THE FOOD HABITS, GROWTH AND EMIGRATION OF JUVENILE CHINOOK SALMON (ONCORHYNCHUS TSHAWYTSCHA) FROM A STREAM-POND ENVIRONMENT

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
JON JOSEPH LAUER
1969

ABSTRACT

THE FOOD HABITS, GROWTH AND EMIGRATION OF JUVENILE CHINOOK SALMON (<u>ONCORHYNCHUS TSHAWYTSCHA</u>) FROM A STREAM-POND ENVIRONMENT

By

Jon Joseph Lauer

Chinook salmon juveniles (*Oncorhynchus tshawytscha*) were studied to determine the food habits, growth and effect of size on emigration from a stream-pond environment. The chinook salmon studied had failed to emigrate from a tributary of the Thunder Bay River (Michigan) after their release on 12 May, 1968.

Comparisons of drift organism samples and stomach contents for six sampling periods from 12 June to 26 July showed that the chinook preferred cladocerans, midge larvae and midge pupae, each 54.6%, 19.7% and 18.7% of the total diet by number respectively. Midge adults and collembolans were also preferred, but constituted a minor portion of the diets. Copepods and tubificid worms were present in the drift in large numbers, but were seldom present in the diets. Piscivorous food habits were observed only in a few individuals over 85 mm fork length. The possibility of major competition with forage fish species for food is discussed.

Growth appeared to be rapid. A rate of 18 mm/month was determined for the months of May, June and July.

The observed emigration of the chinook salmon juveniles is believed to have been forced by intra-specific

competition for food and space. No relationship between size and emigration timing was observed. The study was terminated when low dissolved oxygen caused mass chinook salmon mortalities.

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1969

ACKNOWLEDGEMENTS

I would like to express sincere appreciation to Dr. Howard E. Johnson under whose guidance this study was made. Appreciation is also expressed to Dr. Eugene W. Roelofs for the advice and suggestions he gave, and to Dr. T. Wayne Porter for his help with the identification of some invertebrates.

I am deeply indebted to a fellow graduate student, Thomas E. Mears, for all the time and assistance he gave me, and to my wife, Carol, for reviewing and typing my paper. I also wish to express thanks to Robert Drummond, Dean Eyman, Richard Moreau and Wilbert C. Wagner for the information and assistance they gave me.

I am grateful for the financial assistance from the Agricultural Experiment Station, Michigan State University, and for the cooperation of Alpena Community College, especially from its president, Jack Petoskey, all of which allowed me to work on the project.

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INTRODUCTION

In 1967 the chinook salmon (Oncorhynchus tshawytscha) was reintroduced into the Great Lakes region (Tody, 1967). Prior attempts to establish the species had met with only temporary success (Hubbs and Lagler, 1958).

Successful establishment of the chinook salmon in the Great Lakes will require sound knowledge of the factors that affect its survival. The chinook salmon has been studied extensively in its native environment on the Pacific Coast. However, significant differences probably exist between the two environments that would affect management of the species.

The life history phase that is most important for chinook salmon management is the freshwater[1] phase, prior to emigration. At this time, mortalities in the salmon are highest (Rutter, 1904). Thus, the more time juveniles spend in freshwater, the smaller the adult return will be.

Studies by French and Wahle (1959), Mattson (1962, 1963) and Riemers and Loeffel (1967) discount a concept long held by biologists concerning emigration. The concept is

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[1] "Freshwater" in this paper means waters inland from the oceans or Great Lakes.

that juveniles from parent stocks which typically enter freshwater as adults in the spring (spring run chinook salmon) or the fall (fall run chinook salmon) emigrate at one year and three months of age, respectively. Rather, they found that juveniles from both spring and fall runs spend from a few months to over a year in freshwater.

Variable timing of emigration has also been observed in hatchery stocks of steelhead trout (*Salmo gairdnerii*) (Wagner, 1968). Wagner (1968) states that individual fish released *en masse* from a hatchery will not all be in a migratory disposition, and that some will take up residency in the stream for varying periods of time. Chinook salmon probably display similar behavior.

Both fish that fail to emigrate at their "normal expected emigration time" (residuals) and fish that are released prior to that time, are affected similarly by the environment. Available food, predators, competitors, water temperatures and dissolved oxygen play key roles in determining survival.

Growth rate also is important because it has an association with emigration. Reimers and Loeffel (1967) state that the larger chinook salmon juveniles appear to emigrate earliest.

To determine the effect of size on emigration, as well as the food habits and growth rate of fall run chinook salmon juveniles in Michigan, I studied a population of chinook salmon in Fletcher Creek, a tributary to the Thunder

Bay River. These salmon were hatched and reared to fingerling size by the Alpena Community College from eyed eggs obtained from a race selectively bred by Dr. L.R. Donaldson at the University of Washington (Donaldson and Menasveta, 1961). The plant consisted of 65,000 fingerlings marked with a right pelvic fin clip, and released 158 days after the last eggs had hatched. The population studied was largely a residual stock which had remained in the stream after their release on 12 May, 1968. The study period, from 12 June to 26 July, was terminated prematurely due to the nearly complete mortality of young salmon caused by low dissolved oxygen conditions in the stream.

DESCRIPTION OF STUDY AREA

Physical Features

The study area was the lower end of Fletcher Creek just above the point the creek empties into the Ninth Street Dam reservoir located on the Thunder Bay River at Alpena Michigan (Figure 1). The creek forms a small pond (900 M^2, maximum depth 1.3 M) which has deep fast flowing water over a gravel bottom at the upper end, graduating to shallow, slow flowing water over a muck bottom with dense aquatic vegetation at the lower end. The creek enters the study pond via a culvert from a larger pond on the upstream side of Long Rapids Road. The larger upper pond is shallow (maximum depth 1 M), muck bottomed, and supports dense growths of algae and submergent aquatic plants. A series of intermittent springs in Fletcher Creek and the upper pond provide the main flow of water to the study pond. During periods of low rainfall the stream flow is greatly reduced.

Temperature Measurements

Temperatures in the pond were measured with a Taylor Maximum-Minimum thermometer that was suspended in the main current. Daily temperatures fluctuated an average of 7.3 C during the study period (Figure 2). The daily high and low water temperatures were fairly stable except for a cool period from 22-28 June and for a warm period 14-22

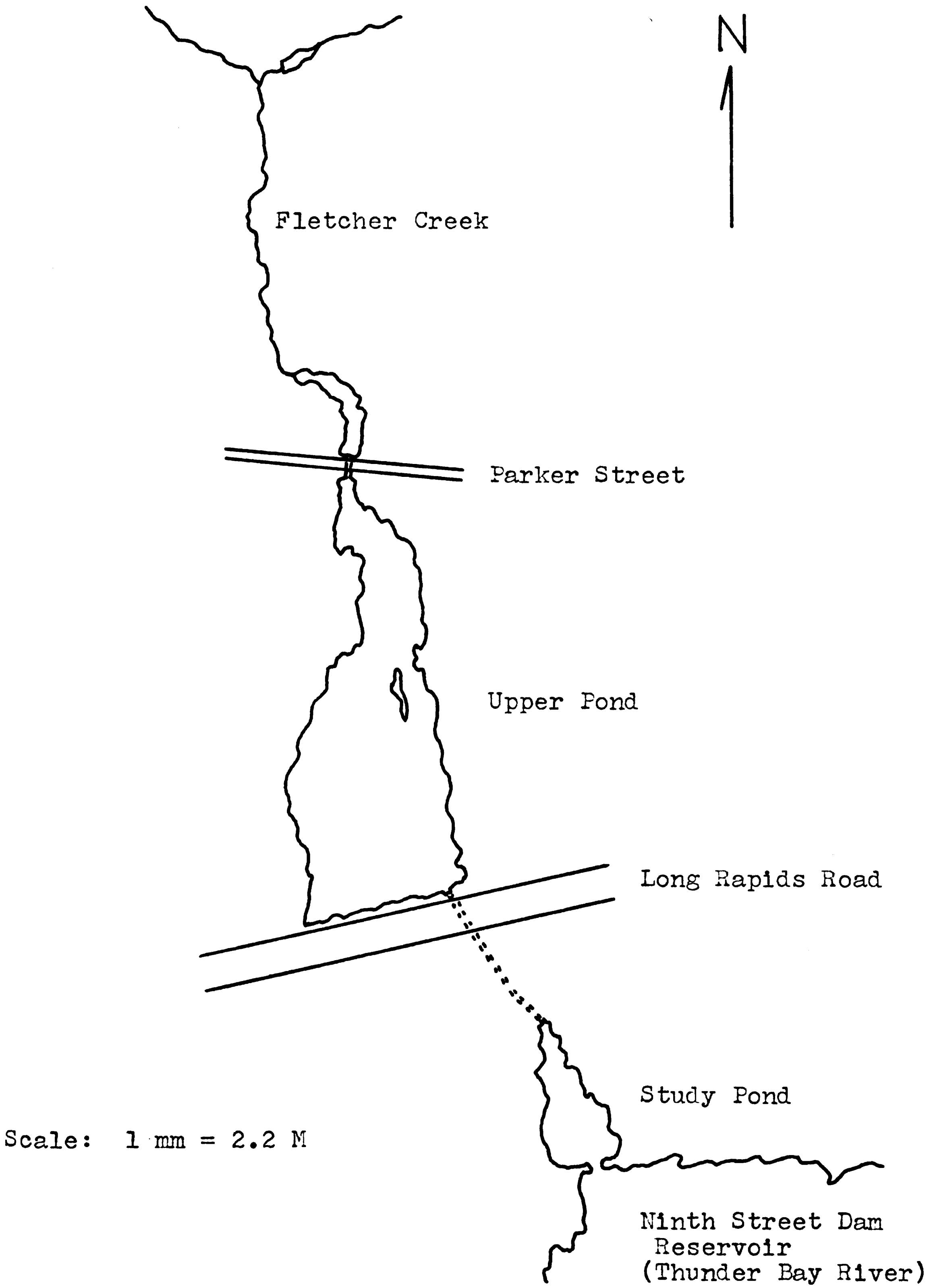

FIGURE 1.--The location of the study pond on Fletcher Creek (Sec. 16, T 31 N R 8 E Mich. M).

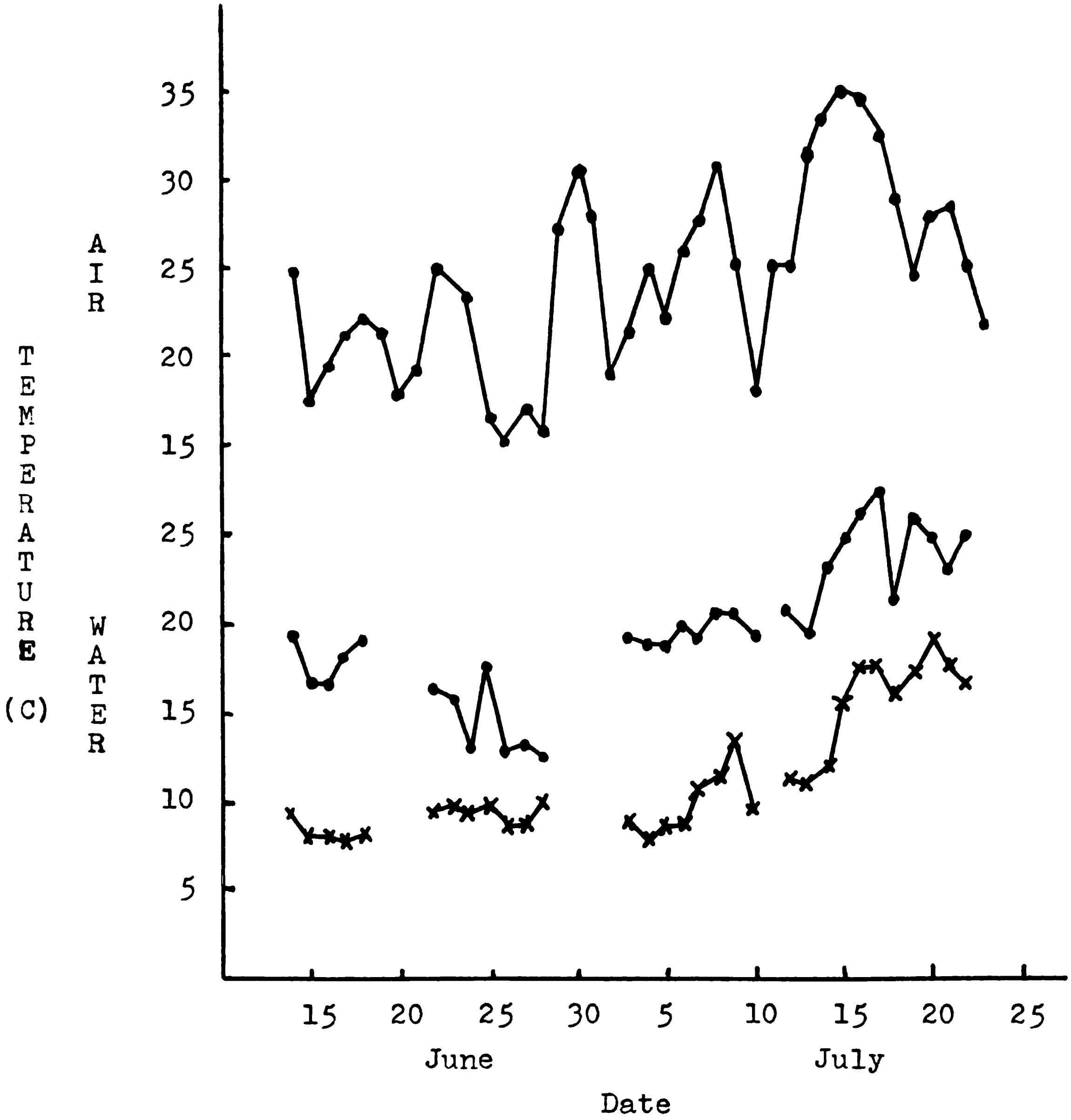

FIGURE 2.--Daily maximum and minimum water temperatures in the study pond, and maximum air temperatures (recorded at Phelps Colins Field, Alpena Michigan, by the U.S. Weather Bureau.) Maximum water and air temperatures are represented by dots; minimum water temperatures are represented by x's.

July. The changes in water temperature followed the same trend as the changes in maximum daily air temperature (Figure 2).

Flow Measurements

Nine measurements of Fletcher Creek discharge at the study pond were made during the study period according to the float method as described by Welch (1948) (Figure 3). I observed the increase and decrease of the flow to be dependent on rainfall, which was the main source of water for the springs that feed Fletcher Creek. The low flows of mid-July corresponded to the "drying up" of several springs in Fletcher Creek. On 20 July surface discharge from the study pond ceased and only subsurface discharge was observed after that date.

Chemical Measurements

On 2 and 26 July, diurnal measurements of dissolved oxygen, total alkalinity, and pH were made on Fletcher Creek at the study pond (Table 1). Single measurements of hardness were made on 9 and 26 July. The Standard Winkler Method (Alsterberg modification, Hach, 1967) was used to determine dissolved oxygen. Standard titration methods as outlined by Hach (1967) were used to determine total alkalinity (phenolphthalein and brom cresol green-methyl red indicators - N/50 sulfuric acid titrant) and hardness (ManVer^R indicator and TitraVer^R titrant). A Beckman pH meter (model H) was used to measure pH.

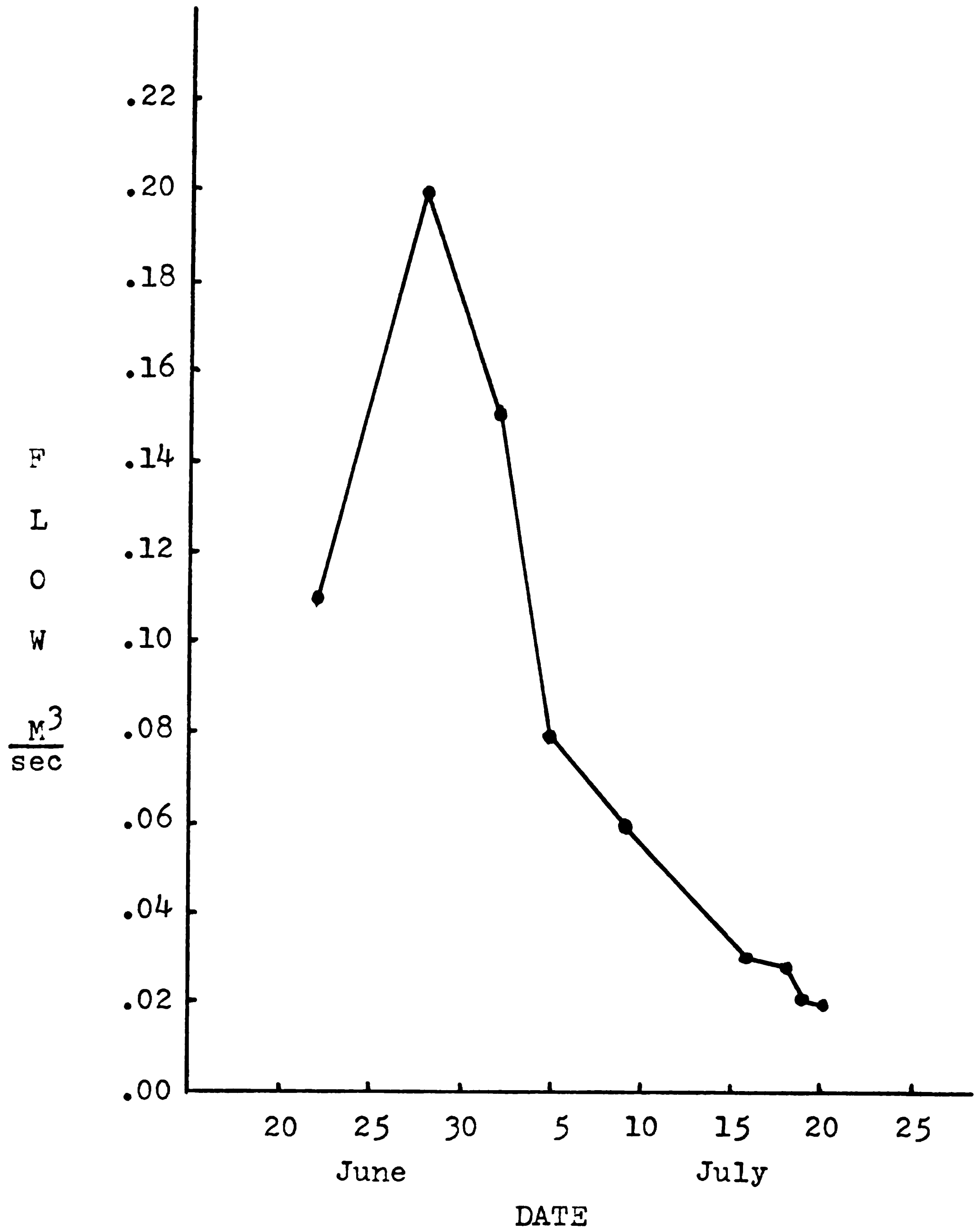

FIGURE 3.--Flow measurements for the study pond.

TABLE 1.--Diurnal limnological measurements for the study pond on 2 July and 26 July, 1968. The measurements for 2 July are listed above the measurements for 26 July.

	Time[1]											
Parameter	0730	0930	1130	1330	1530	1730	1930	2130	2330	0130	0330	0530
Air Temperature (C)	-- --	15.8 20.1	17.2 23.1	17.0 23.6	19.0 24.0	16.5 24.7	14.5 20.5	11.0 20.0	10.4 20.0	10.2 21.0	-- 20.8	8.8 17.0
Water Temperature (C)	12.0 18.8	12.3 18.5	12.8 19.4	13.0 21.8	14.5 22.5	15.0 23.5	14.5 23.4	13.5 23.0	12.8 22.0	12.0 20.5	-- 20.4	10.2 20.0
pH	7.7 --	-- 7.5	-- 7.4	-- 7.6	-- 7.7	-- 7.8	-- 8.0	-- 8.0	-- 7.9	-- 7.6	-- 7.6	-- 7.5
Total Alkalinity (ppm $CaCO_3$)	-- --	264 262	-- --	248 250	-- --	249 236	-- --	234 224	-- --	244 236	-- --	250 244
Dissolved Oxygen (ppm)	6.6 4.8	7.8 5.4	12.4 6.8	12.2 8.2	16.2 9.8	17.8 11.8	16.2 13.0	15.8 13.0	14.4 12.4	10.2 10.6	-- 10.2	8.0 10.8
Total Hardness (ppm $CaCO_3$)	276 (9 July) 270 (26 July)											

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[1] E.D.S.T.

The limnology is characteristic of a body of water that supports abundant plant life (Table 1). The dissolved oxygen concentrations were highest in the late afternoon and lowest in the early morning. This oxygen pulse reflects the daily photosynthetic cycle. The diurnal uptake of carbon dioxide by the plants during photosynthesis caused the total alkalinity in the pond to decrease and the pH to increase from non-photosynthesis levels (Reid, 1960). From the total alkalinity and pH measurements the pond water was classified as hard and slightly alkaline (Sawyer, 1960; Reid, 1961).

Biological Life

The major species of filamentous algae collected throughout the study pond were *Spirogyra* spp., *Oscillatoria* spp., *Cladophora* spp. and *Hormidium* spp. In the lower end of the pond, the aquatic plants *Potamogeton pectinatus* and *P. Richardsonii* were abundant on the muck and sand muck bottom. *Typha* sp., *Scirpus* sp., *Sparganium* sp., and *Solanum* sp. comprised the dominant emergent vegetation.

The most common invertebrates in the pond were: freshwater sponges (Porifera); aquatic snails (Gastropoda); fingernail clams (Sphaeriidae); leeches (Hirudinea); tubifix worms (Tubificidae); copepods (Canthocamptidae and Cyclopidae); cladocera (*Eurycercus lamellatus*); ostracods (Ostracoda); crayfish (Astacidae); midge larvae and pupae (Tendipedidae and Helidae); damselfly naiads (Odonata); mayfly naiads (Ephemeroptera); water boatmen (Corixidae); and Collembola.

The fish species collected from the pond are listed in Table 2 in their order of abundance. The abundance was determined from observations, and from seining and poisoning collections described later.

The entire study area is a waterfowl sanctuary. Ducks were often observed feeding in both of the ponds on Fletcher Creek.

TABLE 2.--*Fish species collected from the study pond during June, July, and August 1968 listed in order of abundance.*

Chinook Salmon	*Oncorhynchus tschawytscha*[1]
Northern Redbelly Dace	*Chrosomus eos*[1]
Creek Chub	*Semotilus atromaculatus*[2]
Brook Stickleback	*Eucalia inconstans*[2]
Central Mudminnow	*Umbra limi*[3]
Bowfin	*Amia calva*[3]
White Sucker	*Catostomus commersoni*[3]
Darters	*Etheostoma* spp.[4]
Banded Killifish	*Fundulus diaphanus*[4]
Tadpole Madtom	*Noturus gyrinus*[4]
Northern Pike	*Esox lucius*[4]
Carp	*Cyprinus carpio*[4]
Yellow Bullhead	*Ictalurus natalis*[4]
Burbot	*Lota lota*[4]

[1] Over 500 collected.

[2] Less than 500 collected.

[3] Less than 100 collected.

[4] Less than 20 collected.

GROWTH AND MIGRATION

To study the growth of juvenile chinook salmon in the study pond and the relationship of size to emigration, both emigrating and residual chinook salmon were collected.

For growth determinations, the residual salmon were collected by seine hauls from several locations in the study pond for each sampling period (Table 3). The fish were anesthetized with MS 222 (Tricane Methanesulfonate), and were measured (fork and total length) to the nearest millimeter. A random sample of the chinook salmon from each collection was preserved in 10% Formalin for stomach analysis, and the remainder of the fish were returned to the pond. The first two collections were exceptions to this procedure in that a random sample was collected, killed in 10% Formalin, and then measured shortly after death.

The collection of emigrating chinook salmon was limited due to restrictions on equipment and material. An improvised fyke net was fished intermittently at the pond outlet from 22 June to 10 July. The net was set to block the width of the outlet channel. However, effectiveness of the net in collecting and retaining fish was impaired by insufficient water flow and by constant clogging with filamentous algae.

To improve collection of emigrants, and to determine possible immigration of salmon from upstream, basket-like wire traps of ¼-inch mesh were placed at the inlet and outlet

TABLE 3.--Numbers of chinook salmon collected, measured and preserved for stomach analysis.

Sampling Dates	Number Seined and Measured	Number Preserved
12 June	44	44
18 June	12	12
28 June	149	14
3 July	13	13
9 July	104	10
16 July	24	6
20 July	32	22
Totals	378	121

of the pond. All of the water entering or leaving the pond flowed through the traps. Both traps were used continuously from 12 to 20 July. Water ceased to flow through the outlet trap on 20 July. Other fish species were collected in the traps incidental to the collection of the salmon.

All of the emigrating salmon collected in the traps and the net were released downstream with the exception of 13 individuals collected after 3 July which were marked by clipping the tip of the caudal fin and released in the upper end of the study pond. None of the 13 marked fish were recaptured.

To make growth and size comparisons with other studies, conversion factors for standard, fork, and total length were determined. These relationships are as follows: fork length = 0.82 total length; fork length = 1.13 standard length. The conversion factor for fork to standard length was calculated from measurements made on 49 preserved specimens selected from all sampling periods to represent the complete range of sizes for those periods. All chinook salmon length measurements given in this paper will be in millimeters fork length unless otherwise specified.

Growth

The ranges and mean lengths of chinook salmon collected on each of seven sampling dates in June and July are shown in Figure 4. The size of the fingerlings at the time of release on 12 May was determined by measuring a sample of

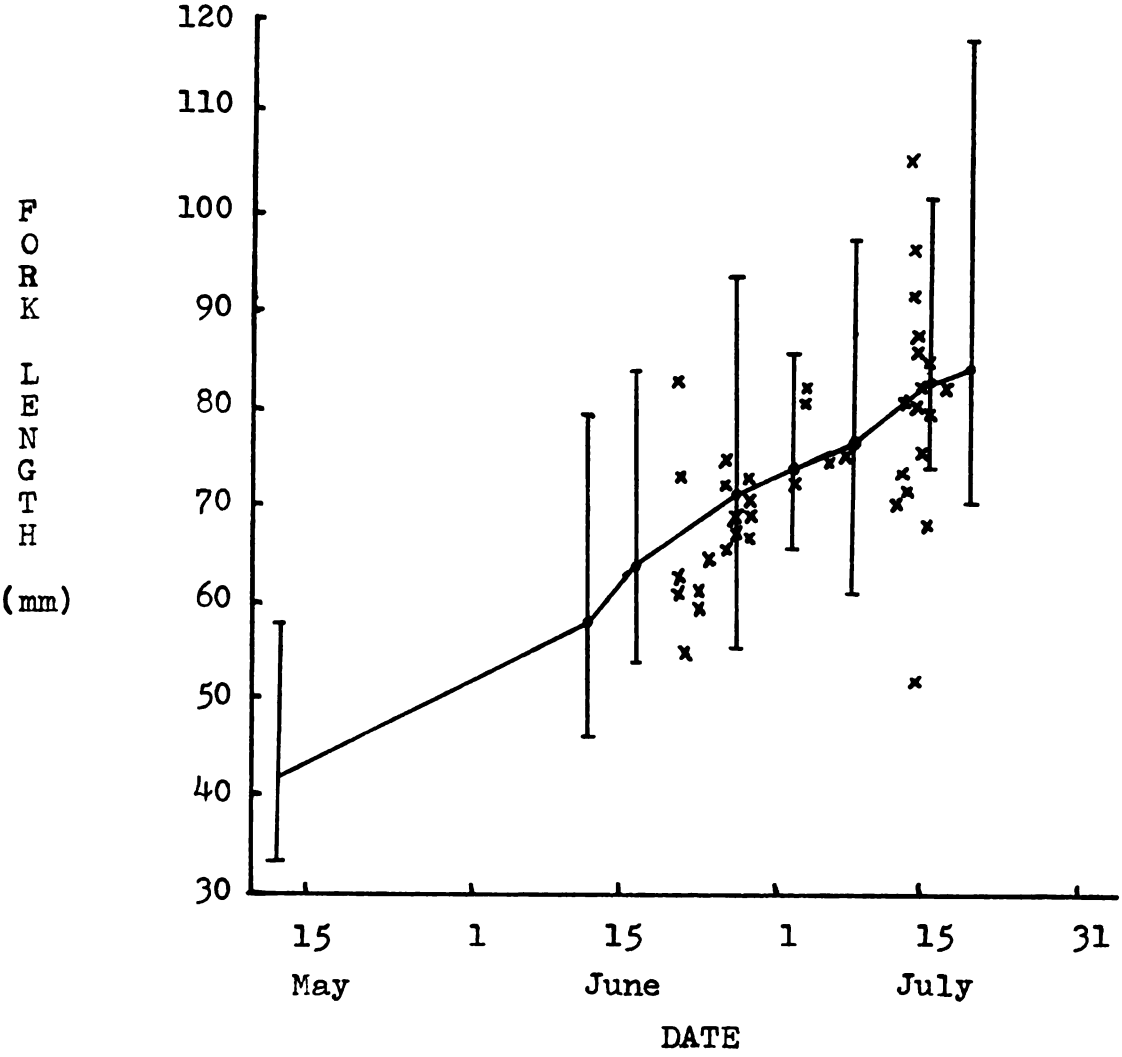


FIGURE 4.--The mean growth rate of the study pond chinook salmon compared to the sizes of the individual emigrants (indicated by x's). The size ranges of the study pond salmon are indicated for each collection.

50 fish that were collected and frozen just prior to the release. The fluctuations in ranges on 18 June and 3 July were probably caused by small sample sizes (Figure 4). The average rate of growth of the salmon during the study period was 18 mm per month.

Emigration

A total of 35 emigrants were collected in the outlet trap and 4 immigrants in the inlet trap. Apparently the 4 immigrants had previously moved upstream and were in the process of emigration at the time of their capture. A comparison of the sizes of the individual emigrants and the average size of the chinook salmon remaining in the pond showed that there was not a relationship between size and emigration (Figure 4).

The possibility of smoltification and aggressive behavior being associated with emigration was also considered. I determined smoltification as the loss of parr marks and increased silveriness. There appeared to be no relationship between smoltification and either emigration or size. Chinook salmon remaining in the pond were as silvery as the emigrants. However, it seemed that the degree of smoltification in the salmon increased from the time the study began until the end of June when it began to decrease.

No characteristic aggressive behavior such as nipping was observed, but the larger chinook salmon occupied dominant positions behind rocks in the water current. The northern redbelly dace and creek chubs occupied the positions farthest downstream.

A minnow trap was placed beside the improvised fyke net, blocking the outlet, in an effort to collect any salmon attempting to re-enter the pond after passing through the outlet, but none were collected.

Junge and Phinney (1963) state that emigration may be blocked by temperature gradients. To determine if a temperature barrier existed below the pond outlet, a thermistor thermometer was used on 24 June to check water temperatures for 300 M south from the outlet until a water depth of 2-3 M was reached. The pond outlet temperature of 16.6 C was traced the entire distance. I concluded that a temperature barrier was not holding the chinook salmon in the pond, and that they could have emigrated as was expected after release.

Population Estimates

To estimate migration and the number of chinook salmon in the study pond, Petersen mark and recapture population estimates (Lagler, 1956) were made on 29 June and 9 July (Table 4). The right pelvic fin was re-clipped for the first population estimate. It had previously been clipped to identify the population, but some regeneration had occurred in nearly all individuals. The fresh clip was easily identified in all the fish marked. However, for the second estimate on 9 July, the "freshness" of the clip was not as

TABLE 4.--<u>Population estimates for chinook salmon, northern redbelly dace and creek chubs in the study pond</u>.

Date	Species	Number Clipped	Number Recaptured/ Total Catch	Population Estimate
29 June	Chinook Salmon	135	21/185	1189
9 July	Chinook Salmon	133*	22/104	630
	Northern Redbelly Dace	215	9/85	1141
	Creek Chub	5	1/39	195

*The 135 chinook salmon marked on 28 June were used, less two known emigrants.

easy to determine and fish that had not been re-clipped on 29 June could have been counted as re-clipped fish. This would have caused an underestimate.

Based on observations and seining success, I would estimate that twice as many chinook salmon were present in the pond at the onset of the study, as there were on the first population estimate on 29 June. Likewise, probably one-tenth of the population of 29 June was present when mortalities were first observed on 20 July.

Mark and recapture estimates of the northern redbelly dace and creek chub populations were made on 9 July with fish marked on 5 July (Table 4). The identifying mark was an anal fin clip.

The relative abundance of different species in the pond was determined by poisoning the pond with rotenone on 16 August. All fish that came to the surface were collected for eight hours after the poison was administered. Few fish were found after that time. The species composition, numbers, and average lengths (total length) are listed in Table 5. Many of the smaller fish became trapped in the submergent vegetation and were not collected as effectively as the larger fish. Because the creek chubs were generally larger than the northern redbelly dace, the population estimate of the former (Table 4) was similar to what was found at poisoning, whereas the latter was not.

TABLE 5.--Number of fish, average total length and length ranges of eleven species of fish collected from the study pond after poisoning with rotenone on 16 August.

Species	Number of Fish	Average Total Length (mm)	Total Length Range (mm)
Northern Redbelly Dace	226	47.7	34-65
Creek Chub	122	60.9	43-120
Brook Stickleback	70	32.2	22-63
Central Mudminnow	4	78.8	75-85
Bowfin	52	153.8	127-184
White Sucker	43	118.2	43-163
Banded Killifish	5	60.4	55-67
Tadpole Madtom	12	66.6	55-82
Northern Pike	7	231.2	222-249
Carp	12	52.3	32-85
Yellow Bullhead	1	81.0	81.0

On 20 July mortalities associated with low dissolved oxygen were observed. Signs of stress had been observed earlier on 16 July. The signs of stress were: darker than normal pigmentation; rapid opercular ventilation; gasping; disorientated swimming at the water surface. No other fish species in the pond demonstrated these signs of stress.

The results of dissolved oxygen measurements made on 16 July and on seven successive days (Table 6) show that low dissolved oxygen levels in the morning increased to saturation or near saturation levels later in the day. The signs of stress were apparent near or below 3 ppm dissolved oxygen. Many mortalities were observed on 20 and 23 July when dissolved oxygen levels were less than 2 ppm. The chinook salmon showed the stress behavior described above, lost equilibrium and sank to the bottom of the pond. Mortalities on both days occurred over the entire pond, so probably many were not observed.

On 23 July when the water was 8% saturated with oxygen, I netted 14 stressed salmon from the pond surface and placed them in a tub of pond water that was aerated to a level of 6.5 ppm (64% saturated at 17.5 C). All but two salmon recovered from their stress symptoms in ten minutes. This indicated that oxygen and not temperature was the lethal factor.

The study was terminated on 26 July when seine hauls indicated the mortality of the salmon was nearly complete.

TABLE 6.--Dissolved oxygen concentrations in the study pond during periods of observed chinook salmon stress.

Date (July)	Time (E.D.S.T.)	Temperature (C)	Dissolved Oxygen (ppm)	Oxygen Saturation (%)
16*	0800	18.0	3.6	38
16	1700	26.0	15.6	150+
17	1815	19.0	5.4	57
18*	0800	20.0	3.0	33
18*	1030	19.6	2.7	28
18	1330	20.0	6.0	65
18	2000	22.7	8.2	94
19*	0730	17.2	2.7	27
19	0930	17.0	3.7	39
19	1900	25.5	12.2	150
20**	0830	18.0	1.8	18
20**	1000	18.2	2.2	24
20**	1100	19.2	2.9	31
20	1200	20.4	3.5	38
21*	1000	18.7	2.9	31
21	1930	22.1	8.6	99
22	0830	19.0	3.2	34
23**	0800	18.0	0.8	8
23**	0930	17.8	2.5	26
23**	1100	18.3	2.3	24
23**	1200	19.0	2.4	26
23	1700	19.7	7.3	78

*Stress observed.

**Stress and mortalities observed.

Discussion

The length of time juvenile salmon remain in tributary streams prior to downstream migration has a significant influence on their survival and return as adults. Extended periods of residence in the tributary streams may result in higher mortalities of the juvenile salmon due to predation, limitations of food and space and adverse environmental conditions, such as wide fluctuations in temperature and dissolved oxygen.

The downstream migration of salmonid juveniles is generally associated with the parr-smolt transformation which results in an active or voluntary emigration (Baggerman, 1960a; Hoar, 1966; Wagner, 1968). Smoltification has been defined by Hoar (1953) as the morphological, biochemical and ethological changes associated with increased endocrine activity and seaward migration. Baggerman (1960a) developed a model of the smoltification process which incorporates both the endocrine system activity and more conventional factors associated with salmonid emigration such as stream flows and water temperatures.

The priming factors of increasing day length and water temperature promote changes in the endocrine balance. Smoltification results when these changes are coordinated with endogenous rhythms. The transformed smolt shows increased activity and increased sensitivity to environmental factors such as water temperature, light intensity, river discharge, and meteorological conditions. These factors in turn serve as releasers for the migratory behavior and orientation of the smolt to its environment (Baggerman, 1960a).

With most anadromous salmonids a threshold size has been associated with smoltification and emigration (Elson, 1957; Reimers and Loeffel, 1967; Bjornn, Craddock and Corely, 1968; Vanstone and Markert, 1968; Wagner, 1968). Thus, the larger individuals tend to emigrate earliest.

Salmonid juveniles of hatchery origin, which are released prior to smoltification, remain as residents in the stream until the transformation takes place (Wagner, 1968). Thus, a premature release of hatchery-reared salmon may contribute to higher mortalities of the juveniles.

Chapman (1962; 1965) and Mason and Chapman (1965) report that aggressive behavior by dominant coho salmon (<u>Oncorhynchus kisutch</u>) juveniles is an important cause of emigration prior to smoltification. They state that dominant coho salmon were the larger and faster growing individuals which occupied territories in riffles or appeared in hierarchies in pools. The density of juvenile coho salmon in the streams was regulated by the aggressive territorial behavior of these dominant individuals. Chapman (1966) feels that competition for a limited amount of food is the basis for the dominant behavior which serves to regulate the distribution of food available to a population. He also states that there appears to be some spatial requirement independent of food supply because some individuals will defend territories even in the presence of an abundance of food.

It is difficult to determine if the chinook salmon emigration from the study pond was voluntary or forced. Certainly the feeding hierarchy in the chinook salmon observed in the study pond could be the basis for forced emigration. As the salmon increased in size, food and space may have become limited. The fact that large as well as small salmon were captured emigrating from the pond (Figure 4) does not contradict the supposition that the emigrations were forced. Chapman (1966) states that the dominant fast growing salmonid may outgrow its territory even though food is more than adequate, and may be forced to move to a more suitable location.

Density-caused dispersion may also be the reason for the migration of chinook salmon into the upstream pond. Chinook salmon planted in the Ocqueoc River near Millersburg, Michigan were observed to move about 2 km upstream to a barrier, in addition to movement downstream after their release (Drummond, *pers. comm.*, 1968).

On the basis of adult scale studies, larger chinook salmon juveniles have been reported to emigrate earlier than the smaller individuals (Gilbert, 1914; Rich, 1922, Mattson, 1962; and Reimers and Loeffel, 1967). This is not confirmed by comparing the size of the study pond chinook salmon emigrants with the size of the individuals remaining in the pond, nor by the idea of forced migration described by Chapman (1962) in which large numbers of smaller salmon would be expected to emigrate first. One possible explanation is that chinook salmon juveniles do not exhibit dominant behavior to the degree coho salmon juveniles do; however, this is not verified by the work of Edmundson, Everest and Chapman (1968) and Reimers (1968).

A more plausable explanation can be made if the authors who state that larger chinook salmon emigrate earlier are referring to active, voluntary emigration, which is associated with smoltification and movement to the ocean. Forced emigration is movement due to unfavorable conditions resulting from the limitations of food and space. If favorable habitat could not be found by the forced emigrants, the evidence given by Chapman (1966) indicates that they would be eliminated by predation. Only those juveniles left in the stream to smoltify and emigrate would survive to maturity. Since smoltification is related to size, the larger individuals remaining in the stream would probably be the first to emigrate, survive and return.

In comparisons of hatchery plantings in California, Cope and Slater (1957) and Warner, Fry and Culver (1961) found that chinook salmon released at a younger age returned at a greater average size, but in fewer numbers than those released as yearlings or near-yearlings. Warner *et al.*

(1961) found no differences in the returns of adult fall or spring run chinook salmon when the juveniles were released as either fingerlings or yearlings. Somewhat similar results were reported by Cope and Slater (1957).

The growth rate (18 mm/month) of the study pond chinook salmon was greater than what Rutter (1904) reported for Sacramento River chinook salmon (10 mm/month) of the same age. The better growth rate of the chinook in the study pond may reflect genetic differences in the two stocks or more favorable environmental conditions. However, Rutter's data were collected from the main stem of the Sacramento River and may have included emigrants from different racial stocks for each sampling period. Variations in the size of different emigrating stocks would introduce considerable variation in the determination of growth rate. The approximate growth rate of 15 mm/month for chinook salmon in the Klaskanine River, a tributary of the Columbia River (Reimers and Loeffel, 1967), was only slightly less than that of the study pond population. To explain differences in growth rates, environmental conditions associated with the growth rates, such as food abundance, water temperatures and dissolved oxygen levels, must be known. In most instances, these conditions are not given in the literature.

Controlling the growth rate of hatchery salmon may be a means of controlling their emigration upon release.

The growth could be regulated so that the fish would reach their threshold size for smoltification at the desired release time. If necessary, artificial photoperiod regulation, as described by Baggerman (1960b), could be used to induce smoltification.

One very important factor in obtaining good adult returns is the imprinting of juveniles to return to their parent stream. Imprinting in salmonids is believed to be most rapid at the time of smoltification (Lichtenheld, 1966). Wagner (1969) indicates that although much stronger imprints occur during the period of smoltification, imprinting is not limited to that time. A possible explanation is provided by Lichtenheld (1966) who found that juvenile steelhead trout desmoltified if not allowed to migrate, but then resmoltified after a period of time. This apparently endogenous cycle took place without the priming factors of increasing photoperiod and temperature. The process of imprinting is believed to be continuous during downstream migration (Lichtenheld, 1966; Wagner, 1969). Stream odors and physical objects are suggested as important parameters used as cues in the imprint process. Wagner (1969) states that adults probably return by following the imprint stimuli in reverse sequence.

Whether salmon are released prior to smoltification and reside, or are a residual population that failed to emigrate as expected, predators, low dissolved oxygen levels and high water temperatures increase their mortalities. All of these factors could be important in the selection of a stream for stocking in Michigan.

A chinook salmon predator study was not made in the study pond. However, it is possible that some of the reduction in population size in the pond can be attributed to predation. The bowfin and northern pike in the study pond (Table 5) suggest this possibility.

Predation on juvenile sockeye slamon (*Oncorhynchus nerka*) is reported by Foerster (1968) to be of great significance in effecting the return of adult sockeye. He cites several studies that give evidence of high rates of predation on both fry and fingerling sockeye. Similarly, Rutter (1904) states that predation on chinook salmon juveniles is high in their early life. The major species reported to be predatory on chinook salmon are the squawfish (*Ptychocheilus oregonense*), Dolly Varden trout (*Salvelinus malma*), yearling steelhead trout, yearling coho salmon, yearling chinook salmon, and sculpin (*Cottus* spp.) (Rutter, 1904; Clemens, 1934; Korn, *et al.*, 1967).

The importance of predation on chinook salmon juveniles in the Great Lakes tributaries can only be speculated. The seasonal distribution and activities of both predators and prey, which is of great importance in determining predation (Foerster, 1968) can be estimated. Chinook salmon planted in streams and rivers would be subject to predation by brown trout (Salmo trutta), yearling steelhead trout, yearling coho salmon, yearling chinook salmon, northern pike, smallmouth bass (Micropterus dolomieui), and walleye (Stizostedion vitreum). Salmon fingerling stocked in lakes, bays, or reservoirs would be subject to predation by bowfin, crappie (Pomoxis spp.), largemouth bass (Micropterus salmoides), smallmouth bass, northern pike, yellow perch (Perca flavescens), and walleye.

Several factors are mentioned in the literature as important in the reduction of predation. These factors are: predator removal (Foerster and Ricker, 1941); increasing the size of the planting or migration (Neave, 1953; Hunter, 1959); increasing the size of the individual migrant salmon (Foerster, 1954; Burrows, 1963); removal of temperature barriers (Junge and Phinney, 1963; Mihursky and Kennedy, 1967); reduction of the water temperature (Moffett, 1949; Thompson, 1959), which would place the migrant in an activity range that is optimum with respect to reduced activity of the predator (Burrows, 1963).

The fate of the chinook salmon that emigrated prior to the study is not known. Several facts do give evidence for a potentially large loss due to predation: the chinook salmon had a small average size at release; they were released into a shallow impoundment containing many predators; and they were planted about three weeks after the release of

100,000 coho salmon yearlings below the impoundment outlet.

The residual chinook salmon in the study pond suffered mortalities due to low dissolved oxygen. Comparisons of Figures 2 and 3 and Table 6 show that temperatures in the pond increased as flows and early morning oxygen concentrations decreased in mid-July leading to the mortalities of the salmon.

Slower, quieter waters are reported by Hutchinson (1957) to be prone to oxygen deficit in the summer months if they are productive of algae or aquatic plants. Nocturnal respiration of the plants causes the greatest deficit in the early morning. A slight deficit was noticeable in the diurnal dissolved oxygen cycles (Table 1). Because the pond above the study area on Fletcher Creek (Figure 1) had dense aquatic vegetation, and because the pond discharge was low, nocturnal respiration of the aquatic vegetation was the most probable cause of the low dissolved oxygen concentrations. The situation was compounded by high water temperatures which are inversely related to dissolved oxygen concentrations at saturation (Hutchinson, 1957), and by a biological oxygen demand caused by increased flow of particulate matter in the water resulting from ducks feeding in the creek.

Chapman (1939) subjected juvenile chinook salmon to low dissolved oxygen concentrations in closed containers and found that levels of 2.66 ppm (25% saturated - 13.5 C) distressed most individuals and produced considerable mortality. This is very close to the approximate 30% saturation and 3 ppm level I observed to initiate stress symptoms in chinook salmon juveniles. Chapman also found the fish to exhibit considerable individual variation in their susceptibility to low dissolved oxygen levels. The individual salmon I found alive in the pond after the two days of observed mortalities exhibited individual variation that allowed them to survive normally lethal levels. Similar individual variation is described by Fry (1957).

The sublethal effects of low dissolved oxygen are also quite important. In work with coho salmon, Davidson _et_ _al_. (1959) found that 90% of the salmon fed restricted diets survived 2.0 ppm dissolved oxygen (20% saturated at 18 C) for 30 days, but suffered a 6.7% loss in weight. At 2.9 ppm (30% saturated at 18 C) and at 9.0 ppm (95% saturated at 18 C) dissolved oxygen, the salmon suffered no mortalities and gained 28.1% and 42.0% in weight respectively. In another study, reduction of dissolved oxygen levels below saturation was accompanied by a similar reduction in growth when coho salmon were fed unrestricted rations (Herrmann, Warren, and Doudoroff, 1962). The apparent reason is that the more food a fish consumes, the more oxygen it requires because of the energy required by assimilation (Doudoroff and Shumway, 1967).

Salmon will avoid low dissolved oxygen concentrations. Whitmore, Warren, and Doudoroff (1960) found chinook salmon juveniles to show marked avoidance of low dissolved oxygen, especially at higher temperatures. When the temperature was 22.8 C, they would avoid oxygen levels of 4.5 ppm (52% saturated), but not 6.0 ppm (68% saturated). At 12.3 C, oxygen levels of 4.5 ppm (42% saturated) were not avoided. These data indicate the absolute oxygen concentration is more important for respiration than the percentage saturation. This position is held by Fry (1957).

Beamish (1964) found that the rate oxygen was consumed in brook trout (*Salvelinus fontinalis*) and brown trout increased with the temperature of water, indicating that a temperature increase not only reduces the amount of oxygen that can be saturated in water, but it also increases the demand the fish has for oxygen by increased metabolism and maintenance requirements.

It is difficult to evaluate the effects that high water temperatures (or fluctuating temperatures as well) had on the mortality of the chinook salmon in the study pond. Temperatures at times that stress or mortalities were observed were below 20 C (Table 6), well below the ultimate lethal limit Brett (1952) set for Pacific salmon juveniles at 25.1 C. Temperatures near or above this lethal limit were recorded on six days in mid-July (Figure 2) with no observed mortalities. A plausable explanation can be made from Breder's (1927) experiment with brook trout. He found that high temperatures caused little stress when large amounts of oxygen were present. High water temperatures in the study pond were accompanied by high levels of dissolved oxygen (Table 6). The time of day when most photosynthesis in aquatic vegetation occurred would probably be during the period of highest water temperature. This situation would create high levels of dissolved oxygen in the pond, especially since the water flow was low (Figure 3).

The temperature range for maximum productivity of salmon fingerlings is given by Burrows (1963) as 10.00 C to 15.55 C. Not only is it the preferred range, but temperatures above or below it are conducive to the development of disease in both young and adult salmon. In chinook salmon juveniles, food consumption, which is a determinant of growth, increases 60% for every 5.5 C raise in temperature from 4.5 C to 15.5 C (Burrows, 1963). Because the oxygen demand of a fish increases with increasing food consumption (Herrmann _et al._, 1963), a temperature increase causes a two-part oxygen demand. One part is caused by increased body maintenance requirements (Beamish, 1964), and the other part by increased assimilation requirements.

The effect that both temperature and dissolved oxygen have on growth and survival of a fish depends on factors such as species differences, physiological state, acclimation, synergisms with pollutants and water chemistry (Mihursky and Kennedy, 1967; Doudoroff and Shumway, 1967). Consequently, control of environmental conditions whenever possible can greatly increase production of salmonids (Burrows and Combs, 1968).

FOOD HABITS

Wagner (1968) states that fish released prior to parr-smolt transformation may not smoltify if the environment has a reduced food supply. A study was made to determine the food habits and possible feeding selectivity of residual chinook salmon in the study pond. The residual chinook salmon specimens collected and preserved for the growth studies (Table 3) were also used for the stomach analysis. In addition, 29 northern redbelly dace, (33-55 mm total length), 9 creek chubs, (45-82 mm total length), and 7 brook stickleback, (38-56 mm total length), collected and preserved with the salmon on the sampling dates listed in Table 3, were used to determine possible competition with the salmon for food items in the study pond.

Analysis of Stomach Contents and Drift Organisms

The stomachs from the esophagus to the gut were dissected from each fish, and the contents were enumerated according to taxonomic groups. Only those organisms in a somewhat whole condition were included in the enumeration. I arbitrarily determined "somewhat whole condition" as: cladocerans, copepods, and ostracods which contained body contents in addition to a recognizable exoskeleton; midge larvae, pupae and adults with body contents and two body regions still intact; and all identifiable collembolans and tubificid worms. I believe that some of the bias caused by slow digesting food organisms (Lagler, 1956) was eliminated using this procedure. The percentage composition of the total combined stomach contents for each sampling period was calculated for the salmon.

Only 8 of the 121 stomachs examined were empty or near empty, indicating that the food supply was abundant. Cladocerans, midge larvae and midge pupae were the major food items consumed by the salmon for most sampling periods (Table 7). All other food items were consumed in much smaller numbers.

Feeding selectivity was determined by comparing the abundance of specific food organisms in the salmon's diet with the abundance of these organisms in the environment. Drift organism samples collected with a Wisconsin plankton net at the inlet of the pond were used for the comparisons. The mouth of the net was held for two minutes in the fast current with three-fourths of the net opening under the water, and one-fourth above the surface. A two minute sample was considered sufficient to get a representative sample. The samples were preserved in 70% ethyl alcohol.

The drift organisms collected were analyzed in the same manner as the stomach contents. The relative selectivity of chinook salmon for each food item was calculated according to the method described by Inlev (1961). The electivity index equation is

$$E = \frac{r_i - p_i}{r_i + p_i}$$

TABLE 7.--The mean numbers of eight food organisms consumed per fish for six sampling periods, and the percentage of each food organism in the total diet.

Food Organism	Percentage of Diet	Mean Number of Each Organism Consumed per Fish					
		Sampling Date					
		12 June	18 June	28 June	2 July	9 July	16 July
Cladocerans	54.6	4.6	4.9	9.8	24.3	43.5	13.2
Copepods	2.2	0.2	0.1	3.6	0.1	0.0	0.7
Midge Larvae	19.4	7.5	4.0	10.4	6.9	4.9	9.0
Midge Pupae	18.7	6.8	0.9	7.1	1.3	8.0	21.9
Midge Adults	1.3	0.3	0.4	0.8	0.1	0.1	2.3
Tubificids	0.3	0.3	0.0	0.1	0.0	0.0	0.0
Collembolans	1.9	0.1	1.0	0.7	0.0	0.1	0.2
Ostracods	0.9	0.7	0.5	0.2	0.0	0.1	0.0

where r_i is the percentage of a food item in the fish ration, and p_i is the percentage of the same item in the environment. An index of +1 indicates positive selection and -1 negative selection for the food item. The corresponding stomach content and drift organism sample used for the electivity calculations are listed in Table 8.

Selectivity

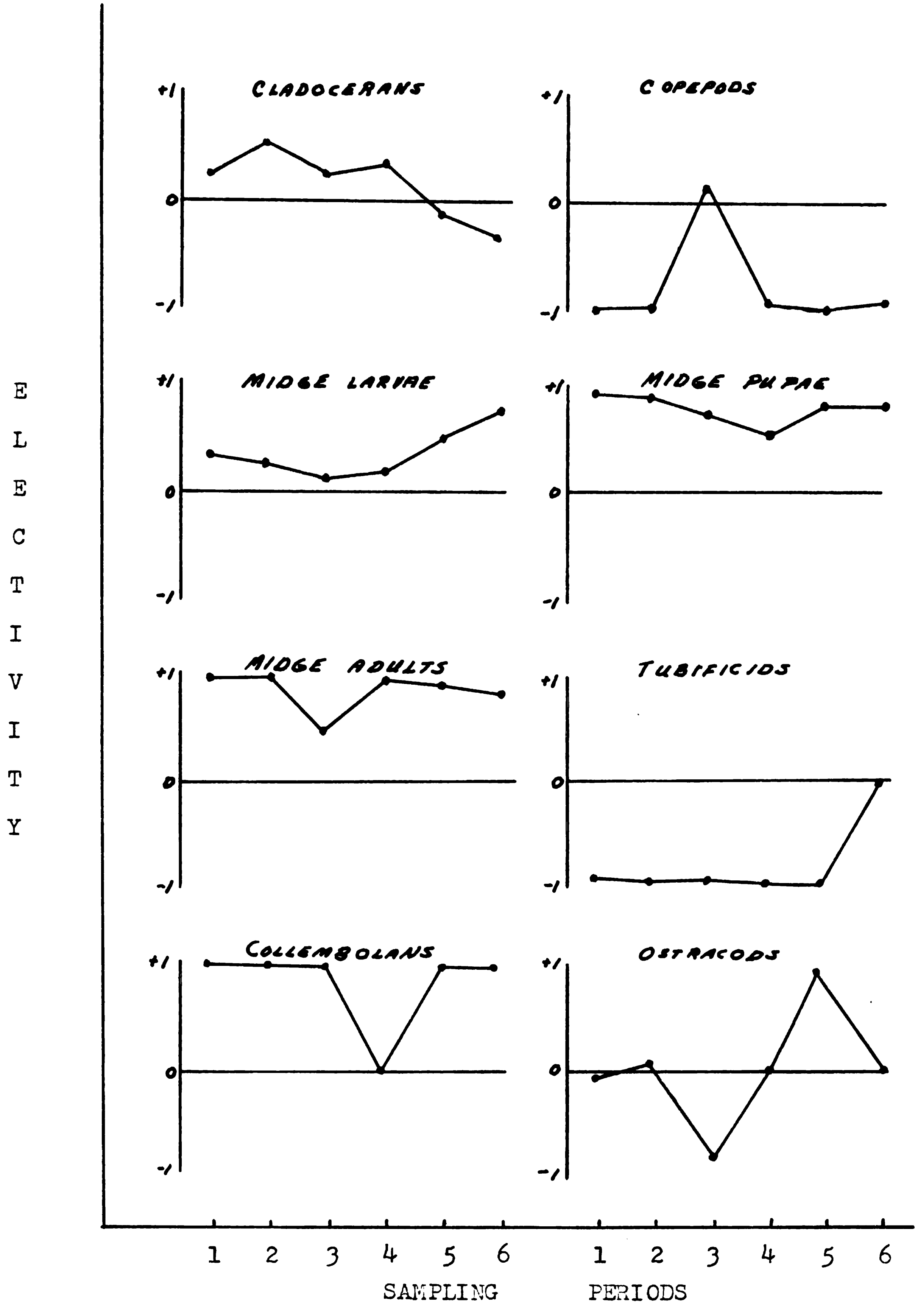
A comparison of the percentage composition of stomach contents and drift samples for six different sampling periods indicates selectivity for and against food items as well as a change in preference with time (Figure 5).

Although the feeding activity of the chinook salmon was observed to be primarily restricted to floating or drifting objects near the upper reaches of the pond, their food habits probably changed throughout the day, depending on any cycles of food abundance in the study pond. On quiet evenings the chinook salmon were distributed throughout the pond and apparently fed at the surface on adult midge and other flying insects. Changes in feeding behavior, and in drift organism abundance throughout the day, would bias the interpretation of the electivity index. Therefore, the results of this study apply only to the time of day the samples were collected.

TABLE 8.--Dates and times of chinook salmon stomach sample and drift organism sample comparisons.

Comparison	Stomach Sample		Drift Sample	
	Date	Time	Date	Time
1	12 June	1500	14 June	1300
2	18 June	1430	14 June	1300
3	28 June	0900	26 June	0800
4	3 July	1445	2 July	0800
5	9 July	1300	9 July	0800
6	16 July	1300	16 July	0800

FIGURE 5.--Electivity indices for eight food items consumed by 78 juvenile chinook salmon collected on sampling periods 1 (12 June), 2 (18 June), 3 (28 June), 4 (2 July), 5 (9 July) and 6 (16 July).


ELECTIVITY
CLADOCERANS
COPEPODS
MIDGE LARVAE
MIDGE PUPAE
MIDGE ADULTS
TUBIFICIDS
COLLEMBOLANS
OSTRACODS
+1
0
-1
1 2 3 4 5 6
1 2 3 4 5 6
SAMPLING PERIODS

Piscivorous Feeding

The termination of the study in July limited collection of larger individuals to nine chinook salmon (mean = 94 mm). Some of them were collected, prior to the cessation of flow over the weir, on 15 and 16 July, and others showing stress symptoms were collected on 20 July. Several stomachs were nearly empty. Examination showed: 11.1% cladocerans, 11.8% midge larvae, 55.3% midge pupae, 5.2% midge adults, 4.8% brook stickleback (under 22 mm total length), and 9.4% miscellaneous insects. One individual contained seven partially digested stickleback juveniles. Even though small forage fish were often observed in the pond, no other incidents of piscivorous feeding were found.

Competition

The major forage fish species in the study pond, including northern redbelly dace, creek chubs, and brook stickleback, were abundant (Table 4; Table 5) and undoubtedly did compete with the chinook salmon for food. The stomachs of the chubs and dace contained small quantities of cladocerans, copepod, and midge pupae. The stickleback stomachs contained the same food items in larger amounts than the dace or chubs, but in much smaller quantity than the chinook salmon.

Discussion

The availability of sufficient food to sustain juvenile salmon for an extended period is a necessary consideration for the introduction of salmonids to a new area (Chapman and Quistorff, 1938). Growth rate, which is a reflection of food supply (Burrows, 1963; Chapman, 1965), has previously been shown to be an important factor in determining survival of salmonid juveniles.

Shapovalov and Taft (1954) state that the food of young salmonids of a given species depends on the locality, time of year, size of fish, and relative abundance of food items. However, consideration must also be given to food preference by the species.

The feeding behavior I observed in the chinook salmon was similar to that described by Rutter (1904). Their behavior indicated they were sight feeders that showed preference for certain food items. The same feeding behavior was described by Ricker (1937) for juvenile sockeye salmon and by Shapovalov and Taft (1954) for juvenile steelhead trout and coho salmon. The fact that chinook salmon juveniles show preference for certain food items is demonstrated by the application of Inlev's (1961) index for electivity to my study pond data.

Cladocerans, 54.6% of the total food items, tended to decline in preference with increasing age and size of the chinook salmon juveniles. A high negative preference was found for copepods (2.2% of the total diet), possibly because they were generally much smaller than the cladocerans. Similar to the findings of Galbraith (1967) for rainbow trout and yellow perch, the chinook salmon appeared to feed selectively on the larger cladocerans and copepods.

Midge larvae (19.7% of the total diet) increased in preference through the sampling periods, but midge pupae (18.7% of the total diet) remained in steady preference. The high degree of selection for midge adults and collembolans is insignificant because they were only 1.3% and 1.9%, respectively, of the chinook salmon diet. Ostracods were only 0.9% of the total diet, and appeared to be eaten only incidentally. The highly negative preference for tubificids (0.3% of the total diet) is difficult to explain since they were of the same general size as the midge larvae. Although unlikely, it is possible that the tubificids were digested much faster than other food items. Other soft bodied food items in the diet were often found in excellent condition.

Food preference by chinook salmon in a bonafide stream situation in Michigan could possibly differ from what was found in the study pond. I examined the stomach contents of 22 chinook juveniles (mean = 79.3 mm) obtained from Robert Drummond (District Fish Biologist, Michigan Department of Natural Resources) which were collected on 30 and 31 May, 1968 from the Ocqueoc River north of Rogers City, Michigan. The contents by enumeration were: 68.8%

cladocerans, 21.9% midge adults, 7.9% copepods, 1.2% midge pupae, and 12.0% Ephemeroptera naiads. Seven of the fish contained all of the cladocerans, indicating they either had a high individual preference for cladocerans, or they had been located in the environment where these food items were in abundance. I observed similar "individual preference" in the salmon from the study pond.

Several studies of juvenile chinook salmon food habits have been made by biologists on the Pacific Coast, but they list only the organisms found in the stomach samples, and not what was available in the environment. Rutter (1904) summarized the stomach contents of the 198 specimens (mean = 75 mm) he collected in all months of the year as: 32.0% larval insects, 43.2% naiad or pupal insects, 15.2% flying insects, 1.6% terrestrial insects and 8.0% crustaceans by number. Three fish had eated 98% of all crustaceans found. The main food items were from the orders Coleoptera, Diptera, Ephemeroptera, Hymenoptera and Plecoptera. In a sample of 20 juvenile chinook salmon (mean = 67 mm) from brackish water he found that amphipods, copepods and adult insects were 2.5%, 74.0% and 23.4% by number, respectively. Only one fish had been eaten.

In examining stomach contents of immature chinook salmon from Alaskan rivers, Chamberlain (1907) found that the food was almost wholly insects from the water surface, with amphipods being eaten occasionally by larger chinook salmon in estuaries. Clemens (1934) examined the stomach contents of 64 chinook salmon juveniles (under 83 mm standard length) from Shuswap Lake, British Columbia and reported that in addition to terrestrial insects and Tendipedidae larvae, pupae and adults, large numbers of cladocerans and copepods were eaten. Chapman and Quistorff (1938) found that chinook salmon collected in the north central Columbia River drainage lived almost entirely on insects. The most abundant insects were: Diptera larvae, beetle larvae, stonefly nymphs and leaf hoppers in the 301 chinook salmon (44-152 mm standard length) examined. Heg (1952) lists the contents of 60 chinook salmon fingerlings collected in the Duwamish River estuary from May through July (no age or size given) as: 43% Diptera larvae, pupae and adults; 32% marine crustaceans; 20% terrestrial insects; 3% mayfly and stonefly larvae; and 1% freshwater crustaceans by number.

The food habits of chinook salmon juveniles from Pacific Coast rivers differ somewhat from what Clemens (1934) reported for chinook salmon from a lake environment, or from what I found from the study pond salmon, in that the former contained few crustaceans. The difference is probably explained by the fact that cladocerans and copepods normally do not inhabit streams (Pennak, 1953). I did find large numbers of cladocerans and copepods in the stomachs of some chinook salmon collected from the Ocqueoc River, but there is a lake on the river that may have been the source of the crustaceans.

The food habits of juvenile coho salmon, sockeye salmon and steelhead trout in a stream environment are very similar to those of the chinook salmon in a stream environment (Chapman and Quistorff, 1938; Shapovalov and Taft, 1954). Similarly, juvenile sockeye salmon and young rainbow trout in lake environments feed heavily on cladocerans and copepods (Ricker, 1937; Galbraith, 1967). The food items preferred by juvenile chinook salmon in the Great Lakes environments would probably not differ from the food items preferred in Pacific Coast environments.

Few authors have reported separately the food habits of the larger juvenile chinook salmon over 90 mm. Rutter (1904) found yearling (residual) chinook salmon to prey on alevin or sac fry chinook salmon, and Korn _et_ _all_, (1967) found them to prey on other salmonid fry.

Although small immature forage fish were present in the study pond in June and July, and even on occasion were collected in drift samples, only the larger salmon juveniles were found to prey on them. I did not find any reference in the literature to piscivorous food habits in small chinook salmon (under yearlings) other than the one instance reported by Rutter (1904). This implies that, until juvenile chinook salmon reach a large size (over 85 mm) they are in direct competition with forage fish species for food.

The food habits of the northern redbelly dace, creek chubs and brook stickleback were similar to those of the chinook salmon. The threespine stickleback (Gasterosteus aculeatus) is reported to be a major competitor of young sockeye salmon in some lake systems (Foerster, 1968). Conceivably the brook stickleback could be a major competitor with residual chinook salmon in a reservoir or pond. However, the chinook salmon generally occupied the upper end of the pond over the gravel bottom, and the stickleback occupied weeded areas in the lower end of the pond which probably eliminated direct competition.

The northern redbelly dace and creek chubs occupied some of the same areas of the pond as the chinook salmon, but I observed size dominance to play a major role in selecting feeding sites. The salmon appeared to be dominant in selecting feeding sites which probably eliminated some competition for food.

The presence of adult alewife (Alosa pseudoharengus) in large numbers on spawning runs to the river mouths and bays in the spring months (Odell, 1934; Brooks and Dodson, 1965; Wagner pers. comm., 1969) presents the threat of serious competition for food with migrating juvenile chinook salmon in the Great Lakes. Wagner (pers. comm., 1969) reports that the alewife in Little Bay de Noc fed during the entire period they were in the bay. He listed the main food items as cladocerans and copepods. Brooks and Dodson (1965) and Smith (1968) have cited evidence that alewife are dominant in competition with other fish for the larger plankton.

The present practice of planting fall run chinook salmon in the spring places the juvenile chinook salmon, at a size where they feed on plankton, in a location where competition for food is great. Korn _et_ _al_. (1967) in a study of salmonid migratory behavior in small impoundments, found the salmon tended to cease migration once they reached the quieter water of the reservoir. Based on this information, I think that juvenile chinook salmon will reside temporarily in river mouths and bays after downstream migration to these areas. Young salmon in the ocean do feed in bays and along shores during their first summer (Hoar, 1953). If the chinook salmon juveniles were of a large enough size to have piscivorous feeding habits, some competition might be avoided.

Wagner (_pers_. _comm_., 1969) reported that the alewife in Little Bay de Noc spawn in late June and larval alewife should be present by the first of July. Perhaps by planting larger chinook salmon at this time, greater returns of larger individuals could be obtained. The interaction of alewife and chinook salmon should be investigated.

SUMMARY AND
RECOMMENDATIONS FOR MANAGEMENT

I could find little conclusive evidence of any pattern in chinook salmon migration from the study pond. The 39 migrants collected at the pond exit were similar in size to the chinook salmon remaining in the pond. Evidence of smoltification (loss of parr marks and increased silveriness) was present in the migrants, but to no greater extent than in most individuals in the study pond. There were individual differences in the degree of smoltification, but I did not observe a size relationship.

I do believe that much of the migration was forced migration due to lack of suitable habitat for a large number of salmon. This would explain the lack of any size or smoltification relationship in the migrants. Emigration probably occurred continuously during the study period.

The growth rate of the chinook salmon appeared as good or better than that reported for Pacific Coast chinook salmon. Explanations are difficult because of the many factors that affect growth. Dissolved oxygen, water temperature and available food are reported to be the most important factors influencing growth. The importance of growth or more precisely, size, on survival and return of the chinook salmon can not be over-emphasized. Larger salmonid juveniles smoltify and emigrate faster, compete better and are preyed upon less than smaller juveniles. Control of smoltification may be possible through controlled growth and photoperiod regulation.

The results of the food studies indicate that the study pond chinook salmon positively selected cladocerans and midge larvae, pupae and adults as their main food items. Competition for food between the salmon and forage fish species in the pond did occur, but I believe it was limited by the dominant behavior the chinook salmon displayed in the selection of feeding sites. Food was apparently abundant and should not have interfered with smoltification.

Although it was not studied, competition between alewife and juvenile chinook salmon in the Great Lakes could limit the success of the introduction because of their similar food habits and presence in the same areas in the spring.

The larger chinook salmon I examined exhibited piscivorous feeding habits to some degree. Because of this, the possibility of coordinating the planting of larger chinook salmon with the hatching of young alewife should be investigated.

Another possibility for sport fishing management in the Alpena area is to plant spring run chinook salmon. Because there is probably a temperature and physical barrier to upstream migration, the adults returning in the spring may delay in the deeper parts of Thunder Bay and be exposed to the sport fishery throughout the summer.

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