INTERNAL REPORT 92

ROLE OF BENTHIC AND LITTORAL FISH IN THE PRODUCTIVITY AND ECOLOGY OF THE LAKE WASHINGTON DRAINAGE

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INTRODUCTION

The primary objective of the Western Forest Biome Studies is a multidisciplinary approach to develop a mathematical model of the ecosystem which will aid in understanding the mechanisms of productivity. To determine productivity in terms of fish, an estimate of their relative abundance is required that can be expanded later into estimates of biomass or energy. The early work of the Washington Cooperative Fishery Unit on Lake Washington revealed that certain non-salmonid and non-game species, such as peamouth and northern squawfish, were numerous and that we should determine their importance in the overall ecology and productivity of the drainage. To form a base from which we could develop our program, we prepared two reports. First, we developed a checklist of fishes for the drainage that summarizes our current knowledge of their occurrence in streams or lakes and their relative abundance (Wydoski 1972a). This list will be revised as we gain additional information on the drainage from current and future research on the aquatic environment. In addition, we compiled an annotated bibliography that provides a ready reference source of the published and unpublished information for use by our students and others who are studying the drainage (Wydoski 1972b).

The primary role of the Washington Cooperative Fishery Unit in the IBP was to determine the standing crop and production of selected benthic and littoral fish in the lakes of the drainage. To accomplish this goal, we planned our studies into three phases with the following objectives: (1) to develop a practical sampling scheme to determine the seasonal distribution and relative abundance of selected fish species, (2) to obtain biological data on the life history of selected species that will be required to estimate various population parameters later, and (3) to develop models that will allow us to understand the biological basis of fish productivity in lakes. In the remainder of this report we will outline the rationale for our approach to these studies and summarize our progress in 1972.

Fish populations in large lakes and reservoirs are difficult to sample because of differences in the behavior of the various species that are affected by biological, chemical, and physical factors. Of the 36 known species of fish in the Lake Washington drainage, 25 are native and the remaining 11 have been introduced and have become established. Because of behavioral differences among the species, a combination of sampling gear was required to determine the distribution and relative abundance.

Lakes Washington, Sammamish, and Chester Morse are all deep and have a relatively narrow band of littoral zone bordering their shores. Also, many obstructions are found in this zone. For example, Lakes Washington and

Sammamish have numerous docks along their shorelines and Chester Morse contains many tree stumps in the littoral zone. For these reasons the use of movable gear such as otter trawls or beach seines is not feasible. Therefore we had to choose passive gear that could be used to sample the entire lake. Monofilament nylon gill nets, with nine mesh sizes, were chosen as our basic gear. Gill nets can be fished throughout the lake at all depths and the selectivity of the nets can be readily determined. Horizontal gill nets are used to sample benthic fish inhabiting the littoral and profundal zones of the lakes, while vertical gill nets are used to sample the pelagic and benthic fish that inhabit the limnetic and profundal zones. For various reasons, fish that are generally associated with the bottom are sometimes found in the limnetic zone. This combination of gill nets has enabled us to determine the horizontal and vertical distribution of several abundant species throughout the lake. In addition, frame (fyke) nets were used to sample the shallow bays of the littoral zone. Earlier, electrofishing gear was used to study the biology of the largemouth bass in Lake Washington (Stein 1970). This gear was used to supplement the biological samples for various life history investigations.

PROGRESS TO DATE

During 1971 and 1972 our effort was concentrated on field studies to fulfill parts of Objectives 1 and 2. We determined a statistically sound sampling scheme for Lake Washington that allowed us to sample fish on a randomized basis in four different depth strata. Gill nets were set over a 24-hour period and the nets were lifted after 12 hours so catches could be separated by time of day (day or night). All data from each set were punched on IBM cards, following a standard format sheet In addition, biological data for selected species are being placed on IBM cards following a standard format with a single card for each specimen.

Bartoo (1972) summarized the vertical and horizontal distribution of four abundant species (northern squawfish, peamouth, yellow perch, and adult sockeye salmon) in Lake Washington by season. A brief summary, with an example of the data from Bartoo's thesis, is provided in Appendix 1. These data have been used to design a time schedule for 1973 that will provide information on the relative abundance of several species throughout Lake Washington during the spring period when the fish are actively moving and we can get reliable data on their abundance. Bartoo is continuing his studies for the Ph.D. degree. He will use data collected in 1973 as well as various biological data to model fish productivity in lakes.

Hansen (1972) summarized the selectivity of vertical and horizontal nylon monofilament gill nets for peamouth, yellow perch, and northern squawfish in Lake Washington. Also, he summarized the catch-per-unit-of-effort (number of fish/square foot of net/1 hour of fishing) for both types of nets. An abstract of his M.S. thesis with an example are provided in Appendix 2. These data are needed to evaluate catch curves for selected species so that survival rates can be determined and the age composition of the populations can be estimated. Hansen's analysis was made only on those species that were readily caught in the gill nets in Lake Washington. As our studies expand into Lakes Sammamish and Cheseer Morse, we will determine the selectivity of the nets for species that are abundant and readily caught by this gear in these lakes. For example, Chester Morse contains rainbow trout and Dolly Varden in much greater numbers per unit of area than the other two lakes. We will determine the selectivity of gill nets for these species during 1973.

In addition to these two M.S. theses, the Cooperative Fishery Unit prepared the following reports relating to the Biome studies: Coniferous Forest Biome Bulletin No. 1, Internal Reports 34 and 42, and 13 unpublished reports. The unpublished reports were primarily research projects undertaken by undergraduate students in Fisheries 409. This course enables the students (Juniors and Seniors) to put into use a broad range of their background, exposes them to field work and technical writing, and brings them into contact with our graduate students. Although each student taking the course requires more than the usual student-professor contact, we feel that this course provides an exceptionally fine learning experience for the student. At the same time, we are able to gain information on the drainage that could not be obtained by our limited number of graduate students (see attached list summarizing Unit studies of the Lake Washington watershed). Two additional M.S. theses (Imamura and Nishimoto) and five undergraduate research project reports are in preparation.

Kenneth Imamura is summarizing fyke net catches that were made in shallow bays. His tentative thesis title is "Life history and movements of the brown bullhead in Lake Washington." This study will add to our understanding of this abundant species in the ecology of shallow areas and help in the development of an overall scheme to sample benthic fishes in the littoral zone.

Michael Nishimoto is summarizing the "Life history of the peamouth *(Mylocheilus caurinus)* in Lake Washington." This abundant cyprinid appears to form a significant proportion of the biomass in Lake Washington. This study will contribute to the goals of the Coniferous Biome Studies by providing valuable life history input that will be needed to model the ecosystem. The thesis should be completed during spring quarter and is significant because it demonstrates that the growth rate of this minnow has changed in response to the reversed eutrophication of the lake.

Fred Olney is working with Bartoo in sampling the lakes for data on relative abundance of abundant and common fish and is working on a M.S. thesis that will describe the "Ecology of the northern squawfish, *Ptychocheilus oregonensis*, in Lake Washington." This predaceous cyprinid reaches a large size in the lake and has been found to prey on juvenile sockeye salmon in the limnetic zone at certain times of the year. This study involves the life history and ecology of the squawfish with an emphasis on food habits (see Appendix 3 for a description of the study and examples of the data summaries. The other life history studies will contain similar data for other species).

Keith Wyman has begun his M.S. research project on "An Ecological comparison of two unexploited salmonid populations" in Lake Chester Morse. Rainbow trout and Dolly Varden coexist in this lake that has been closed to fishing and probably supports the only unexploited populations of these species in the State of Washington. The primary objectives of this study will be to estimate the population of both species and to compare their distributions in the lake and their interactions through a study of their life histories. To date, about 350 fish have been tagged with serially numbered Floy anchor tags. In addition, scale samples for age determination and other biological data have been collected from each fish.

FUTURE WORK

With the completion of his M.S. thesis, Bartoo began a Ph.D. program to document the energy flow of the higher consumers (Objective 3) and to estimate the biomass of important fish species in lakes of the Coniferous Forest Biome. Using the studies of Hansen (1972) and Bartoo (1972) as well as data from yet unpublished reports, the month of May 1973 was chosen as the optimum time for a short intensive sampling program to capture a large representative sample of the important fish in Lake Washington. Catch-per-unit-of-effort information will provide the basis for determining the relative abundance of important species. This information and other biological data will be used to estimate the biomass of selected fish. A preliminary study, using the peamouth as an example, appears to provide a reasonable estimate for this species. It is expected that this method will also provide reasonable estimates of northern squawfish and yellow perch.

During 1973, primary emphasis will be placed on obtaining estimates of biomass for the important species in Lake Washington. Spot sampling of Lake Sammamish in 1973 will provide the necessary input to outline a time schedule by depth strata for estimating the biomass of important species in this lake during 1974. Wyman's study of Lake Chester Morse in 1973 and 1974 will provide biomass estimates of the important species in that lake by June of 1974.

Unsponsored graduate students and undergraduate research projects will supplement the main studies of the lakes in the drainage. Also, the Unit expects to have several graduate students investigate the productivity of the tributary streams to Lake Washington and to determine the effects of man's alterations of these streams on their productivity.

COOPERATION AND COORDINATION WITH OTHER AQUATIC INVESTIGATORS

Our studies will complement those of Burgner and co-workers that involve estimation of juvenile sockeye salmon abundance using an echo integrator and a midwater trawl. The echo integrator provides information on the abundance and location of fish in the water column. The mid-water trawl is adequate to sample sockeye fry and smaller juveniles. Our vertical gill nets with nine mesh sizes will provide a breakdown of species composition and the size composition in the pelagic as well as the benthic species. The use of horizontal gill nets and fyke nets in the shallow bays of the littoral zone provides input where other types of gear cannot be used.

Andrew Repsys, one of Burgner's students, will work closely with Wyman on Lake Chester Morse. Both students will sample with gill nets, fram (fyke) nets, and a Lake Merwin trap net. While Wyman will concentrate on the population dynamics of the rainbow and Dolly Varden, Repsys will follow food consumption and energy flow through this somewhat simple ecosystem. Information on interactions between the two species for food will be needed by

Wyman to explain differences in other ecological parameters. Repsys will need information on the population size of both species to determine the energy flow. He will need the plankton data of Welch and co-workers to determine the selectivity of young salmonids in their feeding habits. Also, the pygmy whitefish is known to feed extensively on plankton.

S. L. Shanbhogue, one of DeLacy's students, will obtain samples of peamouth, yellow perch, and prickly sculpin from Unit students to determine food habits and consumption rates for these abundant species in Lake Washington. Food consumption rates are needed to follow transfer processes and to construct models of the aquatic ecosystems. Samples of all three species will be particularly valuable to provide live specimens to perform the laboratory work on the consumption rates.

APPENDIX 1. Summary of M. S. Thesis (Bartoo 1972).

The thesis analyzed and summarized data from the 69 vertical gill net sites that were sampled through 1972. The horizontal distributions of four abundant species were summarized for 4 predetermined depth strata using relative fish numbers as an indication of population sizes in each stratum. In general, the species investigated moved from the deeper portions of the lake where they wintered to the shorelines and bays in the spring. The fish remained along shorelines and in bays during the summer months and moved offshore to deep water again in the fall. Using the height of capture for the fish sampled, the vertical distribution of the fish each of the different strata was described. Yellow perch were found to be very closely associated with the bottom regardless of depth or season. Peamouth, although less closely associated with the bottom, tended to remain near the bottom in shallow areas. Squawfish seemed to favor mid-depths, drawing closer to the bottom as the water depth declined.

The effect of water temperature, pH and dissolved oxygen was related to the fish distributions. Oxygen and pH showed no discernible pattern when compared to fish distributions. Temperature, however, appeared to have a marked influence on the observed fish distributions. A range of temperatures available to the fish during each season was compared to the mean temperature where the fish were captured. Both the peamouth and the yellow perch were found in water at nearly the warmest temperatures available during each season. Squawfish moved to the warmest waters during summer, but small sub populations were found in cooler waters during spring and fall.

Figures 1 and 2 show examples of the results from this thesis. Figure 1 shows the combined vertical and horizontal distributions of northern squawfish throughout the year. Note the change in height of each sub population as the year progresses. Figure 2 shows the temperatures associated with the squawfish in Figure 1. The temperature preferences provide a possible reason for the observed fish distributions.

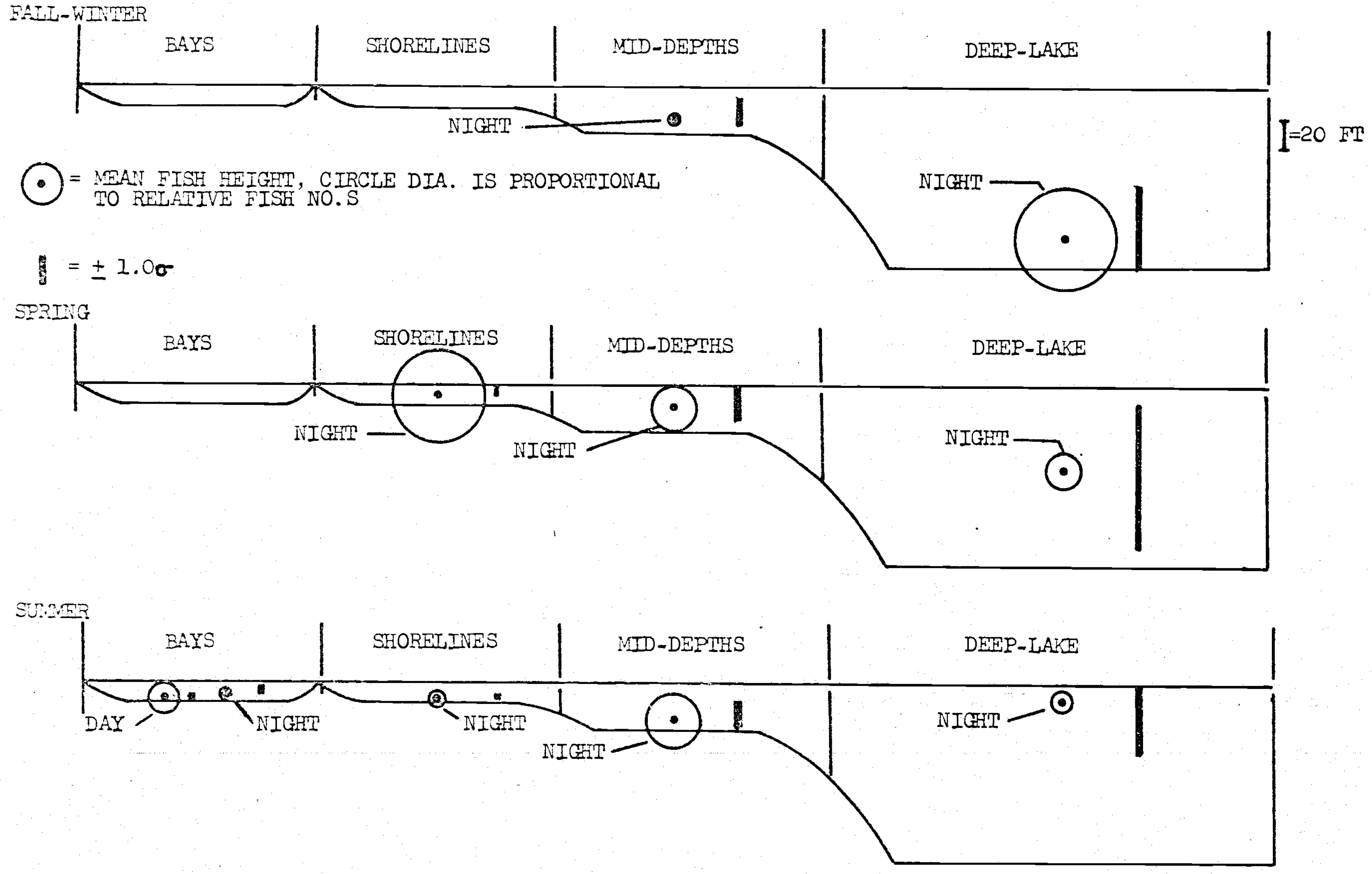

FIGURE 1. COMBINED VERTICAL AND HORIZONTAL DISTRIBUTIONS OF NORTHERN SQUAWFISH FOR ALL SEASONS AND DEPTH REGIONS WHERE TESTABLE NUMBERS OF FISH WERE CAUGHT.

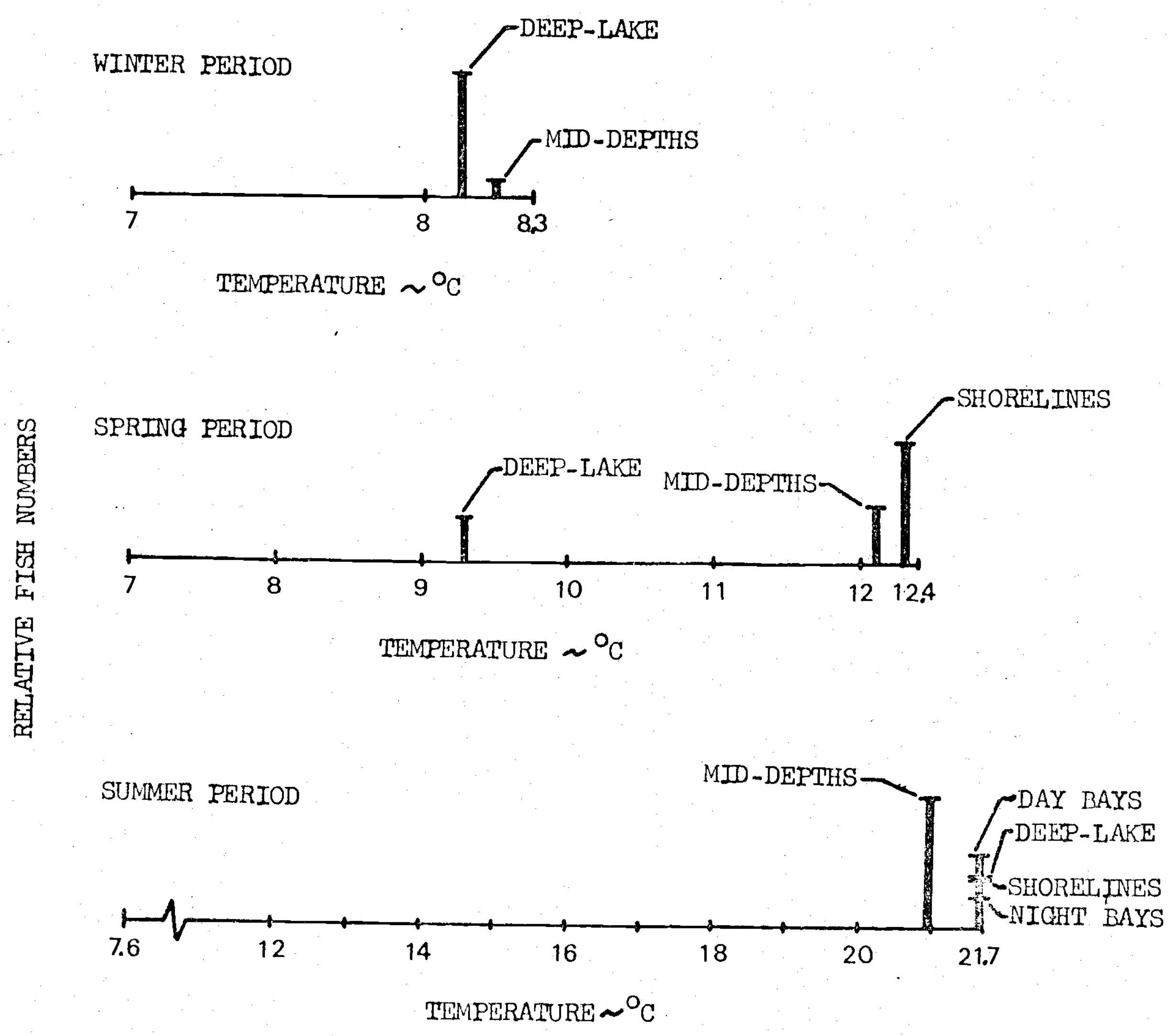

FIGURE 2. AVERAGE TEMPERATURE RANGES AVAILABLE TO NORTHERN SQUAWFISH AND TEMPERATURES ASSOCIATED WITH THE MEAN HEIGHTS OF EACH FISH GROUP

APPENDIX 2. Abstract of M. S. Thesis (Hansen 1972).

All sampling gear is selective in capturing fish. Although gill nets can be used to sample anywhere in a lake, this gear is particularly selective as to the sizes of fish that will be captured by each mesh. Various factors such as the shape of the fish, its swimming strength, and the elasticity of the twine will affect the selectivity of gill nets. Because of the morphology of the lakes in the Lake Washington drainage, gill nets were chosen as the basic gear to be used in sampling benthic fishes that inhabit the littoral and profundal zones.

The vertical gill nets used were six feet wide and could be fished to a depth of 200 feet. The horizontal gill nets were six feet high, 11 feet long, and contained varying mesh sizes. Both nets contained stretched mesh in sizes of 1.0 to 5.0 by 0.5-inch increments.

Sixteen of 28 species of fish reported to be in the lake were captured in the vertical nets and 20 species were captured in the horizontal nets. However, due to factors such as fish behavior, only three species (peamouth, northern squawfish, and yellow perch) were captured in numbers large enough to determine the selectivity of the gear. A fourth species, the sockeye salmon, could be caught in large numbers during certain times in its life cycle. Sockeye smolts were caught by the smallest mesh sizes and adults were readily caught by the larger mesh sizes. These four species are among six that are considered to be abundant in Lake Washington. The brown bullhead and prickly sculpin that are also abundant in the lake were not captured readily in gill nets.

Selectivity and efficiency analyses of the three species resulted in selectivity curves similar to those for yellow perch captured in vertical nets (Figure 1). The smaller mesh sizes were less efficient for yellow perch as is evident from the greater leptokurtosis in the curve for the small mesh sizes. Also, the large mesh sizes (greater than 3.0-inch stretched mesh) did not catch many fish since there are few, if any, perch larger than 400 mm in the lake.

The length frequencies (catch curves) for peamouth, yellow perch, and northern squawfish caught in the vertical nets (hung on a 1.5: 1 basis) were significantly different from the length frequencies for the horizontal nets (hung on a 2: 1 basis) For all species captured in the nets, the larger meshes were more efficient than the smaller ones. Also, the catch-per-effort (number of fish/square foot of net/1 hour of fishing) was higher for horizontal nets than for the vertical nets. During the study, a change in the diameter of the twine was made for one panel in the horizontal net, resulting in a different length frequency of the catch.

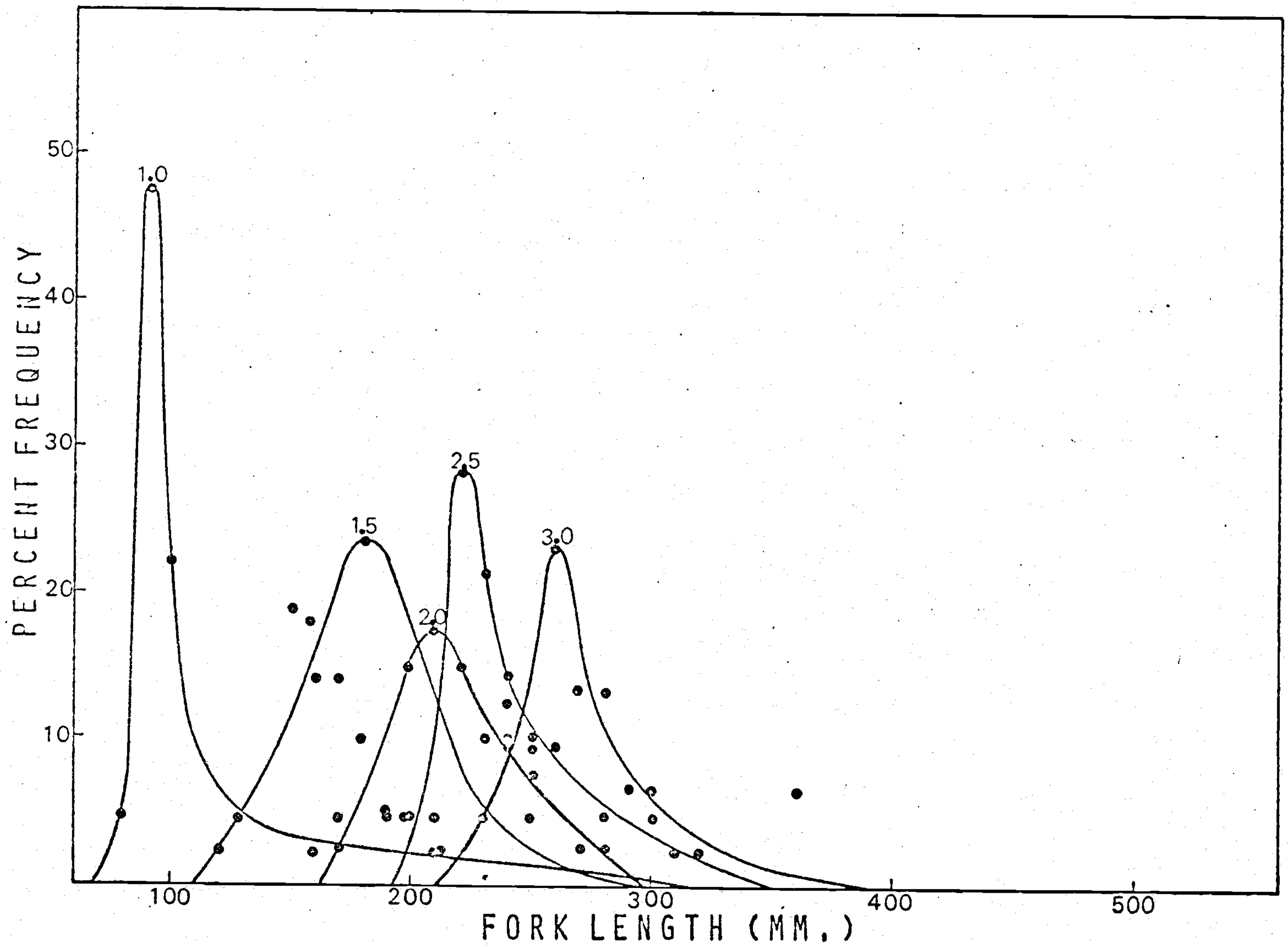

FIGURE 1. Length-frequencies of yellow perch from vertical gill nets that captured 30 fish or more.

APPENDIX 3. Progress report on the ecology of the northern squawfish in Lake Washington (Fred Olney).

This study will focus on the ecology of the squawfish in Lake Washington and will include a detailed summary of the life history of this species. Some of the work completed during 1972 is summarized here.

Preliminary analysis of age and growth was made in 1972 and will be expanded during 1973. Scale samples from 108 squawfish were obtained and a body-scale relationship was calculated by the method of least squares. The equation that describes the relationship is TL = 8.436 + 3.631 SR, where TL = total length in mm and SR = anterio-lateral scale radius in mm X 42. Back-calculation of growth was made by applying the size of the cale at the end of each growing season to this equation. Males have a greater increment of growth than females up to the fifth year (Table 1). From the end of the fifth growing season and later, the females are larger at the end of each succeeding growing season. In addition, males appear to have a higher natural mortality than females. While females were found up to age 13, males were only found up to age 9. A better picture of mortality rates and longevity will be realized when all the data have been summarized.

Stomach samples from 273 squawfish have been analyzed. The food items are summarized by percentage frequency of occurrence (Figure 1). Only fish between 250-620 mm total length have been analyzed. Smaller fish will be analyzed during 1972 and the percentage of the total volume will be determined for each food category. Although chironomids (midges) are found in many stomachs, these insects only make up a small proportion of the volume. The larger squaw ish feed mainly on fish and crayfish throughout the year.

Seasonal variation in the diet was found to be due to differences in the distribution of the squawfish. During the winter, squawfish are generally found in deeper areas of the lake near the bottom. Cottids, longfin smelt, and sockeye, along with unidentifiable fish remains comprise the bulk of the diet at that time. Crayfish, inhabiting the shallow littoral zone, are completely absent from the diet during winter. In summer the squawfish are found in the warm littoral zone and are distributed over the entire bottom of the lake at all seasons and are consumed throughout the year. Food habits of the northern squawfish indicate that this fish is an opportunistic feeder and will eat whatever organisms are available.

The greater part of the data will be analyzed during the next two quarters and the thesis will be written during the summer.

TABLE 1. Calculated lengths at the end of each year of life for northern squawfish in Lake Washington.

Age Group	No. of Fish	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
							MALES							
I	19	69.1												
II	0													
III	1	59.3	139.1	208.1										
IV	4	79.2	200.9	287.3	338.8									
V	7	78.5	175.5	255.7	302.2	325.8								
VI	6	77.4	159.8	236.1	296.4	338.9	366.1							
VII	9	76.3	152.9	243.7	296.0	329.0	367.9	396.6						
VIII	6	74.5	156.2	241.9	292.4	335.9	367.9	392.2	415.1					
IX	3	77.4	152.6	217.9	272.4	318.2	355.9	383.5	411.5	434.3				
Average		74.0	162.4	241.5	299.7	329.6	364.5	390.8	413.3	434.3				
Increm.		74.0	88.4	79.1	58.2	29.9	34.9	26.3	22.5	21.0				
Number		55	36	36	35	31	24	18	9	3				
							FEMALES							
I	19	69.1												
II	0													
III	1	81.1	197.2	288.0										
IV	2	75.6	169.9	251.7	300.7									
V	12	77.1	174.7	273.1	318.9	355.2								
VI	6	73.1	136.2	217.2	278.9	328.3	368.3							
VII	5	72.3	158.7	220.5	296.0	358.5	403.5	437.6						
VIII	7	81.4	178.4	250.3	310.5	361.0	400.6	441.6	467.8					
IX	6	32.1	152.6	226.3	267.3	310.5	353.4	389.7	424.2	446.0				
X	3	72.7	154.7	247.0	291.6	321.8	355.9	382.4	415.1	445.2	469.2			
XI	4	73.1	138.4	222.7	277.1	335.2	381.7	416.9	451.4	478.6	505.9	520.4		
XII	2	73.8	153.7	222.7	289.8	327.9	386.1	435.1	476.8	502.2	531.3	560.3	593.0	
XIII	1	73.8	146.4	197.2	288.0	335.2	360.6	389.7	422.4	444.2	462.3	484.1	502.2	531
Average		75.4	160.1	237.9	291.9	337.1	376.4	413.3	443.0	463.2	499.0	521.6	547.6	531
Increm.		75.4	84.7	77.8	54.0	45.2	39.3	36.9	26.7	20.0	35.8	22.6	26.0	
Number		68	49	49	48	46	34	28	23	16	10	7	3	

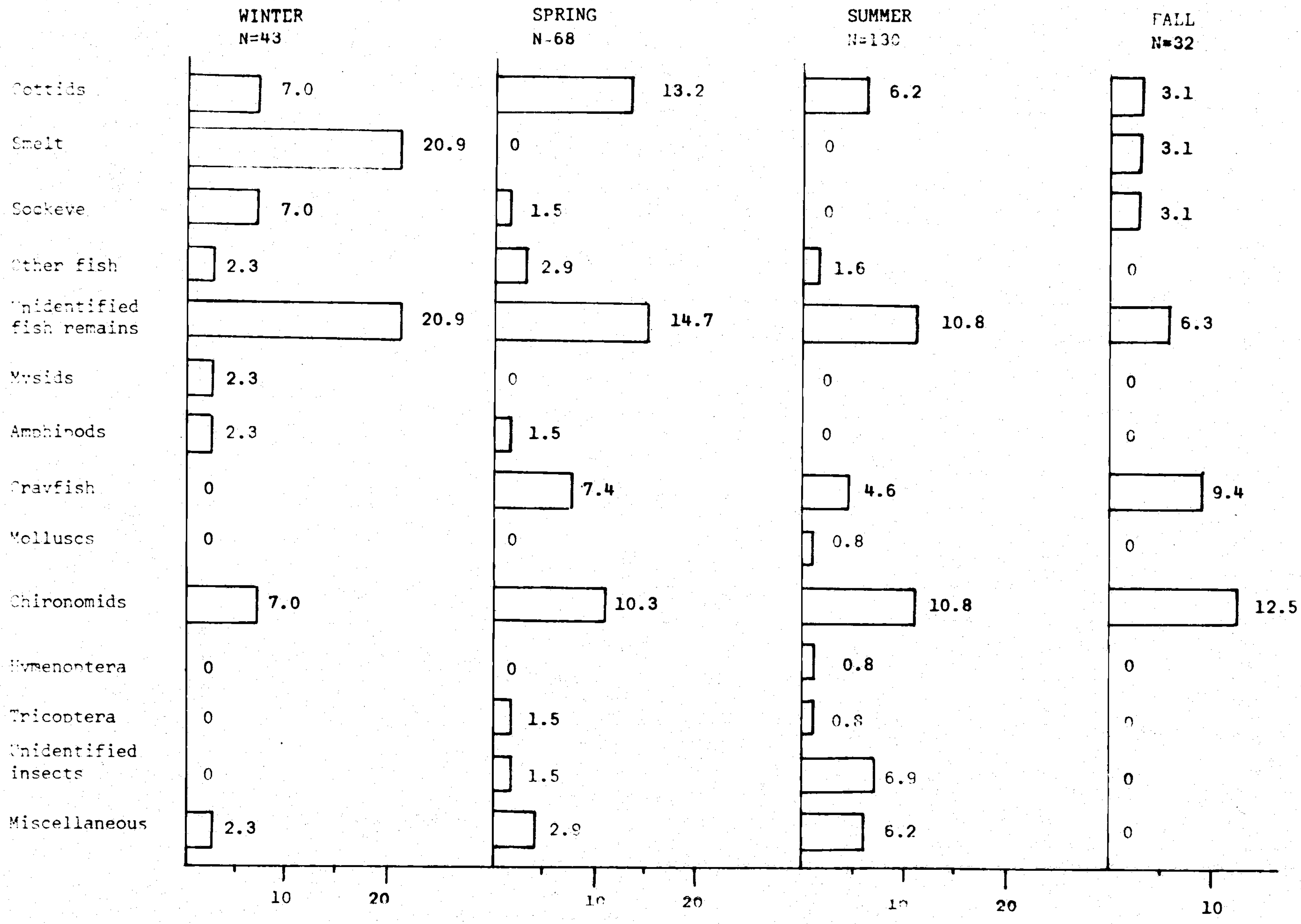

FIGURE 1. Frequency of occurrence of food items for squawfish 250-620mm. total length.