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SIZE SELECTIVE PREDATION ON DAPHNIA BY RAINBOW TROUT AND YELLOW PERCH [1]

By Merle G. Galbraith, Jr.

Abstract

The size of the zooplankton consumed by rainbow trout and yellow perch was studied in two Michigan lakes and compared with the size of the limnetic zooplankton. One of the study lakes was managed for both rainbow trout and warmwater game fish (a "combination" lake), and the other was managed solely for rainbow trout after it was reclaimed with toxaphene. Plankton samples were collected in the summer both before and after the introduction of rainbow trout, and compared with plankton in the stomachs of fish taken at the same time.

Daphnids were the only zooplankton consumed by rainbow trout in both lakes and by yellow perch in the combination lake even though there were many other genera of zooplankters. Both species were very size selective and usually consumed only Daphnia over 1.3 mm in size while ignoring the many and often more numerous smaller zooplankton. Despite the broad range in size of these trout (7.9 to 17.2 inches) and yellow perch (2.8 to 9.8 inches), there was no strong evidence of an association between their length and the size of the Daphnia they consumed.

Introduction of rainbow trout in the combination lake had no apparent effect on the daphnid population. However, changes in the net plankton did occur in the trout lake after the introduction of rainbow trout, smelt, and fathead minnows. Most obvious changes were: (1) the complete elimination of D. pulex and subsequent replacement by two other smaller species within 4 years, (2) a decrease in the average size of the daphnids from 1.4 mm to 0.8 mm, (3) a decrease in the percentage of daphnids larger than 1.3 mm from an average of 53.8% to 4.7%, and (4) a reduction in the volume and percentage of daphnids comprising the net plankton even though there was no reduction in their numbers. The gap left by the elimination of the large Daphnia was filled by other smaller zooplankters.

Effects of predation on Daphnia, as well as the interactions between daphnids and planktivorous fishes are discussed. This study emphasizes the importance of determining the abundance of zooplankton of the proper sizes in the plankton when the survival of planktivorous fishes in lakes is investigated.

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This report is part of a comprehensive investigation of the relationship of food to the survival of rainbow trout (*Salmo gairdneri*) planted in Michigan lakes. Examination of the stomach contents of the rainbows has indicated that *Daphnia* was the principal form of plankton being utilized. The objective of this study was to determine the size of daphnids being consumed, and the effect, if any, fish predation might have upon the size composition of the *Daphnia* population.

Many investigations have been concerned with the density or biomass of daphnids and have assumed that numbers or mass were the important indices of their availability to fish. Little consideration has been given to the size of *Daphnia* comprising the plankton or to those consumed by fish. Hall (1964) observed that adult ciscoes (*Leucichthys artedi*) and black crappies (*Pomoxis nigromaculatus*) fed extensively on the large *Daphnia pulex* present in early spring but did not eat the smaller adults of *Daphnia galeata mendota* which also were present. Gerking (1962) noted that bluegills (*Lepomis macrochirus*) selected the larger *Daphnia*. He compared the size distribution of *Daphnia* from net plankton catches with the size distribution of *Daphnia* from bluegill stomachs. Data were published recently which indicated size-specific predation of fish upon zooplankton populations (cf. Brooks and Dodson, 1965). This study indicated that alewives (*Alosa pseudoharengus* and *A. aestivalis*) eliminated the *Daphnia* in some Connecticut lakes. Brooks and Dodson observed changes in the size distribution of daphnids in the net plankton after alewives were introduced into one of the lakes but did not examine stomachs to determine the size of the cladocerans consumed by the alewives. In this paper, data are presented on the size-frequency distribution of Daphnia found within stomachs of rainbow trout and yellow perch (Perca flavescens), and on the relationship of the size frequency of Daphnia in the plankton to that in fish stomachs.

Lakes studied

Two lakes in the central area of Michigan's upper peninsula were studied during the summer months of 1958, 1959, 1960, and 1965; additional data of a somewhat more limited nature were collected in 1957, 1961, and 1964. Sporley Lake is 76 acres in area and has a maximum depth of 36 feet. Rooted aquatic plants are sparse. Sand is the prevailing bottom type and it extends out to the 20-foot contour; beyond that depth the bottom type is composed mainly of organic matter. Total alkalinity ranges from 11 to 32 ppm of calcium carbonate. During the summer months there is little oxygen below 30 feet. The fish population was completely eradicated by treating the lake with toxaphene in the fall of 1955. The lake remained toxic to fish until 1959. Rainbow trout were planted in the fall of 1959, and have been planted each fall since 1959 at the rate of 40 fingerlings and 13 legal trout (7 to 9 inches) per acre. Fathead minnows (Pimephales promelas) appeared in the lake in 1960, and the smelt (Osmerus mordax) was illegally introduced in 1962.

In contrast to Sporley, Stager Lake is more eutrophic. Aquatic vegetation is abundant and the bottom soil in the shoal areas (less than 20 feet in depth) is composed of sand as well as organic matter. Total alkalinity varies between 60 and 137 ppm of calcium carbonate. The maximum depth is 51 feet and it contains three major depressions over 20 feet in depth. During the summer months there is little oxygen below 25 feet. The principal species of game fish in Stager Lake are yellow perch, bluegills, largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), common suckers (*Catostomus commersoni*) and pumpkinseeds (*Lepomis gibbosus*). Rainbow trout were introduced in this lake in the fall of 1958. The lake has been stocked each fall with legal rainbows (7 to 9 inches) at a rate of 27 fish per acre.

Methods

Net plankton and fish stomachs were collected at each lake during July, August, and September before and after the introduction of trout; some additional collections were also made in late fall and in the spring. Fish used for stomach samples were collected in different areas of the lake with gill nets, trap nets, seines, and by hook and line.

Twenty-five plankton collecting stations were established within the open-water area of each lake. Locations of stations were established by means of a table of random numbers. Data from these stations were used to follow the abundance of *Daphnia*. In addition, two stations at Stager Lake and three at Sporley Lake were selected at random from the above series of stations. Samples from these stations only provided the data on the size-frequency distribution of *Daphnia* as time did not permit counts in the remaining collections.

Plankton samples were collected with a Clarke-Bumpus sampler equipped with a No. 10 mesh net. The sampler was lowered, with the mouth of the net closed, to a depth of 28 feet in Sporley Lake and to 25 feet in Stager Lake. The net was then opened and retrieved vertically at a rate of approximately 1 1/4 meters per second. This procedure insured sampling of the entire water column of the epilimnion of both lakes. There were only small amounts of oxygen present at depths below the stratum sampled in Stager Lake, and sampling commenced only a few feet off the bottom in Sporley Lake. Hence there probably were very few Daphnia within the central areas of these lakes; i.e., the vertical water column subtended by the 25-foot contour (Stager) and 28-foot contour (Sporley), that were not sampled. This procedure integrates the population at all depths into the samples, but it omits plankters in the peripheral area; i.e., the zone outside the 25- and 28-foot contours.

Samples of Daphnia from the net plankton and from stomach samples were identified to species, measured, and counted. Dr. J. L. Brooks of Yale University identified samples of Daphnia collected in both lakes. Length measurements were made from the top of the head to the base of the spine. Length measurements were made to the nearest 0.14 mm.

Daphnia from the monthly plankton samples were inspected to determine their size at maturity. The length of the smallest Daphnia to contain eggs was considered to be the size at maturity. Additional information on size at maturity was obtained by observing D. pulex in a laboratory culture held at temperatures similar to those encountered during the summer in Stager and Sporley lakes (64-70 F).

Selection of daphnids by trout and perch

Daphnia from the plankton subsamples selected for length measurements were arbitrarily grouped into 0.28 mm size groups. The percentage of occurrence of Daphnia in these size groups was calculated separately for each sample and an average was computed for each month of collection. The length frequency of the Daphnia in the net plankton was compared with length frequency in the stomach samples for monthly periods during which fish usually consumed Daphnia (Fig. 1).

The range in length of Daphnia from the combined net plankton samples was 0.4 to 2.9 mm, and the length-frequency distribution of the daphnids was usually bimodal (Fig. 1 and Fig. 2). Major exceptions were at Sporley Lake from July through October of 1964. When bimodality occurred, the mode for the smaller daphnids contained chiefly immature individuals. The other mode consisted mostly of instar-IV and mature daphnids.

Measurements of 6,252 Daphnia eaten by 35 rainbow trout and 5,768 eaten by 24 yellow perch show these fish to be very selective. They usually chose Daphnia over 1.3 mm long and ignored the many and often more numerous, smaller individuals. These data represent the contents of fish stomachs collected over several years and during different seasons. However, to demonstrate the size selectivity of fish on daphnids, only the data collected during the summer months,

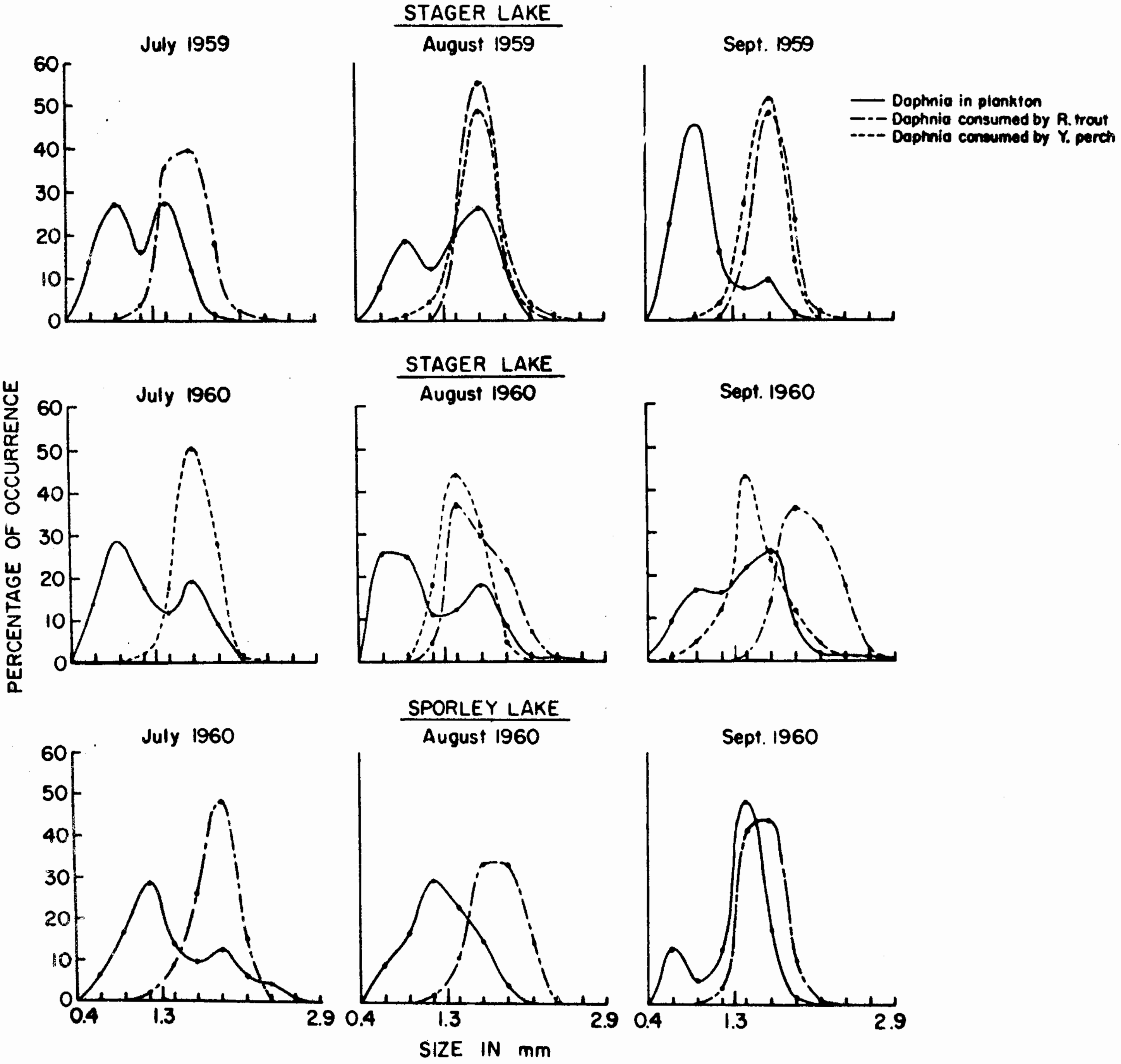

Figure 1.--Comparison of the length-frequency distribution of Daphnia spp. in the net plankton and in the stomachs of rainbow trout and yellow perch.

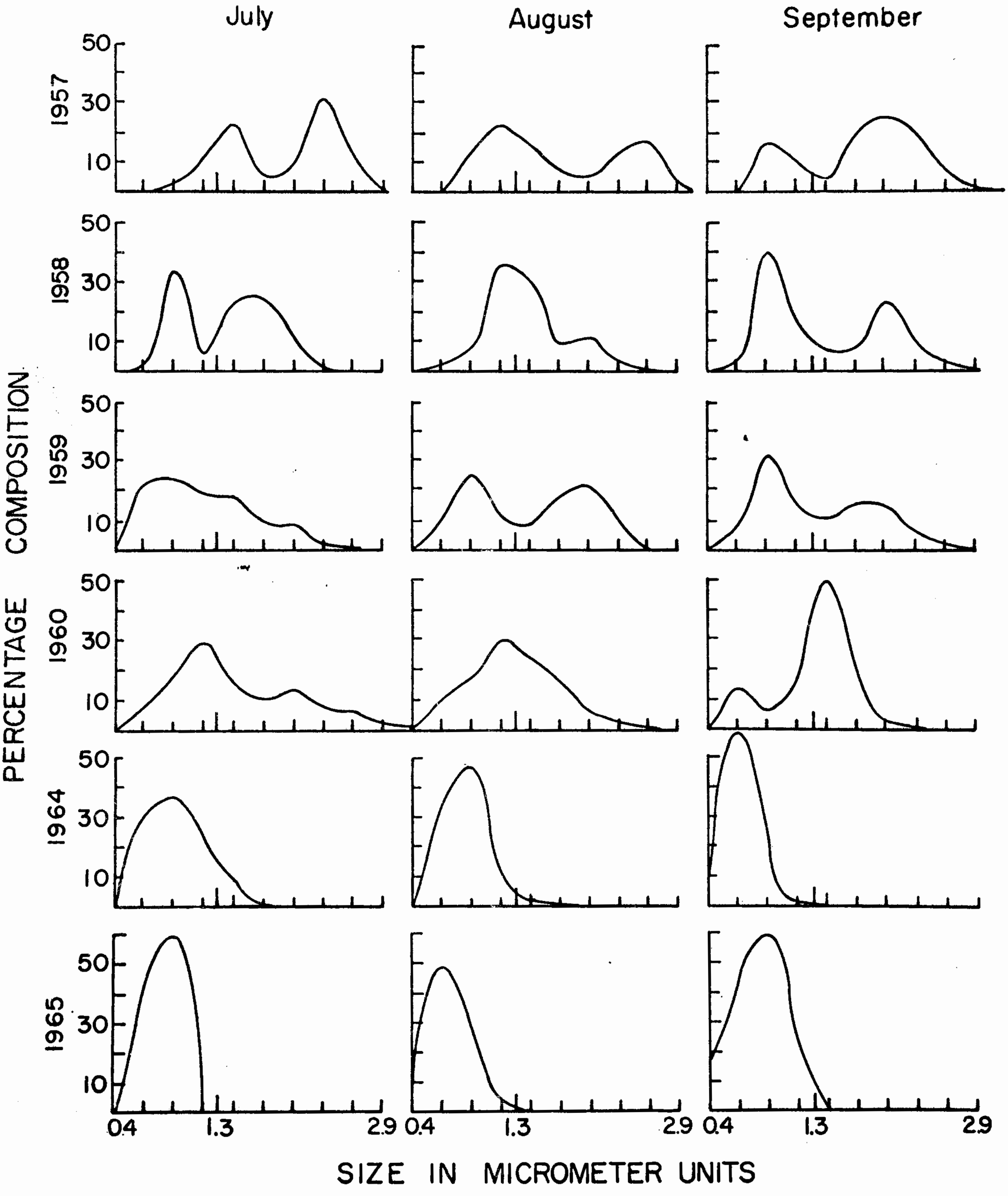

Figure 2.--Length-frequency distribution of Daphnia spp. in the net plankton of Sporley Lake.

when plankton collections were made simultaneously, are presented in Figure 1. These data represent the daphnids consumed by 24 trout and 17 perch. In spite of the fact that as much as 46% of the Daphnia population in Sporley Lake and 58% in Stager Lake consisted of these smaller individuals, 96% of those eaten by trout and 82% by perch were larger than 1.3 mm. This clearly indicates the degree of selectivity exhibited by these fish.

The length ranges of the fish feeding on Daphnia were 7.9-17.2 inches for rainbow trout and 2.8-9.8 inches for yellow perch. To determine if there was an association between length of fish and size of Daphnia consumed, regression lines were calculated separately for rainbow trout and yellow perch in Stager Lake and for the rainbows in Sporley Lake. The slope of the line for rainbow trout in Stager Lake was significant ($b = 0.051$, $P < 0.01$), but the regression lines for the other two populations were not significant at the 5% level. Therefore, it is difficult to generalize from these data about the relationship between length of fish and size of Daphnia consumed. The mean length of Daphnia consumed by rainbow trout (both lakes combined) and yellow perch of various sizes is shown in Figure 3.

The striking difference between size frequency of daphnids eaten and those taken in plankton catches suggests that trout and perch select the larger individuals. Either the fish capture Daphnia one at a time and then select and ingest only the larger individuals, or they indiscriminantly ingest all sizes which are then screened automatically by the gill rakers. One or the other of these mechanisms must be operative since very few

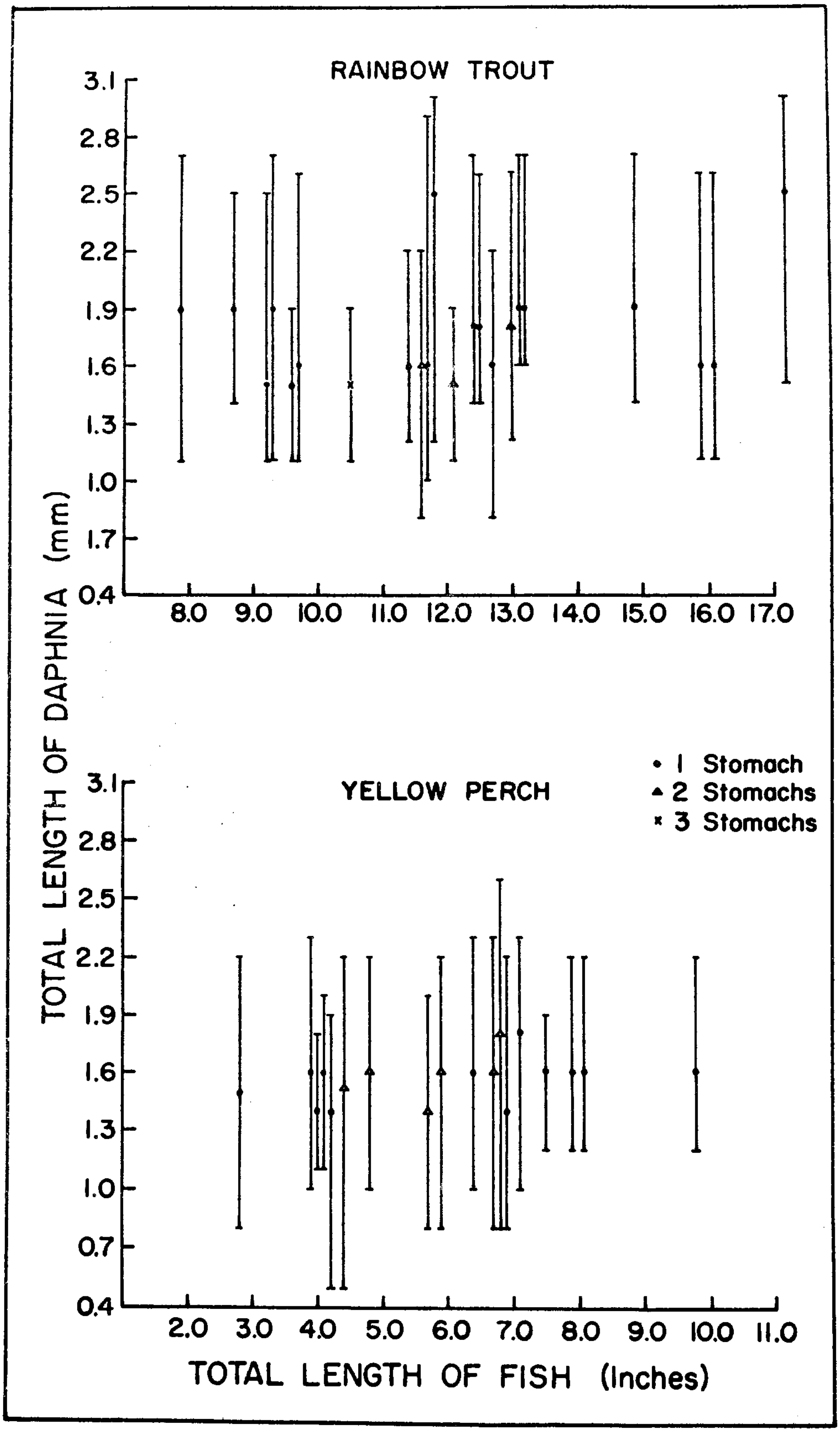

Figure 3. --Mean (symbols) and range (vertical bars) in length of Daphnia spp. taken from stomachs of rainbow trout and yellow perch of various lengths collected in Stager and Sporley lakes during 1959 and 1960.

of the smaller copepods and cladocerans were found in stomachs even though they were usually very abundant in the plankton. Seldom were other cladocerans or copepods found in the stomachs of trout or perch. When present they were at least as large as the smallest Daphnia consumed.

The distinct lower limit of the size distribution of Daphnia in trout and perch stomachs (1.3-1.4 mm) suggests a mechanical selection of some sort such as filtration by the gill rakers. If filtration by gill rakers is the selective mechanism, few gill-raker spacings smaller than 1.4 mm would be expected. I measured the spacings between the proximal ends of the gill rakers of 26 rainbow trout which ranged in size from 4.2 to 18.2 inches, and 10 yellow perch which ranged from 1.5 to 13.2 inches. The proportion of gill-raker openings under 1.1 mm (length of the smallest Daphnia found in stomachs) was calculated for each species. The proportion of gill-raker spaces under 1.1 mm decreased as the size of the fish increased. However, for fish less than 12.0 inches long the number of gill-raker openings smaller than 1.1 mm was greater than the number larger than 1.1 mm. Hence it is clear that a large fraction of spacings were of the size that should have filtered out plankters smaller than those found in stomachs unless these smaller individuals, which are of a much smaller dimension if passed through head or tail first, were forced through the gill rakers. It is unlikely that all of them would pass through in this manner but at least some should have been ingested. The largest spacings on any gill arch adjoin the bend in the gill arch (Fig. 4), and most of the straining action would be expected in this area since it is in the path of

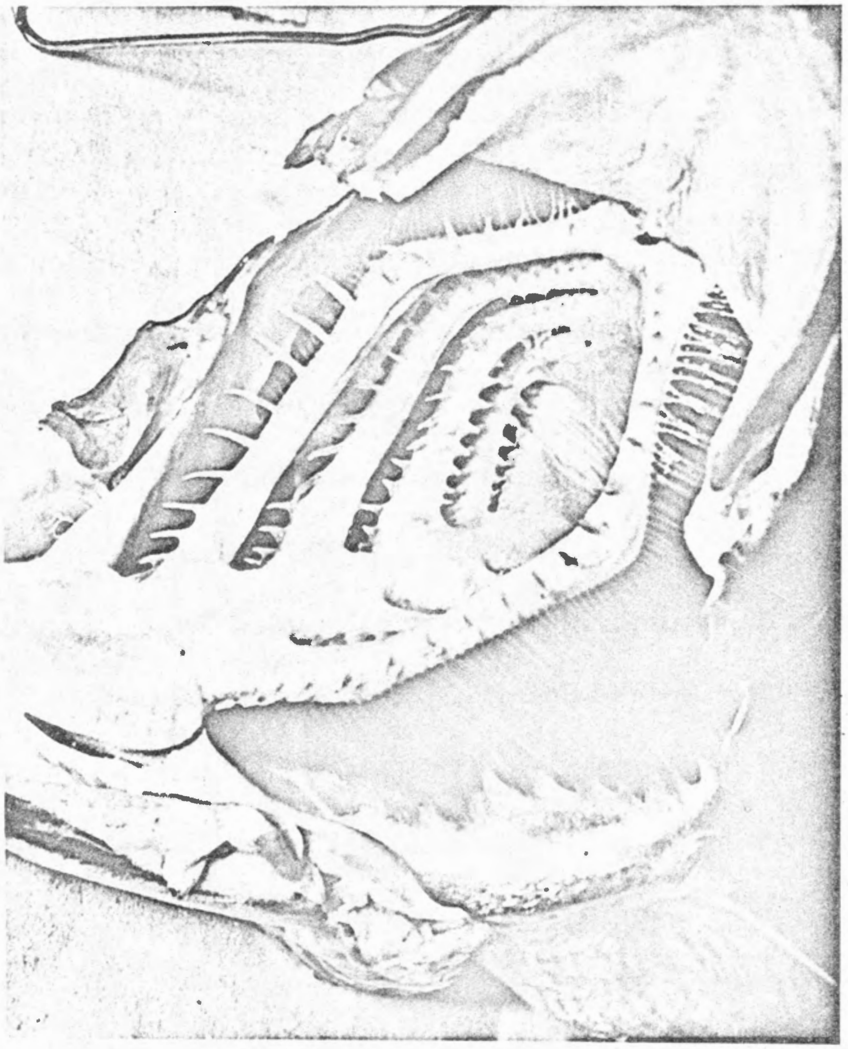

Figure 4.--Gill arch of rainbow trout showing the difference in relative size of the spacings between gill rakers.

least resistance to the flow of water. To see if spacing in this area would account for the observed size selection, I calculated the proportion of spacings smaller than 1.4 mm between the 4th and 12th gill rakers of rainbow trout. As in other regions of the gill rakers, a fairly high percentage (20%) of the spacing was less than 1.4 mm indicating that many smaller plankters should have been retained if filtration was the only mechanism involved.

The above data indicate that rainbow trout and yellow perch depend on some form of discrimination to some extent when feeding on zooplankton. If these fish simply strain plankton, they do so only in portions of the lake which have high concentrations of a preferred size and species of plankter. If large and small Daphnia are intermixed and distributed rather uniformly throughout the lake, the selection of the large individuals from the many sizes available would not appear to be a very efficient method of obtaining food if this is the only method of capturing daphnids. Large Daphnia may congregate by themselves and thus permit unselective feeding but very few instances have been reported where extensive concentrations of large Daphnia were observed. Studies by Ragotzkie and Bryson (1953) and McNaught and Hasler (1961) both revealed localized concentrations of Daphnia in Lake Mendota, but neither mentioned the sizes of the individuals comprising these concentrations. On November 11, 1965, I observed concentrations of Daphnia of all sizes along the shoreline of Johnson Lake, Marquette County, Michigan. In this instance Daphnia were concentrated both below the surface and on the surface film, but those which floated were almost all large Daphnia. Schools of trout were observed feeding at the surface at this time and an examination of their stomachs indicated that they were feeding only on the large *Daphnia*. Concentrations of this sort would permit visual discrimination and increase the efficiency of collecting food.

Changes in populations of *Daphnia* spp. and fish, 1956-1965

Treatments of lakes with toxaphene eliminate zooplankters as well as fish. In 1956, the year following treatment of Sporley Lake, the only species of *Daphnia* detected was *D. pulex*. No other species was encountered until the summer of 1960 when a few *D. retrocurva* appeared in samples. Between 1960 and 1964 several dramatic changes in the characteristics of the *Daphnia* populations occurred. These changes coincided in time with the stocking of trout, the appearance of minnows and smelt, and the subsequent buildup of large populations of minnows and smelt. A comparison of the samples collected in the summers of 1964 and 1965 with those collected from 1958 through 1960 showed that the following changes occurred in the net plankton of Sporley Lake after the buildup of the fish population: (1) *D. pulex* completely disappeared and was replaced by *D. retrocurva* and *D. galeata mendota*; (2) the average size of the *Daphnia* decreased from 1.4 mm (1958-60) to 0.8 mm (1964-65); (3) the percentage of *Daphnia* larger than 1.3 mm dropped from an average of 53.8% to an average of 4.7%; and (4) during some monthly collections in 1964 and 1965 there were no individuals larger than 1.3 mm (Table 1). A two-way analysis of variance (stations and years) was performed on

Table 1.--Average density of *Daphnia* and percentage of *Daphnia* larger than 1.3 mm in plankton samples from Stager and Sporley lakes

Year and month of collection	Stager Lake		Sporley Lake	
	Number per liter	Percentage larger than 1.3 mm	Number per liter	Percentage larger than 1.3 mm
1958				
July	7.6	13.5	2.2	62.0
August	6.1	23.0	2.3	52.5
September	2.5	35.1	0.5	44.9
1959				
July	2.2	32.8	1.1	36.3
August	2.6	51.2	0.6	55.3
September	4.8	27.1	1.7	47.9
1960				
July	3.8	43.0	1.8	43.1
August	3.4	38.5	3.1	46.1
September	4.5	58.6	3.1	68.8
1964				
July	-	-	13.4	8.8
August	-	-	1.9	3.3
September	-	-	1.2	0.0
1965				
July	-	-	0.02	0.0
August	-	-	0.7	1.8
September	-	-	13.6	0.0

both the volumetric data and percentage composition data (Table 2). These analyses showed a significant difference between years ($P < 0.01$). An orthogonal contrast of 1964 and 1965 compared with years 1958 through 1960 showed a significant decrease ($P < 0.01$) in the volume of *Daphnia* and in the percentage of *Daphnia* in the net plankton. Although volume decreased, there was little indication of a reduction in the density (Table 1). In fact, during July 1964 and September 1965, the density levels were higher than at any previous time (Table 1). During this same period, the density also dropped to its lowest level (July 1965). Such extreme fluctuations suggest that the *Daphnia* population had become less stable.

At Stager Lake, the fish fauna and the invertebrate fauna were well established before the introduction of trout. The species composition of both faunas in this lake was more diversified than in Sporley Lake. *D. g. mendota* and *D. retrocurva* were the only *Daphnia* species detected until 1959 when *D. pulex* appeared in small numbers. However, *D. g. mendota* and *D. retrocurva* remained dominant throughout the summer of 1960, the last year the lake was sampled. None of the changes which occurred in Sporley Lake after the introduction of rainbow trout were apparent at Stager Lake. This lack of change in the *Daphnia* population is not surprising because one would not expect that the introduction of a new predator would affect the food supply of a diversified community as much as a community containing relatively few species, at least not in such a short time. The wider variety of food species available to fish in Stager Lake should then act to buffer the effects of predation on any one species.

Table 2.--Average volume per total vertical haul and percentage composition by volume of Daphnia in the summer net plankton of Sporley Lake

Year	Average volume (ml)		Percentage composition in net plankton	
	Mean	Standard error	Mean	Standard error
1958	0.16	0.02	84.5	1.21
1959	0.11	0.02	58.8	1.64
1960	0.23	0.01	72.2	1.49
1964	0.10	0.04	33.3	1.57
1965	0.03	0.01	13.3	1.30

Differences between lakes in the average size and size range of the Daphnia were apparent (Figs. 1 and 2). When D. g. mendota and D. retrocurva were the dominant species in both lakes (1958-1960 in Stager Lake and 1964-1965 in Sporley Lake), the daphnid population in Stager Lake had a much broader size range and larger average size than the daphnids in Sporley Lake. When D. pulex was the only species present in Sporley Lake, there was little difference between lakes in the size range of the daphnids.

The maximum size of Daphnia and the size at which they first become mature is indicative of the food level present (Hall, 1964; Richman, 1958). A higher food level brings about a larger maximum size and a larger size at the onset of reproduction. In Stager and Sporley lakes before 1960 the average size of D. pulex at maturity was 1.8 mm, indicating little difference in food level. However, in 1960 in Sporley Lake some D. pulex were reproducing at a size of 1.2 mm. The appearance of smaller primiparous individuals in 1960 indicates that the food level for this species had declined. The smaller size at the onset of reproduction of D. g. mendota and D. retrocurva in Sporley Lake in 1964 (0.8 mm) compared to their size at maturity in Stager Lake from 1958 to 1960 (1.4 mm), is further evidence that the food level in Sporley Lake was low after 1960.

Discussion

Knowledge of the size of Daphnia consumed by fish and the size at which Daphnia become mature is essential to understanding trophic relationships between daphnids and plankton-feeding fishes. Summer fluctuations in Daphnia populations arise through changes in the number of egg-producing females present. The size at which females first reproduce varies for different species of Daphnia and for a given species in different lake environments. The effect of fish predation on daphnid populations will depend upon whether or not the size range of the Daphnia consumed by fish includes mature or immature individuals. Smith (1963) concluded from Slobodkin's (1959) data that, at a specific growth rate, the removal of young more effectively reduces population density than does the removal of adults. Thus, if only the larger mature individuals are eaten, a sufficient number of reproducing females may survive to sustain the population. But, if fish prey on both mature and immature daphnids, the number of surviving adults may be insufficient to sustain the population. This seems to have taken place in Crystal Lake, Connecticut (Brooks and Dodson, 1965). Predation might also create a small and unstable population.

At this point, it is of interest to review the history of events in these two Michigan lakes from the point of view of these possible interactions between daphnids and plankton-feeding fishes. No adverse effects from fish predation upon Daphnia are indicated in the case of Stager Lake where rainbow trout and yellow perch were consuming mostly adult Daphnia. Before the introduction of trout a few Daphnia appeared in stomachs of very small perch. After introduction of the trout, the intensity of fish predation on Daphnia by rainbow trout and yellow perch seems to have increased somewhat during the summer, but the rate of consumption remained low. In Stager Lake it appeared that other food items were available and fish predation on *Daphnia* was not intensified enough by the introduction of a new species to have an appreciable influence upon the various populations of *Daphnia*.

The events in Sporley Lake, however, give strong indication of interactions between the fish and *Daphnia* populations. This lake is perhaps less productive of benthic and planktonic foods than Stager Lake, and the variety of bottom food organisms may well have been reduced due to earlier treatments with fish toxicants.

Daphnia pulex apparently was the first species to gain a foothold after the lake was poisoned. From 1957 to 1959, before the introduction of fish, it matured at a large size (1.8 mm or more). Rainbow trout planted in 1959 in Sporley Lake fed upon immature as well as mature *D. pulex*. Thereafter, yearly plantings of rainbows and predation by increasing numbers of smelt and minnows appear to have had important effects upon the daphnid populations. Stomachs of smelt and minnows contained copepods, *Daphnia*, and other Cladocera which ranged between 0.3 and 0.7 mm in size. It is very likely that cropping of immature *D. pulex* by these three fishes led to the disappearance of this species between 1960 and 1964. Interspecific competition among these daphnids also may have contributed to the elimination of *D. pulex*. Sometime during this same period *D. retrocurva* and *D. g. mendota* began to increase.

By the summer of 1964 and 1965, plankton collections revealed that Daphnia of large size had been eliminated and that there had been a reduction in the volume of Daphnia. Concurrently there was an increase in the numbers and volume of Bosmina, Chydorus, and (to a lesser extent) copepods. These smaller forms of zooplankton filled the niche left by the reduction of Daphnia. This sequence of changes agrees with Brooks and Dodson's size-efficiency hypothesis; i.e., with the elimination or reduction of larger zooplankton by predation, smaller species become dominant. However, contrary to Brooks and Dodson's findings, all Daphnia in Sporley Lake did not disappear. Instead, their density remained at about the same level even though the volume decreased. Perhaps alewives are more efficient predators on daphnids than trout, smelt, and fathead minnows, and are able to eliminate all Daphnia.

The predation on only those daphnids of a certain size by rainbow trout and yellow perch can be considered to be age specific as well as size-specific. For example, since the trout and perch selected mostly those Daphnia over 1.3 mm, they were actually selecting only individuals of certain ages. Since body size for any given age varies under different environmental conditions, the age composition of Daphnia over 1.3 mm will vary between lakes, and may vary from year to year in the same lake. Hence, age-specific predation may have different effects on the daphnid population of any given lake. Because the removal of Daphnia by fish in Stager and Sporley lakes was not proportional to their size- or age-frequency distribution in the plankton population, it cannot be assumed that predation did not alter the age distribution as was assumed by Hall (1964) to compute his theoretical minimum turnover time for Daphnia in Baseline Lake, Michigan.

The intense removal of daphnids of only a certain age (or size) would increase the turnover time of the Daphnia population beyond that expected if removal of individuals was proportional to their frequency of occurrence in the various age classes. (The term "turnover" is defined as the time it takes to completely replace the population.) By increasing the turnover time, the Daphnia population would be subjected to predation over a longer period of time. Consequently, the population might be even more adversely affected by fish predation.

Tappa (1965) believed that, because size differences among species of Daphnia are minor, predation would not account for numerical differences between two coexisting species unless one was isolated from the other and selectively preyed upon. My data suggest the overall size difference between species is not as important as the size that a species first becomes primiparous. Hence, isolation of a species would not have to occur in order for predation to cause relative differences in abundance between several coexisting species.

Many Michigan lakes planted with rainbow trout, especially those managed for both trout and warmwater game fishes, usually provide good returns to anglers during the first 3 to 5 years. In some lakes, such as Stager Lake, good returns are provided over even a longer period. However, in less fertile lakes survival and catches usually become so poor after 3 to 5 years that they no longer provide a sizeable fishery despite continued stocking. The hypothesis has been advanced that when trout are first introduced into rather infertile lakes containing warmwater species they are able to effectively exploit a food niche not in use by other fish. Failure to survive in subsequent years suggested that the trout soon eliminated this food supply and were forced to compete for food utilized by other fishes.

The succession of events which occurred at Sporley Lake suggests that the eventual failure of trout plantings in other poor trout lakes which contain warmwater fishes might be explained on the basis of the elimination of the larger zooplankton species from predation by the additional trout. Subsequently, the trout failed to compete successfully with the indigenous fishes for the remaining food. This hypothesis is based on the premise that, although other warmwater species such as perch also utilize larger *Daphnia*, trout are more dependent on them for food either at certain stages of their life or at certain periods of the year. More evidence is needed, however, to determine whether or not the supply of *Daphnia* is critical to survival and, if so, when. Preliminary examinations of stomach samples collected during other periods of the year indicate that *Daphnia* are not utilized as much by fish during the summer as they are at other times of the year.

It is clear from this study that the usual measurements of abundance of *Daphnia*, i.e., numerical counts or total volume, can be quite meaningless as far as indicating their availability to plankton-feeding fish. On the basis of these measurements there may seem to be an adequate supply of *Daphnia* when actually the fish may be forced to turn to other foods if Daphnia of the proper size are not available. For example, trout were not eating Daphnia in Sporley Lake in September of 1964 and 1965 although during the same period in other years large numbers of Daphnia were found in trout stomachs. The September plankton collections for both these years indicated an abundance of Daphnia, but few were of the size utilized by rainbows. Thus the abundance of Daphnia of the proper size, rather than total numbers or volume, has an important bearing on the successful management of rainbow trout and other plankton-feeding fishes in lakes.

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INSTITUTE FOR FISHERIES RESEARCH

Merle G. Galbraith, Jr.

Report approved by G. P. Cooper

Typed by M. S. McClure

Appendix*

Table A. --Total length of fish used to determine the size of daphnids consumed, arranged according to lake, species, and monthly periods of collection

Lake and species	Year, month, and length (inches)									
	1959			1960				1961		1963
	July	August	September	July	August	September	November	April	October	April
Stager										
Rainbow trout	10.5	12.5	12.1	-	15.9	13.1	9.6	11.6	14.2	9.4
	11.4	13.0	12.1	-	-	14.9	10.5	11.8	-	11.3
	11.6	13.2	13.0	-	-	17.2	16.1	12.0	-	13.2
	11.7	-	-	-	-	-	-	12.1	-	-
Yellow perch	-	4.4	2.8	4.1	4.0	4.2	5.9	-	5.7	-
	-	4.8	3.9	7.1	4.4	5.7	6.7	-	7.9	-
	-	6.7	4.8	-	-	6.8	7.5	-	8.1	-
	-	6.9	5.9	-	-	-	-	-	9.8	-
	-	-	6.4	-	-	-	-	-	-	-
	-	-	6.8	-	-	-	-	-	-	-
Sporley										
Rainbow trout	-	-	-	7.9	9.3	9.2	-	-	-	-
	-	-	-	8.7	12.4	9.7	-	-	-	-
	-	-	-	11.8	-	10.5	-	-	-	-
	-	-	-	-	-	11.6	-	-	-	-
	-	-	-	-	-	12.7	-	-	-	-

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* Appendix not submitted for publication.

Appendix

Table B.--Summary of percentage of gill raker spacings smaller than 1.1 mm and 1.4 mm in rainbow trout and yellow perch

Species, and length (inches)	First arch	Second arch	Third arch	Fourth arch	Total percentage of gill raker spacings	
					Less than 1.1 mm	Less than 1.4 mm*
Rainbow trout						
4.2	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0
6.5	87.5	87.5	92.9	0.0	91.1	0.0
7.1	87.5	87.5	92.9	90.9	89.5	93.8
9.1	53.3	66.7	78.6	88.9	69.8	84.4
9.8	53.3	46.7	73.3	72.8	60.7	78.1
9.8	60.0	80.0	73.3	81.8	73.2	87.5
10.5	66.7	60.0	66.7	66.7	65.0	71.9
10.8	60.0	60.0	60.0	50.0	58.2	75.0
11.1	46.7	40.0	60.0	60.0	50.9	71.9
11.3	43.8	56.2	57.1	76.9	57.6	56.2
12.0	37.5	43.8	42.9	36.4	40.4	46.9
12.2	20.0	13.0	40.0	66.7	35.0	34.4
13.0	46.7	53.3	66.7	73.3	60.0	62.5
13.2	40.0	40.0	46.7	50.0	43.6	53.1
13.2	43.8	40.0	57.1	81.8	53.6	84.4
13.5	46.7	33.3	40.0	50.0	41.8	59.4
13.9	37.5	62.5	35.7	45.5	45.6	40.7
14.2	33.3	26.7	53.3	71.5	45.8	46.9
14.2	31.2	31.2	43.8	46.2	37.7	37.5
14.5	6.7	26.7	26.7	53.3	23.2	12.5
14.7	12.5	0.0	35.7	64.3	26.7	25.0
15.4	12.5	18.8	12.5	38.5	19.7	6.2
16.4	6.2	12.5	12.5	25.0	13.3	3.1
17.6	0.0	1.9	26.7	28.6	18.0	9.4
18.2	0.0	0.0	20.0	40.0	15.0	6.2
Yellow perch						
1.5	0.0	0.0	0.0	0.0	0.0	0.0
2.2	0.0	0.0	0.0	0.0	0.0	0.0
3.5	0.0	0.0	0.0	0.0	0.0	0.0
6.7	0.0	82.0	0.0	83.3	92.7	93.5
6.9	0.0	0.0	0.0	0.0	0.0	0.0
7.2	0.0	0.0	90.9	0.0	97.8	96.9
8.1	0.0	91.7	72.7	0.0	91.1	87.5
8.3	92.3	97.7	90.0	0.0	89.1	84.4
9.0	0.0	58.3	75.0	87.5	80.0	74.2
13.2	66.7	25.0	58.3	80.0	56.6	40.6

* Spacing measurements made between 4th and 12th gill raker.