AN ABSTRACT OF THE THESIS OF

Richard Carmichael for the degree of Master of Science in Fisheries presented on April 22, 1983

Title: Feeding ecology and aspects of the biology of largemouth bass, rainbow trout, brown trout, and relict dace and the dietary overlap of largemouth bass and rainbow trout with canvasback and redhead ducks at Ruby Marsh, Nevada

Abstract approved: Redacted for Privacy

Howard F. Horton

Seasonal food habits, relative prey preference, daily food consumption rates and growth rates of largemouth bass (*Micropterus salmoides*) inhabiting the South Sump of Ruby Marsh, Nevada (Fig. 1) were studied during 1980 and 1981. In the absence of forage fish, the diets of adult and juvenile bass consisted primarily of coenagrionid damselfly nymphs, aeshnid dragonfly nymphs and libellulid dragonfly nymphs. There was little seasonal variation in the diet composition. Young-of-year (YOY) bass fed on zooplankton and aquatic insects during the summer and aquatic insects during the fall. Juvenile and adult bass showed similar prey preferences and those prey types that attained the largest size were generally the most preferred. The low percentage of empty stomachs indicated a high availability of prey; however, daily food consumption rates at 17.9 C and 21.4 C for fish between 153 and 330 mm total length (TL) were low when compared to the daily food consumption rates of bass of comparable size in other

waters. The average length at age of Ruby Marsh bass was considerably smaller than the average length at age of bass in most other lakes and reservoirs. Few Ruby Marsh bass reached lengths > 360 mm TL. Annual and peak growth rates were slow for all sizes of fish and growth slowed considerably with size. Fish 300 mm TL and greater showed little or no growth over an entire year. We attributed the slow growth and small maximum size to the short growing season and the quality and quantity of prey consumed.

The diet and relative prey preference of age 1+, 2+ and 3+ rainbow trout (*Salmo gairdneri*) and the diet of brown trout (*S. trutta*) in the South Sump were studied during 1980 and 1981. The diet of brown trout consisted entirely of invertebrates of which physid snails, chironomid subadults and coenagrionid damselfly nymphs were the primary food items. The diet of all age groups of rainbow trout also consisted entirely of invertebrates. Age 1+ rainbow trout fed primarily on chironomid subadults, coenagrionid damselfly nymphs, talitrid scuds and lymnaeid snails. The diet of age 2+ rainbow trout consisted of the same prey types as that of age 1+ rainbow trout, however, snails were more important in the diet of age 2+ fish. Lymnaeid snails and physid snails were the primary prey of age 3+ rainbow trout. The order of prey preference for all three age-groups of rainbow trout was similar and chironomid subadults were the most preferred prey item. In general, the feeding strategies of brown and rainbow trout at Ruby Marsh are similar to the feeding strategies of these species in other waters in that they are omnivorous predators which utilize those prey organisms which are most abundant.

The food habits and current distribution of the endemic relict dace (Relictus solitarius) were studied at Ruby Marsh, from 1980-1982. Locations of relict dace populations were mapped and recorded. Populations were found in six locations, of which five were in springheads which were isolated from intrusion by largemouth bass (Micropterus salmoides). One population was found in the main area of the marsh (Dace Bay Fig. 2) which is inhabited seasonally by largemouth bass. The current distribution indicates that a significant reduction in the distribution of relict dace has occurred since the introduction of largemouth bass in the early 1930's. A food habits study indicated that coenagrionid damselfly nymphs, chironomid subadults, baetid mayfly nymphs and cladocerans were the primary prey consumed by the relict dace.

The dietary overlap of age-specific groups of largemouth bass (Micropterus salmoides) and rainbow trout (Salmo gairdneri) with breeding adult and duckling canvasback (Aythya valisineria) and redhead (Aythya americana) ducks was investigated during 1980 and 1981 in the South Sump. We used Shoeners (1970) percent overlap index to assess the extent of co-utilization of food resources and we developed an index of percent contribution of prey to determine the degree to which co-utilized prey contributed to the dietary overlap. In most cases the dietary overlap was less than 40%. The diets of age-specific groups of rainbow trout generally overlapped with the diets of both species of ducks to a greater extent than did the diets of age-specific groups of largemouth bass. The diets of breeding adult canvasbacks and canvasback ducklings typically overlapped with the diets of both species of fish to a greater extent than did the diets of breeding adult redheads and redhead ducklings. Co-utilization of odonate nymphs, gastropods and chironomid subadults accounted for a major portion of the dietary overlap.

FEEDING ECOLOGY AND ASPECTS OF THE BIOLOGY OF LARGEMOUTH BASS, RAINBOW TROUT, BROWN TROUT, AND RELICT DACE AND THE DIETARY OVERLAP OF LARGEMOUTH BASS AND RAINBOW TROUT WITH CANVASBACK AND REDHEAD DUCKS AT RUBY MARSH, NEVADA

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I thank my mother for giving me the kind of support which only a mother can provide and a special thanks goes to my wife, Dolores L. Eisele, who contributed in so many ways to the completion of this thesis. She provided technical assistance, ideas and constant support and friendship throughout the duration of this project.

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FEEDING ECOLOGY AND ASPECTS OF THE BIOLOGY OF LARGEMOUTH BASS, RAINBOW TROUT, BROWN TROUT, AND RELICT DACE AND THE DIETARY OVERLAP OF LARGEMOUTH BASS AND RAINBOW TROUT WITH CANVASBACK AND REDHEAD DUCKS AT RUBY MARSH, NEVADA

I. GENERAL INTRODUCTION

This thesis consists of four manuscripts which report on the feeding ecology and aspects of the biology of largemouth bass (*Micropterus salmoides*), rainbow trout (*Salmo gairdneri*), brown trout (*S. trutta*) and relict dace (*Relictus solitarius*) and the dietary overlap of largemouth bass and rainbow trout with canvasback (*Aythya valisineria*) and redhead (*A. americana*) ducks at Ruby Marsh, Nevada. The investigations were conducted during 1980 and 1981 to characterize aspects of the predator-prey system in the South Sump (Fig. 1) of Ruby Marsh.

The specific objectives of my studies at Ruby Marsh were:

1. To determine the food habits of young-of-year, juvenile and adult largemouth bass.
2. To determine the relative prey preference, growth rates and daily food consumption rates of size specific groups of largemouth bass.
3. To specify the food habits of age-specific groups of rainbow trout and brown trout, and the relative prey preference of age-specific groups of rainbow trout.
4. To determine the food habits and current distribution of relict dace in Ruby Marsh.

Figure 1. Location of Ruby Marsh and location of the South Sump at Ruby Marsh.

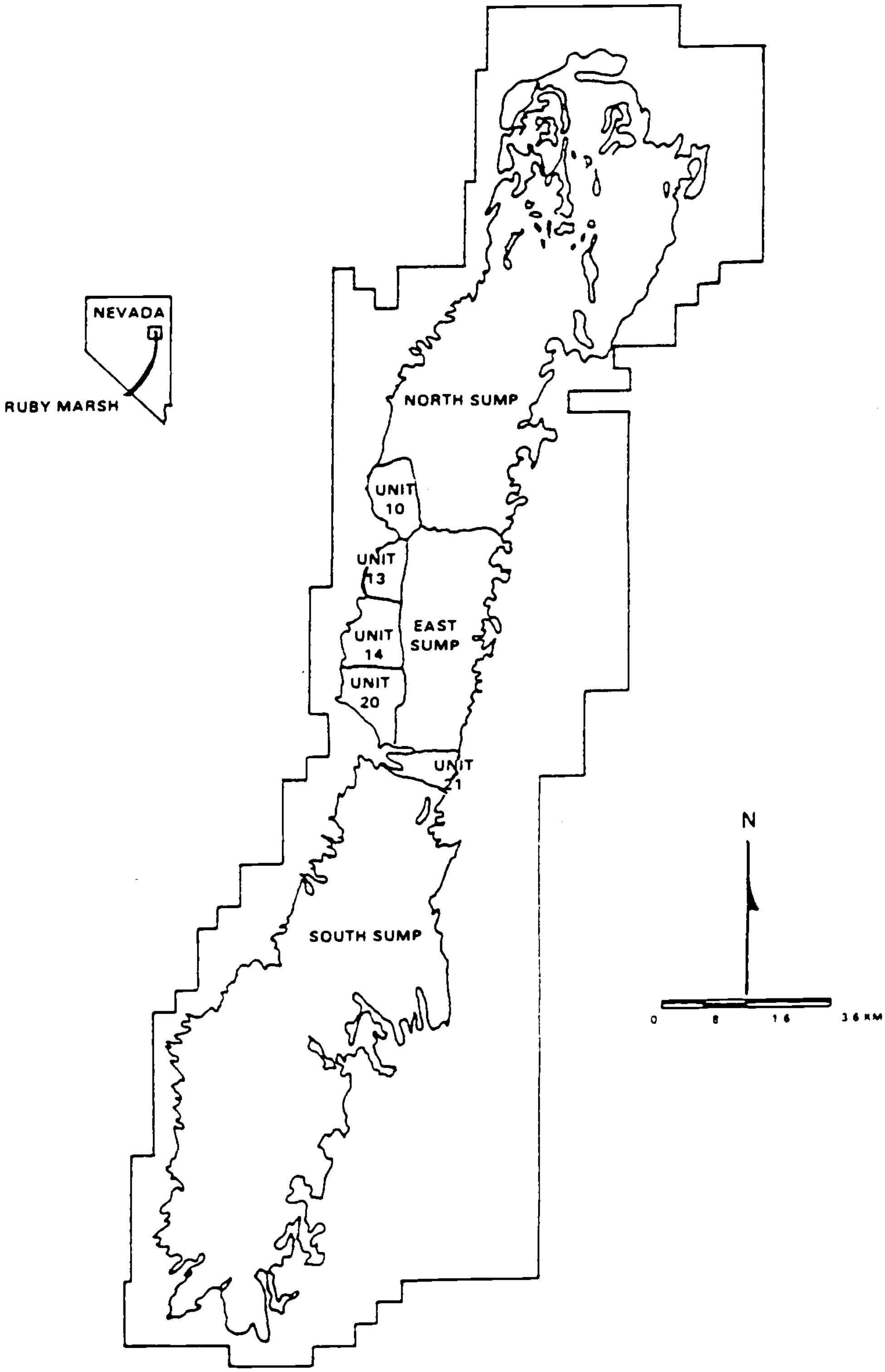
NEVADA
RUBY MARSH
NORTH SUMP
UNIT 10
UNIT 13
UNIT 14
EAST SUMP
UNIT 20
UNIT 21
SOUTH SUMP
N

Figure 1.

5. To estimate the degree of dietary overlap of largemouth bass and rainbow trout with canvasback and redhead ducks.

The four manuscripts reporting on the results of my research were written in the format prescribed by the Transactions of the American Fisheries Society. There was unavoidable repetition of the description of the study area and the methods sections among the four papers.

The manuscripts are titled:

1. Feeding ecology, growth and daily food consumption rates of largemouth bass at Ruby Marsh, Nevada.
2. Feeding ecology of rainbow trout and brown trout at Ruby Marsh, Nevada.
3. Food habits and distribution of relict dace at Ruby Marsh, Nevada.
4. The dietary overlap of largemouth bass and rainbow trout with canvasback and redhead ducks.

Ruby Marsh is located within the boundaries of Ruby Lake National Wildlife Refuge (NWR). The refuge was established in 1938 as a migratory bird refuge and the present management goals emphasize increased production of canvasback and redhead ducks. The South Sump (Fig. 1) is the primary area used for nesting and feeding by these two species of waterfowl. The South Sump is shallow, springfed and typically shows little seasonal variation in water level. Marsh production of aquatic invertebrates and vegetation is thought to be low although quantitative evidence to support this is lacking.

The South Sump supports a substantial recreatonal fishery for largemouth bass and rainbow trout and a small fishery for brown trout. According to Hubbs et al. (1974) the relict dace is the only fish native to the Ruby Marsh area. Largemouth bass were introduced in 1932 (Trelease 1948) and the population is self sustaining. Trout stocking began in the early 1940's (Trelease 1948) and has been maintained as a management practice to this time. It appears that little successful trout reproduction occurs and population levels are maintained by annual releases.

The relict dace inhabited the springs, spring outflows and entire area of the marsh previous to the introduction of largemouth bass (Hubbs et al. 1974). Apparently, high predation rates by largemouth bass eliminated relict dace from most areas of the marsh (Hubbs et al. 1974) and relict dace now have a limited distribution. Presently no forage fish are available in most areas of the South Sump forcing the largemouth bass and trout to rely almost exclusively on invertebrates for food. Aquatic invertebrates are an important prey of ducklings and breeding adult canvasbacks and redheads (Bartonek and Hickey 1969). Low production and overlapping utilization of the aquatic invertebrate food resource by fish and canvasbacks and redheads are possible factors which restrict the production of these two species of ducks.

Water level manipulation in the South Sump may be used to stimulate invertebrate and vegetation production with the ultimate goal of increasing canvasback and redhead production. The goal of these studies was to establish predrawdown biological conditions which can be used to assess the changes in the biology brought about by drawdowns and also to estimate the degree of dietary overlap between the major predatory fishes, and the canvasback and redhead ducks.

II. FEEDING ECOLOGY, GROWTH AND DAILY FOOD CONSUMPTION RATES OF LARGEMOUTH BASS AT RUBY MARSH, NEVADA[1]

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ABSTRACT

Seasonal food habits, relative prey preference, daily food consumption rates and growth rates of largemouth bass (*Micropterus salmoides*) inhabiting the South Sump of Ruby Marsh, Nevada (Fig. 1) were studied during 1980 and 1981. All largemouth bass were collected by electroshock except for young-of-year (YOY) bass which were collected with a dip net. In the absence of forage fish, the diets of adult and juvenile bass consisted primarily of coenagrionid damselfly nymphs, aeshnid dragonfly nymphs and libellulid dragonfly numphs. There was little seasonal variation in the diet composition. YOY bass fed on zooplankton and aquatic insects during the summer and aquatic insects during the fall. Juvenile and adult bass showed similar prey preferences and those prey types that attained the largest size were

[1]Technical Paper No. , Oregon Agricultural Experiment Station.

generally the most preferred. The low percentage of empty stomachs indicated a high availability of prey; however, daily food consumption rates at 17.9 C and 21.4 C for fish between 153 and 330 mm total length (TL) were low when compared to the daily food consumption rates of bass of comparable size in other waters. The average length at age of Ruby Marsh bass was considerably smaller than the average length at age of bass in most other lakes and reservoirs. Few Ruby Marsh bass reached lengths > 360 mm TL. Annual and peak growth rates were slow for all sizes of fish and growth slowed considerably with size. Fish 300 mm TL and greater showed little or no growth over an entire year. We attributed the slow growth and small maximum size to the short growing season and the quality and quantity of prey consumed.

INTRODUCTION

The biology of the largemouth bass (*Micropterus salmoides*) has been studied extensively since the early 1900's due to their importance as a sportfish and their widespread geographical distribution. Most waters inhabited by largemouth bass support some type of forage fish which often serve as the primary prey of juvenile and adult bass (Heidinger 1975). The South Sump of Ruby Marsh, Nevada (Fig. 1) is void of forage fish in all areas except Dace Bay (Fig. 2) and a few isolated springheads and outflows. As a consequence, the largemouth bass are forced to rely almost exclusively on invertebrates for food. In this study we determine the seasonal food habits of young-of-year, juvenile and adult largemouth bass; the relative prey

Figure 2. Location of Dace Bay and wetland classification of the South Sump.

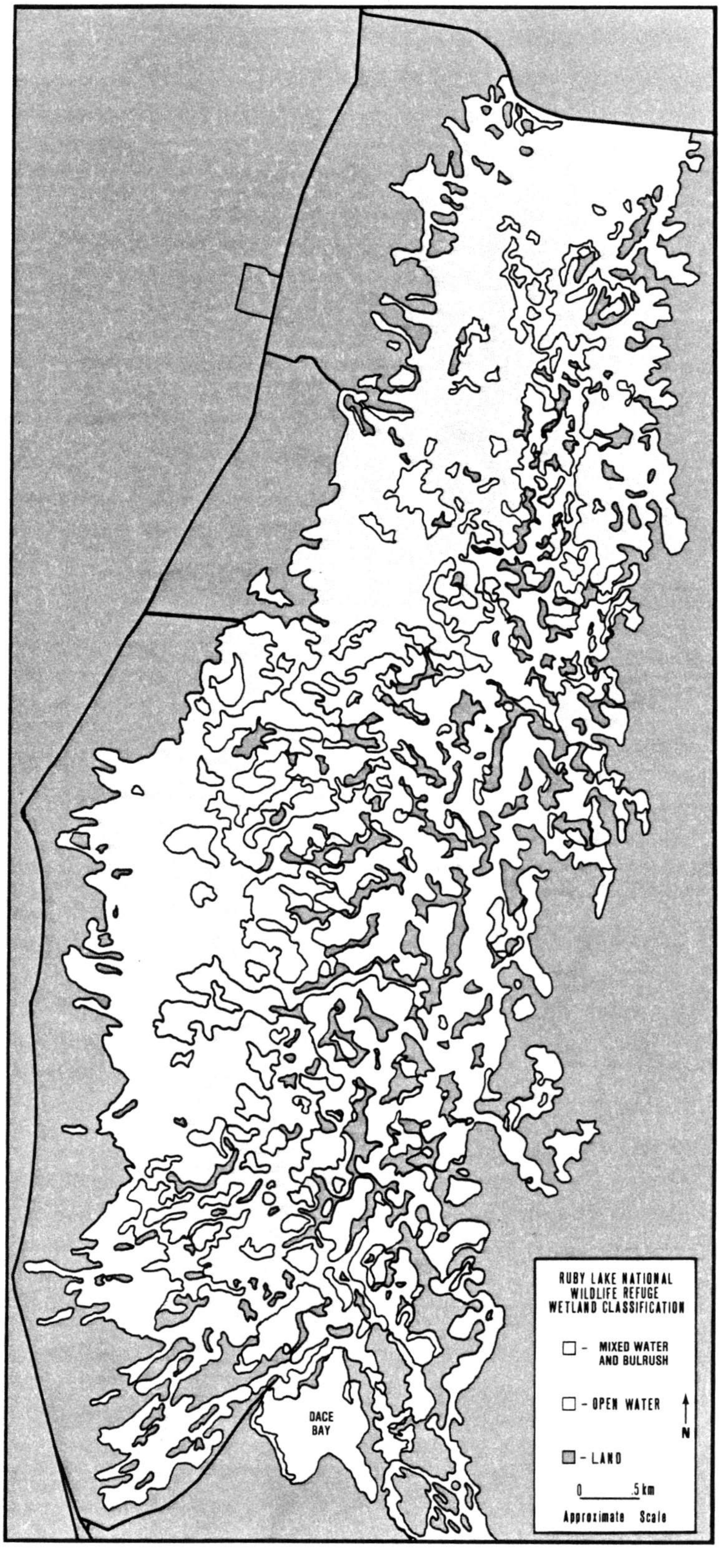
RUBY LAKE NATIONAL
WILDLIFE REFUGE
WETLAND CLASSIFICATION
- MIXED WATER AND BULRUSH
- OPEN WATER
- LAND
N
0 .5 km
Approximate Scale
DACE BAY

Figure 2.

preference of juvenile and adult largemouth bass; and the growth rates and daily food consumption rates of size specific groups of largemouth bass. Our study was a component of a comprehensive investigation conducted from 1980-1982 to characterize aspects of the predator-prey system in the South Sump.

Aspects of the biology of the largemouth bass in the South Sump are somewhat different from those of largemouth bass in other waters. Emig (1966) and Carlander (1977) summarized the findings of investigations on the food habits of largemouth bass. In general, young-of-year bass feed on microcrustaceans (Mullan and Applegate 1970; Heidinger 1975), switch to insects as juveniles, and change to fish, crayfish and other large prey as adults (Zweiacker and Summerfelt 1973; Shelton et al. 1979). This dietary transition is typical of most largemouth bass throughout a variety of habitat types. At Ruby Marsh, however, the last transition does not occur due to the absence of forage fish. Diet appears to be an important factor in growth of largemouth bass. Largemouth bass that feed primarily on fish show higher growth rates than those that feed on insects (Shelton et al. 1979). The predator prey system and other environmental factors such as year around cold water temperatures make the food habits, growth rates, relative prey preference and food consumption rates for bass at Ruby Marsh unique.

According to Hubbs et al. (1974) Ruby Marsh was only inhabited by the relict dace (Relictus solitarius) previous to the introduction of largemouth bass in 1932 or 1933 (Trelease 1948). The relict dace were eliminated from most areas of the marsh due to high predation rates by bass (Hubbs et al. 1974) and now exist only in isolated springs which border the marsh and in Dace Bay (Fig. 2). Largemouth bass are seasonal inhabitants of Dace Bay. We also compare the diets of largemouth bass in the presence and absence of relict dace.

The findings of our study provide a basis for future comparisons which will allow for the assessment of changes in the biology of the largemouth bass brought about by a natural or man-induced drawdown. The results of our study also provide a partial basis for determining the degree of dietary overlap between largemouth bass and canvasback (*Aythya valisineria*) and redhead (*Aythya americana*) ducks, as well as documenting selected life history aspects of largemouth bass in the absence of forage fish.

STUDY AREA

Ruby Marsh is located in the northeastern corner of Nevada, 96 km southeast of the town of Elko. According to Hubbs et al. (1974) the marsh occupies the area which was once the southern arm of pluvial Lake Franklin. The South Sump encompasses the southern end of the marsh and is bordered by mountains to the east and west. It occurs at an elevation of 1,830 m and occupies a total of 2,962 hectares at the high water line. The South Sump is a maze of interconnected channels and pools (Fig. 2) of which 1,570 hectares are shallow water areas interspersed with emergent vegetation, 918 hectares are open water areas of $<$ 5 m maximum depth and 474 hectares are upland (Ruby Lake N.W.R. 1982).

Water input into the South Sump is primarily from the numerous springs surrounding its border. Water temperatures remain cool throughout the year and only rise above 15 C from May through September; water temperatures reach a maximum of about 24 C during this period. Ice generally covers the marsh from December through February. The entire shoreline area is covered with dense stands of hardstem bulrush (*Scirpus acutus*) and during the warmer months the bottom is typically covered with dense mats of submerged vegetation. Muskgrass (*Chara sp.*), pondweeds (*Potamageton sp.*), watermilfoil (*Myriophyllum sp.*), and bladdlerwort (*Utricularis vulgaris*) are the prominent submerged vegetation types.

METHODS

We collected largemouth bass from 3 May 1980 to 26 October 1981 at irregular intervals. All fish were collected by electrofishing with the exception of the young-of-year fish $<$ 3 months old which were collected with a dip net. A pulsed direct current electrofishing system similar to that described by Sharpe (1964), with 2.0 to 3.0 amps was used.

To investigate seasonal food habits, we designated the monthly periods as: spring (Mar-May), summer (Jun-Aug) and fall (Sep-Nov). We analyzed largemouth bass stomach contents collected from Dace Bay separately from those fish collected from other areas of the South Sump. We collected fish from most areas of the marsh which were accessible by boat and also during all hours of the day and night. We recorded total lengths (TL) to the nearest 1 mm and weights were recorded to the nearest 1 g. Most measurements were taken by the same individual to minimize measurement error. We took scale samples from below the lateral line at the tip of the left pectoral fin (Prentice and Whiteside 1974) and otoliths were removed from 44 fish for scale-age verification. Scales were mounted between microscope slides and were read on a microfiche reader at 42x. The two criteria used for annulus identification were: 1) narrowly spaced circuli preceded and followed by widely spaced circuli (Lagler 1952; Carlander 1961); 2) cutting over of circuli on the lateral field of the scale (Carlander and Whitney 1961; Chugunova 1963). Otoliths were lightly burned to highlight the annuli, immersed in alcohol, and were read under a 20X binocular microscope using a dark background. We originally read scales twice and the age was used if both readings were in agreement. If the first two readings differed, the scale was read again until agreement between two readings was reached. This same procedure was used to establish the age from otoliths. Otolith ages were used to assess the accuracy of ages from scale readings.

For the the food habits and relative prey preference analyses we divided fish into three groups: 1) young-of-year (age 0+), 2) juvenile (age 1-3+), and 3) adult (age 4+ - 11+). Size at maturity was determined from data (unpublished) collected during a 1981 creel census and age at maturity was determined from size at age data (Table 1).

We removed the stomach contents of fish > 125 mm TL with a stomach flush (Seaburg 1957; Swenson and Smith 1973). Those fish < 125 mm TL were killed upon capture by severing the spinal chord just posterior

Table 1. Sample size (N), mean weight and mean total length of age 0+ through age 11+ largemouth bass collected from the South Sump of Ruby Marsh, Nevada, 1980 and 1981.

Age	N	Weight (g) ($\bar{x}$ ± S.E.)	TL (mm) ($\bar{x}$ ± S.E.)
0+	42	1.4 ± 0.3	39 ± 4
1+	69	14 ± 2	97 ± 3
2+	119	56 ± 5	155 ± 3
3+	175	125 ± 3	203 ± 1
4+	103	216 ± 4	245 ± 2
5+	60	288 ± 5	274 ± 1
6+	184	346 ± 4	292 ± 1
7+	133	393 ± 6	304 ± 1
8+	51	442 ± 10	314 ± 2
9+	12	430 ± 23	315 ± 4
10+	3	517 ± 76	315 ± 18
11+	1	520	325

of the brain and the stomach contents were removed surgically. We preserved all stomach contents in 70% ethanol and analyzed them in the laboratory. Prey items were identified, counted, dried at 65 C for 24 hours and weighed to the nearest 1 mg. Drying at 65 C for 24 hours was sufficient to remove all moisture. Weights of gastropods and pelecypods which were in shells were multiplied by 0.30 and caddisfly larvae were removed from the case previous to drying. Therefore, dry weights of all gastropods (unidentified, Lymnaeidae, Physidae, Planorbidae) caddisfly larvae (Limnephilidae, Phryganeidae), and pelecypods (Sphaeriidae) were recorded as tissue only. Unidentified gastropods actually belonged to either the Lymnaeidae or the Physidae family but could not be differentiated. The stomachs of juvenile and adult fish were classified as empty if they contained < 1 mg of dried food and the stomachs of young-of-year were considered empty if they contained no food. We evaluated types, numbers and dry weights of prey items by percent occurrence (Windell and Bowen 1978), and mean percent (aggregate proportion) of dry weight and number (Swanson et al. 1974). The advantages in using mean percent over total percent are discussed by Swanson et al. (1974).

We evaluated relative prey preference by the procedure described by Johnson (1980). This method is based on ranked utilization and availability data and allows for the use of statistical tests for differences in relative preference. Many other indices of selectivity are available (Hess and Rainwater 1939; Ivlev 1961; Jacobs 1974; Neu et al. 1974), however, we used this method because of its ease of interpretation and the statistical tests which can be applied. The results provide an ordering of the most preferred to least preferred prey category based on the mean difference in rank of usage and availability (Johnson 1980). We used an F test ($P < 0.001$) to determine if all prey categories were equally preferred and the test for significant difference ($P \approx 0.05$) in preference rank between each prey category (Bayesian decision procedure, Waller and Duncan 1969) was conducted as outlined by Johnson (1980). We took prey availability samples with an aquatic invertebrate sweepnet (mesh = 0.5 mm) (Merritt _et al._ 1978). We took samples immediately following the collection of fish and in the same location. The opening of the net was immersed into the benthic vegetation above the substrate level for each sweep of the net. During 1981, we took between three and six sweeps for each availability sample and in 1982 five 1.5-m sweeps were taken for each availability sample. Samples were immediately preserved in 10% Formalin and were sorted in the laboratory. Sorting was conducted with the aid of a 10X binocular microscope and all invertebrates with the exception of zooplankton were removed. Invertebrates were identified, counted, dried at 65 C for 24 hours and weighed to the nearest 1 mg.

Ranking of usage and availability was based on mean percent of number and all adult aquatic insects, terrestrial insects and zooplankton were omitted from the preference analysis. We were interested in relative prey preference on a broader level than the diet, therefore, the families Corixidae and Notonectidae were combined into the prey category Hemiptera for the preference analysis. We combined unidentified snails and the families Lymnaeidae and Physidae into the prey category Gastropoda and the families Limnephilidae and Phryganeidae were combined into the prey category Trichoptera. We combined the families Gyrinidae, Haliplidae, Dytiscidae, and Hydrophilidae into the prey category Coleoptera and we combined the families Glossiphonidae and Erpobdellidae into the prey category Hirudinea. A total of 14 prey categories were used in the preference analysis. We determined relative preference rankings for each prey category only for juvenile and adult largemouth bass which were collected from areas other than Dace Bay. We did not assess preference on a seasonal basis, rather we choose to assess it on an overall basis. Young-of-year bass were omitted because our availability sampling was not adequate for quantification of zooplankton abundance.

We estimated growth rates of size-specific groups from the change in total length of tagged fish. We tagged 500 largemouth bass from 27 June 1980 to 5 August 1980. Disk-dangler tags were placed through the pterygiophores just below the dorsal fin and TL and weight were recorded for each tagged fish. Fish were tagged in 58 locations throughout the South Sump including Dace Bay to insure an adequate dispersion of tagged fish. Tagged fish were recaptured by hook and line as well as electroshock. We recorded weights on recaptured fish when possible but many of the fish recaptured by sportsmen were dehydrated and an accurate weight could not be obtained. Tagged fish were recaptured from 6 Jul 1980 to 17 Nov 1981.

We calculated growth rates for three size groups; 175-225 mm TL, 226-260 mm TL and 261-305 mm TL, based on size at tagging. Based on size at age (Table 1), fish between 175-225 mm TL are primarily age 3+ fish but large age 2+ fish also fall in this range. The size group 226-260 mm TL primarily included age 4+ fish but also includes the largest age 3+ fish and the smallest age 5+ fish. The largest size group 261-305 mm TL included the largest age 4+ fish through age 11+ fish. We calculated growth rates for fish which were recaptured between 21 and 60 days after tagging and growth rates were also calculated for fish recaptured between 327 and 443 days after tagging. The growth rates of fish recaptured between 21 and 60 days after tagging represent maximum growth rates occurring during the warmest period of the year (Aug-Sep) and were estimates of the peak growth rate; growth rates of fish recaptured between 331 and 443 days represent growth rates over the entire year and will be referred to as the annual growth rate.

To estimate daily food consumption rates we used a simple depletion model presented by Elliott and Persson (1978):

$$dS/dt = F - RS$$

where R = the exponential gastric evacuation rate, F = the constant rate of food consumption per t units of time, S = quantity of food in the stomach, and dS/dt = change in quanitity of food in the stomach over change in time. We estimated consumption rates as dry weight of digestible organic matter and live weight of prey as described by Elliott and Persson (1978). To estimate S we collected the stomach contents of 69 fish on 12-13 Jun 1980, at 2-hour intervals over a 24-hour period at a mean water temperature of 17.9 C, and on 2-3 Jul 1981, we collected the stomach contents of 94 fish at 2-hour intervals over a 24-hour period at a mean water temperature of 21.4 C. The stomach contents of each fish were placed on tissue paper to remove surface moisture, weighed to the nearest 1 mg, dried at 65 C for 24-hour and placed in a muffle furnace for 8 hour. The remaining ash was weighed and chitin was assumed to be 2.5% of the damp dry weight (Kitchell and Windell 1968). We then determined dry weight of digestible organic matter as: dry weight - ash weight - chitin (Windell 1967). We calculated sample means of dried digestable organic matter for each time period and we used an F test ($P \leq 0.05$ and 0.01) to test for a significant difference among the 12 means at 17.9 C and the 12 means at 21.4 C. We used the F test to test the assumption of $ds/dt = 0$. We calculated mean quantities of dry weight of digestible organic matter over the entire 24-hour period for all sizes of fish combined at each temperature and also for the same size groups for which growth rates were estimated, thus it was possible to estimate daily food consumption rates for size specific groups and for all size groups combined.

We estimated the gastric evacuation rate (R) in the laboratory as outlined by Elliott (1972). We collected largemouth bass of approximately equal length (range 193-219 mm TL) from the marsh and used them in the feeding experiment. Fish were held individually in 23 liter tanks with a constant flow of 0.445 l/min of spring water at a temperature of 21.1 C (range 20.0-22.2 C). We exposed fish to natural lighting conditions and five fish were used in each of five feeding trials. We starved fish for 72 hours previous to each feeding trial to ensure that their stomachs were empty at the time of ingestion. We used libellulid dragonfly nymphs in the feeding experiments because odonate nymphs comprised a large proportion of the diet and libellulid nymphs could be obtained from the marsh in sufficient quantities to conduct the experiment. We fed each fish approximately 1000 mg (range 996-1005 mg) of live libellulid nymphs which were voluntarily consumed within a 30-minute period. We removed the stomach contents of one fish with a stomach flush after the food had been in the stomach for 4 hours and the stomach contents of the remaining four fish were removed in successive 4 hour intervals. We then determined the dry weight of digestible organic matter of these samples as previously described. The dry weight of digestible organic matter in 1000 mg of live libellulid nymphs was determined from five 1000 mg samples (range 999-1000 mg). These five values represent the dry weight of digestible organic matter at time 0.

We assumed that the relationshp between dry weight of digestible organic matter remaining in the stomach and time was exponential (Tyler 1970; Elliott 1972; Thorpe 1977) and we fit the data to the following regression equation (Elliott, 1972).

$$\text{Log}_e\ Y_x = \text{Log}_e\ A - RX$$

where Y_x = the dry weight of digestible organic matter remaining in the stomach, and $A = Y_x$ for the regression equation at $X = 0$. R = constant relative rate of gastric evacuation and X = time between meal intake and removal or digestion time (Elliott 1972). The regression coefficient of the fitted regression line is equal to R. R at 17.9 C was estimated from R at 21.1 C through the relationship developed by Adams _et al._ (1982) of

$$Y = 61.93\ e^{-0.00592\ x}$$

where Y = time to 95% digestion and x = temperature (C) and the relationship developed by Elliott (1972) of

$$x_p = \log_e \left(\frac{100}{100-P} \right) \frac{1}{R}$$

where x_p = time (hour) taken for gastric evacuation of P% of dried digestible organic matter and R = constant relative rate of gastric evacuation.

RESULTS

Food Habits

The sample sizes of young-of-year, juvenile and adult largemouth bass collected from the South Sump and Dace Bay are presented in Table 2. Less than 10% of the stomachs examined from young-of-the-year bass during summer were empty, whereas over 50% of the stomachs from this age group were empty in the fall. A sample size of 0 (Table 2) is shown for the spring season because young-of-year bass collected during the spring had formed one annulus and were therefore classified as juveniles. During the summer young-of-year bass fed extensively on baetid mayfly nymphs (38.9% by wt and 19.9% by no.), and waterfleas (Daphnidae) (20.0% by wt and 65.1% by no.) (Table 3). During the fall the diet consisted primarily of five prey items. Aeshnid dragonfly nymphs, damselfly nymphs (Coenagrionidae), talitrid scuds, and baetid mayfly nymphs comprised 100% of the dry weight and these four prey items and waterfleas comprised 100% of the number (Table 3).

Table 2. Sample size and percent empty stomachs of largemouth bass collected from the South Sump and Dace Bay during spring, summer and fall at Ruby Marsh, Nevada, 1980 and 1981.

Location Life Stage	Spring N	Spring % empty	Summer N	Summer % empty	Fall N	Fall % empty
South Sump						
Young-of-year	0	--[a]	31	9.7	11	54.5
Juvenile	86	22.1	194	8.2	52	42.3
Adult	207	6.3	243	12.3	76	27.6
Dace Bay						
Juvenile	6	0.0	25	24.0	0	--
Adult	12	0.0	9	0.0	0	--

[a] measure non-applicable

Table 3. Percent occurrence, mean percent dry weight, and mean percent number of prey items utilized by young-of-year largemouth bass during summer and fall in the South Sump, Ruby Marsh, Nevada, 1980 and 1981.

Prey item	Summer			Fall		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Odonata						
Aeshnidae nymph	0.0	0.0	0.0	20.0	25.0	20.0
Coenagrionidae nymph	3.6	6.7	<0.1	20.0	21.4	13.3
Diptera						
Chironomidae subadult	7.1	6.7	3.1	0.0	0.0	0.0
Amphipoda						
Talitridae	7.1	<0.1	1.1	20.0	25.0	20.0
Hemiptera						
Corixidae	10.7	6.7	2.9	0.0	0.0	0.0
Ephemeroptera						
Baetidae nymph	32.1	38.9	19.9	40.0	28.6	26.7
Caenidae nymph	3.6	<0.1	0.2	0.0	0.0	0.0
Cladocera						
Daphnidae	78.6	20.0	64.1	20.0	<0.1	20.0
Ostracoda	25.0	13.3	3.9	0.0	0.0	0.0
Copepoda	35.7	<0.1	4.8	0.0	0.0	0.0
Non-identified material	--[a]	7.8	--	--	0.0	--

[a] measure non-applicable

The annuli of juvenile fish (age 1+-3+) were highly distinct, however no otoliths were collected from age 1+ or age 3+ fish. Two otoliths were collected from fish aged at 2+ from scales, and there was 100% agreement between the scale and otolith readings. Odonate nymphs dominated the diet of juvenile fish during all three seasons (Table 4). Damselfly nymphs comprised over 30% of the number during spring, summer, and fall and also comprised the largest proportion of dry weight during spring and summer (Table 4). Aeshnid dragonfly nymphs were the most important prey item during the fall (41.8% by wt) and were also important to a lesser extent during the other seasons. Baetid mayfly nymphs were an important prey item during the spring but were utilized little during fall and summer (Table 4). Adult insects comprised only a small proportion of the diet during any season.

We had difficulty in distinguishing annuli laid down after the fifth annulus. The circuli appeared to overlap and distinct annuli could not be detected in many cases. The percent agreement between ages estimated from scales and ages estimated from otoliths decreased from 100% agreement for fish aged at 4+ from scales to 27.6% for fish aged at 6+ to 8+ from scales. We read otoliths from seven fish which were aged at 4+ from scales and we read otoliths from six fish aged at 5+ from scales. Of these six 5+ fish, four were aged at 5+ from otoliths, one at 4+ and one at 6+ (66% agreement). Twenty-nine otolith samples were collected from fish aged at 6+ to 8+ from scales. Of these 29, only eight of the otolith ages were in agreement with the ages from scales, five (17.2%) of the ages from scales were greater than the ages from otoliths and 11 (40.7%) of the ages from scales

Table 4. Percent occurrence, mean percent dry weight, and mean percent number of prey items utilized by juvenile largemouth bass during spring, summer and fall in the South Sump, Ruby Marsh, Nevada, 1980 and 1981.

Prey item	Spring			Summer			Fall		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Odonata									
Aeshnidae nymph	23.9	16.7	12.5	44.4	24.3	9.8	56.7	41.8	29.2
Aeshnidae adult	0.0	0.0	0.0	2.8	1.8	0.3	0.0	0.0	0.0
Libellulidae nymph	22.4	15.6	7.1	10.7	3.8	2.3	20.0	11.8	13.2
Libellulidae adult	0.0	0.0	0.0	2.2	1.3	<0.1	0.0	0.0	0.0
Coenagrionidae nymph	59.7	28.1	32.1	86.0	43.5	50.2	53.3	28.4	32.6
Coenagrionidae adult	1.5	<0.1	0.2	19.7	4.6	5.0	0.0	0.0	0.0
Diptera									
Chironomidae subadult	25.4	2.7	8.2	23.0	2.5	4.6	3.3	<0.1	<0.1
Chironomidae adult	3.0	0.1	0.3	2.2	0.3	0.9	0.0	0.0	0.0
Amphipoda									
Talitridae	26.9	6.1	14.0	32.0	5.5	10.2	33.3	8.1	18.8
Gammaridae	7.5	5.1	3.5	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda									
Unidentified	0.0	0.0	0.0	0.6	<0.1	<0.1	0.0	0.0	0.0
Lymnaeidae	0.0	0.0	0.0	2.8	<0.1	0.1	0.0	0.0	0.0
Physidae	0.0	0.0	0.0	0.6	<0.1	<0.1	0.0	0.0	0.0
Planorbidae	1.5	<0.1	<0.1	3.9	<0.1	0.3	0.0	0.0	0.0
Pelecypoda									
Sphaeriidae	0.0	0.0	0.0	2.8	0.9	0.1	0.0	0.0	0.0
Trichoptera									
Limnephilidae larvae	0.0	0.0	0.0	2.8	1.5	1.1	3.3	3.3	3.3
Phryganeidae larvae	1.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera									
Dytiscidae	0.0	0.0	0.0	1.1	0.3	0.0	0.0	0.0	0.0
Haliplidae	0.0	0.0	0.0	1.1	<0.1	<0.1	0.0	0.0	0.0
Chrysomelidae	0.0	0.0	0.0	3.9	0.3	0.7	0.0	0.0	0.0
Hemiptera									
Corixidae	0.0	0.0	0.0	11.2	1.2	1.7	3.3	1.5	0.3
Gerridae	0.0	0.0	0.0	2.2	0.2	0.2	0.0	0.0	0.0
Notonectidae	3.0	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. Continued

Prey item	Spring			Summer			Fall		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Hydracarina	0.0	0.0	0.0	3.9	0.1	0.3	0.0	0.0	0.0
Ephemeroptera									
Baetidae nymph	35.8	16.2	20.0	35.4	4.6	9.2	13.3	2.0	2.5
Baetidae adult	0.0	0.0	0.0	1.7	<0.1	0.2	0.0	0.0	0.0
Caenidae nymph	0.0	0.0	0.0	3.9	<0.1	0.1	0.0	0.0	0.0
Hirudinea									
Glossiphonidae	0.0	0.0	0.0	0.6	<0.1	0.1	0.0	0.0	0.0
Erpobdellidae	0.0	0.0	0.0	1.1	0.5	1.1	0.0	0.0	0.0
Cladocera									
Daphnidae	0.0	0.0	0.0	3.4	<0.1	1.1	0.0	0.0	0.0
<u>Micropterus</u>	0.0	0.0	0.0	3.4	0.2	1.0	0.0	0.0	0.0
Vegetation	3.0	1.6	--[a]	0.6	<0.1	--	3.3	3.1	--
Other	0.0	0.0	0.0	3.6	0.1	0.3	0.0	0.0	0.0
Non-identified material	--	5.3	--	--	2.3	--	--	0.0	--

[a] measure non-applicable

were less than the ages from otolith. These results clearly indicate that accuracy of aging by scales decreases beyond age 4+; however, for the separation into young-of-year, juvenile and adult groups aging from scales was considered accurate. Maraldo and MacCrimmon (1979) found high agreement between ages from otoliths and ages from scales for largemouth bass up to age 7+. However, the ages of fish older than 7+ were consistently underestimated from scales.

As was the case with juvenile largemouth bass, adults fed extensively on odonate nymphs (Table 5). Damselfly nymphs were an important prey item during all seasons and aeshnid dragonfly nymphs were the most important by dry weight during summer (30.2%) and fall (42.6%) and were also important during the spring (Table 5). Baetid mayfly nymphs comprised 21.7% of the number during the spring but contributed little to the diet during the other two seasons. The remainder of the diet was comprised of a variety of other prey items (Table 5) and adult insects were utilized little during any season.

The diet of both juvenile and adult largemouth bass collected from Dace Bay was different from the diet of fish collected from the other areas of the South Sump. Relict dace comprised over 50% of the dry weight of prey consumed by juveniles during the summer and 32.3% during the spring (Table 6). Baetid mayfly nymphs, damselfly nymphs and water boatman (Corixidae) were also important prey of juvenile bass in Dace Bay. Adult largemouth bass in Dace Bay fed primarly on relict dace which comprised 84.8% of the dry weight during the spring and 75.8% during the summer (Table 6).

Table 5. Percent occurrence, mean percent dry weight, and mean percent number of prey items utilized by adult largemouth bass during spring, summer and fall in the South Sump, Ruby Marsh, Nevada, 1980 and 1981.

Prey item	Spring			Summer			Fall		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Odonata									
Aeshnidae nymph	54.6	21.0	7.9	52.6	30.2	13.6	78.2	42.6	25.6
Aeshnidae adult	0.0	0.0	0.0	17.8	11.7	3.6	0.0	0.0	0.0
Libellulidae nymph	30.4	12.3	5.3	14.6	3.7	2.8	41.8	19.8	8.2
Libellulidae adult	1.0	0.5	0.0	2.3	1.2	0.1	0.0	0.0	0.0
Coenagrionidae nymph	87.1	27.0	35.8	80.8	26.7	42.4	76.4	15.6	23.5
Coenagrionidae adult	0.5	0.1	<0.1	16.9	3.7	4.6	0.0	0.0	0.0
Diptera									
Chironomidae subadult	34.0	2.2	4.6	23.0	4.0	6.6	1.8	0.1	0.3
Chironomidae adult	1.0	<0.1	0.1	1.4	<0.1	0.1	0.0	0.0	0.0
Empididae adult	0.0	0.0	0.0	0.5	0.2	0.2	0.0	0.0	0.0
Amphipoda									
Talitridae	35.1	3.0	9.2	28.2	2.2	6.0	38.2	4.6	14.4
Gammaridae	22.2	6.3	4.9	2.3	0.5	<0.1	30.9	3.8	3.6
Gastropoda									
Unidentified	4.6	1.2	0.9	5.6	1.2	1.5	0.0	0.0	0.0
Lymnaeidae	10.8	1.3	1.4	10.8	2.0	2.7	3.6	0.1	0.7
Physidae	0.5	0.3	0.1	2.8	0.8	0.3	1.8	<0.1	0.3
Planorbidae	1.0	<0.1	0.5	0.9	<0.1	0.1	0.0	0.0	0.0
Pelecypoda									
Sphaeriidae	2.6	0.4	<0.1	0.5	<0.1	<0.1	0.0	0.0	0.0
Trichoptera									
Limnephilidae larvae	3.1	0.8	0.3	2.3	0.8	0.6	3.6	0.2	0.5
Phryganeidae larvae	1.0	0.3	0.1	0.9	0.4	0.4	0.0	0.0	0.0
Phryganeidae adult	0.5	<0.1	<0.1	1.4	0.5	0.6	0.0	0.0	0.0
Coleoptera									
Gyrinidae	1.0	<0.1	0.1	0.5	<0.1	0.1	0.0	0.0	0.0
Dytiscidae	20.6	3.9	1.8	3.8	0.4	0.4	16.4	2.9	2.2
Haliplidae	1.0	<0.1	0.3	1.1	0.1	0.1	0.0	0.0	0.0
Chrysomelidae	0.5	0.1	0.1	4.2	0.1	0.4	0.0	0.0	0.0
Hydrophilidae	0.5	0.5	0.5	0.5	0.2	0.2	0.0	0.0	0.0

Table 5. Continued

Prey item	Spring			Summer			Fall		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Hemiptera									
Corixidae	22.2	2.4	1.8	13.1	0.8	1.4	7.3	0.7	1.0
Gerridae	0.5	<0.1	<0.1	6.6	0.6	1.0	1.8	0.2	0.2
Notonectidae	6.7	0.7	0.3	1.4	0.2	0.3	5.4	2.7	2.4
Formicidae	0.0	0.0	0.0	0.9	<0.1	0.1	0.0	0.0	0.0
Hydracarina	0.5	<0.1	<0.1	1.9	<0.1	<0.1	0.0	0.0	0.0
Ephemeroptera									
Baetidae nymph	68.4	10.2	21.7	24.4	1.1	4.1	52.7	2.2	12.1
Baetidae adult	0.0	0.0	0.0	1.9	<0.1	0.2	0.0	0.0	0.0
Caenidae nymph	0.5	0.3	<0.1	0.9	0.1	0.1	0.0	0.0	0.0
Hirudinea									
Glossiphonidae	2.1	0.9	0.5	0.9	0.3	0.4	1.8	1.3	0.4
Erpobdellidae	10.3	2.7	0.5	0.9	1.0	0.3	0.0	0.0	0.0
Cladocera									
Daphnidae	0.5	<0.1	<0.1	0.5	<0.1	<0.1	0.0	0.0	0.0
Copepoda	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Relictus	0.0	0.0	0.0	2.3	2.0	1.4	0.0	0.0	0.0
Micropterus	1.0	0.1	0.5	2.3	0.9	2.0	3.6	1.8	3.6
Fulica	0.0	0.0	0.0	0.5	<0.1	0.5	0.0	0.0	0.0
Vegetation	8.2	0.3	--[a]	8.9	1.2	--	9.0	0.9	--
Other	3.8	0.6	0.6	2.6	0.4	0.9	1.8	0.1	1.3
Non-identified material	--	0.6	--	--	0.8	--	--	0.3	--

[a] measure non-applicable

Table 6. Percent occurrence, mean percent dry weight, and mean percent number of prey items utilized by juvenile and adult largemouth bass in Dace Bay, Ruby Marsh, Nevada, 1980 and 1981.

	Juvenile						Adult					
	Spring			Summer			Spring			Summer		
Prey item	Occurrence (%)	Dry weight ($\overline{x}$%)	Number ($\overline{x}$%)	Occurrence (%)	Dry weight ($\overline{x}$%)	Number ($\overline{x}$%)	Occurrence (%)	Dry weight ($\overline{x}$%)	Number ($\overline{x}$%)	Occurrence (%)	Dry weight ($\overline{x}$%)	Number ($\overline{x}$%)
Odonata												
Aeshnidae nymph	0.0	0.0	0.0	15.8	1.7	1.2	25.0	3.4	6.7	0.0	0.0	0.0
Aeshnidae adult	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.1	1.6
Libellulidae nymph	0.0	0.0	0.0	5.3	0.6	0.1	8.3	8.3	8.3	11.1	4.0	2.2
Coenagrionidae nymph	33.3	33.3	33.3	63.2	11.8	14.1	41.7	0.7	8.0	77.8	7.3	19.9
Diptera												
Chironomidae subadult	0.0	0.0	0.0	10.5	0.7	2.7	8.3	0.9	4.9	0.0	0.0	0.0
Amphipoda												
Talitridae	16.7	16.7	16.7	0.0	0.0	0.0	8.3	0.1	2.5	0.0	0.0	0.0
Trichoptera												
Limnephilidae larvae	0.0	0.0	0.0	10.5	5.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera												
Gyrinidae	0.0	0.0	0.0	5.3	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Dytiscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	1.3	1.6
Hemiptera												
Corixidae	16.7	1.0	8.3	64.4	18.5	24.6	41.7	1.3	7.9	66.7	5.5	19.9
Gerridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.2	1.6
Ephemeroptera												
Baetidae nymph	16.7	16.7	16.7	57.9	6.8	22.2	16.7	0.1	1.5	44.4	0.4	9.1
Baetidae adult	0.0	0.0	0.0	5.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Hirudinea												
Erpobdellidae	0.0	0.0	0.0	0.0	0.0	0.0	8.3	<0.1	1.7	0.0	0.0	0.0
Relictus	33.3	32.3	25.0	84.2	51.7	31.9	91.7	84.8	58.5	88.9	75.8	44.1
Vegetation	0.0	0.0	--[a]	0.0	0.0	--	0.0	0.0	--	22.2	3.2	--
Non-identified material	--	0.0	--	--	2.3	--	--	0.0	--	--	2.2	--

[a] measure non-applicable

Relative Prey Preference

We collected prey availability samples that corresponded with the collection of 200 juvenile largemouth bass. Aeshnid dragonfly nymphs had the greatest mean difference in rank of usage and availability and therefore were the most preferred prey (Table 7). The second and third most preferred prey (Gammaridae and Hemiptera) actually contributed little to the diet by weight or number (Table 3); and damselfly nymphs, which were important in the diet, were the 10th most preferred prey (Table 7). We collected 290 adult largemouth bass with corresponding prey availability samples for preference analyses. The order of preference of adult bass (Table 8) was similar to that of juvenile bass. Aeshnid dragonfly nymphs were the second most preferred prey category and damselfly nymphs were the 11th most preferred prey (Table 8). Many of the prey categories which contributed little to the diet ranked high in order of preference for both juvenile and adult fish.

Growth Rates

A total of 84 tagged fish were recaptured and total lengths were recorded for 46 fish that had been tagged for more than 20 days. We choose 21 days as the minimum growth period because we felt this was a sufficient period of time for detectable size changes. All recaptured fish had grown for either 20 to 60 days or 326 to 455 days (Table 9).

The average peak growth rate of fish between 178 and 225 mm TL at tagging was 0.442 mm/day (S.E. = 0.033 mm/day) however, this estimate is only based on a sample size of 2. The average annual growth rate

Table 7. Mean difference in rank of usage and availability, preference rank and rank of those prey categories with significant difference ($P \approx 0.05$) in preference rank for major prey categories utilized by juvenile largemouth bass in the South Sump, Ruby Marsh, Nevada, 1980-81.

Prey category	Mean difference in rank	Preference rank	Prey categories with significant difference in preference rank
Aeshnidae nymph	-3.13	1	3-14
Gammaridae	-2.81	2	3-14
Hemiptera	-2.21	3	1,2,5-14
Libellulidae nymph	-1.84	4	1,2,5-14
Hirudinea	-0.90	5	1-4,9-14
Coleoptera	-0.60	6	1-4,9-14
Caenidae nymph	-0.46	7	1-4,11-14
Baetidae nymph	-0.33	8	1-4,11-14
Trichoptera larvae	-0.05	9	1-6,11-14
Coenagrionidae nymph	0.25	10	1-6,11-14
Hydracarina	1.30	11	1-10,13,14
Chironomidae subadult	1.88	12	1-10,13,14
Talitridae	3.98	13	1-12,14
Gastropoda	4.96	14	1-13

Table 8. Mean difference in rank of usage and availability, preference rank and rank of those prey categories with significant difference ($P \approx 0.05$) in preference rank for major prey categories utilized by adult largemouth bass in the South Sump, Ruby Marsh, Nevada, 1980-81.

Prey category	Mean difference in rank	Preference rank	Prey categories with significant difference in preference rank
Gammaridae	-3.90	1	3-14
Aeshnidae nymph	-3.69	2	3-14
Hemiptera	-2.29	3	1,2,5-14
Caenidae nymph	-2.14	4	1,2,6-14
Libellulidae nymph	-1.64	5	1-3,6-14
Baetidae nymph	-1.09	6	1-5,8-14
Hydracarina	-0.51	7	1-5,10-14
Coleoptera	-0.49	8	1-6,10-14
Hirudinea	-0.03	9	1-6,10-14
Trichoptera larvae	0.53	10	1-9,11-14
Coenagrionidae nymph	2.15	11	1-10,13-14
Chironomidae subadult	2.17	12	1-10,13,14
Talitridae	5.35	13	1-12
Gastropoda	5.57	14	1-12

Table 9. Size at tagging, growth period and growth increment for largemouth bass tagged and recaptured in the South Sump, Ruby Marsh, Nevada, 1980-81.

Size at tagging		Growth Period (days)	Growth increment	
Total length (mm)	Weight (g)		Total length (mm)	Weight (g)
279	330	21	1	-8
225	179	22	9	2
265	253	24	7	10
281	335	31	8	25
295	362	36	10	38
294	380	41	9	20
211	140	40	19	5
277	289	47	11	23
305	385	49	5	45
275	276	55	13	-1
295	388	60	2	-8
215	153	326	18	44
304	378	326	0	--[a]
293	424	328	7	-10
274	292	330	6	20
217	163	333	23	57
297	345	333	15	--
293	336	333	7	-5
286	320	334	3	5

Table 9. Continued

Size at tagging		Growth Period (days)	Growth increment	
Total length (mm)	Weight (g)		Total length (mm)	Weight (g)
216	142	334	28	98
193	117	333	33	66
178	83	339	33	47
190	104	345	39	60
241	209	347	7	1
301	391	347	9	9
228	180	350	21	65
238	198	353	21	30
190	105	355	44	66
297	355	357	6	30
270	298	360	12	24
237	201	367	15	39
277	295	367	12	35
224	168	367	32	97
245	214	368	6	--
216	159	373	19	21
206	128	375	37	72
204	125	385	36	70
265	265	388	10	30
225	170	392	31	70

Table 9. Continued

Size at tagging		Growth Period (days)	Growth increment	
Total length (mm)	Weight (g)		Total length (mm)	Weight (g)
221	151	394	39	84
221	151	395	41	29
275	284	397	13	21
230	173	414	30	--
220	134	428	36	--
267	276	430	20	--
302	435	444	6	19

[a] data incomplete

for this same size group was 0.089 mm/day (S.E. = 0.005 mm/day) (Table 10). No estimates of peak growth rate were obtained for fish betwen 226 and 260 mm TL at tagging. The average annual growth rate for this size group was 0.045 mm/day (S.E. = 0.009 mm/day) (Table 10). Fish between 261 and 305 mm TL at tagging had an average peak growth rate of 0.189 mm/day (S.E. = 0.034 mm/day) and an average annual growth rate of 0.025 mm/day (S.E. = 0.003 mm/day) (Table 10).

Food Consumption Rates

The damp-dry, live weight of libellulid nymphs consumed, the number of libellulid nymphs consumed and the dry weight of digestible organic matter remaining in the stomach after 4, 8, 12, 16 and 20 hours of digestion at 21.1 C for each feeding trial are presented in Table 11. Regurgitation occurred on two occassions and only four observations were recorded at 12 and 16 hours of digestion (Table 11). The dried digestible organic matter in 1000 mg of libellulid nymphs was 148 mg (S.E. = 3 mg). The five estimates of the dried digestible organic matter in 1000 mg were included with the other 23 observations (Table 11) in the regression of dried digestible organic matter against digestion time as zero time estimates.

The regression equation describing the relationship between dried digestible organic matter and digestion time at 21.1 C was $\text{Log}_e\ Y = \text{Log}_e\ 150 - 0.127\ x$ ($r = -0.87$), thus the evacuation rate at 21.1 C was 0.127 (95% CI = ± 0.030). Through the relationships described by Elliott (1972) and Adams et al. (1982), we converted the evacuation rate of 0.127 at 21.1 C to the evacation rate of 0.106 at 17.9 C.

Table 10. Size range (mm TL) at time of tagging, peak growth rate, annual growth rate, and sample sizes (N) used to calculate growth rates of largemouth bass in the South Sump, Ruby Marsh, Nevada, 1980-1981.

Size range (mm TL)	Peak growth rate (mm/day ± S.E.)	N	Annual growth rate (mm/day ± S.E.)	N
178-225	0.442 ± 0.033	2	0.089 ± 0.005	15
226-260	--[a]	0	0.045 ± 0.009	6
261-305	0.189 ± 0.034	9	0.025 ± 0.003	14

[a] no estimate obtained

Table 11. Damp-dry, live weight of libellulid nymphs consumed, number of libellulid nymphs consumed, length of time between meal intake and removal and dry weight of digestible organic matter remaining in the stomach after removal for individual largemouth bass used in the feeding experiment to estimate the gastric excavation rate at 21.1 C, Jul-Aug 1981.

Damp-dry, live weight of dragonfly nymphs consumed (mg)	Number of dragonfly nymphs consumed	Hours between meal intake and removal	Dry weight of digestible organic matter after removal (mg)
1000	12	4	85
997	13	8	49
1001	14	12	42
996	13	16	33
999	15	20	19
1001	11	4	95
999	14	8	60
1000	12	12	39
1000	12	16	36
1002	13	20	32
1002	9	4	74
998	10	8	57
999	10	16	22
1002	10	20	18

Table 11. Continued.

Damp-dry, live weight of dragonfly nymphs consumed (mg)	Number of dragonfly nymphs consumed	Hours between meal intake and removal	Dry weight of digestible organic matter after removal (mg)
1001	10	4	83
1002	10	8	55
998	10	12	42
999	10	16	18
1002	10	20	3
996	9	4	84
1000	10	8	60
997	11	12	31
1005	10	20	2

Time of day, water temperatures, sample sizes and the mean quantity of dried digestible organic matter in the stomachs of fish collected on 12-13 Jun 1980, and on 2-3 Jul 1981, are presented in Table 12. The size range of the fish collected on 12-13 Jun 1980, was 153 to 324 mm TL and 37 to 443 g weight, and the fish collected on 2-3 Jul 1981 ranged in size from 175 to 330 mm TL and from 84 to 540 g weight. The quantity of dried digestible organic matter in the stomachs for all samples was highly variable and large S.E. were associated with all means (Table 12). We found no significant difference ($F_{0.05, 11, 82}$) among the 12 mean quantities of dried digestible organic matter in the stomachs of fish collected on 2-3 Jul 1981, and we also found no significant difference ($F_{0.01, 11, 57}$) among the 12 mean quantities of dried digestible organic matter in the stomachs of fish collected on 12-13 Jun 1980. Therefore, we made the assumption that the quantity of food in the stomach remained constant over the 24-hour periods (Darnell and Meierotto 1962; Pennington 1982). We considered that fish size may have been a factor causing the large variation in the quantity of food for all samples; however, expressing the quantity of food as a proportion of the body weight actually increased the variation.

Since we did not find any significant difference among the means over the 24-hour periods, we pooled the data and estimated S as the mean of all samples at each temperature for the three size specific groups and for all size groups combined. The mean dry weight of digestible organic matter in the stomachs of the three size specific groups of largemouth bass and for all size groups combined over the

Table 12. Time of day, sample size (N), temperature and dry weight of digestible organic matter in the stomachs of largemouth bass collected over 24-hour periods on 12-13 Jun 1980 and on 2-3 Jul 1981, in the South Sump of Ruby Marsh, Nevada.

Date Time of day	N	Temperature (C)	Dry weight of digestible organic matter ($\bar{x}$ mg ± S.E.)
June 12-13, 1980			
0400	3	17.2	143 ± 47
0600	5	17.8	194 ± 92
0800	5	17.8	68 ± 34
1000	7	17.8	126 ± 40
1200	4	17.8	408 ± 141
1400	6	17.8	355 ± 170
1600	4	19.4	68 ± 62
1800	6	18.9	76 ± 48
2000	8	18.3	121 ± 41
2200	7	17.8	308 ± 73
2400	7	17.2	77 ± 27
0200	7	17.2	101 ± 55
	$\Sigma = 69$	$\bar{x} = 17.9$	$\bar{x} = 166 \pm 24$

Table 12. Continued

Date Time of day	N	Temperature (C)	Dry weight of digestible organic matter ($\bar{x}$ mg ± S.E.)
July 2-3, 1981			
0600	6	21.1	239 ± 58
0800	8	21.1	131 ± 39
1000	8	21.7	68 ± 23
1200	7	22.2	130 ± 35
1400	7	22.2	262 ± 139
1600	8	22.8	151 ± 48
1800	8	22.2	160 ± 47
2000	9	21.1	113 ± 54
2200	9	21.7	67 ± 67
2400	8	20.6	110 ± 52
0200	7	20.0	134 ± 40
0400	9	20.6	112 ± 33
	Σ = 94	$\bar{x}$ = 21.4	$\bar{x}$ = 135 ± 16

24-hour periods at 17.9 C and 21.4 C are presented in Table 13. At 17.9 C the mean dry weight of digestible organic matter in the fish < 226 mm TL was significantly less ($t_{0.05,\ 23}$) than the mean dry weight of digestible organic matter in the stomachs of fish between 226 and 260 mm TL and fish > 260 mm TL. There was no significant difference ($t_{0.20,\ 6}$) between the mean dry weight of digestible organic matter in the stomachs of fish between 226 and 260 mm TL and fish > 260 mm TL. At 17.9 C fish < 225 mm TL consumed 1,932 mg of live prey over the 24-hour period and fish between 226 and 260 mm TL consumed 3,128 mg of live prey over the 24-hour period (Table 13). Fish > 260 mm TL consumed 3,371 mg of live prey over the 24-hour period at 17.9 C (Table 13). The consumption rate of all size groups combined was 2,851 mg of live prey.

At 21.4 C the mean dry weight of digestible organic matter in the stomachs of fish < 226 mm TL was not significantly different ($t_{0.20,\ 41}$) than the mean dry weight of digestible organic matter in the stomachs of fish between 226 and 260 mm TL. The dry weight of digestible organic matter in the stomachs of fish > 260 mm TL was significantly greater than ($t_{0.05,\ 25}$) the quantity in the stomachs of fish between 226 and 260 mm TL and fish < 226 mm TL. Fish < 226 mm TL consumed 2,723 mg of live prey over the 24-hour period at 21.4 C and fish between 226 and 260 mm TL consumed 2,223 mg of live prey over the 24-hour period (Table 13). Fish > 260 mm TL consumed 3,439 mg of live prey over the 24-hour period. The consumption of all size groups combined was 2,770 mg of live prey at 21.4 C (Table 13).

Table 13. Temperature, sample size, dried digestible organic matter in the stomachs and daily food consumption of size specific groups of largemouth bass at Ruby Marsh, Nevada, 1980 and 1981.

Temperature (C)	N	Total length (mm)	Dried digestible organic matter ($\bar{x}$ mg ± SE)	Daily consumption: Dried digestible organic matter (mg)	Daily consumption: Live prey (mg)
17.9	24	< 226	113 ± 22	286	1,932
17.9	7	226-260	182 ± 76	463	3,128
17.9	37	> 260	196 ± 41	499	3,371
17.9	68	153-324	166 ± 24	422	2,851
21.4	42	< 226	132 ± 20	403	2,723
21.4	26	226-260	108 ± 26	329	2,223
21.4	26	> 260	167 ± 39	509	3,439
21.4	94	175-330	135 ± 16	410	2,770

DISCUSSION

The food habits of young-of-year largemouth bass at Ruby Marsh are similar to those of young-of-year in other lakes and reservoirs with zooplankton and small insects composing most of the diet during the summer and insects being the dominant prey during the fall. Emig (1966), Applegate and Mullan (1967), and Clady (1974) all reported similar food habits for young-of-year largemouth bass.

The few studies which have described the food habits of largemouth bass in the absence of forage fish have shown some similar and some dissimilar findings than ours. Rogers (1967) found that young largemouth bass 30 mm TL or longer had similar diets in prey composition and size composition, however, he did not describe all the prey types which were present in the system to allow for a comparision with Ruby Marsh. The diets of juvenile and adult bass at Ruby Marsh consisted of larger invertebrates than did the diet of young-of-year bass, however, the diets of juvenile and adult fish were similar in prey composition and prey size composition. The diet of largemouth bass in a lake in Ontario which was void of forage fish was similar to the diet of largemouth bass in Ruby Marsh with odonate nymphs and mayfly nymphs comprising a majority of the diet (Bennett 1948). It was surprising that the degree of cannabilism by young-of-year, juvenile and adult bass was low at Ruby Marsh. We attribute this to the abundance of both submergent and emergent vegetation which provided a vast amount of cover for the small fish. Although the diet of young-of-year bass varied considerably between summer and fall, the prey composition of the juvenile and adult diet varied little between seasons. While there were shifts in the importance of the major prey items through the seasons, the diet consisted of the same prey types. A comparison of the diet of fish collected from Dace Bay and the diet of fish collected from other areas of the South Sump shows that when forage fish are available they are used extensively, particularly by adult bass. The most preferred prey categories by juvenile and adult fish in areas other than Dace Bay were the prey which attain a large size and are not extremely rare (aeshnid dragonfly nymphs and gammarid amphipods). This preference indicated a prey selection partially based on size.

The length at each age for Ruby Marsh largemouth bass is considerably smaller than the length at age in most other waters (Carlander 1977). Very few fish reach lengths > 360 mm TL and the size differences between age-classes is small (Table 1), particuarly from the fifth year on. Growth rates slow considerably with size (Tables 1 and 10), with growth nearly ceasing at about 300 mm TL.

At 17.9 C there was a trend for increasing food consumption per day with size (Table 13); however, at 21.4 C fish < 226 mm TL had a greater daily food consumption rate than did fish between 226 and 260 mm TL. There was no consistent trend of increased or decreased consumption rate with temperature (Table 13). Fish > 260 mm TL consumed approximately the same quantity of prey at 17.9 C and as they did at 21.4 C; and fish between 226 and 260 mm TL consumed less prey at 21.4 C than they did at 17.9 C. Fish < 226 mm TL had a greater consumption at 21.4 C than at 17.9 C. The daily consumption rate expressed as percent of body weight tended to be less than has been reported in other studies, particularly for larger fish. Studies that have estimated the consumption rates for largemouth bass have used other methods and have determined the rates in terms of forage fish. Heman *et al.* (1969) reported the daily food consumption rate of a 454 g fish to be 1.2 to 2.6% of body weight. We estimated the daily consumption rate of a 454 g fish to be 0.7% of body weight at 17.9 C and 0.8% of body weight at 21.4 C. Lewis *et al.* (1974) reported that fish betwen 90 and 450 g consumed 4.9% of their body weight of gizard shad (*Dorosoma cepedianum*) per day. We found that a 90 g fish consumed 2.1% of body weight per day at 17.9 C and 3.0% of body weight per day at 21.4 C which is considerably less than was reported by Lewis *et al.* (1974). In general it appears that fish of all sizes consumed less prey per day than fish in other waters. We believe this is a result of the insect prey base and the absence of forage fish. Because insects typically do not obtain as large a size as most forage fish, one successful prey capture of an insect does not yield the quantity or quality of food that one succesful prey capture of a forage fish yields. Zweiacker and Summerfelt (1973) and Dubets (1954) suggested that largemouth bass which feed on forage fish are diurual predators. Apparently, the prey size and quality forces the Ruby Marsh bass to feed at all times of the day and night.

Zweiacker and Summerfelt (1973) indicated that percent empty stomachs is a good indicator of available forage. The low percentage of empty stomachs that we found would indicate a high availability of prey. It appears the numbers of prey available and the number of prey consumed is not low but the small size of prey keeps the consumption rates low.

The consumption rates, prey composition, and year around cold water temperatures are all implicated in the small size at age, slow growth and small maximum size. With fish of all sizes consuming less food per day than fish of equal sizes in other waters, the overall energy intake is less. Further, the quantity of energy per gram of prey consumed is less for insects than for fish, crayfish and other prey (Cummins and Wuycheck 1971) which are typically utilized by largemouth bass. The ratio of energy intake to energy expense of capture is far less for an insect feeding predator compared to a forage fish feeding predator of equal size. Year around cold water temperatures only provide a short period of time when conditions are good for growth--thus limiting the time available for growth.

Largemouth bass at Ruby Marsh do not attain large sizes because of the short growing season and the insect diet which limits the potential for growth. The fish apparently reach an energetic balance at about 315 mm where the energy expended for maintenance over an entire year is about equal to the energy intake--thus, there is not energy available for growth. We feel that the growth rates slow with increasing size due to the limited size of available prey and the decrease in food intake as percent of body weight with increasing body size. The largest fish and the heaviest fish which we captured were all collected from Dace Bay. The fish that were feeding on relict dace were heavier for a given length than fish that were not feeding on dace. This indicates that growth and maximum size of the largemouth bass at Ruby Marsh are closely related to diet.

The largemouth bass at Ruby Marsh can be characterized as an insectivorous predator feeding at a lower trophic level than is typical for this species. Daily food consumption rates are low and growth rates are slow with a majority of the growth occurring during the summer months. Densities of fish appear to be high as shown by high catch rates and large annual harvest (Green 1981). In the absence of forage fish the juvenile and adult largemouth bass feed at one trophic level lower than if forage fish were present; therefore, a larger biomass of largemouth bass is supported in the absence of forage fish than would be supported if forage fish were present due to the nature of energy loses and transfer through the food chain (Slobodkin 1961).

III. FEEDING ECOLOGY OF RAINBOW TROUT AND BROWN TROUT AT RUBY MARSH, NEVADA[1]

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ABSTRACT

The diet and relative prey preference of age 1+, 2+ and 3+ rainbow trout (Salmo gairdneri) and the diet of brown trout (S. trutta) in the South Sump of Ruby Marsh, Nevada, (Fig. 1) were studied during 1980 and 1981. Trout were collected by electrofishing at night and by angling and electrofishing during the day. The diet of brown trout consisted entirely of invertebrates of which physid snails, chironomid subadults and coenagrionid damselfly nymphs were the primary food items. The diet of all age groups of rainbow trout also consisted entirely of invertebrates. Age 1+ rainbow trout fed primarily on chironomid subadults, coenagrionid damselfly nymphs, talitrid scuds and lymnaeid snails. The diet of age 2+ rainbow trout consisted of the same prey types as that of age 1+ rainbow trout, however, snails

[1] Technical Paper No.   , Oregon Agricultural Experiment Station.

were more important in the diet of age 2+ fish. Lymnaeid snails and physid snails were the primary prey of age 3+ rainbow trout. The order of prey preference for all three age-groups of rainbow trout was similar and chironomid subadults were the most preferred prey item. In general, the feeding strategies of brown and rainbow trout at Ruby Marsh are similar to the feeding strategies of these species in other waters in that they are omnivorous predators which utilize those prey organisms which are most abundant.

INTRODUCTION

Numerous studies have documented the food habits of rainbow trout (Salmo gairdneri), and brown trout (Salmo trutta), in lentic and lotic waters (Carlander 1969; Moyle 1976). No thorough investigation of the food habits of these species has been conducted at Ruby Marsh or in any similar habitat. In this study we determine the diet and relative prey preference of age-specific groups of rainbow trout and the diet of brown trout in the South Sump (Fig. 1) of Ruby Marsh, Nevada.

Marshes typically undergo natural periodic drawdowns, however due to the nature of the water source water levels at Ruby Marsh remain fairly constant. Water level manipulation may be used in the South Sump to stimulate aquatic invertebrate and plant production. This study was conducted to establish baseline food habits information which will be useful in assessing the response of rainbow trout and brown trout populations to any man induced or natural drawdown. The food habits information also provides a partial basis for determining the degree of dietary overlap between rainbow trout and canvasback (*Aythya valisineria*) and redhead (*Aythya americana*) ducks.

The relict dace (*Relictus solitarius*) is the only fish native to Ruby Marsh (Hubbs *et al.* 1974). Trout stocking began in 1942 and largemouth bass (*Micropterus salmoides*) were introduced in 1932 (Trelease 1948). Rainbow trout and brown trout do not reproduce successfully in Ruby Marsh and population levels are maintained by annual releases. Both species of trout are typically released as catchable size yearlings. Many rainbow trout larger than 1 kg are harvested each year indicating good growth rates (Green 1981). The majority of the trout planted are rainbow trout but small numbers of brown trout are also released.

Relict dace were eliminated from most areas of the marsh due to high predation rates by largemouth bass (Hubbs *et al.* 1974). Relict dace do not inhabit the areas of the South Sump where rainbow trout and brown trout are found; and because no other forage fishes are available, these trouts must rely exclusively on invertebrates as prey. Previous studies of the food habits of these two trout species have shown that the diets are highly variable from system to system depending principally on the types of prey which are available. In lakes and reservoirs zooplankton, aquatic invertebrates, terrestrial invertebrates and fishes have all been shown to be important prey for both species (McAfee 1966; Carlander 1969; Moyle 1976). The diets of these two species in Ruby Marsh are somewhat different than has been reported from other lakes, reservoirs or streams in previous studies (Frost 1950; Reimers *et al.* 1955; Carlander 1969; Chaston, 1969;

Elliott 1973; Moyle 1976); however, the feeding stategies of these two fishes in Ruby Marsh are generally the same as found in other waters.

STUDY AREA

Ruby Marsh is located in the northeastern corner of Nevada, 96 km southeast of the town of Elko. According to Hubbs *et al.* (1974) the marsh occupies the area which was once the southern arm of pluvial Lake Franklin. The South Sump encompasses the southern end of the marsh and is bordered by mountains to the east and west. It has an elevation of 1,830 m and occupies a total of 2,962 hectares at the high water line. It is a maze of interconnected channels and pools (Fig. 2) of which 1,570 hectares are shallow water areas interspersed with emergent vegetation, 918 hectares are open water areas of less than 5 m maximum depth and 474 hectares are upland (Ruby Lake N.W.R. 1982).

Water input into the South Sump is primarily from numerous springs surrounding its border. Water temperatures remain cool throughout the year only rising above 15 C from May through September reaching a maximum of about 24 C during this period. Ice generally covers the marsh from December through February. The entire shoreline area is covered with dense stands of hardstem bulrush (*Scirpus acutus*) and during the warmer months the bottom is typically covered with dense mats of submerged vegetation. Muskgrass (*Chara sp.*), pondweeds (*Potamageton sp.*), watermilfoil (*Myriophyllum sp.*), and bladdlerwort (*Utricularis vulgaris*) are the prominent submerged vegetation types.

METHODS

We collected rainbow trout and brown trout from 15 May 1980 to 26 Nov 1981 at irregular intervals. Collections were made by electrofishing and angling. A pulsed direct-current electrofishing unit similar to that described by Sharpe (1964), with 2.0-3.0 amps, was used. Fish were difficult to collect during the day because the extreme clarity and shallow depth of the water made avoidance by fish a problem. The majority of trout we collected during daylight hours were caught by angling with spinners and nightime collections were made by electrofishing.

To investigate seasonal food habits, we designated the monthly periods as: winter (Dec-Feb), spring (Mar-May), summer (Jun-Aug), and fall (Sep-Nov). We attempted to collect rainbow trout and brown trout during all seasons, all feeding periods and from all areas of the South Sump which were accessible by boat. Due to the low abundance of brown trout, stomach samples representing all feeding periods and all areas of the marsh could not be obtained therefore brown trout of all age groups and seasons were analyzed as one group.

Fish were immediately killed upon capture by severing the spinal cord just posterior to the brain to prevent regurgitation. We recorded total lengths (TL) to the nearest 1 mm and weights to the nearest 1 g. For our study the same individual recorded most of the lengths and weights to minimize error. We took scale samples from each fish midway between the dorsal fin and the lateral line slightly anterior to the dorsal fin (Klavano 1958). We mounted the scales between microscope slides and read them on a microfiche reader at 42X.

The two criteria we used for annulus identification were: (1) narrowly spaced circuli preceeded and followed by widely spaced circuli (Lagler 1952; Carlander 1961), (2) cutting over of circuli on the lateral field of the scale (Carlander and Whitney 1961; Chugunova 1963). Originally we read each scale twice and the age was used if both readings were in agreement. If readings differed, we read the scale again until agreement between two readings was reached. We divided fish into three age groups: age 1+ (age 1-2), age 2+ (age 2-3), age 3+ (age 3-5). The age 1+ fish consisted of recently stocked fish as well as fish which had spent up to 9 months in the marsh.

Immediately after trout were captured, we removed the stomach contents and preserved them in 70% ethanol. Prey items were identified, counted, dried at 65 C for 24 hours and then weighed to the nearest 1 mg. Drying at 65 C for 24 hours was sufficient to remove all moisture. Weights of gastropods and pelecypods which were in shells were multiplied by 0.30 and caddisfly larvae were removed from the case previous to drying. Therefore, dry weights of all gastropods (unidentified, Lymnaeidae, Physidae, Planorbidae), caddisfly larvae (Limnephilidae, Phryganeidae) and pelecypods (Sphaeriidae), were recorded as tissue only. The unidentified gastropod category actually was either lymnaeid or physid snails but could not be identified as one or the other. We classified stomachs as empty if they contained less than 1 mg of dried food. Types, numbers and dry weights of prey items were evaluted by percent occurrence (Windell and Bowen 1978) and mean percent of weight and number (Swanson et al. 1974). Advantages in using mean percentage over total percentage are thoroughly discussed by Swanson _et al._ (1974).

Relative prey preference was evaluated as described by Johnson (1980). This method utilizes ranked prey usage and availability data and allows for the use of statistical tests for significant differences in preference. Many other measure of selectivity (Hess and Rainwater 1939; Ivlev 1961; Jacobs 1974; Neu _et al._ 1974) are available, however this method was used because of its ease of interpretation and the statistical tests which can be applied. The results of this procedure provide an ordering of most preferred prey to least preferred prey based on the mean difference in rank of usage and rank of availablity. An F test ($P < 0.001$) was used to determine if all prey categories were equally preferred or some prey categories were significantly preferred over others. The test for significant difference ($P \approx 0.05$) in preference between each prey (Bayesian decision procedure [Waller and Duncan 1969]) category was approached with the procedure described by Johnson (1980).

We took prey availability samples with an aquatic invertebrate sweepnet (mesh = 0.05 mm) (Merritt _et al._ 1978). Samples were taken immediately following the collection of fish in the same location. The opening of the net was immersed into the benthic vegetation above the substrate level for each net sweep. We immediately preserved samples in 10% Formalin and sorted them in the laboratory. Sorting was conducted with the aid of a 10X binocular scope and all invertebrates with the exception of zooplankton were removed. Invertebrates were identified, counted, dried for 24 hours at 65 C, and weighed to the nearest 1 mg. Ranking of usage and availability data was based on mean percent of number; all adult aquatic insects, terrestrial invertebrates and zooplankton were omitted in the preference analysis. We were interested in relative prey preference on a broader level than the diet; therefore, for the preference analysis the families Corixidae and Notonectidae were combined into the prey category Hemiptera. Unidentified snails and the families Lymnaeidae and Physidae were combined into the prey category Gastropoda and the families Limnephilidae and Phryganeidae were combined into the prey category Trichoptera. The families Gyrinidae, Haliplidae, Dytiscidae and Hydrophilidae were combined into the prey category Coleoptera and the families Glossiphonidae and Erpobdellidae were combined into the prey category Hirudinea. We used a total of 14 prey categories in the preference analysis. Relative preference rankings for each prey category were determined only for the three age groups of rainbow trout. We did not assess preference on a seasonal basis, rather we choose to assess it on an overall basis. Availability samples could not be obtained through the ice during the winter therefore preference ranking only pertains to the time period of March through November.

RESULTS

Brown Trout Food Habits

We examined a total of 15 brown trout stomachs of which most were collected during the summer at night. These fish ranged from 255 to

546 mm TL and from 160 to 2,120 g in weight. Only one of the 15 (6.7%) stomachs examined were empty. We identified 19 prey types from the 14 stomachs which contained food. The diet consisted entirely of invertebrate food items, and physid snails occurred in 57.1% of the stomachs and comprised 24.6% of the weight and 23.8% of the number (Table 14). They were the dominant prey in weight and occurred in a higher percent of the stomachs than any other prey. Midge subadults (Chironomidae) were the second most important prey by weight (24.3%) and the first by number (32.0%) and occurred in 50.0% of the stomachs (Table 14). Damselfly nymphs (Coenagrionidae) comprised 19.0% of the weight and 14.6% of the number. Dragonfly nymphs (Aeshnidae and Libellulidae) and Lymnaeid snails were also important prey items. A number of other prey items were utilized but they contributed little to the diet (Table 14).

Rainbow Trout Food Habits

We examined a total of 84 age 1+ rainbow trout stomachs. We collected 49 during the spring, 17 during the summer and 18 during the fall (Table 15). Means and ranges of total length and weight for age 1+ fish are presented in Table 15. Few of the stomachs examined were empty with less than 6.0% empty in each season. Stomachs collected during the spring contained more prey types than stomachs collected during summer or fall (Table 16). No one particular prey item dominated the diet during any season and all prey items were invertebrates. Midge subadults were the most important prey item during the spring (% occurrence = 89.6, % wt = 22.7, % number = 27.1)

Table 14. Percent occurrence, mean percent dry weight and mean percent number of prey items utilized by brown trout at Ruby Marsh, Nevada, 1980 and 1981.

Prey item	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Odonata			
Aeshnidae nymph	35.7	5.8	4.8
Libellulidae nymph	21.4	7.5	4.0
Coenagrionidae nymph	50.0	19.0	14.6
Diptera			
Chironomidae subadult	50.0	24.3	32.0
Chironomidae adult	7.1	0.2	1.5
Amphipoda			
Talitridae	28.6	0.2	0.9
Gastropoda			
Unidentified	7.1	1.2	0.8
Lymnaeidae	14.3	6.1	7.7
Physidae	57.1	24.6	23.8
Pelecypoda			
Sphaeriidae	7.1	<0.1	0.1
Coleoptera			
Dytiscidae	14.3	4.1	2.2
Haliplidae	14.3	0.5	0.1
Hemiptera			
Corixidae	7.1	0.1	0.1
Formicidae	7.1	0.1	2.5
Ephemeroptera			
Baetidae nymph	21.4	2.8	1.5
Caenidae nymph	28.6	0.2	0.6
Cladocera			
Daphnidae	21.4	1.5	2.6
Trichoptera			
Phryganeidae larvae	14.3	0.7	0.4
Non-identified material	--[a]	0.5	--

[a] measure non-applicable

Table 15. Sample size, mean and range of total length and weight and percent empty stomachs of age 1+, age 2+ and age 3+ rainbow trout at Ruby Marsh, Nevada, 1980 and 1981.

Age group	Total length (mm)		Weight (g)		Spring		Summer		Fall		Winter	
	Mean	Range	Mean	Range	N	% empty	N	% empty	N	% empty	N	% empty
1+	293	161-362	291	41-630	49	2.0	17	5.9	18	5.6	0	--[a]
2+	397	320-445	711	435-1100	29	6.9	20	10.0	6	0	5	0
3+	479	400-620	1378	860-3000	32	3.1	26	11.5	19	0	15	0

[a] measure not applicable

Table 16. Percent occurrence, mean percent dry weight and mean percent number of prey items utilized by age 1+ rainbow trout at Ruby Marsh, Nevada, 1980 and 1981.

	Spring			Summer			Fall		
Prey item	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Odonata									
Aeshnidae nymph	4.2	0.4	0.1	6.3	0.5	<0.1	47.1	7.9	1.3
Libellulidae nymph	2.1	0.3	0.1	6.3	<0.1	2.2	17.6	4.7	0.6
Libellulidae adult	0.0	0.0	0.0	6.3	6.1	<0.1	0.0	0.0	0.0
Coenagrionidae nymph	62.5	11.5	9.6	50.0	15.1	10.6	70.6	20.7	22.3
Coenagrionidae adult	12.5	0.3	0.2	12.5	<0.1	0.1	0.0	0.0	0.0
Diptera									
Chironomidae subadult	89.6	22.7	27.1	62.5	15.4	17.9	29.4	0.2	0.4
Chironomidae adult	54.2	13.3	7.5	12.5	1.6	0.7	5.9	<0.1	<0.1
Amphipoda									
Talitridae	66.7	6.6	10.4	56.3	18.3	22.1	76.5	12.9	33.1
Gammaridae	2.1	1.7	<0.1	0.0	0.0	0.0	5.9	0.5	0.2
Gastropoda									
Unidentified	27.1	5.7	2.6	6.3	0.3	0.2	23.5	1.4	1.5
Lymnaeidae	33.3	3.2	2.3	25.0	8.9	9.2	47.1	23.1	15.3
Physidae	16.7	3.1	2.7	6.3	<0.1	<0.1	41.2	5.7	7.7
Planorbidae	33.3	1.1	1.4	6.3	<0.1	0.7	35.3	1.2	1.3
Pelecypoda									
Sphaeriidae	12.5	0.2	0.4	6.3	2.5	<0.1	0.0	0.0	0.0
Trichoptera									
Limnephilidae larvae	6.3	1.1	0.1	6.3	1.6	0.4	0.0	0.0	0.0
Phryganeidae larvae	4.2	<0.1	<0.1	0.0	0.0	0.0	5.9	5.9	6.3
Phryganeidae adult	6.3	1.8	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera									
Gyrinidae	10.4	0.5	0.1	6.3	0.1	0.1	11.8	0.2	0.4
Dytiscidae	10.4	0.4	0.1	12.5	0.9	5.2	11.8	0.2	0.2
Haliplidae	43.8	3.7	1.4	12.5	0.5	0.3	11.8	0.1	0.2
Chrysomelidae	4.2	0.7	0.3	18.8	2.6	1.5	0.0	0.0	0.0
Hemiptera									
Corixidae	6.3	0.7	0.2	0.0	0.0	0.0	5.9	0.4	0.2
Notonectidae	4.2	0.3	<0.1	0.0	0.0	0.0	5.9	0.1	<0.1

Table 16. Continued

Prey item	Spring			Summer			Fall		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Gerridae	4.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Formicidae	0.0	0.0	0.0	6.3	0.1	0.1	0.0	0.0	0.0
Hydracarina	29.2	0.9	2.4	12.5	0.3	3.6	0.0	0.0	0.0
Ephemeroptera									
Baetidae nymph	31.3	2.2	1.8	12.5	7.2	7.0	23.5	0.2	0.6
Caenidae nymph	16.7	0.4	0.6	25.0	1.5	1.9	0.0	0.0	0.0
Hirudinea									
Erpobdellidae	0.0	0.0	0.0	6.3	3.4	0.4	0.0	0.0	0.0
Cladocera									
Daphnidae	37.5	5.0	26.6	18.8	5.8	13.4	11.8	1.1	11.6
Ostracoda	4.2	0.4	1.7	6.3	0.6	2.6	0.0	0.0	0.0
Vegetation	27.1	3.0	--[a]	6.3	0.1	--	29.4	13.5	--
Other	25.0	0.3	0.4	6.3	<0.1	<0.1	0.0	0.0	0.0
Non-identified material	--	8.4	--	--	6.9	--	--	0.0	--

[a] measure non-applicable

and the second most important prey during the summer (% occurrence = 62.5, % wt. 15.4, % number = 17.9) but contributed little during the fall (Table 16). Damselfly nymphs were used extensively during spring (% occurrence = 62.5, % wt. = 11.5, % number = 9.6), summer (% occurrence = 50.0, % wt. = 15.1, % number = 22.3) and fall (% occurrence = 70.6, % wt = 20.7, % number = 22.3). Talitrid scuds were the most important prey item in number during the summer (22.1%) and fall (33.1%) and comprised 18.3% of the weight during summer and 12.9% during the fall. Lymnaeid snails were the most important prey item by weight during the fall but were utilized little during the spring and summer. Water fleas (Daphnidae) were important by number during the spring (26.6%) and summer (13.4%) but contributed little by weight during any season (Table 16).

We examined 60 age 2+ rainbow trout stomachs. Twenty-nine were collected during the spring, 20 during the summer, six during the fall and five during the winter. Means and ranges of total length and weight are presented in Table 15. None of the stomachs examined during the fall and winter were empty and less than 11.0% were empty during the spring and summer. The diet was more diverse in the spring and summer than it was during the fall and winter (Table 17). Talitrid scuds were the most important prey item by weight (19.2%) and number (30.2%) during the spring and were also utilized extensively during the fall (% occurrence = 100.0, % wt. = 17.9, % number = 24.1) but were not utilized at all during the winter (Table 17). Lymnaeid snails were the most important prey item by weight during the summer

Table 17. Percent occurrence, mean percent dry weight and mean percent number of prey items utilized by age 2+ rainbow trout at Ruby Marsh, Nevada, 1980 and 1981.

	Spring			Summer			Fall			Winter		
Prey item	Occurrence (%)	Dry weight ($\overline{x}$%)	Number ($\overline{x}$%)	Occurrence (%)	Dry weight ($\overline{x}$%)	Number ($\overline{x}$%)	Occurrence (%)	Dry weight ($\overline{x}$%)	Number ($\overline{x}$%)	Occurrence (%)	Dry weight ($\overline{x}$%)	Number ($\overline{x}$%)
Odonata												
Aeshnidae nymph	7.4	2.8	2.0	5.6	2.7	0.4	33.3	2.9	0.6	0.0	0.0	0.0
Aeshnidae adult	3.7	0.9	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Libellulidae nymph	3.7	0.4	0.1	10.0	2.1	1.5	16.7	2.7	0.2	0.0	0.0	0.0
Coenagrionidae nymph	92.6	18.6	17.8	66.7	19.6	15.4	100.0	27.1	23.4	40.0	0.7	4.0
Coenagrionidae adult	3.7	<0.1	<0.1	11.1	0.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Diptera												
Chironomidae subadult	88.9	10.0	12.5	88.9	15.3	19.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae adult	51.9	3.6	4.4	16.7	0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda												
Talitridae	88.9	19.2	30.2	50.0	4.0	9.2	100.0	17.9	24.1	0.0	0.0	0.0
Gammaridae	18.5	3.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda												
Unidentified	37.0	2.5	1.4	33.3	4.0	2.4	0.0	0.0	0.0	40.0	8.0	9.0
Lymnaeidae	51.9	15.2	5.8	55.6	23.6	16.7	100.0	44.3	25.5	100.0	58.4	72.3
Physidae	22.2	3.3	0.8	22.2	8.9	5.2	0.0	0.0	0.0	20.0	10.5	9.7
Planorbidae	51.9	0.2	1.6	5.6	0.1	1.1	0.0	0.0	0.0	20.0	0.6	5.0
Pelecypoda												
Sphaeriidae	11.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera												
Limnephilidae larvae	33.3	1.3	0.4	5.6	0.6	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Phryganeidae larvae	3.7	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera												
Gyrinidae	7.4	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dytiscidae	14.1	0.2	0.1	5.6	0.4	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Haliplidae	63.0	3.9	2.1	22.2	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Chrysomelidae	7.4	1.0	1.3	11.1	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Hemiptera												
Corixidae	25.9	1.3	0.3	22.2	1.0	1.5	16.7	0.1	0.1	0.0	0.0	0.0

Table 17. Continued

Prey item	Spring			Summer			Fall			Winter		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Gerridae	7.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Formicidae	3.7	<0.1	0.1	5.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	25.9	5.6	5.1	16.7	4.2	8.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera												
Baetidae nymph	33.3	1.7	1.0	16.7	0.1	0.8	33.3	0.3	0.2	0.0	0.0	0.0
Baetidae adult	7.0	<0.1	<0.1	5.6	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Caenidae nymph	37.0	0.1	0.3	11.1	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Hirudinea												
Glossiphonidae	3.7	<0.1	<0.1	5.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Erpobdellidae	0.0	0.0	0.0	11.1	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera												
Daphnidae	25.9	1.6	11.8	27.8	4.5	13.7	50.0	3.7	26.0	0.0	0.0	0.0
Ostracoda	3.7	<0.1	0.3	5.6	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Vegetation	14.8	0.7	--[a]	11.1	0.2	--	16.7	0.2	--	60.0	21.7	--
Other	2.2	0.2	0.1	11.9	0.3	0.5	8.0	<0.1	<0.1	7.5	<0.1	<0.1
Non-identified material	--	1.0	--	--	5.1	--	--	0.8	--	--	0.0	--

[a] measure non-applicable

(23.6%), fall (44.3%) and winter (58.4%) and occurred in 100.0% of the stomachs during fall and winter. Physid snails were important during the fall and winter but comprised only a small part of the diet during the other seasons (Table 17). Damselfly nymphs were important during the spring (% occurrence = 92.6, % wt. = 18.6 % number = 17.8), summer (% occurrence = 66.7, % wt. = 19.67, % number 15.4) and fall (% occurrence = 100.0, % wt. 27.1, % number = 23.4). Water fleas were important by number during spring, summer and fall but comprised little of the weight during any season (Table 17).

We examined the stomach contents of 92 age 3+ rainbow trout. Thirty-two were collected during the spring, 26 during the summer, 19 during the fall and 16 during the winter. None of the stomachs were empty during fall and winter, and less than 12.0% were empty in the other seasons. As with age 1+ and 2+ fish the diet was more diverse during spring and summer than during fall and winter (Table 18). Lymnaeid snails were the dominant prey item during all four seasons comprising over 33.5% of the weight during each season (Table 18). Midge subadults were important during the spring (% occurrence = 64.5, % wt. = 12.5, % number = 15.4) and summer (% occurrence = 65.2, % wt. 13.8, % number = 20.2). Damselfly nymphs comprised approximately 10% of the weight during each season (Table 18) and unidentified snails and physid snails were also important prey items during each season (Table 18). Talitrid scuds comprised over 20% of the number during the spring and fall and accounted for 15.8% of the weight during fall.

Table 18. Percent occurrence, mean percent dry weight and mean percent number of prey items utilized by age 3+ rainbow trout at Ruby Marsh, Nevada, 1980 and 1981.

Prey item	Spring			Summer			Fall			Winter		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Odonata												
Aeshnidae nymph	32.3	4.1	0.4	17.4	1.7	0.6	15.8	1.5	0.1	0.0	0.0	0.0
Libellulidae nymph	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.1	<0.1	13.3	2.7	0.5
Coenagrionidae nymph	80.6	10.5	11.6	43.5	13.2	11.2	84.2	11.5	17.2	33.3	8.6	12.7
Coenagrionidae adult	3.2	<0.1	<0.1	4.3	<0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Diptera												
Chironomidae subadult	64.5	12.5	15.4	65.2	13.8	20.2	15.8	<0.1	0.1	6.7	0.1	1.2
Chironomidae adult	22.6	1.2	1.4	4.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Empididae adult	3.2	0.6	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda												
Talitridae	90.3	6.0	20.8	26.1	3.8	6.4	78.9	15.5	29.3	26.7	0.2	4.4
Gammaridae	22.6	1.7	0.4	0.0	0.0	0.0	5.3	0.1	<0.1	6.7	6.6	4.3
Gastropoda												
Unidentified	54.8	9.5	8.5	56.5	9.5	7.2	42.1	4.5	3.7	46.7	8.7	10.5
Lymnaeidae	71.0	33.5	26.0	69.6	48.7	40.3	68.4	36.1	32.0	73.3	55.6	63.4
Physidae	38.7	4.5	2.7	34.8	2.0	4.0	47.4	13.1	8.7	40.0	2.1	2.6
Planorbidae	22.6	0.2	0.3	13.0	0.3	0.1	21.1	0.8	0.7	13.3	0.2	0.3
Trichoptera												
Limnephilidae larvae	6.5	<0.1	<0.1	4.3	0.3	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Phryganeidae larvae	9.7	3.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	6.7	<0.1	0.1
Phryganeidae adult	0.0	0.0	0.0	4.3	4.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera												
Gyrinidae	0.0	0.0	0.0	0.0	0.0	0.0	10.5	0.1	<0.1	0.0	0.0	0.0
Dytiscidae	9.7	0.1	0.1	4.3	<0.1	<0.1	10.5	0.2	0.1	0.0	0.0	0.0
Haliplidae	35.5	2.7	2.9	8.7	<0.1	0.1	21.1	0.4	0.3	0.0	0.0	0.0
Chrysomelidae	12.9	0.1	<0.1	4.3	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0

Table 18. Continued

Prey item	Spring			Summer			Fall			Winter		
	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)	Occurrence (%)	Dry weight ($\bar{x}$%)	Number ($\bar{x}$%)
Hemiptera												
Corixidae	19.4	0.5	0.2	8.7	0.1	<0.1	26.3	1.2	1.2	0.0	0.0	0.0
Notonectidae	6.5	0.6	0.6	0.0	0.0	0.0	21.1	4.2	0.6	0.0	0.0	0.0
Gerridae	6.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Formicidae	9.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	12.9	1.6	2.2	4.3	0.2	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera												
Baetidae nymph	38.7	2.2	2.7	13.0	<0.1	0.1	26.3	4.1	4.7	0.0	0.0	0.0
Baetidae adult	3.2	<0.1	<0.1	4.3	<0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Caenidae nymph	6.5	0.8	0.9	8.7	0.1	0.1	5.3	3.1	1.2	0.0	0.0	0.0
Hirudinea												
Glossiphonidae	9.7	<0.1	0.2	8.7	0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Erpobdellidae	6.5	<0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera												
Daphnidae	6.5	<0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	3.2	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda	0.0	0.0	0.0	4.3	0.8	2.9	0.0	0.0	0.0	0.0	0.0	0.0
Vegetation	9.7	0.2	--[a]	0.0	0.0	--	15.8	1.0	--	20.0	8.6	--
Other	9.7	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	6.7	<0.1	0.3
Non-identified material	--	2.1	--	--	0.2	--	--	2.4	--	--	6.7	--

[a] measure non-applicable

Rainbow Trout Prey Preference

We used seventy-two age 1+ rainbow trout in the relative prey preference analysis for this age group. Midge subadults were the most preferred prey category (Table 19). The second through the ninth most preferred prey categories (Table 19) were organisms that comprised less than 8.0% of the number in the diet (Table 16). Damselfly nymphs, talitrid scuds and gastropods were all important prey items; however, they ranked tenth, 13th and 14th in preference, respectively (Table 19). We used 40 age 2+ rainbow trout in the relative prey preference analysis for this age group. The relative prey preference for age 2+ fish was similar to that of age 1+ fish with midge subadults being the most preferred prey category (Table 20). Again the second through the seventh most preferred prey categories contributed little to the diet. Damselfly nymphs, talitrid scuds and gastropods were the eighth, 11th and 13th most preferred prey (Table 20), respectively, even though they were all important prey items in the diet (Table 17). We used 51 age 3+ in the preference analysis for this age group. Gastropods were the least preferred prey category (Table 21) even though they were the most important prey item in the diet. Midge subadults were the most preferred prey category and damselfly nymphs were the ninth most preferred prey. Again the prey categories which were ranked second through eighth in preference contributed little to the diet.

Table 19. Mean difference in rank of usage and availability, preference rank and rank of those prey categories with significant difference ($P \approx 0.05$) in preference rank for major prey categories utilized by age 1+ rainbow trout in South Sump of Ruby Marsh, Nevada, 1980-81.

Prey category	Mean difference in rank	Preference rank	Prey categories with significant difference in preference rank
Chironomidae subadult	-4.56	1	3-14
Coleoptera	-3.73	2	3-14
Hemiptera	-1.49	3	1-2, 4-14
Gammaridae	-1.03	4	1-3, 7-14
Baetidae nymph	-0.45	5	1-3, 8-14
Caenidae nymph	-0.41	6	1-3, 8-14
Libellulidae nymph	-0.38	7	1-4, 12-14
Hirundinea	0.58	8	1-7, 12-14
Hydracarina	0.83	9	1-7, 12-14
Coenagrionidae nymph	1.24	10	1-7, 12-14
Aeshnidae nymph	1.60	11	1-7, 12-14
Trichoptera larvae	2.40	12	1-11
Talitridae	2.62	13	1-11
Gastropoda	2.78	14	1-11

Table 20. Mean difference in rank of usage and availability, preference rank and rank of those prey categories with significant difference ($P \approx 0.05$) in preference rank for major prey categories utilized by age 2+ rainbow trout in South Sump of Ruby Marsh, Nevada, 1980-81.

Prey category	Mean difference in rank	Preference rank	Prey categories with significant difference in preference rank
Chironomidae subadult	-4.73	1	3-14
Coleoptera	-3.57	2	3-14
Hemiptera	-1.68	3	1,2, 5-14
Baetidae nymph	-0.84	4	1,2, 10-14
Gammaridae	-0.58	5	1-3, 10-14
Libellulidae nymph	-0.34	6	1-3, 10-14
Caenidae nymph	0.15	7	1-3, 11-14
Coenagrionidae nymph	0.27	8	1-3, 11-14
Hydracarina	0.49	9	1-3, 11-14
Hirundinea	0.94	10	1-7, 11-14
Talitridae	2.11	11	1-10
Aeshnidae nymph	2.27	12	1-10
Gastropoda	2.61	13	1-10
Trichoptera larvae	2.89	14	1-10

Table 21. Mean difference in rank of usage and availability, preference rank and rank of those prey categories with significant difference ($P \approx 0.05$) in preference rank for major prey categories utilized by age 3+ rainbow trout in South Sump of Ruby Marsh, Nevada, 1980-81.

Prey category	Mean difference in rank	Preference rank	Prey categories with significant difference in preference rank
Chironomidae subadult	-4.13	1	3-14
Coleoptera	-3.44	2	3-14
Hemiptera	-1.63	3	1,2, 5-14
Baetidae nymph	-0.81	4	1,2, 10-14
Gammaridae	-0.60	5	1-3, 7-14
Caenidae nymph	-0.15	6	1-3, 10-14
Libellulidae nymph	0.27	7	1-5, 10-14
Hydracarina	0.52	8	1-5, 12-14
Coenagrionidae nymph	0.79	9	1-6, 12-14
Talitridae	1.56	10	1-7, 14
Hirundinea	1.59	11	1-7
Aeshnidae nymph	1.88	12	1-9
Trichoptera larvae	2.06	13	1-9
Gastropoda	2.10	14	1-10

DISCUSSION

Rainbow trout and brown trout typically inhabit lakes, reservoirs and streams and are infrequently found in marshes. The food habits of these two fishes were thoroughly reviewed by McAfee (1966), Carlander (1969) and Moyle (1976). In all three reviews rainbow trout and brown trout are characterized as opportunistic predators which typically utilize those prey items which are most abundant. Although the habitat at Ruby Marsh is somewhat unique for both species, their feeding strategies are similar to those of fish in other waters in that they fed primarily on the prey organisms which were most abundant (Table 22).

Brown trout are known to be piscivorous predators (Wales 1946), however the brown trout at Ruby Marsh did not feed on largemouth bass or rainbow trout which are the only fish available as prey. Brown trout at Ruby Marsh fed on aquatic invertebrates which were associated with the aquatic vegetation. Gastropods have not been reported to be an important prey of brown trout, but they were the most important prey at Ruby Marsh.

The diet of the rainbow trout varied considerably with season as it did at Lake Crowley (Pister 1962) and Convict Creek (Maciolek and Needham 1952). During the spring and summer the diet of all three age-specific groups consisted of more prey types than during the fall and winter. Aquatic insects comprised a significant portion of the diets during spring and summer but during the fall and winter gastropods were the dominant prey. The feeding strategies of the

Table 22. Mean percent number of major prey categories in availability samples and utilized by age 1+, age 2+ and age 3+ rainbow trout during all seasons at Ruby Marsh, Nevada, 1980 and 1981.

Age-Specific group	Prey category	Availability ($\overline{x}$ %)	Utilization ($\overline{x}$ %)
Age 1+	Talitridae	49.7	17.1
	Coenagrionidae	19.1	12.2
	Chironomidae	8.4	19.8
	Gastropoda	11.4	13.3
Age 2+	Talitridae	38.5	20.1
	Coenagrionidae	23.3	16.4
	Chironomidae	13.0	12.1
	Gastropoda	12.1	24.1
Age 3+	Talitridae	53.9	16.4
	Coenagrionidae	9.5	12.9
	Chironomidae	10.1	11.2
	Gastropoda	15.3	48.9

rainbow trout changed with age as evident from the increased importance of gastropods from age 1+ fish to age 3+ fish. It is possible that during the fall and winter fewer aquatic insects are available and gastropods become the only abundant prey forcing all age groups to rely on them. As the fish become older they continue to feed on the gastropods through all seasons and do not switch to the insect diet during the spring and summer. This concept would account for the seasonal and age-specific differences in the diets. In previous studies gastropods have not been shown to be a highly important prey for rainbow trout.

Although the diets of rainbow trout varied between age-specific groups the order of relative prey preference was similar. Many of the prey categories which contributed little to the diet ranked high in preference and other prey categories which were important in the diet ranked low in preference. When a particular prey is highly abundant its relative preference can be low even when the utilization is high, as was the case with gastropods.

Unlike the largemouth bass at Ruby Marsh, the trout attain lengths in excess of 620 mm and weights in excess of 3 kg. Apparently the prey base in combination with other environmental factors provides conditions which allow for fast growth in trout and slow growth in largemouth bass. In general, the feeding strategies of brown and rainbow trout fit the pattern described by McAfee (1960), Carlander (1969) and Moyle (1976) in that they are omnivorous predators which utilize those prey organisms which are most abundant.

IV. FOOD HABITS AND DISTRIBUTION OF RELICT DACE AT RUBY MARSH, NEVADA

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ABSTRACT

The food habits and current distribution of the endemic relict dace (*Relictus solitarius*) were studied at Ruby Marsh, Nevada, (Fig. 1) from 1980-1982. Relict dace were collected by electrofishing and with a dip net. Locations of relict dace populations were mapped and recorded. Populations were found in six locations, of which five were in springheads which were isolated from intrusion by largemouth bass (*Micropterus salmoides*). One population was found in the main area of the marsh (Dace Bay Fig. 2) which is inhabited seasonally by largemouth bass. The current distribution indicates that a significant reduction in the distribution of relict dace has occurred since the introduction of largemouth bass in the early 1930's. A food habits study indicated that coenagrionid damselfly nymphs, chironomid subadults, baetid mayfly nymphs and cladocerans were the primary prey consumed by the relict dace.

[1] Technical Paper No. , Oregon Agricultural Experiment Station.

INTRODUCTION

The relict dace, *Relictus solitarius,* is the only native fish of the six species which inhabit Ruby Marsh, Nevada. This study was part of an overall investigation conducted during 1980-1982 to determine the food habits of the fishes inhabiting the South Sump (Fig. 1) of Ruby Marsh. We conducted this study to further the understanding of the life history of the relict dace. The specific objectives of our study were to determine the current distribution and to describe food habits of the relict dace.

Ruby Marsh is located in the northeastern corner of Nevada within the boundaries of Ruby Lake National Wildlife Refuge. The marsh is situated at has an elevation of 1,828 m and is bordered by the Ruby Mountains to the west and the Maverick Spring Range to the east. Much of the water entering the South Sump comes from springs arising at the base of the Ruby Mountains. The earliest reference to fish life in the Ruby Marsh area was by King (1878) and it is most likely that the fish referred to by King (Ibid.) was the relict dace (Hubbs *et al.* 1974).

Present management goals at Ruby Lake NWR emphasize increased production of canvasback (*Aythya valisineria*) and redhead (*Aythya americana*) ducks. Water level manipulation is considered as a possible means for increasing production of the aquatic vegetation and invertebrates that are utilized by these two species of waterfowl. One area within the South Sump, which will be referred to as Dace Bay (Fig. 2), and the springs which border the South Sump are areas which are inhabited by the relict dace. Man induced or natural water level changes in relict dace habitats may alter the prey base and thus affect the food habits of the relict dace. Water level changes may also cause a change in the current distribution of the relict dace.

Little information about the life history of the relict dace is available in the literature. Taxonomic description and aspects of the life history are discussed by Hubbs et al. (1974). The relict dace is a monotypic genus which was not described until 1972 (Hubbs and Miller 1972). Its distribution is limited to four valleys: Steptoe Valley, Butte Valley, Goshute Valley and Ruby Valley, all located in the northeastern corner of Nevada (Hubbs et al. 1974).

Relict dace are primarily found in springs, spring outflows and shallow marsh habitats. The maximum recorded standard length is 100+ mm; however, the populations in Ruby Valley are dwarfed and do not reach 100 mm (Hubbs et al. 1974).

A survey by Hubbs in 1934 (Hubbs et al. 1974) indicated that relict dace were abundant in the springs, spring outflows and the main area of Ruby Marsh. Largemouth bass (*Mircopterus salmoides*) were introduced in 1932 (Trelease 1948) and apparently eliminated the relict dace from many areas of the marsh. A survey by Ruby Marsh refuge personnel in 1967 indicated that dace populations were restricted to four springs which were isolated from those areas inhabited by largemouth bass (Hubbs et al. 1974). The 1967 survey did not include sampling of all the possible areas where relict dace could have occurred.

The information generated from our study adds knowledge to the life history of the relict dace and provides a basis for determination of any dietary change which may occur due to changes in prey composition and abundance. The distributional information allows an assessment of any future expansion or decline in the distribution of relict dace.

METHODS

Distribution

All areas within the South Sump that were accessible by boat were electroshocked from 3 May 1980 to 26 Oct 1981 at irregular intervals. We used a pulsed direct-current electrofishing system similar to that described by Sharpe (1964). Our sampling was conducted simply to determine whether relict dace were present or absent from a given area. The springheads and outflows were electroshocked from 15 Apr 1980 to 30 Nov 1980 with a pulsed direct-current, backpack shocker. A few springs were also sampled by sweep net from 17 Apr 1982 to 15 Jul 1982. All areas where relict dace were encountered were mapped by township, range, and section as were the previously known locations. We classified each location where relict dace were found as springhead, springhead and outflow, or marsh habitat. There were a few springs located at the north end of the marsh which were not sampled.

Food Habits

We conducted the food habits investigation in Dace Bay. This area is located at the southernmost end of the South Sump and supports the largest population of relict dace at Ruby Marsh. This is the only marsh-type habitat where relict dace occur at Ruby Marsh, all other populations being located in springheads and spring outflows. Dace Bay occupies a total of 43 hectares of shallow water < 1 m in depth. Unlike many of the other areas of the marsh this area undergoes periodic drawdowns and was nearly dry in the fall of 1981. Dace Bay is completely surrounded by hardstem bulrush (*Scirpus sp.*) and the bottom supports dense mats of submerged vegetation (*Chara sp.*) during the summer. The bay is relatively isolated from the rest of the marsh and has only one small connection in the northwest corner. A small number of largemouth bass also inhabit Dace Bay during the spring and summer.

We collected 50 relict dace from 22 Apr to 22 July 1981. The dace were immediately killed by severing the spinal chord just posterior to the brain and then preserved in 10% Formalin. Standard length was recorded to the nearest 1 mm and weight was recorded to the nearest 0.1 g. The contents of the first one-half of the gut were removed in the laboratory. Stomach contents were analyzed with the aid of a 10X binocular microscope. We determined types, numbers, and estimated volumes of prey items as described by Windell and Bowen (1978). Food habits data were summarized by percent occurrence (Windell 1971), mean percent of number and estimated volume (Swanson *et al.* 1974).

RESULTS

Distribution

Relict dace were found in six separate locations which are listed in Table 23. Four populations were found in springheads on the western edge of the marsh (Narcissa Spring, Rameriz Spring, Divingboard Pond, unnamed spring) and the outflows of three of these springs also contained relict dace. One population was found in a springhead (Dace Spring) on the eastern edge of the marsh and the sixth population was found in Dace Bay. No relict dace were found in areas of the South Sump where high densities of largemouth bass occurred. The relict dace in Dace Bay appear to be seasonal residents because no specimens were found there in the early spring of 1981 prior to April 22. Small numbers were encountered on April 22 and larger numbers of fish were encountered each sampling period thereafter.

Food Habits

We collected stomach samples on four occasions and examined the contents of 32 females and 18 males. The standard length of the females ranged from 34 to 78 mm and the weight ranged from 0.9 to 11.5 g. The standard length of the males ranged from 26 to 48 mm and the weight ranged from 0.4 to 3.1 g. Eleven of the 50 stomachs we examined were empty and a total of 12 prey categories were identified. Percent occurrence, mean percent number and mean percent estimated volume of prey are presented in Table 24. We found waterfleas

Table 23. Habitat type, location and name of area where relict dace were found at Ruby Marsh, Nevada, 1980-82.

Habitat	Location	Name of area
Springhead and outflow	Sec. 27, T. 26 N., R.57E. White Pine County	unnamed
Springhead and outflow	Sec. 2 & 3. T. 25 N., R.57E. White Pine County	Narcissa Spring
Springhead and outflow	Sec. 34, T. 26 N., R.57E. White Pine County	Ramirez Spring
Springhead and outflow	Sec. 15 & 16, T. 27 N., R.58E. Elko County	Spring 139 or Dace Spring
Springhead	Sec. line 18-19, T. 27 N., R.58E. Elko County	Divingboard Pond
Marsh	Sec. 1 & 2, T.25 N., R.57E. White Pine County	Dace Bay or Alkali Bay

Table 24. Percent occurrence, mean percent number and mean percent volume of prey items utilized by relict dace at Ruby Marsh, Nevada, 1981.

Prey Item	Occurrence (%)	Number ($\overline{x}$%)	Volume ($\overline{x}$%)
Odonata			
Coenagrionidae nymph	23.7	11.0	12.3
Diptera			
Chironomidae subadult	28.9	20.5	17.3
Amphipoda			
Talitridae	2.6	0.2	0.4
Hemiptera			
Corixidae	7.9	4.2	4.3
Ephemeroptera			
Baetidae nymph	21.0	12.9	11.6
Caenidae nymph	5.3	1.8	3.0
Hirudinea			
Erpobdellidae	5.3	0.9	1.4
Cladocera			
Daphnidae	36.8	25.6	8.3
Ostracoda	5.3	3.0	0.8
Copepoda	10.5	5.4	1.2
Annelida cocoons	15.8	14.5	8.5
Non-identified	--[a]	--	30.9

[a] measure non-applicable

(Daphnidae) in 36.8% of the stomachs and they were the most important prey by number at 25.6%. Although waterfleas accounted for the greatest percent of number they comprised only 8.3% of the volume. The largest portion of the volume consisted of non-identifable materials (30.9%). We found damselfly nymphs (Coenagrionidae) in 23.7% of the stomachs and they were the second most important identified prey by volume (12.3%). Midge subadults (Chirononidae) occurred in 28.9% of the stomachs and were the most important identified prey by volume (17.3%) and the second most important by number (20.5%). Baetid mayfly nymphs comprised 12.9% of the number and 11.6% of the volume. Annelida cocoons were the third most important prey by number (14.5%) and the fourth by volume (8.5%). The remaining proportions were distributed among the other six prey categories.

DISCUSSION

Distribution

The distribution at Ruby Marsh has been greatly reduced since 1934 when relict dace inhabited the entire area of the marsh (Hubbs *et al.* 1974). Extensive sampling in the marsh and spring habitats produced fish in only six locations. According to Hubbs *et al.* (1974) relict dace were found in three springs on the edge of the marsh during 1967 and only one of these springs contained dace (Divingboard Pond) during 1980-82. The relict dace that inhabit Dace Bay are subject to predation by largemouth bass; however, this population persists. Largemouth bass were found in Dace Bay only at times when relict dace were present and in densities far less than were seen in other areas of the South Sump. Apparently the difficulty in entering Dace Bay from the other areas of the South Sump and the seasonally fluctuating water levels prevent large numbers of largemouth bass from becoming established. Dace Bay was nearly dry in the fall of 1981, has dried completely in past years and has a thick ice cover during winter. Apparently the relict dace which inhabit this area either die off or move up the spring outflows into the springs located to the south during these dry periods and to overwinter. During the spring when water levels are high the relict dace apparently move into Dace Bay from the southern springs and repopulate the area.

A natural or man induced drawdown in the South Sump may allow for expansion of the present range of relict dace through reduction of predation by the largemouth bass. The relict dace have explosive reproductive capabilities as shown by their rapid increase in numbers from spring through summer of 1981 in Dace Bay. With a lower density of largemouth bass in the South Sump, relict dace may be able to expand their range into other areas of the South Sump. Continued monitoring of their distribution following any drawdown may aid in understanding the causes of their decline since 1934.

Food Habits

The feeding habits of the relict dace are similar to those of the most closely related fishes, the speckled dace (*Rhinycthys osculus*) and the tui chub (*Gila bicolar*). The tui chub is an opportunistic feeder which utilizes a variety of invertebrates associated with benthic substrates and plants (Moyle 1976). In ponds in Lassen County, California, tui chubs fed primarily on aquatic insect larvae and crustaceans (Kimsey and Bell 1956) and in Big Sage Reservoir the diet consisted of plants, plankton, insect larvae and small fish (Kimsey and Bell 1955). Jhingran (1948) found that speckled dace fed on insect larvae, insect nymphs, insect adults and algae. In Lake Tahoe speckled dace fed primarily on benthic invertebrates (Miller 1951).

The relict dace at Ruby Marsh are highly omnivorous as were speckled dace and tui chubs in other lakes. They utilized a variety of prey types, although most were those which are associated with benthic substrates and plants. They did not utilize any adult insects and little algae or vascular plant material was consumed. More research is necessary to completely understand the life history of these unique fish and to provide an adequate foundation for their proper management.

V. DIETARY OVERLAP OF LARGEMOUTH BASS AND RAINBOW TROUT WITH CANVASBACK AND REDHEAD DUCKS AT RUBY MARSH, NEVADA

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ABSTRACT

The dietary overlap of age-specific groups of largemouth bass (*Micropterus salmoides*) and rainbow trout (*Salmo gairdneri*) with breeding adult and duckling canvasback (*Aythya valisineria*) and redhead (*Aythya americana*) ducks was investigated during 1980 and 1981 at Ruby Marsh, Nevada (Fig. 1). We used Shoeners (1970) percent overlap index to assess the extent of co-utilization of food resources and we developed an index of percent contribution of prey to determine the degree to which co-utilized prey contributed to the dietary overlap. In most cases the dietary overlap was less than 40%. The diets of age-specific groups of rainbow trout generally overlapped with the diets of both species of ducks to a greater extent than did the diets of age-specific groups of largemouth bass. The diets of

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[1] Technical Paper No. , Oregon Agricultural Experiment Station.

breeding adult canvasbacks and canvasback ducklings typically overlapped with the diets of both species of fish to a greater extent than did the diets of breeding adult redheads and redhead ducklings. Co-utilization of odonate nymphs, gastropods and chironomid subadults accounted for a major portion of the dietary overlap.

INTRODUCTION

In this study we determine the degree to which the diets of two species of fish overlap with those of two species of ducks at Ruby Marsh, Nevada during 1980-81. Most investigations of food and habitat overlap and partitioning have focused on closely related species (Cody 1968; Shoener 1970; Werner and Hall 1977; George and Hadley 1979). The great interest in this subject has emerged from the importance of food resource partitioning in species interactions and community structure and organization (Pianka 1974; Hurlbert 1978). Although fish and waterfowl often utilize the same habitat for foraging, few studies have focused on the overlap in food utilization between these two groups. Studies by LaBastille (1974), Pehrsson (1974), Eriksson (1979) and Eadie and Keast (1982) indicate that competition for food between fish and waterfowl may be a factor affecting waterfowl production.

The South Sump (Fig. 1) of Ruby Marsh supports high densities of breeding canvasback (*Aythya valisineria*) and redhead (*Aythya americana*) ducks as well as a naturalized population of largemouth bass (*Micropterus salmoides*) and a planted population of rainbow trout

(Salmo gairdneri). Production of these waterfowl species is thought to be below capable levels at Ruby Marsh. No forage fish are available as prey for largemouth bass and rainbow trout forcing these fishes to rely almost exclusively on invertebrates for food. Aquatic invertebrates are known to be important food for breeding female canvasbacks and canvasback ducklings and to a lesser extent for breeding female redheads and redhead ducklings (Bartonek and Hickey 1969). A factor which may depress canvasback and redhead production is the overlap in utilization of the invertebrate food resource by fish and ducks. This study was designed to determine the dietary overlap between age-specific groups of largemouth bass and canvasback and redhead ducks of various reproductive stages and between age-specific groups of rainbow trout and canvasback and redhead ducks of various reproductive stages. We did not attempt to quantify competition between these species because of limitations and theoretical problems (Colwell and Futuyma 1971; May 1975; Wiens 1977).

Largemouth bass were introduced into Ruby Marsh in the early 1930's and the stocking of rainbow trout began in the 1940's (Trelease 1948). Prior to the introduction of these fishes, Ruby Marsh was inhabited only by the relict dace (Relictus solitarius) (Hubbs et al. 1974) which were eliminated from most areas of the marsh due to high predation rates by the largemouth bass. This small cyprinid has much different feeding habits than that of the largemouth bass or rainbow trout. The small size of the relict dace prevents it from consuming large invertebrates that can be used by largemouth bass and rainbow trout. Although a populations estimate has not been made, the South

Sump supports a large population of largemouth bass and over 100,000 are harvested annually by sportsmen (Green 1981). The rainbow trout population is presently maintained by an annual release of about 5,000 fish (Green 1981). Although results of our study do not permit us to determine if largemouth bass and rainbow trout in the South Sump limit the production of canvasbacks and redheads, we will be able to speculate on that possibility.

STUDY AREA

Ruby Marsh is located in the northeastern corner of Nevada, 96 km southeast of the town of Elko. According to Hubbs and Miller (1972) the marsh occupies the area which was once the southern arm of pluvial Lake Franklin. The South Sump encompasses the southern end of the marsh and is bordered by mountains to the east and west. It has an elevation of 1,830 m and occupies a total of 2,962 hectares at the high water line. The South Sump is a maze of interconnected channels and pools of which 1,570 hectares are shallow water areas interspersed with emergent vegetation, 918 hectares are open water areas of less than 5 m maximum depth and 474 hectares are upland (Ruby Lake N.W.R. 1982).

Water input into the South Sump is primarily from numerous springs surrounding its border. Water temperatures remain cool throughout the year only rising above 15 C from May through September reaching a maximum of about 24 C during this period. Ice generally covers the marsh from December through February. The entire shoreline areas is covered with dense stands of hardstem bulrush (_Scirpus acutus_) and during the warmer months the bottom is typically covered with dense mats of submerged vegetation. Muskgrass (Chara sp.), pondweeds (Potamageton sp.), watermilfoil (Myriophyllum sp.), and bladdlerwort (Utricularis vulgaris), are the prominent submerged vegetation types.

METHODS

We collected food habits data of rainbow trout, largemouth bass, canvasbacks and redheads during spring (Mar-May) and summer (Jun-Aug) of 1980 and 1981. Details of the food habits study of age-specific groups of largemouth bass and rainbow trout are presented in previous text and details of the food habits study of canbasback and redhead ducks are presented in Noyes (1982). Food habits data were summarized by mean percent of dry weight (Swanson et al. 1974), as were the overlap values.

Many indices are available for use in the calculation of dietary overlap (Horn 1966; Levins 1968; Shoener 1970; Pianka 1974; Hurlbert 1978; Petraitis 1979; Wallace 1981). We chose Shoeners (1970) percent overlap index:

$$\text{(1)} \qquad \alpha = 1 - 0.5 \left(\sum_{i=1}^{n} \left| P_{xi} - P_{yi} \right| \right)$$

where P_{xi} = proportion of food category i in the diet of species x and P_{yi} = proportion of food category i in the diet of species y, for use in this study. Our choice was based on ease of interpretation and favorable reviews given the method by Hurlbert (1978) and Wallace (1981). We calculated percent overlap values between age 1-3 + largemouth bass, and canvasback and redhead prelaying females, laying females, incubating females, males which were paired with prelaying females (prelaying males), and males which were paired with laying females (laying males) which were collected during the spring of 1980 and 1981. We also calculated percent overlap values between age 4+ and older (4+) largemouth bass, age 1+, age 2+, age 3+ - 5+ (3+) rainbow trout and the above described groups of canvasbacks and redheads which were collected during the spring of 1980 and 1981. Brooding females and ducklings of both species were collected during the summer and therefore we calculated overlap values between the above specific groups of fishes, as well as young-of-year bass and the brooding females and ducklings of both species which were collected during the summer of 1980 and 1981. These dietary overlap values will be referred to as general overlap.

We also calculated overlap values between age-specific groups of largemouth bass which were collected from the same location as were individual ducks. On some occasions largemouth bass stomach samples were collected 24 hours after a duck had been collected in the same location. We calculated mean percent dry weight of each prey category for each largemouth bass sample that corresponded with a duck. Overlap values were then calculated between individual ducks and the group of largemouth bass that were collected from the same location. We calculated mean percent overlap values for each reproductive stage of each sex for both species of ducks with age-specific groups of largemouth bass. These dietary overlap values will be referred to as site-specific overlap.

To identify the degree to which each prey category contributed to the general overlap we developed the percent contribution:

$$\text{(2)} \qquad \text{\% contribution of prey i} = \frac{\min (P_{xi}, P_{yi})}{1 - 0.5 \left(\sum_{i=1}^{n} \left| P_{xi} - P_{yi} \right| \right)}$$

where min (P_{xi}, P_{yi}) = minimum proportion of food category i in the diet of species X and Y, and P_{xi} = proportion of food category i in the diet of species X, and P_{yi} = proportion of food category i in the diet of species y. In order to represent the percent contribution of a prey category to the general overlap between: all largemouth bass and all canvasbacks, all largemouth bass and all redheads, all rainbow trout and all canvasback, and all rainbow trout and all redheads, we summed the numerator and denominator of equation two for each combination of fish and ducks.

RESULTS

The sample sizes of canvasback and redheads of each reproductive stage by sex and the sample sizes of age-specific groups of largemouth bass and rainbow trout that we used in the calculation of general overlap are presented in Table 25. The sample size of the above mentioned groups of canvasback and redheads and age-specific groups groups of largemouth bass that we used in the calculaton of site-specific overlap are presented in Table 26.

The general overlap between largemouth bass and canvasback was below 50% during all reproductive stages (Table 27). The highest overlap occurred between incubating females and age 1-3+ and age 4+

Table 25. Sample sizes of male and female canvasback and redhead ducks of various reproductive stages and the corresponding sample sizes of age-specific groups of largemouth bass and rainbow trout that were used in the calculation of general dietary overlap, Ruby Marsh, Nevada, 1980 and 1981.

Reproductive stage	Sex	Redhead N	Canvasback N	Largemouth bass N			Rainbow trout N		
				YOY	Age 1-3+	Age 4+	Age 1+	Age 2+	Age 3+
Prelaying	Female	13	15						
Laying	Female	11	6						
Incubating	Female	6	12	0	64	194	48	27	31
Prelaying	Male	6	6						
Laying	Male	3	2						
Brooding	Female	7	7	15	176	213	15	18	23
Duckling	Female & Male	30	27						
TOTAL		76	75	15	240	407	63	45	54

Table 26. Number of sample locations where both age-specific groups of largemouth bass and male and female canvasback and redhead ducks of various reproductive stages were collected. The number of locations also represents the sample size of ducks used in the calculation of site-specific dietary overlap at Ruby Marsh, Nevada, 1980 and 1981.

Reproductive stage	Sex	Number of sample locations (canvasback with age 1-3 + largemouth bass)	Number of sample locations (canvasback with age 4 + largemouth bass)	Number of sample locations (redheads with age 1-3 + largemouth bass)	Number of sample locations (redheads with age 4 + largemouth bass)
Prelaying	Female	3 (5)[a]	6 (45)	2 (2)	2 (6)
Laying	Female	2 (4)	6 (25)	2 (11)	2 (9)
Incubating	Female	4 (11)	7 (26)	1 (2)	2 (5)
Brooding	Female	1 (7)	1 (4)	0 (0)	0 (0)
Duckling	Female & Male	9 (22)	10 (27)	5 (18)	5 (9)
Prelaying	Male	2 (4)	4 (39)	0 (0)	0 (0)
Laying	Male	0 (0)	1 (6)	1 (4)	1 (1)
TOTAL		21 (53)	35 (172)	11 (37)	12 (30)

[a] Sample size of largemouth bass corresponding with the given number of sample locations.

Table 27. General percent overlap in the diets of age-specific groups of largemouth bass with male and female canvasback and redhead ducks of various reproductive stages, Ruby Marsh, 1980 and 1981.

Species Reproductive stage	Sex	Largemouth bass YOY	Age 1-3+	Age 4+
CANVASBACK				
Prelaying	Female	-[a]	4.3	4.7
Laying	Female	-	14.2	17.4
Incubating	Female	-	39.5	43.6
Brooding	Female	5.2	29.3	34.2
Duckling	Female & Male	8.9	13.5	16.9
Prelaying	Male	-	0.0	2.8
Laying	Male	-	0.0	0.0
REDHEAD				
Prelaying	Female	-	7.8	9.0
Laying	Female	-	24.6	25.4
Incubating	Female	-	3.6	6.7
Brooding	Female	0.2	0.2	0.2
Duckling	Female & Male	11.8	7.5	8.4
Prelaying	Male	-	0.7	1.6
Laying	Male	-	6.6	7.7

[a] no samples collected

largemouth bass at 39.5% and 43.6%, respectively (Table 27). The diet of brooding females overlapped slightly less than 30% with age 1-3+ largemouth bass and 34.2% with age 4+ largemouth bass. General overlap was less than 20% between all other canvasback and both age groups of (Table 27). In most cases the site-specific overlap was less than the general overlap (Table 28). Site-specific overlap between canvasback and both age groups of largemouth bass did not exceed 20% (Table 28). General overlap between largemouth bass and redheads was generally low. The general overlap between both age groups of largemouth bass and laying females obtained a maximum of about 25% (Table 27) and all other general overlap values were less than 12% (Table 27). The site-specific overlap between age 4+ largemouth bass and prelaying redhead females was 17.7% and all other values were less than 6% (Table 28).

There were a number of prey categories that were utilized by both largemouth bass and canvasbacks, however, the majority of the dietary overlap occurred through common utilization of five prey categories (Table 29). Overlapping utilization of aeshnid dragonfly nymphs accounted for 40.0% of the general overlap and damselfly nymphs (Coenagrionidae), midge subadults (Chironomidae), libellulid dragonfly nymphs and gastropods were the other four prey categories which contributed substantailly to the dietary overlap (Table 29). The same prey categories that were important in the dietary overlap between canvasbacks and largemouth bass were also important in the dietary overlap between redheads and largemouth bass. The percent contribution of aeshnid dragonfly nymphs was 30.9% and the percent

Table 28. Site-specific percent overlap in the diets of age-specific groups of largemouth bass with male and female canvasback and redhead ducks of various reproductive stages, Ruby Marsh, Nevada, 1980 and 1981.

Species Reproductive stage	Sex	Largemouth bass Age 1-3+	 Age 4+
CANVASBACK			
Prelaying	Female	0.0	9.9
Laying	Female	1.0	3.0
Incubating	Female	15.3	12.8
Brooding	Female	13.2	18.0
Duckling	Female & Male	1.8	6.8
Prelaying	Male	0.0	10.4
Laying	Male	-[a]	0.0
REDHEAD			
Prelaying	Female	0.0	17.7
Laying	Female	0.0	5.3
Incubating	Female	1.8	2.6
Duckling	Female & Male	4.6	4.4
Laying	Male	0.0	0.0

[a] no samples collected

Table 29. Percent contribution of prey items to the general overlap in the diets of largemouth bass with canvasback and redhead ducks, Ruby Marsh, Nevada, 1980 and 1981.

Prey item	Contribution (%) to dietary overlap of largemouth bass with canvasback ducks	Contribution (%) to dietary overlap of largemouth bass with redhead ducks
Odonata		
Coenagrionidae nyumph	27.2	26.8
Aeshnidae nymph	40.0	30.9
Libellulidae nymph	10.5	1.8
Ephemeroptera		
Baetidae nymph	0.1	16.6
Diptera		
Chironomidae subadult	10.3	15.7
Gastropoda		
Physidae and Lymnaeidae	8.1	4.6
Other Invertebrates	3.8	3.6
TOTAL	100.0	100.0

contribution of damselfly nymphs was 26.8% (Table 29). Midge subadults, mayfly nymphs (Baetidae) and gastropods were also utilized by both largemouth bass and redheads.

The general overlap values between canvasbacks and rainbow trout were higher than they were with largemouth bass (Table 30). General overlap showed an increase with increasing age of the trout and the values did not exceed 27% between age 1+ rainbow trout and canvasbacks. General overlap between age 3+ rainbow trout and canvasback ducklings was 55.3% and between age 2+ fish and ducklings the value was 49.7% (Table 30). The general overlap between prelaying females, prelaying males, laying males and all age groups of rainbow trout was less than 15% (Table 30). The general overlap between rainbow trout and redheads was generally lower than with canvasbacks. General overlap only reached 30% between incubating female redheads and age 3+ rainbow trout while the majority of the other values were less than 20% (Table 30).

Gastropods were the most important prey in the dietary overlap between rainbow trout and canvasbacks, contributing 65% (Table 31). Overlapping utilization of four prey categories accounted for a majority of the overlap between redheads and rainbow trout (Table 31). Midge subadults, gastropods, aeshnid dragonfly nymphs, and damselfly nymphs were the four prey categories used by both redheads and rainbow trout with the greatest percent contribution values.

Table 30. General percent overlap in the diets of age-specific groups of rainbow trout with male and female canvasback and redhead ducks of various reproductive stages, Ruby Marsh, Nevada, 1980 and 1981.

Species Reproductive stage	Sex	Rainbow trout Age 1+	Age 2+	Age 3+
CANVASBACK				
Prelaying	Female	4.4	6.9	6.6
Laying	Female	22.9	34.5	38.0
Incubating	Female	26.7	43.8	49.7
Brooding	Female	16.6	27.2	25.9
Duckling	Female & Male	25.1	49.7	55.3
Prelaying	Male	12.0	13.6	13.6
Laying	Male	0.0	0.0	0.0
REDHEAD				
Prelaying	Female	17.4	16.1	14.9
Laying	Female	22.8	22.9	25.1
Incubating	Female	28.2	28.6	30.1
Brooding	Female	0.0	0.2	0.1
Duckling	Female & Male	9.0	8.0	6.4
Prelaying	Male	2.3	2.5	1.2
Laying	Male	6.7	7.5	10.4

Table 31. Percent contribution of prey items to the general overlap in the diets of rainbow trout with canvasback and redhead ducks, Ruby Marsh, Nevada, 1980 and 1981.

Prey item	Contribution (%) to dietary overlap of rainbow trout with canvasback ducks	Contribution (%) to dietary overlap of rainbow trout with redhead ducks
Odonata		
Coenagrionidae nyumph	15.5	17.2
Aeshnidae nymph	5.2	5.6
Libellulidae nymph	0.4	0.5
Trichoptera		
Limnephilidae larvae	2.2	6.8
Ephemeroptera		
Baetidae nymph	0.1	4.2
Diptera		
Chironomidae subadult	9.7	37.0
Gastropoda		
Physidae and Lymnaeidae	65.2	20.5
Other Invertebrates	1.7	8.2
TOTAL	100.0	100.0

DISCUSSION

Our study clearly shows that the diets of canvasbacks and redheads do overlap with those of largemouth bass and rainbow trout. The magnitude of this overlap varies considerably with species and reproductive stage in the ducks and with species and age in the fishes. The study conducted by Noyes (1982) showed that canvasbacks and redheads generally utilized animal matter to a greater extent during their reproduction stages following pre-laying; thus, the greatest dietary overlap occurred during post pre-laying stages.

Apparently when largemouth bass and ducks fed at the same location, the dietary overlap was much less than on a general basis, however this difference may partially be attributed to the small sample sizes associated with the site-specific values. This shows that food partitioning at specific locations is somewhat different than food partitioning through the season throughout the marsh. As Hurlbert (1978) points out, conclusions with regard to the influence of dietary overlap on production are difficult at best and without other information on resource production should be avoided. Furthermore no standard levels of dietary overlap can be said to be indicative of exploitation competition although Zaret and Rand (1971) and Mathur (1977) concluded that dietary overlap levels exceeding 60% were biologically significant in fish populations. It is possible that dietary shifts in the canvasbacks and redheads have occurred since the introducton of largemouth bass and rainbow trout because of the different predation pressure exerted on the aquatic invertebrate community by these two species compared with the predation pressure exerted by the previously abundant relict dace. The importance of bass eggs in the diet of laying female redheads (Noyes 1982) indicates that dietary shifts have occurred since the introduction of largemouth bass.

The dietary overlap which is of most concern to us occurs between largemouth bass and incubating and brooding female canvasbacks. Due to the abundance of the largemouth bass a much greater proportion of the shared prey items are being consumed by the bass population than are being consumed by either the canvasback or the redhead populations. It is possible that the utilization by largemouth bass of those prey which are important to the ducks is limiting the prey availability. However, results of a study by Eadie and Keast (1982) showed that areas which supported populations of both goldeneyes and perch (Perca fluviatilis), had a tendency to have higher invertebrate productivity over those areas which were inhabitted by only perch or goldeneyes.

We are less concerned with the dietary overlap between the rainbow trout and the ducks because trout numbers are maintained by stocking and numbers are small, particularly in the older age groups where the highest overlap occurs. Eriksson (1979) showed that goldeneyes (Bucophula clangula), in Scandinavia preferred lakes void of fish over lakes which were inhabited by fish. The aquatic invertebrate populations were less abundant in the lakes which contained fish thus making them less desirable for feeding areas for the goldeneyes. Recent work by Eadie and Keast (1982) showed that dietary overlap between goldeneyes and perch was high on lakes in Ontario, Canada, and that food resources were limited in some areas of co-occurrence. The introduction of largemouth bass into Lake Atitlán caused the Atitlán grebe (Podilymbus giyas), to significantly alter its diet and reduced its production (LaBastille 1974). This reduction in production was attributed to competition for insects and crustaceans between the largemouth bass and the Atitlán grebe and also to predation by largemouth bass on the Atitlán grebe. With the conclusion of ongoing research on the aquatic invertebrates, which are utilized by both fish and ducks, further conclusions about the importance of this dietary overlap to the production of canvasback and redheads may be drawn. The studies by LaBastille (1974), Erikson (1979) and Eadie and Keast (1982) and the results of this investigation indicate that the overlapping utilization of the aquatic invertebrate food resource may be implicated in the production of these two species of waterfowl, however other factors may be limiting their production.

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