mississippi River have been investigated by Anderson (1959) and Rogers and Korschgen (1966). Rogers and Korschgen (1966) included 88 lesser scaup collected on the Keokuk Pool in fall of 1948. Korschgen also examined 12 canvasback gizzards from the Keokuk Pool and provided these data for my use. Lesser scaup in both studies contained a high occurrence of animal food; molluscs composed nearly 90 percent of the total volume of organic material.

In my study, gizzards and some esophagi were collected from 440 ducks and coots in the fall of 1966 and 1967. Scaup and canvasbacks comprised 71 and 10 percent of the total, respectively. Because esophagi or proventriculi were usually not available for ducks collected by hunters, only gizzard contents were examined to estimate fall foods. A comparison of gizzards and esophageal contents from the same birds revealed biases when food habits were based only on gizzard contents (Thompson 1969). Therefore, gizzard contents could only be used to indicate general differences in food habits of similar species collected in similar areas. The percentage of birds containing a particular food item is known as the frequency of occurrence for that item (Table 3).

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Table 3. Number and percent frequency of food items in gizzards collected at the Keokuk Pool, fall of 1966 and 1967.

	Lesser scaup (270)[a]		Canvasback (59)		Ring-necked duck (32)		Common goldeneye (24)		Ruddy duck (24)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Animal foods										
Gastropoda										
Campeloma crassula	57	21	8	14	9	28	5	21	1	4
Amnicola lacustre	13	5	2	3	2	6	0	0	0	0
Somatogyrus isogonus	90	33	11	19	4	2	2	8	1	4
Lioplax sulculosa	27	10	2	2	1	3	0	0	0	0
Pleurocera acuta	22	8	3	5	2	6	0	0	0	0
Viviparus georgianus	2	1	0	0	0	0	0	0	0	0
Fontigens nickliniana	52	19	3	5	1	3	2	8	3	12
Valvata tricarinata	5	2	0	0	0	0	0	0	0	0
Physa spp.	1	T	1	2	0	0	0	0	0	0
Unidentified gastropoda	184	68	19	32	13	41	10	42	7	29
Pelecypoda										
S. *transversum*	107	40	18	30	14	44	3	12	5	21
S. *striatinum*	205	76	15	35	16	50	5	21	9	38
Pisidium spp.	2	1	0	0	0	0	0	0	0	0
Unionidae	26	10	9	15	0	0	2	8	0	0
Unidentified pelecypoda	247	92	32	54	23	72	14	58	14	58
Insecta										
Hexagenia sp.	36	13	27	46	6	19	1	4	10	42
Trichoptera	19	7	6	10	3	9	4	17	2	8
Chironomidae	4	2	6	10	1	3	4	17	2	8
Corixidae	5	2	1	2	1	3	3	12	0	0
Odonata	0	0	0	0	1	3	0	0	0	0
Elmidae	2	T	0	0	0	0	0	0	0	0
Plecoptera	1	T	0	0	0	0	0	0	0	0
Unidentified insecta	7	3	1	2	4	12	1	4	3	12
Crustacea										
Amphipoda	1	T	0	0	1	3	0	0	0	0
Cambarinae	1	T	0	0	0	0	0	0	0	0
Other										
Fish	2	1	0	0	0	0	0	0	0	0
Leech	7	3	0	0	0	0	1	4	0	0
Mite	0	0	0	0	0	0	0	0	0	0
Unidentified animal	1	T	0	0	1	3	0	0	0	0
Total animal	253	94	47	80	30	94	20	83	22	92
Plant foods										
Seeds										
Polygonum spp.	17	6	2	3	1	3	1	4	3	12
Potamogeton spp.	22	8	22	37	8	25	6	25	2	8
Scirpus spp.	6	2	8	14	3	9	2	8	3	12
Sagittaria spp.	0	0	0	0	0	0	1	4	0	0
Unidentified seeds	16	6	6	10	7	22	3	12	0	0

Table 3. *Continued.*

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Table 3. *Continued.*

	Lesser scaup (270)[a]		Canvasback (59)		Ring-necked duck (32)		Common goldeneye (24)		Ruddy duck (24)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Plant										
Ceratophyllum sp.	0	0	0	0	0	0	0	0	0	0
Lemna sp.	2	1	4	7	3	9	3	12	0	0
Algae	0	0	0	0	0	0	0	0	0	0
Unidentified plant	7	3	8	14	9	28	9	27	0	0
Total plant	52	19	27	46	16	50	14	58	7	29
Gravel	245	91	59	100	32	100	23	96	24	100
Shot (ingested)	2		1	2	0	0	0	0	0	0

[a] Sample sizes are in parentheses.

Lesser Scaup

Scaup gizzards contained a high occurrence of animal foods, especially molluscs. Sixty-eight percent of the gizzards contained unidentified gastropods, 76 percent contained sphaeriids, and 91 percent contained unidentified pelecypods, mostly sphaeriids. Occasionally seeds and other plant material were found.

Molluscs were found less abundant in the 220 scaup examined by Anderson (1959), but plant materials occurred at a much higher frequency than in my study. Both snails and plant materials occurred in approximately 26 percent of the birds in Anderson's study. Forty-six percent of the 88 scaup gizzards examined by Rogers and Korschgen (1966) contained gastropods while 27 percent contained pondweeds. Mayflies occurred in approximately 13 percent of the scaup in each of the three studies.

Gizzard contents from 1966 and 1967 varied with the site where collected (Table 4). When this table on utilization was compared with Ponar grab samples taken within the duck concentration areas (Table 5), it was apparent that, in general, scaup collected where clam density was high contained more clams than ducks collected elsewhere. This was especially noticeable on concentration areas U-2 and U-3 (Fig. 1) where clam density was highest. Agreement between gastropod abundance at a particular site and gastropod occurrence in scaup collected from that site was not as good.

Scaup collected from area L-5 contained many more chironomids than scaup collected elsewhere. Scaup from areas U-2 and U-3 contained many mayflies, whereas ducks from M-7 contained few. Mayflies (*Hexagenia* sp.) were more abundant in Ponar samples from U-3 than in other areas.

It is important to recognize two possible sources of bias that might affect the validity of the comparison between Ponar samples and gizzard contents: First, the gizzard may retain hard items for several weeks and it is impossible to be certain the ducks had fed where they were collected; second, sample sizes were small.

Canvasbacks

Gastropods and sphaeriids occurred less frequently in canvasbacks than in lesser scaup (Table 3). Forty-six percent of the canvasbacks contained *Hexagenia* sp., whereas Anderson (1959) found *Hexa-*

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Table 4. Number and percent frequency of food items in gizzards from lesser scaup collected at various sites of Keokuk Pool during fall 1966–67.

	All areas (270)[a]	Backwaters (17)		L-5 (23)		M-2 (33)		Between M-4 and M-5 (80)		M-5 (43)		M-7 (39)		U-2 (9)		U-3 (14)	
	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
S. transversum	40	10	59[b]	10	44	14	42	24	30	17	40	15	38	5	56[b]	9	65[b]
S. striatinum	76	8	47[b]	18	78	18	55	70	88	41	95[b]	34	87	4	44[b]	11	78
F. nickliniana	19	2	12	4	17	5	15	16	20	9	21	9	23	2	22	4	29
C. crassula	21	0	0[b]	4	17	5	15	20	25	11	26	13	34[b]	1	11	2	14
S. isogonus	33	1	6[b]	2	9[b]	5	15	34	42	19	44	16	41	0	0[b]	2	14
Unidentified gastropoda	68	8	47	2	9[b]	18	55	60	75	34	79	30	77	4	44	11	78
Unidentified pelecypoda	92	16	94	2	9[b]	26	78[b]	79	99	42	98	38	98	9	100	14	100
Unionidae	10	1	6	1	4	0	0	4	5	7	17	6	15	2	22	4	29[b]
Trichoptera	7	0	0	4	17	2	6	5	6	3	7	4	10	0	0	1	7
Hexagenia sp.	13	3	18[b]	2	9	6	18	6	8	3	7	1	3	8	89[b]	7	50[b]
Polygonum sp.	6	5	29[b]	3	13	7	21[b]	0	0	0	0	1	3	0	0	1	7
Potamogeton spp.	8	4	24[b]	1	4	8	24[b]	1	1	0	0	5	13	1	11	1	7
Unidentified seeds	6	2	12	2	9	7	21[b]	3	4	0	0	1	3	0	0	0	0

[a] Sample sizes are in parentheses.
[b] Marked difference from overall percentage occurrence.

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Table 5. Mean number of organisms per square meter found on concentration areas in Keokuk Pool, October 1967.

Area	Number of Ponar grab samples	*S. transversum*	*Hexagenia*	Unionidae	Gastropoda
U-2	6	5693	19	0	19
U-3	6	1394	138	15	96
M-2	7	664	6	0	36
M-5	4	1451	4	10	96
M-7	6	1734	61	134	54
L-5	5	993	0	0	73

genia sp. in only 11 percent of the canvasbacks he examined.

The percentage of plant foods, particularly seeds, was much higher in canvasbacks than in lesser scaup. Anderson (1959) reported especially high occurrences of pondweeds in canvasbacks.

Ring-necked Duck

Food habits of ring-necked ducks seemed intermediate between those of lesser scaup and canvasbacks (Table 3). Ring-necked ducks contained lower percentages of unidentified gastropods, sphaeriids, mayflies, caddisflies, midges, and pondweeds than did scaup but greater percentages than did canvasbacks. Plant material occurred more frequently in ring-necked ducks than in scaup or canvasbacks. Anderson (1959) found gastropod remains in 12 percent of the ring-necked ducks he examined, compared with 41 percent in this study. Plant foods were much more common in Anderson's study; pondweeds and smartweeds appeared in over 42 percent of the 120 gizzards he examined.

Common Goldeneye

Only 24 common goldeneyes were collected during the falls of 1966 and 1967 (Table 3). Unidentified gastropods remains occurred more often in goldeneyes than in ringnecks and unidentified pelecypods occurred in 58 percent of the goldeneye gizzards. Martin et al. (1951) reported that 77 percent, by volume, of the goldeneye's diet was animal food. Madsen (1954) found molluscs and amphipods in 68 percent of the goldeneyes collected from brackish water in Denmark.

Ruddy Duck

Few ruddy ducks contained gastropods and sphaeriids, but 58 percent contained unidentified pelecypods (Table 3). Aquatic insects were comparatively more important than in most other ducks. Seeds and other plant materials occurred less frequently in ruddy ducks in my study than in data reported by Martin et al. (1951). Sincock (1962) found animal food in 20 percent of the gizzards collected in North Carolina in late fall.

American Coot

Coots (*Fulica americana*) frequented backwaters more often than diving ducks. These coots fed extensively on aquatic vegetation on or near the water's surface, but coots on the open river dived for their food.

Fifteen coots were collected in backwaters and 16 were collected in open water. Gizzard contents from the two groups were distinctly different (Table 6). Coots collected at open-water sites contained foods in occurrences similar to lesser scaup except that two of the more abundant small snails (*Anmicola* sp. and *Fontingens* sp.) did not occur in the coots. Coots collected from backwaters had a much higher occurrence

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Table 6. Foods of two groups of coots collected in backwater and open water areas during fall 1966–67, Keokuk Pool.

	Backwater (15)[a]		Open water (16)	
	Number	Percent	Number	Percent
Animal foods				
Gastropoda				
Campeloma sp.	0	0	3	19
Amnicola sp.	0	0	0	0
Somatogyrus sp.	0	0	2	12
Pleurocera sp.	0	0	1	6
Fontigens sp.	0	0	0	0
Unidentified gastropoda	3	20	10	62
Pelecypoda				
S. transversum	1	7	0	0
S. striatinum	2	13	9	56
Pisidium sp.	0	0	0	0
Unionidae	0	0	0	0
Unidentified pelecypoda	4	27	13	81
Insecta				
Hexagenia sp.	0	0	1	6
Trichoptera	0	0	0	0
Chironomidae	0	0	0	0
Corixidae	1	7	0	0
Odonata	0	0	1	6
Elmidae	0	0	0	0
Plecoptera	0	0	0	0
Unidentified insect	3	20	0	0
Other	0	0	0	0
Plant foods				
Seeds				
Polygonum spp.	6	40	2	12
Potamogeton spp.	2	13	0	0
Scirpus spp.	0	0	0	0
Sagittaris spp.	2	13	1	6
Unidentified seeds	1	7	0	0
Plant				
Ceratophyllum sp.	5	33	0	0
Lemna sp.	5	33	1	6
Algae	5	33	2	12
Unidentified plant	9	60	5	31
Gravel	15	100	16	100
Shot (ingested)	0	0	0	0

[a] Sample sizes are in parentheses.

of plant materials and had much larger, less fatty gizzards than did coots collected from open-water sites.

SPRING FOODS

Food of 159 scaups collected in spring were assessed by the occurrence of food in the gizzard (Table 7) and by enumeration and occurrence of items in the esophagus (Table 8). It was clear that the occurrences of foods in the two fall samples were similar and differed from the occurrences in the two spring samples (Table 7). However, the occurrence of nearly all animal foods was higher in spring than in fall. Presumably the differences in fall and spring food habits reflected changes in bottom fauna.

To further evaluate spring food habits, the contents of 134 esophagi of scaup were analyzed by enumerating each species of food item in the esophagus. These birds were caught in 1968 with trammel nets near area M-4, a site where scaup fed intensively. Molluscs, particularly small fingernail clams, were the major component of esophageal contents (Table 8). The large number of caddisflies and chironomids possibly reflect a large population of insects where these ducks were feeding. In the Keokuk Pool, insects were relatively more abundant in late winter and early spring while the mollusc population peaked in midsummer and declined by winter (Gale 1969). Snails occurred frequently but only in small quantities. Plant materials were not major food items and only *Lemna* sp. accounted for over 6 percent occurrence.

EFFECTS ON BENTHOS

The 134 lesser scaup taken in spring were caught at the same site from March through April 1968 in six samplings. The contents of esophagi were examined and

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Table 7. Seasonal occurrence of food items in 429 lesser scaup gizzards from Keokuk Pool, 1966–68.

	Fall 1966 (46)[a]		Spring 1967 (20)		Fall 1967 (224)		Spring 1968 (139)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Animal foods								
Gastropoda								
Campeloma sp.	6	13	7	35	51	23	51	37
Amnicola sp.	1	2	4	20	12	5	34	24
Somatogyrus sp.	5	11	13	65	85	38	77	55
Lioplax sp.	1	2	7	35	26	12	58	42
Pleurocera sp.	1	2	0	0	21	9	50	36
Viviparus sp.	0	0	2	10	2	1	4	3
Fontigens sp.	6	13	10	50	46	20	75	54
Valvata sp.	3	6	0	0	2	1	0	0
Physa sp.	0	0	0	0	1	T	1	1
Gyraulus sp.	0	0	0	0	0	0	0	0
Unidentified gastropoda	22	48	18	90	162	72	134	96
Pelecypoda								
S. transversum	23	50	19	95	84	38	128	92
S. striatinum	21	46	19	95	184	82	115	83
Pisidium sp.	2	4	0	0	0	0	0	0
Unionidae	1	2	4	20	25	11	38	27
Unidentified pelecypoda	36	78	19	95	211	94	135	97
Insecta								
Hexagenia sp.	8	17	15	75	28	12	79	57
Trichoptera	2	6	13	65	17	8	95	68
Chironomidae	4	9	7	35	0	0	73	52
Corixidae	2	4	0	0	3	1	1	1
Odonata	0	0	0	0	0	0	1	1
Elmidae	0	0	0	0	2	1	0	0
Plecoptera	0	0	0	0	0	0	0	0
Unidentified insecta	0	0	1	5	7	3	9	6
Crustacea								
Amphipoda	0	0	0	0	1	T	0	0
Cambarinae	0	0	0	0	0	0	0	0
Other								
Fish	0	0	0	0	2	1	3	2
Leech	0	0	0	0	7	3	0	0
Mite	0	0	0	0	0	0	1	1
Unidentified animal	1	2	2	10	0	0	0	0
Plant foods								
Seeds								
Polygonum spp.	12	26	1	5	5	2	8	6
Potamogeton spp.	12	26	0	0	10	4	22	16
Scirpus spp.	0	0	0	0	6	3	0	0
Sagittaria spp.	0	0	1	5	0	0	4	3
Unidentified seeds	7	15	1	5	9	4	2	1

Table 7. *Continued.*

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Table 7. *Continued.*

	Fall 1966 (46)[a]		Spring 1967 (20)		Fall 1967 (224)		Spring 1968 (139)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Plant								
Ceratophyllum sp.	0	0	0	0	0	0	0	0
Lemna sp.	2	4	0	0	0	0	0	0
Algae	0	0	0	0	0	0	0	0
Unidentified plant	0	0	0	0	7	3	0	0
Gravel	44	96	17	85	201	90	139	100
Shot (ingested)	0	0	0	0	2	1	2	1

[a] Sample sizes are in parentheses.

counted (Table 8). When data were organized chronologically by capture, six major foods showed changes in use over the month (Fig. 2). The percentage of sphaeriids and chironomids in the diet usually increased with time, while organisms such as large snails decreased. The larger size classes of sphaeriids and chironomids decreased (percentage of total) while small size classes increased in the total (Table 9) suggesting that scaup selected larger food items in the early part of the spring. Large sphaeriids were more abundant in March than in April (Gale 1969). Presumably, small clams grew very slowly, if at all, during this period and were not recruited into larger size classes to replace those lost to predation.

Eight Petersen grab samples were taken in May 1967 at four areas that contained large numbers of diving ducks in daytime during April. For comparison, nine similar samples were collected in areas that received little diurnal use during April. The areas of intensive use by waterfowl had smaller numbers of most benthic species (Table 10). These data may indicate effects of waterfowl use on standing crop of benthos in the spring but they do not explain why birds continued to use areas where food supplies appeared depleted. Possibly diving ducks fed at night in areas not used by waterfowl during the day.

ESTIMATES OF FOOD CONSUMPTION

Because Keokuk Pool is an area of intensive waterfowl use, it seemed important to estimate the consumption of food by diving birds. This was accomplished by combining the estimates of waterfowl use with daily consumption figures from Longcore and Cornwell (1964) and calorie values from Cummins and Wuycheck (1971).

Longcore and Cornwell (1964) allowed captive lesser scaup and canvasbacks to dive for natural food—primarily plants. Scaup consumed an average of 0.026 lb (dry weight) or about 2–3 percent of body weight daily. Using the data of Longcore and Cornwell (1964), we converted weights to calories. Assuming each scaup on Keokuk Pool required at least 54,500 calories daily, as did the birds in the previously mentioned study, they would need to ingest 12.6 grams dry weight of sphaeriids daily. There are about 4,320 calories/gram of dry weight in two species of sphaeriids (Cummins and Wuycheck 1971).

One gram of oven-dry sphaeriid (without the shells) is equivalent to 18.14 grams (damp weight) including shells and mantle fluids (Gale, 1969). Multiplying this conversion factor times the dry weight consumption figure (12.6 grams) gave a consumption figure of 228.7 grams (damp weight) of clams per bird per day.

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Table 8. Numbers of food organisms appearing in 134 esophagi of lesser scaup collected in spring 1968, Keokuk Pool.

	Number of organisms	Number of occurrences	Percentage occurrences
Animal foods			
Gastropoda			
Campeloma sp.	1	1	1
Amnicola sp.	29	18	13
Somatogyrus sp.	25	19	14
Lioplax sp.	32	15	11
Pleurocera sp.	3	2	2
Viviparus sp.	5	3	2
Fontigens sp.	82	33	24
Physa sp.	5	4	3
Pelecypoda			
S. transversum			
S. striatinum	24,776	125	93
Large	197	52	39
Medium	287	49	36
Small	24,292	125	93
Unionidae	5	5	4
Insecta			
Hexagenia sp.	104	26	19
Trichoptera	2,444	85	63
Chironomidae	3,515	119	90
Very large	6	4	3
Pupae	105	30	22
Large	256	59	44
Medium	1,225	105	78
Small	1,923	92	69
Corixidae	28	13	10
Elmidae	5	4	3
Crustacea			
Amphipoda	192	28	21
Other			
Leech	66	24	18
Mite	7	7	5
Plant foods			
Seeds			
Polygonum spp.	1	1	1
Sagittaria spp.	8	7	5
Plant			
Lemna sp.	148	32	24
Gravel	0	0	0
Shot (ingested)	0	0	0

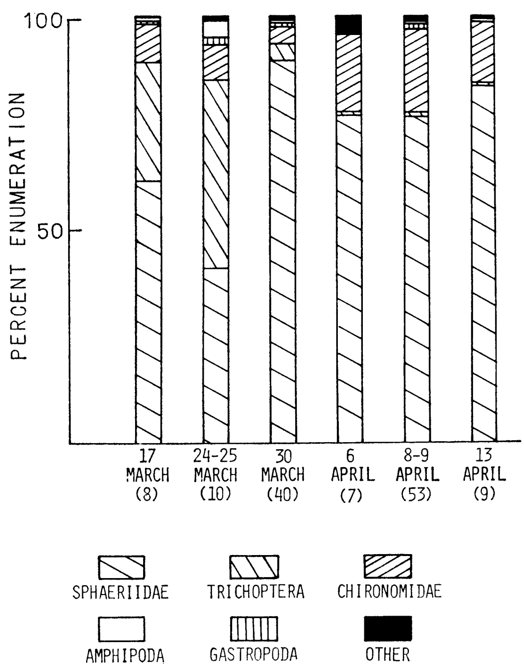

Fig. 2. Percent enumeration of six major food items in the esophagi of 134 lesser scaup taken on Keokuk Pool, spring 1968.

To determine total consumption for the entire area, the number of waterfowl days for lesser scaup, ring-necked ducks, canvasbacks, goldeneyes, and coots in the fall of 1967 was multiplied by the daily consumption figure. The result of 4,800,000 lb of sphaeriids was equivalent to 25 percent of the estimated standing crop (Gale, 1973).

This calculation of total consumption of sphaeriids has several possible sources of error. First, the entire diet of the five species did not consist of sphaeriids, although volume conversions for the spring of 1967 indicated food contents consisted of 85–95 percent fingernail clams, by volume. Secondly, the daily consumption figure provided by Longcore and Cornwell (1964) was for captive birds and is likely to be lower than that for free-flying birds.

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Table 9. Percentage of each size class in the total number of chironomids and fingernail clams found in the esophagi of 134 lesser scaup from 17 March to 13 April 1968, collected at a site of intensive feeding, Keokuk Pool.

	March 17	March 24–30	April 6–13
Chironomidae			
Pupae	0	2	3
Very large	4	0	0
Large	25	16	4
Medium	47	36	30
Small	25	46	64
Total	101	100	101
Sphaeriidae			
Large > 2 mm wide	11	3	0
Small < 2 mm wide	89	97	100
Total	100	100	100

One scaup, collected just after it had stopped feeding, contained 100 large clams. Another scaup, collected by net, contained 1,800 small sphaeriids. One hundred large clams weighed about 25 grams (damp weight) and 1,800 small clams weighed 18–20 grams (damp weight) (Gale 1969). Should 100 large clams be the maximum a scaup could consume in one feeding, the bird would need 9–10 feedings per day to obtain the theoretical 229 grams. Observations of day and night feeding indicate this is possible, especially with the prevalence of night feeding and the abundance of sphaeriids on Keokuk Pool.

DISCUSSION

Population surveys indicate 20 million diving duck days use per year, placing Keokuk Pool among the most heavily utilized areas of inland North America for diving ducks. This study has clearly shown the intensive use of the Keokuk Pool by diving ducks and their utilization of its molluscan fauna.

In addition, the Keokuk Pool provides a substantial commercial and sport fishery. Nord (1967) reported the commercial catch averaged over one million pounds per year from 1953–64, the major species being carp (*Cyprinus carpio*). Jude (1968, 1973) found molluscs were utilized as food by 11 of 13 species of bottom-feeding fish from Keokuk Pool. Fingernail clams occurred in nine of these species and were major components of the food of the carp. Ranthum (1969) found that freshwater drum (*Aplodinotis grunniens*), pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis macrochirus*), and even yellow perch (*Perca flavescens*) utilized fingernail clams as food.

Undoubtedly, the tremendous standing crop of the Keokuk Pool in terms of finger-

Table 10. Comparison of the mean number of organisms per square meter between areas of heavy and light waterfowl use, spring 1967, Keokuk Pool.

	Heavy use (8)[a]		Light use (9)			
	Total number	Average	Total number	Average	t-values	Confidence level (percent)
Chironomidae	2,452	307	3,942	438	1.536	80
Trichoptera	76	10	1,533	171	1.932	90
Hexagenia sp.	3,251	406	1,274	141	1.384	80
Sphaeriidae						
> 2 mm thick	335	42	691	77	1.003	60
< 2 mm thick	8,262	1,032	79,974	8,886	1.894	90
Gastropoda	1,706	214	3,845	428	1.404	80

[a] Number of Peterson grab samples are in parentheses.

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nail clams and other benthic organisms provides a rich food resource for both waterfowl and fish.

On the heavily polluted and altered Illinois River, the disappearance of diving ducks appeared closely related to the disappearance of their food supply, primarily sphaeriids (Mills et al. 1966). The Illinois River commercial fishery, of which carp were a major component, declined steadily over the same period.

One can conclude, if the Keokuk Pool resource is destroyed by siltation, chemical or thermal pollution, stream deepening, water diversion, or a series of such modifications, use of the Keokuk Pool by diving ducks will stop.

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