Effect of diving ducks on benthic food resources during winter in South Carolina, U.S.A.

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Introduction

Recently, increased attention has been focused on the role of the winter period in limiting waterfowl populations (Anderson & Batt 1983). Many current studies suggest that winter food resources may be a limiting factor (Pehrsson 1976; Alexander & Hair 1979; Sayler & Afton 1981) for diving ducks. Benthic food resources may decline over winter and competitive interactions among waterfowl, and between waterfowl and fish, have also been suggested as causes for food limitation (Nilsson 1969; Thompson 1973; Pehrsson 1976). Although recent studies have demonstrated that herbivorous waterfowl may reduce wetland macrophyte production (Smith & Odum 1981; Smith & Kadlec 1985) few studies have directly tested the hypothesis that diving ducks affect their winter invertebrate food resources.

Studies examining the impacts of diving ducks on benthic invertebrates have been complicated by the natural decline in invertebrates during winter and the difficulty of determining what portion of that decline, if any, may have been due to predation by waterfowl. Also, many studies have indirectly extrapolated from estimated feeding rates to total food consumption. In this study, our first objective was to estimate the direct impact of waterfowl predation on benthic invertebrates using exclosures. Secondly, we investigated whether deep waters contained richer food resources, when compared with shallow waters.

Study area and methods

The study was conducted on Par Pond reservoir located on the U.S. Department of Energy's Savannah River Plant in Barnwell County, South Carolina (Fig. 1). The reservoir encompasses 1120 ha of open water, and was formed in 1959 by damming a natural watercourse. From 1959 through 1964, the reservoir received heated cooling water effluents from two reactors and at the time of the present study effluent from one reactor was still being introduced into Par Pond at a point 3.5 km from our nearest sampling site. Nonetheless, thermal profiles of Par Pond (Lewis 1974) have indicated little thermal disturbance of the site, and normal ambient temperatures are typical of other reservoirs in the southeastern U.S.

Thirty exclosures (1 x 2 m) were established in September 1983 along the east and west sides of the Cold Dam (Fig. 1). Exclosure mesh was 5 x 10 cm to allow entry by fish, but excluded waterfowl. Ten exclosures were randomly established in a shallow emergent macrophyte zone (0.5 – 1.75 m) and 20 were randomly established in a deep water zone (3 – 11 m). Each exclosure was marked with a white buoy. The shallow area was dominated by sparse clumps of cattail *Typha* spp., rush *Juncus* spp., and water lily *Nymphaea odorata*. The deep water zone, when vegetation was present, was dominated by milfoil *Myriophyllum* spp., pondweed *Potamogeton* spp., and wild celery *Vallisneria americana*. Quadrats were placed in areas up to 11 m deep because diving ducks were commonly observed feeding at these depths. Five deep-water exclosures were lost during the last two sampling periods and were omitted from the analysis.

Benthic invertebrates were sampled on 1 November 1983, 1 January 1984, and 1 March 1984. One randomly located sediment core (15 cm length x 7.5 cm diameter) was taken inside and one outside (within 3 m along the depth contour) each exclosure on each sampling date. Cores were taken from a boat at depths < 2 m and by scuba divers in deeper water. Macroinvertebrates were separated from sediments using a Number 35 standard sieve (500 μ m) in the laboratory. Invertebrate taxa were identified using Merrit & Cummins (1978) and Pennak (1953). Because of their small individual mass, after being counted a standard sample (> 20 each) of the soft-bodied taxa were dried

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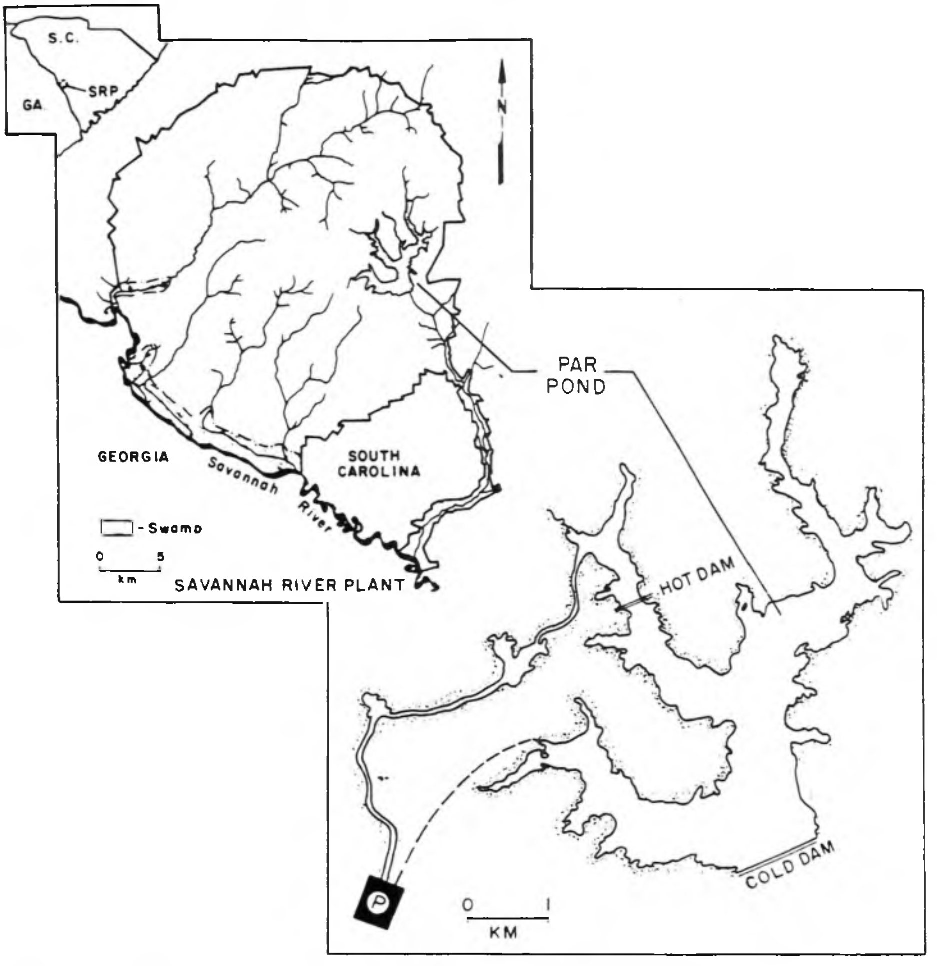

Figure 1. Location of Par Pond on the Savannah River Plant, South Carolina, U.S.A. "P" indicates the location of the reactor.

(80°C) to a constant weight so that a mean mass per individual could be estimated. Clams (Corbiculidae) and snails (Gastropoda) were weighed individually. Chironomids (Chironomidae) were assigned to one of three size classes (0–5, 6–10, and 11–15 mm), and a mean mass was obtained for each class. Waterfowl using Par Pond in 1983–4 were counted weekly from a fixed wing aircraft at an altitude of 90 m and air speed of 130 km/h.

Potential differences between enclosed and unenclosed areas in relation to depth and time were tested with split-plot analyses of variance (Cochran & Cox 1966) on ranked data (Conover & Iman 1981). Analyses were conducted on total biomass and on each taxa's biomass and numbers.

Results

Lesser Scaup *Aythya affinis*, Ring-necked Duck *A. collaris*, Bufflehead *Bucephala albeola* and Ruddy Duck *Oxyura jamaicensis* were the four most numerous waterfowl species using Par Pond (Fig. 2). These birds feed primarily on benthic invertebrates during winter although Ring-necked Duck also consume vegetative matter (Cronan 1957; Stott & Olson 1973; Pehrsson 1976). Waterfowl numbers varied between 2000–3000 from mid-November until January. American Coot *Fulica americana* also occurred in substantial numbers but were not included in the survey due to their herbivorous food habits. Other species that frequented Par Pond in small

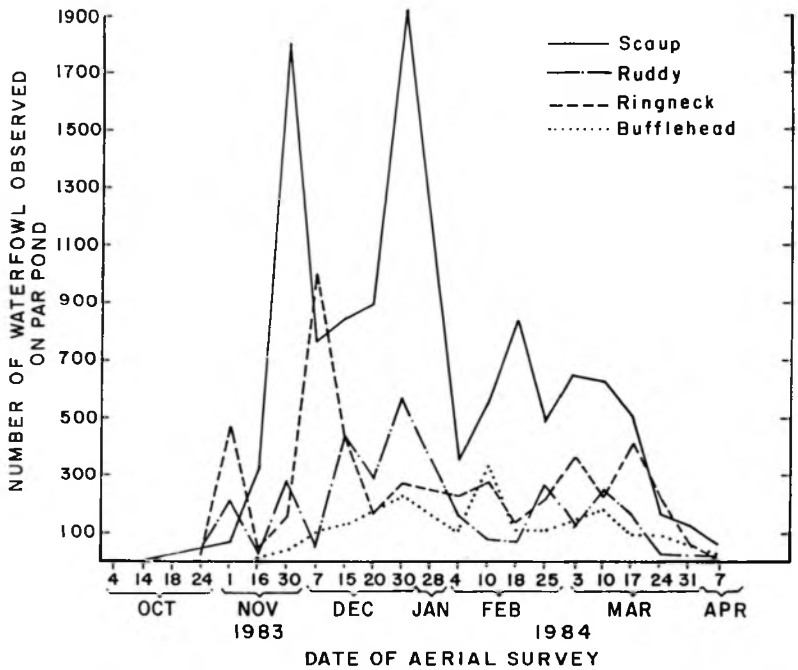

Figure 2. Winter populations of the four most numerous waterfowl species on Par Pond, South Carolina, U.S.A., 1983–4.

numbers during winter were Canvasback *Aythya valisineria*, Common Goldeneye *Bucephala clangula*, Mallard *Anas platyrhynchos*, Gadwall *A. strepera*, American Wigeon *A. americana*, Pied-billed Grebe *Podilymbus podiceps*, and Horned Grebe *Podiceps auritus*.

Twelve taxa were identified in the benthic samples (Table 1). Chironomids were most numerous, but Corbiculidae made up the major portion of the biomass, largely a result of the calcerous shell material (Table 2). *Corbicula fluminea* was the dominant bivalve mollusc in Par Pond during this study. This is a relatively recent change, since 5 years ago *Anodonta imbecillis* (Unionidae) was dominant (Britton & Fuller 1979).

There was no difference ($P > 0.10$) in either numbers (Table 1) or biomass (Table 2) of most invertebrate taxa sampled inside vs. outside the exclosures. However, there was an exclosure – time period interaction for oligochaete biomass and Corbiculidae biomass and numbers ($P < 0.05$). Therefore predation effects were examined for these groups separately by period. Only Corbiculidae numbers varied significantly indicating a predation effect. Numbers of the large and small size classes of Chironomidae and Corbiculidae fluctuated ($P < 0.04$) from November to March whereas the other taxa did not change significantly ($P > 0.10$). Biomass of the large and small size classes of chironomids as well as Corbiculidae biomass also fluctuated ($P = 0.02$) over winter. No ($P > 0.05$) other interactions or differences were noted.

The small size class of chironomids (numbers and biomass) was found primarily ($P < 0.01$) in the shallow water zone (Tables 1 and 2). The reverse was true for the large size class of chironomids ($P < 0.05$). Gastropods and oligochaetes were found in higher numbers and greater biomass ($P < 0.01$) in shallow water zones. No other ($P > 0.10$) depth effects were noted.

Discussion

Waterfowl on Par Pond did not appear to greatly impact benthic food resources. One exception was the number of clams (Corbiculidae) which appeared reduced as a result of waterfowl predation. Experiments

Table 1. Mean number (M²) of invertebrates inside (a) and outside (b) of exclosures on a South Carolina reservoir according to depth (shallow = 0.5 – 1.75m, deep > 3.0m) and season.

Date			Taxa[1] Chironomidae[2] Small	Medium	Large	Corbiculidae	Gastropoda[3]	Oligochaeta
1 Nov. 1983								
	Shallow	a	1425 (439)[4]	44 (29)	0	44 (44)	110 (49)	351 (58)
		b	2061 (360)	153 (66)	0	263 (121)	153 (80)	439 (212)
	Deep	a	647 (278)	702 (221)	691 (351)	241 (129)	22 (15)	77 (46)
		b	175 (52)	428 (126)	241 (83)	132 (52)	0	22 (15)
1 Jan. 1984								
	Shallow	a	1118 (262)	132 (88)	22 (22)	175 (64)	175 (72)	351 (109)
		b	1271 (525)	44 (29)	88 (36)	88 (36)	132 (75)	658 (281)
	Deep	a	205 (81)	249 (111)	965 (292)	322 (163)	0	15 (15)
		b	58 (26)	205 (81)	1433 (332)	161 (76)	102 (102)	88 (60)
1 Mar. 1984								
	Shallow	a	285 (214)	373 (176)	0	175 (85)	417 (195)	373 (135)
		b	439 (191)	88 (88)	0	66 (66)	241 (128)	592 (193)
	Deep	a	15 (15)	117 (52)	702 (325)	117 (42)	44 (32)	15 (15)
		b	44 (23)	249 (137)	921 (307)	73 (46)	58 (45)	15 (15)

[1]Taxa which were also observed in samples but occurred too infrequently to permit statistical analyses were Cuculicidae, Libellulidae, Ceratopoginidae, unknown Lepidoptera, Polycentropidae, Unionidae, Hirudinidae, and Cammaridae.
[2]Chironomidae were separated into three size classes 0–5, 6–10, and > 10mm.
[3]Included three families; Planorbidae, Physidae, and Hydrobiidae.
[4]Standard error in parentheses.

Table 2. Mean biomass (g/m²) of invertebrates inside (a) and outside (b) of exclosures on a South Carolina reservoir according to depth (shallow – 0.5 – 1.7m, deep >3.0m) and season.

Date		Taxa[1] Chironomidae[2] Small	Medium	Large	Corbiculidae	Gastropoda[3]	Oligochaeta	Total biomass
1 Nov. 1983								
Shallow	a	0.200 (0.061)[4]	0.015 (0.010)	0	10.168 (10.168)	9.622 (7.828)	3.112 (0.518)	23.822 (12.375)
	b	0.510 (0.222)	0.054 (0.023)	0	96.490 (48.532)	3.856 (2.020)	3.890 (1.879)	91.495 (50.540)
Deep	a	0.091 (0.039)	0.246 (0.077)	1.021 (0.456)	50.377 (29.001)	0.900 (0.619)	1.556 (1.023)	55.798 (29.848)
	b	0.025 (0.007)	0.150 (0.044)	0.277 (0.095)	22.273 (9.624)	0	0.195 (0.134)	28.333 (10.023)
1 Jan. 1984								
Shallow	a	0.157 (0.037)	0.046 (0.031)	0.025 (0.025)	48.031 (16.186)	4.206 (2.359)	2.161 (0.674)	81.907 (31.284)
	b	0.288 (0.161)	0.015 (0.010)	0.101 (0.041)	45.939 (38.685)	1.271 (0.752)	4.053 (1.733)	51.736 (39.124)
Deep	a	0.029 (0.011)	0.087 (0.039)	1.110 (0.336)	62.941 (28.962)	0	0.090 (0.090)	64.268 (29.243)
	b	0.008 (0.004)	0.072 (0.028)	1.519 (0.376)	56.962 (42.162)	0.118 (0.118)	0.540 (0.368)	59.233 (42.255)
1 Mar. 1984								
Shallow	a	0.040 (0.030)	0.130 (0.062)	0	79.716 (42.073)	9.765 (3.716)	2.296 (0.831)	92.906 (40.600)
	b	0.061 (0.027)	0.031 (0.031)	0	8.439 (8.439)	6.876 (4.489)	3.647 (1.192)	19.054 (9.152)
Deep	a	0.002 (0.002)	0.041 (0.018)	0.807 (0.374)	22.686 (10.695)	0.498 (0.440)	0.090 (0.090)	24.193 (10.952)
	b	0.006 (0.003)	0.087 (0.048)	1.059 (0.353)	82.626 (80.068)	1.043 (0.995)	0.090 (0.090)	86.959 (80.056)

[1]Taxa which were also observed in samples but occurred too infrequently to permit statistical analyses were Cuculicidae, Libellulidae, Ceratopoginidae, unknown Lepidoptera, Polycentropidae, Unionidae, Hirundinidae and Gammaridae.
[2]Chironomidae were separated into three size classes 9–5, 6–10, and > 10mm.
[3]Included three families; Planorbidae, Physidae, and Hydrobiidae.
[4]Standard error in parentheses.

conducted in the littoral zone of Par Pond by Thorp & Bergey (1981) also demonstrated no impact of vertebrate (primarily fish) predators on benthic invertebrates. Similarly, Nilsson (1969) extrapolating from the feeding rates of Greater Scaup *Aythya marila*, Tufted Duck *A. fuligula*, Common Eider *Somateria mollissima* and Common Goldeneye in Sweden found that this species assemblage accounted for only 5% of the decrease in their invertebrate resources during winter. Cooper *et al.* (1984), however, found that Eared Grebe *Podiceps nigricollis* could account for as mucn as 83% of the annual decline in brine shrimp *Artemia monica,* but that Grebe predation had little impact on the long-term population size of brine shrimp.

Biomass and numbers of small chironomids, gastropods and oligochaetes were higher in shallow water versus deep water and Corbiculidae density was independent of depth. Thornburg (1973) also found that in a series of pools in the Mississippi River the deeper pool contained fewer benthic invertebrates. This does not support the hypothesis that deeper waters have relatively rich food resources (Sayler & Afton 1981) and therefore that this factor contributes to intersexual competition and observed intersexual habitat segregation in waterfowl.

An exception to the general trend observed for the majority of the invertebrate taxa was the large chironomids which were found primarily in the deep water zone. For waterfowl species that specialize on chironomids (e.g. Ruddy Ducks) richer food resources were indeed found in deeper waters. The total biomass of all chironomids was clearly greater in the deep water zone supporting the deeper water – richer food supply hypothesis. Different results were reported by Kajak & Dusoge (1975) who reported that numbers and biomass of chironomids decreased as water depth increased.

The division of invertebrate samples between shallow and deep water zones was often large and therefore it might be that the difference was too great to provide a meaningful test of the "water depth – food supply" hypothesis. However, diving duck species utilizing Par Pond commonly feed in water depths ranging from 4–10 m, especially rafts of Lesser Scaup and Ruddy Duck. Erskine (1971) stated that Bufflehead preferred feeding in areas 2–3 m deep. Cronan (1957) noted that Lesser and Greater Scaup along the coast of the northeastern U.S. foraged primarily in waters of < 2 m and the greatest feeding depth was approximately 7 m. Nilsson (1969) found that Greater Scaup, Tufted Duck and Common Goldeneye fed in shallow water less than 3 m. However, Stott & Olson (1973) noted that different species of sea ducks used different habitat and water depths in relationship to the occurrence of preferred food, and Scoters *Melanitta* spp. fed in zones 12 m in depth. We feel, therefore, that in general food resources probably are not "richer" in deeper waters and that the "rich food resource" definition depends upon the particular species being investigated.

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Summary

The effect of diving duck predation on benthic macroinvertebrate numbers and biomass was investigated with the use of exclosures, during winter 1983–84, in a South Carolina reservoir. The relationship of food quality with increasing water depth was also studied. The most numerous waterfowl species occurring that feed on benthic invertebrates were Lesser Scaup *Aythya affinis,* Ring-necked Duck *A. collaris,* Bufflehead *Bucephala albeola,* and Ruddy Duck *Oxyura jamaicensis.* Birds reached peak numbers in early January, and departed in late March. Waterfowl had little overall impact on benthic macroinvertebrate biomass and numbers during winter except for clams (Corbiculidae). For most invertebrate taxa, deeper waters did not contain richer food supplies when compared with shallow waters. A hypothesized relationship of food quality and water depth may not play an important role in the habitat segregation of male and female diving ducks.

References

Alexander, W. C. & Hair, J. D. 1979. Winter foraging behavior and aggression of diving ducks in South Carolina. *Proc. S. E. Assoc. Game and Fish Comm.* 31: 226–32.

Anderson, M. G. & Batt, B. D. J. 1983. Workshop on the ecology of wintering waterfowl. *Wildl. Soc. Bull.* 11: 22–24.

Britton, J. C. & Fuller, S. L. H. 1979. The freshwater bivalve Mollusca (Unionidae, Sphaeriidae, Corbiculidae) of the Savannah River Plant, South Carolina. *U.S. Dept. of Energy SRO-NERP-3*, Washington, D.C.

Cochran, W. C. & Cox, G. M. 1966. *Experimental design.* Wiley Press, New York.

Conover, W. J. & Iman, R. L. 1981. Rank transformations as a bridge between parametric and nonparametric statistics. *Am. Stat.* 35: 124–33.

Cooper, S. D., Winkler, D. W. & Lenz, P. H. 1984. The effect of Grebe predation on a brine shrimp population. *J. Anim. Ecol.* 53: 51–64.

Cronan, Jr., J. M. 1957. Food and feeding habits of the Scaups in Connecticut waters. *Auk* 74: 459–68.

Erskine, A. J. 1971. Buffleheads. *Can. Wildl. Serv. Monogr. Ser.* No. 4.

Kajak, Z. & Dusoge, K. 1975. Macrobenthos of Mikolajskie Lake. *Ekol. Polska* 23: 437–57.

Lewis, Jr., W. M. 1974. Evaluation of heat distributions in a South Carolina reservoir receiving heated water. Pp. 1–27 *in* J. W. Gibbons & Sharitz, R. R. (Eds.) *Thermal ecology.* Atomic Energy Comm. Symp. Ser. 730505, Washington, D.C.

Merritt, R. W. & Cummins, K. W. 1978. An introduction to the aquatic insects of North America. *Kendall-Hunt,* Dubuque, Iowa.

Nilsson, L. 1969. Food consumption of diving ducks wintering at the coast of south Sweden in relation to food resources. *Oikos* 20: 128–35.

Pehrsson, O. 1976. Food and feeding grounds of the Goldeneye *Bucephala clangula* (L.) on the Swedish west coast. *Ornis Scand.* 7: 91–112.

Pennak, R. W. 1953. *Fresh-water invertebrates of the United States.* Ronald Press, New York.

Sayler, R. D. & Afton, A. D. 1981. Ecological aspects of Common Goldeneyes *Bucephala clangula* on the upper Mississippi River. *Ornis Scand.* 12: 99–108.

Smith, L. M. & Kadlec, J. A. 1985. Fire and herbivory in a Great Salt Lake marsh. *Ecology* 66: 259–65.

Smith III, T. J. & Odum, W. E. 1981. The effects of grazing by Snow Geese on coastal salt marshes. *Ecology* 62: 98–106.

Stott, R. S. & Olson, D. P. 1973. Food-habitat relationships of sea ducks on the New Hampshire coastline. *Ecology* 54: 996–1007.

Thompson, D. 1973. Feeding ecology of diving ducks on Keokuk Pool, Mississippi River. *J. Wildl. Manage.* 37: 367–81.

Thornburg, D. D. 1973. Diving duck movements on Keokuk Pool, Mississippi River. *J. Wildl. Manage.* 37: 382–9.

Thorp, J. H. & Bergey, E. A. 1981. Field experiments on responses of a freshwater, benthic macroinvertebrate community to v ertebrate predators. *Ecology* 62: 365–75.

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