FEEDING HABITS OF DOLLY VARDEN CHAR (SALVELINUS MALMA) AT AFOGNAK LAKE, ALASKA

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ABSTRACT

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Stomach contents of 513 Dolly Varden, collected from three different habitats, during the months of May, June and July, 1963, were examined to determine their feeding habits and the extent of their predation on salmon of the Afognak system. Of the 513 Dolly Varden, 261 (50.9 percent) contained food. Analysis of stomach contents, on the basis of percent frequency of occurrence and percent total volume, showed that insects were the most frequently occurring food item (75.0 percent), but that snails, the second most frequent food item, were highest in percent total volume. Analysis of feeding habits on the basis of size showed that Dolly Varden, larger than 30.0 centimeters (fork length), consumed large quantities of insects while the smaller char utilized snails. A relationship between the size of Dolly Varden and the size of Tricoptera utilized was established.

Fish materials consumed by char were carrion (salmon flesh and eggs), salmonids and sticklebacks. Predation on salmonids was highest in the Afognak River where 4 pink salmon fry were consumed by 3 char. In Afognak Lake,

3 unidentifiable salmonids and 13 sticklebacks were eaten by Dolly Varden. It seems unlikely that the Dolly Varden is a serious predator upon the salmon in the Afognak system.

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By

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INTRODUCTION

The environments encountered by an anadromous fish such as the red salmon (Onchorhynchus nerka) are extemely varied. Its life begins and ends in fresh water with the interim spent in salt water. Each of these environments contains numerous factors which act upon the species in various ways and affect its abundance. Thompson (1962) states that the final abundance on the spawning grounds is the net result of the controlling factors that have preceded.

Because of the period of life spent in salt water, it has been difficult to study the biology of the salmon in its entirety. The alternative condition exists which is to study that part of the life history which is most accessible to investigation--the fresh water phase of development. It is the general belief that the fresh water stage is the period during which the major mortalities occur and the studies at this time and place of their impact are of primary importance (Thompson, op. cit.). The fact that major mortalities occur in this environment is supported by Barnaby (1944), at Karluk Lake, who estimated the mortality between egg and seaward migration to be 99.5 percent as compared to an estimated salt water mortality of 78.5 percent.

Foerster (1938), at Cultus Lake, British Columbia, estimated the lake mortality of fry to be 96.0 percent.

Factors which limit the fresh water survival of salmon take on many forms. During the spawning season many previously deposited eggs are destroyed by later spawners preparing their redds. These eggs and any others that are washed downstream, are usually consumed by other fishes such as sculpin and char. Hubbs (1940) notes that there is little chance that any eggs not buried in the gravel would survive. Other losses are due to unfavorable meteorological, chemical and physical conditions, plus attack from disease organisms. To these, Brett and McConnell (1950) added emergence from the gravel and migration to the nursery lake. After the young salmon have reached the nursery lake they are still subjected to many of the same limiting factors plus the addition of predation and competition for food.

Competition

Inter- and intraspecific competition for food occur in salmon populations. Nelson (1959), in Bare Lake, Alaska, found the three-spined stickleback to be a direct competitor of the juvenile red salmon. At Cultus Lake, British Columbia, Ricker (1937) noted that other fish are known to be competitors but considered interspecific competition to be of minor importance. On the other hand, he felt that the intraspecific competition during years of large populations was sufficient to reduce growth.

Predation

Predation has long been considered one of the most important factors depleting the juvenile salmon stock. Observations made by Foerster (1938), at Cultus Lake, British Columbia, indicated that a large fraction of sockeye mortality was due to predation and that the heaviest predation occurred just prior to and at the time of seaward migration. Foerster and Ricker (1941) proved that by controlling the numbers of predatory fishes in Cultus Lake, squawfish (Ptychocheilus oregonensis), Cutthroat trout (Salmo clarki), Dolly Varden char (Salvelinus malma), and coho salmon (Onchorhynchus kisutch), the mean survival rate of juvenile sockeye salmon increased three and one-third times. Ricker (1941) commented that the number of juvenile sockeye occurring in Dolly Varden stomachs ranged as high as 93 with 10 or 12 as an average. Of the other predators cutthroat trout, more numerous than the char, averaged 10 to 15 sockeye per stomach and the coho contained on an average more sockeye than the trout. In rank of predation, although it did consume numerous sockeye, the squawfish was rated lowest. Ricker concluded that on an overall basis the cutthroat trout was the most important consumer of sockeye at all times of the year and that the coho was the most consistent consumer. Although Dolly Varden predation lessened during the summer months, they were still considered one of the primary predators.

In considering all of the possible predators of juvenile salmon, the Dolly Varden char is probably the most often mentioned. Hubbs (1940) states that it is extremely doubtful that any or all of the other predators of salmon are as harmful as the Dolly Varden. In his analysis of Dolly Varden predation Hubbs suggests that they also serve a beneficial role by preying upon other fish which either compete directly for food or are predators of the salmon. Morton and DeLacy (1943) concluded from their studies at Karluk Lake, Alaska, that the predatory nature of the Dolly Varden toward salmon has often been overstated.

In a food study of Dolly Varden at Chignik, Alaska, Roos (1959) found that 9.0 percent of the feeding char contained sockeye. He considered insects to be the major food item, on the basis of percentage occurrence, with sockeye serving a minor role in the diet. The conclusion drawn from the study was that the Dolly Varden is not a serious predator of the sockeye in that system. In a later study of the same system, Roos (1960) found that juvenile coho salmon were serious predators and that their degree of predation was seven times greater than that of Dolly Varden.

Krogius and Krokhin (Roos, 1959, page 254), U.S.S.R. biologists at Lake Dalnee (Kamchatka), found that char were feeding more on sticklebacks than on young sockeye. Because of their competition for food with the young sockeye, the removal of sticklebacks was considered beneficial. On the

Bolshaya River (Kamchatka), Semko (Roos, 1959, page 254) considered the char to be the primary predator of sockeye fry.

Predation by Dolly Varden on sockeye and other salmon has also been reported by other authors: Hartman, Strickland and Hoopes (1962) at Brooks Lake, Alaska; Nelson (1959) Bare Lake, Alaska; Hunter (1959) at Hooknose Creek, British Columbia; Pritchard (1936) in a study at McClinton Creek, Masset Inlet, British Columbia. Studies and observations on estuarine predation by Dolly Varden have been reported by Lagler and Wright (1962); Noerenberg, Roys, Hoffman, Wright and Davis (1964); and Armstrong (1965). All of these authors express opinions on the predatory habits of the Dolly Varden. These opinions vary as much as the systems studied and their associated ecological conditions; the Dolly Varden are reported as being voracious predators in one system and of no consequence as predators in another. The variability that exists in these and the aforementioned reports illustrates the need for thorough investigation of the Dolly Varden in each drainage before valid evaluation can be made of their effect upon young salmon. Lagler (1944) emphasizes this point by stating that the predator problem is largely individual for each system.

As reported by Sheridan, Meehan and Revet (1961), Afognak Lake, Alaska, has a varied history of sockeye salmon production. On the basis of their findings, these

investigators felt that this system could support more sockeye than it does.

During the spring and summer of 1963, the Biological Research Division of the Alaska Department of Fish and Game instituted a study of the life history of the sockeye salmon in the Afognak system. The results of that study are presented by Roelofs (1964). Included in the overall program was the investigation of Dolly Varden feeding habits with reference to predation, which is reported here.

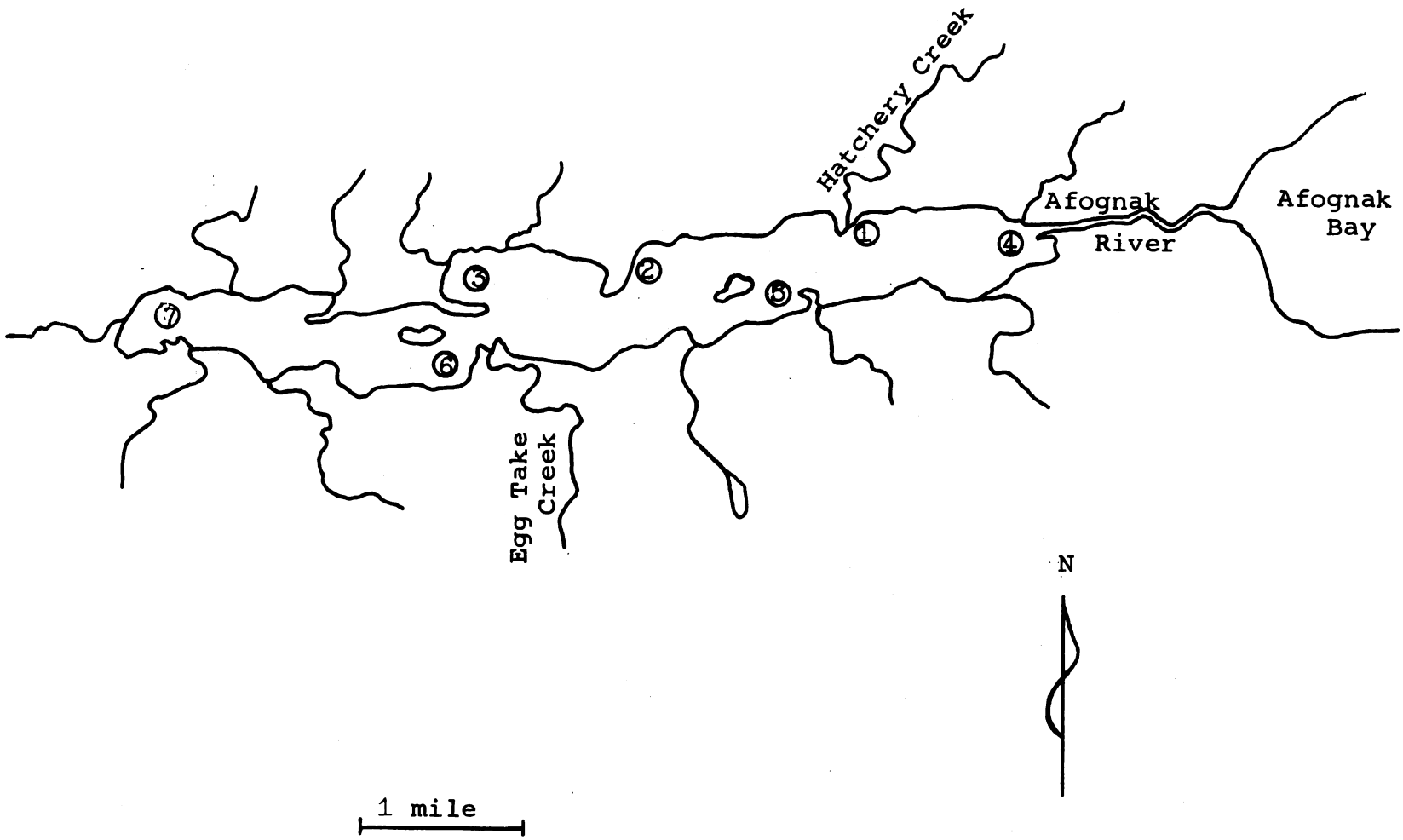
DESCRIPTION OF THE STUDY AREA

Afognak Lake is located on the southwestern end of Afognak Island, Alaska, latitude 58° 07' North and longitude 152° 55' West. The lake is 5.7 miles long and 0.5 miles wide at its widest point. Two small islands divide the lake into approximately three equal portions (Figure 1). The lake has approximately 1300 surface acres of water and a maximum depth of 22 meters. The lake stratifies thermally for a period between May and September.

Numerous tributaries are present in this system and all are utilized to some extent by spawning salmon. Of these streams only two receive the major portion of the sockeye spawning runs, Hatchery and Egg Take Creeks. During the summer of 1963, Egg Take Creek became inaccessible to salmon because of low water conditions which persisted for the major portion of the spawning season. It is not known if this is a frequently occurring condition or if the summer of 1963 was an exception to a normal hydrologic cycle. Hatchery Creek also sustained a reduced stream flow but the effect did not seriously impair the movement of sockeye into that stream.

Drainage from Afognak Lake and its tributaries passes through the Afognak River which is located at the East end

Figure 1. Afognak Lake with its tributaries and outlet streams, indicating sampling stations.


Hatchery Creek
Afognak River
Afognak Bay
1
2
3
4
5
6
7
Egg Take Creek
N
1 mile

of the lake. This stream is 1.5 miles long and has a relatively straight course to salt water. The reduced amount of precipitation in 1963 also affected the flow of the Afognak River. It was noted that the major portion of the immigrating sockeye had entered the lake before the stream flow had reached its lowest point.

Benthic materials in the lake range from silt and detritus to sand, gravel and rocks. Higher aquatic plants are limited to shallow protected coves. Tributaries to the lake contain a variety of benthic materials but predominantly gravel and rocks. Conditions in Afognak River are much the same as the tributaries. Higher aquatic plants are lacking in these streams.

A rather detailed limnological analysis of this system, including a survey of aquatic invertebrates, is presented by Sheridan, Meehan and Revet (1961).

Salmon present in the Afognak system are: pink salmon (Onchorhynchus gorbuscha), that utilize mainly the lower portion of the Afognak River; the silver salmon (Onchorhynchus kisutch), which is found throughout the system; and sockeye salmon (Onchorhynchus nerka), that utilize primarily the lake and its tributaries. Other fishes are the Steelhead (rainbow) (Salmo gairdneri) and Dolly Varden char (Salvelinus malma) which are found throughout the system. The three-spined stickleback (Gasterosteus aculeatus) is found predominantly

in the lake whereas the fresh water sculpin (Cottus aleuticus) inhabits the outlet stream exclusively. It is possible that other species may inhabit or utilize this system.

METHODOLOGY

River Sampling

Because the current and obstructions in the river precluded other available sampling methods, emigrating char were collected by hook and line. Samples were collected during May, 1963, until the emigration was completed on May 31, 1963. The fish were taken to the laboratory facilities for recording of data and analysis of stomach contents. During July, August and September samples of the immigrating char were also collected by hook and line, but because of the low incidence of food in the stomachs, the entire investigation of feeding habits of these fish was conducted at the time of sampling.

Spawning Stream Sampling

During May and June no Dolly Varden were present in either Hatchery or Egg Take Creeks. It was not until late July that a significant number of these fish appeared in Hatchery Creek. Because of low water, Egg Take Creek was inaccessible to the Dolly Varden as well as the salmon; hence no samples were collected from that stream. The movement of Dolly Varden char into Hatchery Creek coincided with the movement of sockeye into that stream for the purpose of spawning. It was at the peak of this spawning run that

Dolly Varden were collected, by means of a 50-foot seine, and taken to the laboratory for analysis.

Lake Sampling

Seven sampling sites were selected in the lake on the basis of their distribution and the habitats they represented (Figure 1). Stations 1 and 6 represent areas near the major spawning streams, Station 2 provided samples from deep water and Stations 3 and 5 presented samples collected from protected coves. Near the mouth of the outlet stream Station 4 was established in an attempt to sample char which might be feeding on emigrating sockeye smolts. Station 7 was a relatively quiet pelagic region of the lake of intermediate depth.

Dolly Varden were collected by means of an experimental gill net which measured 8 feet deep by 100 feet long. The net was composed of four 25-foot sections, each with a different mesh size; the stretched-mesh sizes were 1.0, 2.0, 3.0 and 4.0 inches.

Netting procedures closely followed those of Ricker (1941) in that the net was set from shore outward for only a 24-hour period. This time period was considered sufficient to collect a reasonable number of char and still avoid prolonged digestion of the stomach contents. The small-mesh end of the net was always set in the shallower water. These procedures were followed at each of the sampling stations monthly during May, June and July. With the increasing

number of adult sockeye salmon in the lake during July, and the frequency with which they occurred in the gill net, sampling of Dolly Varden became more difficult. A similar situation was reported by Ricker (op. cit.) at Cultus Lake, British Columbia. Consequently, gill netting operations were terminated after the July series of samples had been collected.

Collection of Data

In all cases, except for those samples collected from the Afognak River during July, August and September, the fish were taken to the laboratory facilities for examination and recording of data. Fork length (centimeters), weight (grams) and sex were noted for each fish, plus date and location of capture. The portion of stomach between the esophagus and the pyloric valve was removed. No attempt was made to identify materials contained in the intestine. Preservation in a solution of 10 percent formalin stopped the digestive processes and allowed the contents to be examined at a later date.

Identification, enumeration and volumetric determination of food items was facilitated by allowing the stomach contents to remain in distilled water for a period of 24 hours prior to examination. Volumetric measurements were made, after blotting the food items on paper toweling to remove excess moisture, by measuring in milliliters the displacement of distilled water.

Analysis of Data

In computing the results of sampling, the various factors which might influence feeding habits were taken into consideration and are discussed in more detail under separate headings.

Components of the stomach contents were analyzed by two methods, percent frequency of occurrence and percent total volume in feeding fish. The percent frequency of occurrence is obtained by dividing the number of fish containing a specific food item by the total number of feeding fish in a particular grouping such as a size group. The percent total volume is determined by dividing the volume of a specific food item by the total volume of materials obtained from a particular group of feeding Dolly Varden.

Each of these methods has certain limitations and individually may present dubious results (Lagler, 1959; Rounsefell and Everhart, 1953; Larimore, 1957). Percent frequency of occurrence merely determines the presence or absence of a food type and gives equal value to all items by magnifying the importance of smaller materials. Analysis of items by percent total volume ignores their frequency of occurrence and does not reflect the food habits of individuals. On the other hand, it does emphasize the importance of larger, more bulky, food items. Both methods are affected by differential digestion rates as are the other procedures for analyzing stomach contents. Therefore, these two methods

are utilized in conjunction with one another for the purpose of obtaining a clearer perspective of Dolly Varden feeding habits. The data are presented in both forms with no further discussion of the limitations of either method.

Bottom Sampling

A limited bottom sampling program was carried out for the purpose of determining relative abundance of benthic organisms in Afognak Lake. Bottom samples were collected at monthly intervals from the vicinities of the seven gill-netting stations. Five Ekman dredge samples were taken along a transect parallel to each gill-net location. These five samples were pooled, the organisms removed and preserved in 10 percent formalin. At a later date, the organisms in these samples were identified and counted.

With bottom sampling and stomach analysis data, an indication is obtained as to the abundance of benthic organisms and their utilization as food by Dolly Varden char.

RESULTS AND DISCUSSION

General Feeding Habits

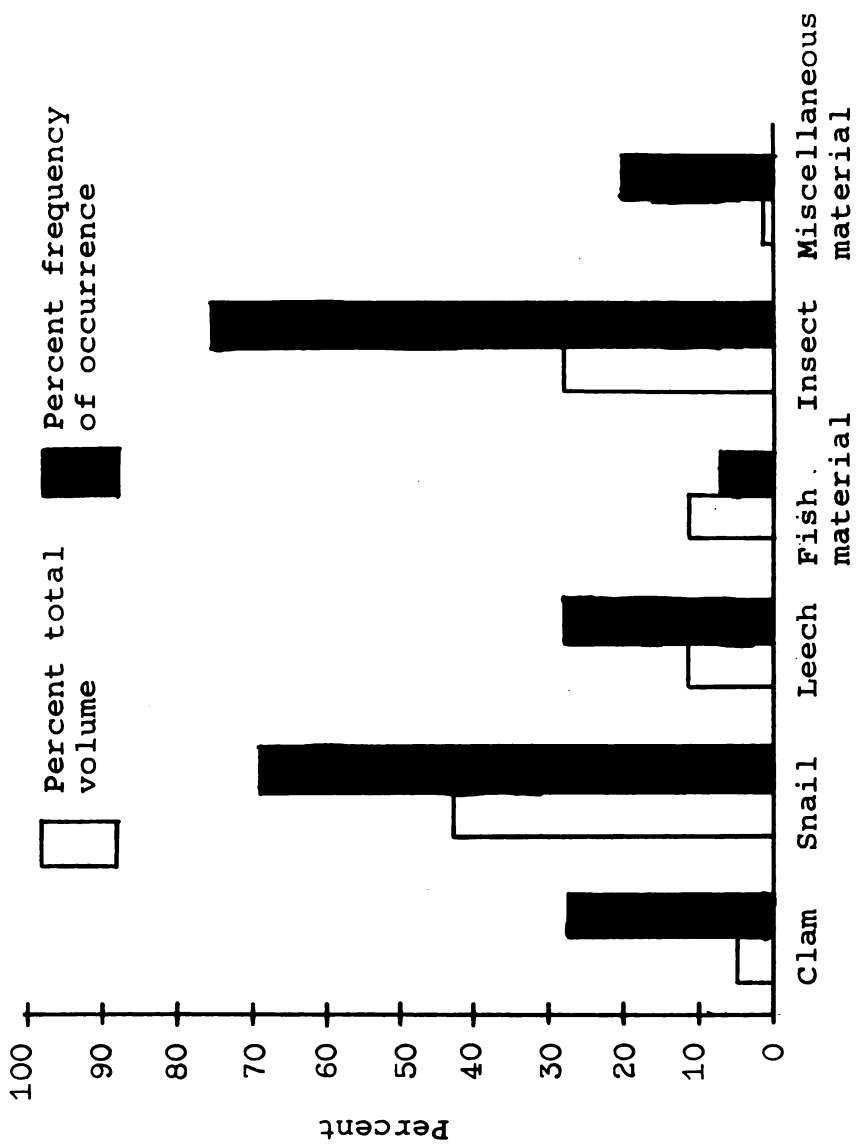
During this study 513 Dolly Varden char were collected for stomach analysis. Of this total, 261 (50.9 percent) contained food and 252 (49.1 percent) were empty. These statistics closely follow those obtained by Roos (1959), who found that 47.2 percent of 5050 Dolly Varden collected from the Chignik system contained food. Data concerning the number and percent of males and females, plus their feeding or non-feeding status are recorded in Table 1. Results of these calculations indicate that a sex ratio of 1:2.2 males to females exists within the feeding population and 1:1.6 over the whole sampled population.

Snails and insects constitute the major food item of Dolly Varden in the Afognak system, with leeches, clams and fish material playing a minor role in the diet. These food items, with the exception of leeches and clams, have been reported to be utilized by Dolly Varden of Bare Lake, Alaska (Nelson, 1959). Insect material, present in 75.0 percent of the stomachs examined, was the most commonly found item (Figure 2). Roos (1959) noted the importance of this item among Chignik Dolly Varden, where its frequency of occurrence was 73.2 percent. Even though insects, represented mainly

Table 1. Summary data of Dolly Varden by habitat indicating percent of total numbers by sex and feeding status.

	All Habitats		Afognak River		Afognak Lake		Hatchery Creek	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total Fish	513		39		410		64	
Feeding	261	50.9	22	56.4	215	53.4	24	37.5
Empty	252	49.1	17	43.6	195	47.6	40	62.5
Total Males	192	37.4	18	46.1	146	35.6	28	43.7
Feeding	81	42.1	8	44.4	65	44.6	8	28.6
Empty	111	57.9	10	55.6	81	55.4	20	71.4
Total Females	321	62.6	21	53.9	264	64.4	36	56.3
Feeding	180	56.0	14	66.7	150	56.8	16	44.5
Empty	141	44.0	7	33.3	114	43.2	20	55.5
Total Feeding	261	50.9	22	56.4	215	53.4	24	37.5
Males	81	31.0	8	36.5	65	30.2	8	33.3
Females	180	69.0	14	63.5	150	69.8	16	66.7

Figure 2. Percent total volume and percent frequency of occurrence of food items occurring in 261 feeding Dolly Varden collected from the Afognak system, 1963.


Percent total volume
Percent frequency of occurrence
Percent
100
90
80
70
60
50
40
30
20
10
0
Clam
Snail
Leech
Fish
Insect material
Miscellaneous material

by the orders Tricoptera and Diptera, occurred most frequently, their percent total volume was exceeded by that of snails. Other food items present in lesser amounts were leeches, which rank third highest in frequency and volume, and clams which occurred in numerous samples but in only small volumes. Fish material constituted a frequency of 7.2 percent and a percent total volume of 11.0. The higher percent total volume is accounted for by the presence of large volumes of carrion in only a few fish. The low frequency of fish material indicates that it is not an important part of the Dolly Varden diet in this system.

Many Dolly Varden contained materials which could not be considered in any of the previous categories. These items are placed under the heading of miscellaneous materials which consists of stones, sticks, leaves and minor arthropods such as spiders. These materials were fairly common in stomachs but constituted only a small part of the total volume.

Feeding Habits by Size

It has frequently been observed that the size of a fish has a direct influence on its feeding habits. Pearse (1921), for example, observed that small rock bass (Ambloplites rupestris) were chiefly insectivorous while larger forms fed primarily on crayfish. With the possibility that a similar situation might exist among Afognak Dolly Varden, feeding habits are analyzed on the basis of size

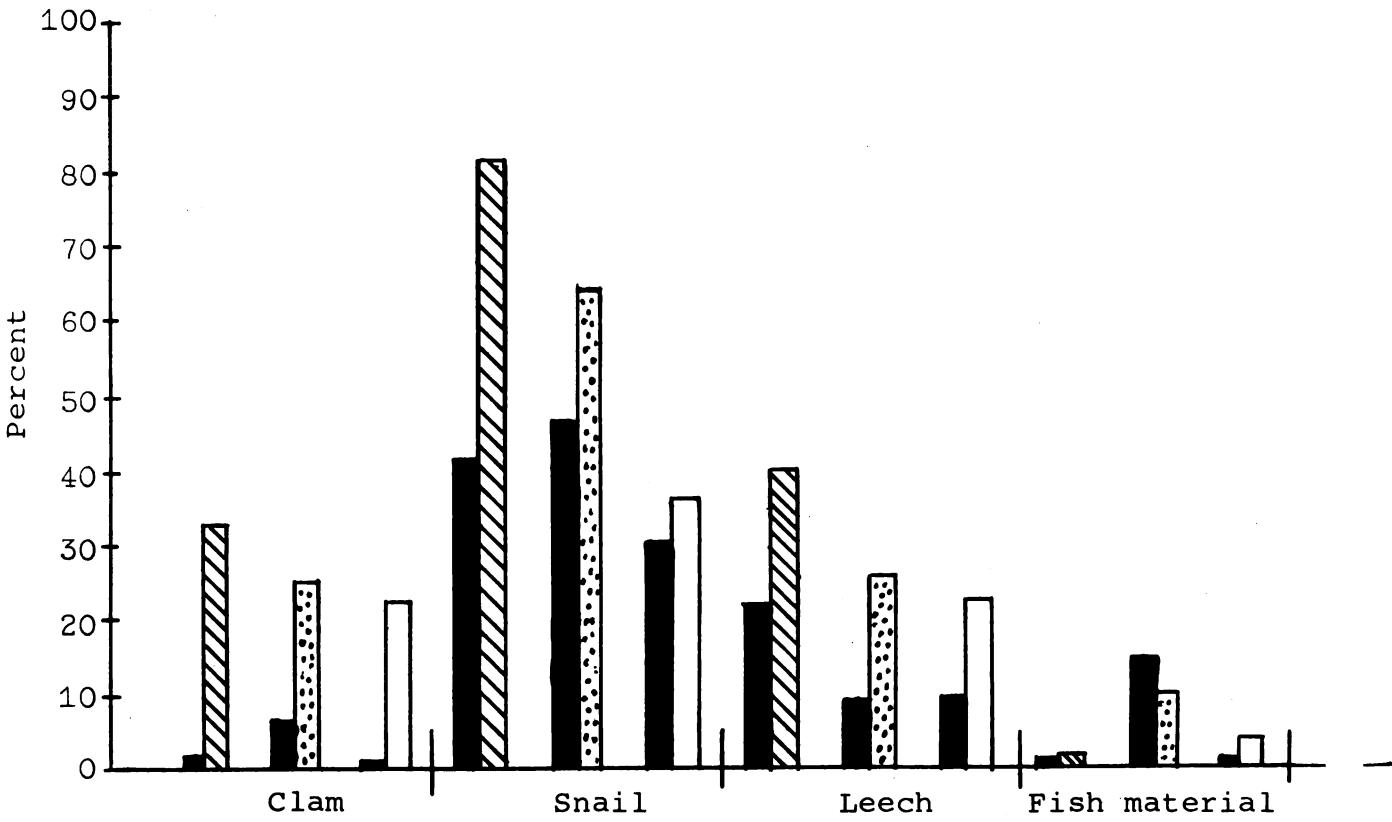
groups. The fork length of feeding Dolly Varden ranged from 11.7 to 33.7 centimeters. These fish were divided into three size groups, less than 20.0, 20.0-29.9, and 30.0 or more centimeters.

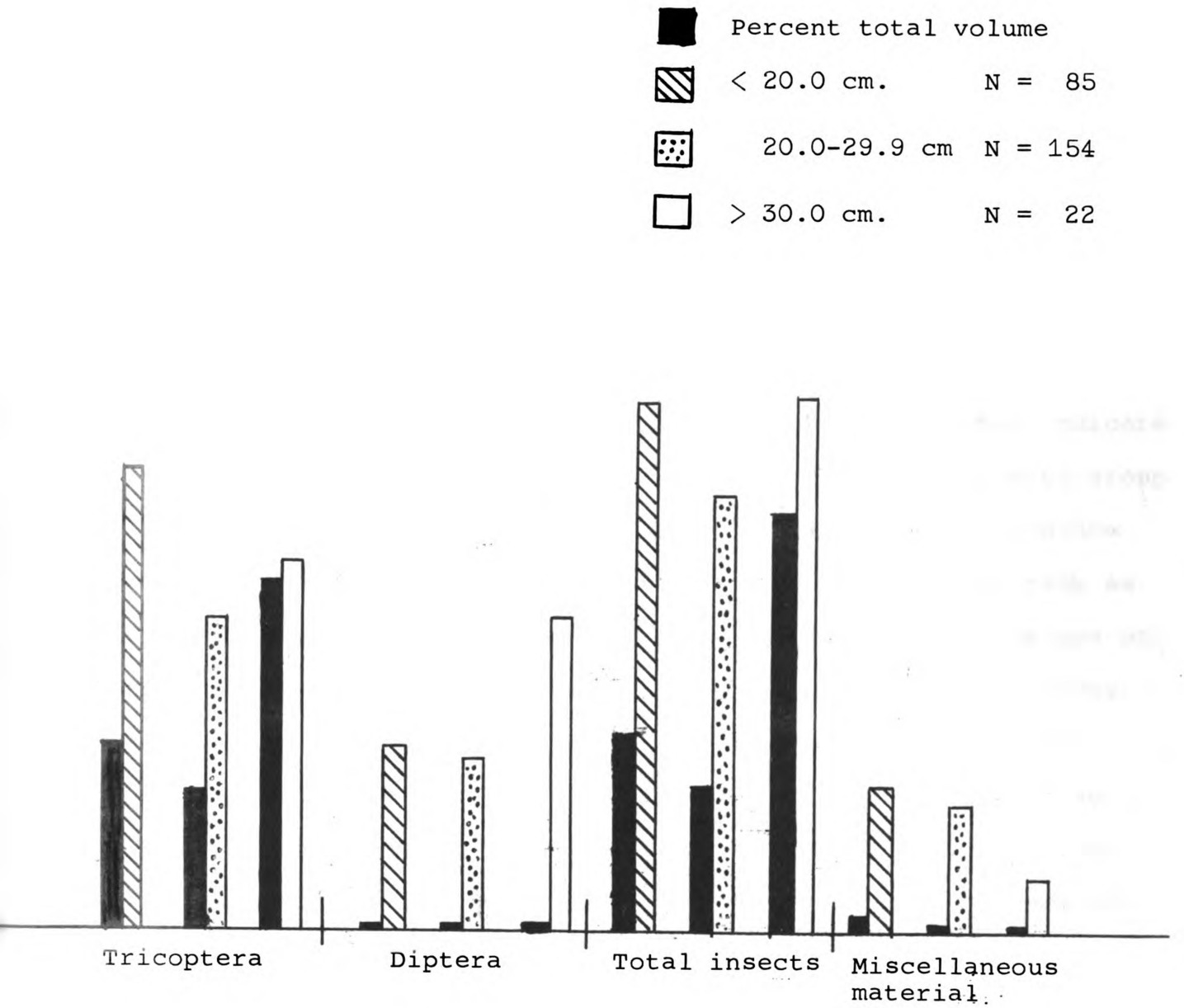
Insects were the most frequently occurring food item in the stomachs of the smallest size group of Dolly Varden. Of this item, Tricoptera was the most abundant order, followed by Diptera. Although snails rank below insects in frequency, their percent total volume was greater (Figure 3). In decreasing importance, leeches, clams and fish material comprised the remaining food items found in the stomachs of these fish.

In the medium size group, 20.0-29.9 centimeters, snails constituted a major portion of the diet with a frequency of 64.2 percent and 45.7 percent total volume. Although the frequency of insects is highest of all the food items (69.4 percent), its percent total volume is only half that of snails. Leeches and clams are utilized to approximately the same degree with frequencies of 25.9 and 25.3 percent, and percent total volumes of 9.3 and 5.9, respectively. Fish material constituted 15.0 percent of the total volume and a frequency of 10.3 percent; the value of fish in the diet is exaggerated because of the consumption of large volumes of carrion by a few of these fish.

The frequency of occurrence and percent total volume of insects consumed by the largest size group of Dolly Varden

Figure 3. Percent total volume and percent frequency of occurrence of food items occurring in the three size groups of Dolly Varden collected from the Afognak system, 1963.




Percent total volume
< 20.0 cm. N = 85
20.0-29.9 cm N = 154
> 30.0 cm. N = 22
Tricoptera
Diptera
Total insects
Miscellaneous material

exceeds that of any other food item utilized. Tricoptera was the most abundant order of insects with 59.0 percent frequency of occurrence and 56.2 percent total volume. Snails were the second most important food item followed by leeches, clams and fish material.

These data suggest that clams, fish material and miscellaneous material are minor items in the diets of the three size groups of Dolly Varden studied. In order of importance they rank fourth, fifth and sixth respectively. Both frequency and volume data obtained for leeches indicate a higher incidence of this item among the smaller size group of Dolly Varden. But, the order of importance of leeches is not changed from one group to another. Leeches rank as the third most important food item among all size groups of Dolly Varden. Although the frequency of snails decreases with increasing fork length of char, the percent total volume data suggest that this relationship may not be so distinct. When the order of importance of snails is considered, they are the primary food item of the two smaller size groups while insects play a dominant role in the diet of Dolly Varden larger than 30.0 centimeters. Of the insects consumed by all size groups, the orders Diptera and Tricoptera were the most prominent. The order Diptera, represented mainly by the family Tendipedidae, constituted a minor portion of the diet among all size groups. The families Phryganeidae, Leptoceridae, Limnephilidae and Hydropsychidae

were the principal representatives of the order Tricoptera. All were consumed in varying amounts but Phryganeidae and Leptoceridae were consistently the most utilized families. Although the order of importance of food items changed slightly, there is no difference in types of food items consumed by the various size groups of Dolly Varden.

No apparent size differences were noted between various food categories consumed by Dolly Varden, i.e., snails, clams, leeches and insects. However, a relationship between size of individuals in a food category and the size of Dolly Varden was noted. In the order Tricoptera, a relationship was apparent between the size of a particular family and the size of Dolly Varden utilizing it. Of the two major families present, Phryganeidae and Leptoceridae, Phryganeidae contains the larger individuals. In the data from Afognak Lake, both percent frequency of occurrence and percent total volume data show that Dolly Varden larger than 30.0 centimeters consume more Phryganeidae than do the smaller members of that species. Also, Leptoceridae occur in larger amounts among the smaller Dolly Varden (Table 2).

Feeding Habits by Habitat

Afognak River. Upon arrival at the Afognak system on May 3, 1963, a large population of Dolly Varden was present in the Afognak River. These were the migrant forms of this species and they were in the process of emigrating from the Afognak system to salt water. With daily observations, it

Table 2. Percent frequency of occurrence and percent total volume of Leptoceridae and Phryganeidae in the three size groups of Dolly Varden collected from Afognak Lake, 1963.

	< 20.0 cm.	20.0-29.9 cm.	> 30.0 cm.
Leptoceridae	59.7*	27.4	0.0
	17.2**	4.9	0.0
Phryganeidae	14.6*	32.2	77.7
	8.1**	16.9	54.9

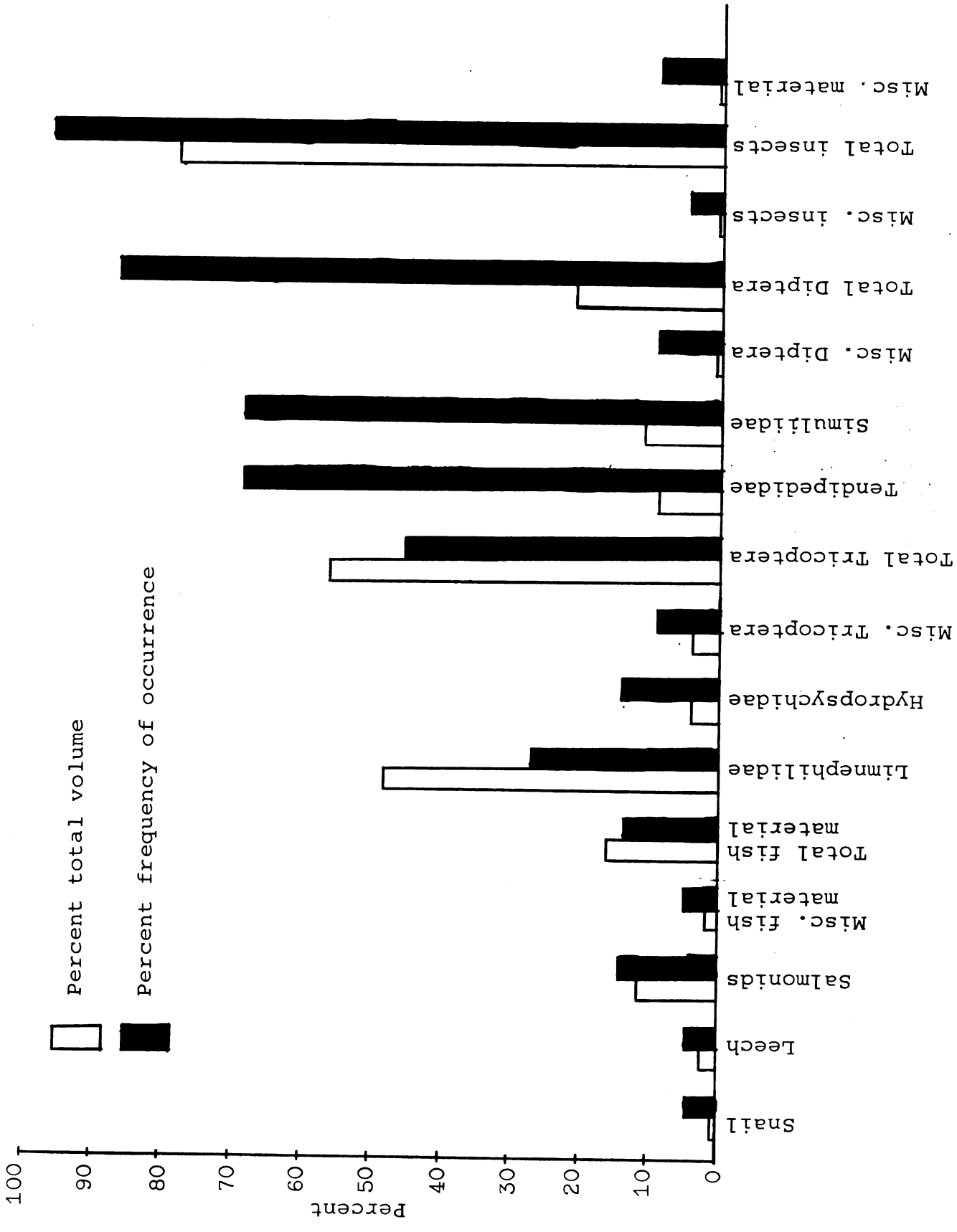
*Percent frequency of occurrence.
**Percent total volume.

was noted that the major portion of the movement had been completed by May 24, 1963. A small number of char passed through the river between May 24 and May 31, at which time the emigration ended.

Samples of the emigrating population were collected for stomach analysis. Results of this investigation revealed that these fish are chiefly insectivorous, feeding mainly on the orders Tricoptera and Diptera (Figure 4). The most frequently occurring order was Diptera (86.3 percent) which is represented by the families Tendipedidae and Simuliidae. Both families were utilized in approximately the same amount. Although Tricoptera is the second most frequent order of insects (45.4 percent), the percent total volume of this order exceeded that of Diptera. The most abundant family of Tricoptera, in both frequency and volume, was Limnephilidae. The family Hydropsychidae was also represented in this order. Fish material constituted a portion of the diet with a frequency of 13.6 percent and 16.2 percent total volume. One Dolly Varden contained a snail of very small volume and another contained a single leech. On the basis of these data it is felt that emigrating Dolly Varden of the Afognak system are primarily insectivorous and that their consumption of other food items is minor.

Dolly Varden began to return to the system in early July. Samples of these immigrating char were collected at

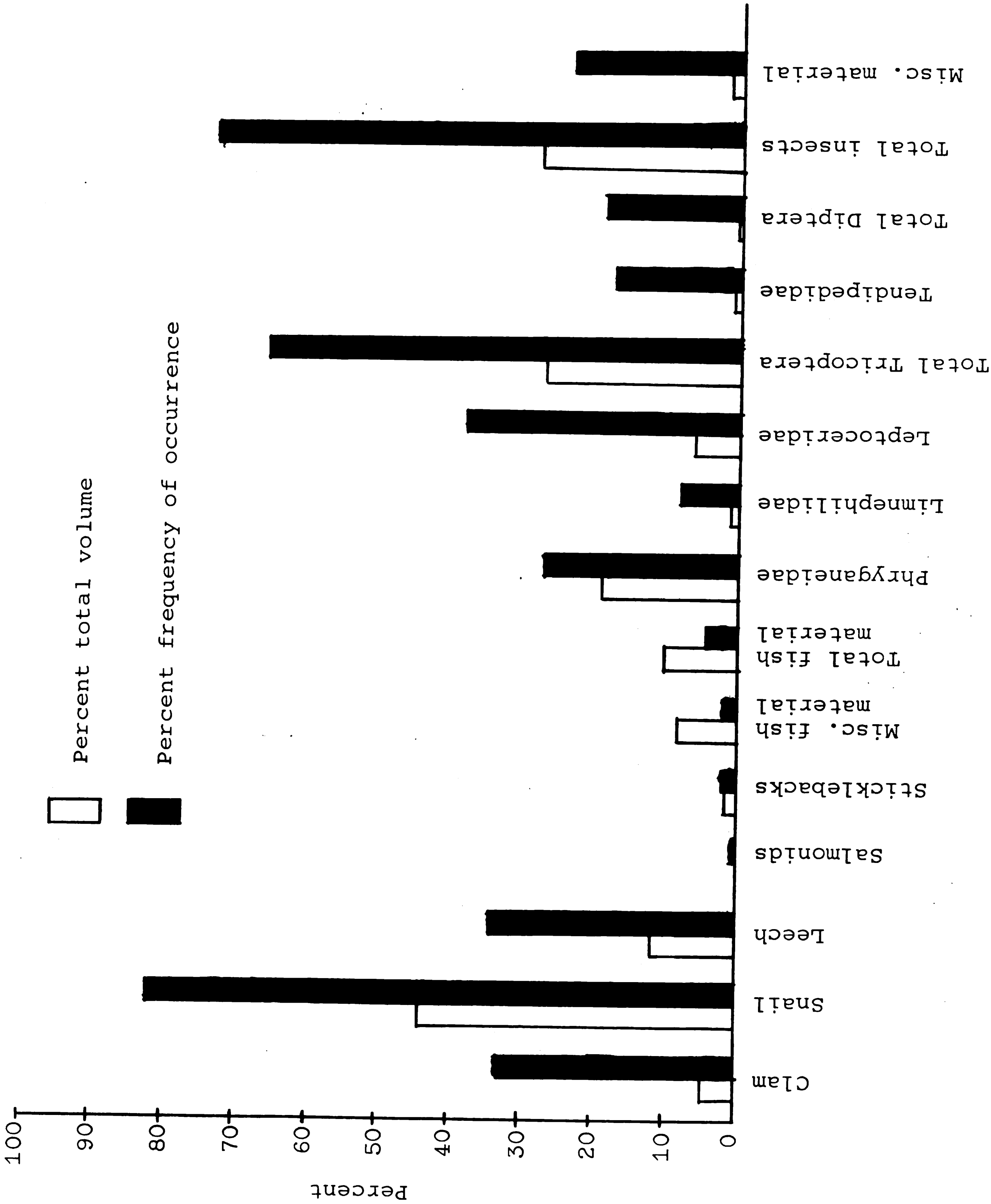
Figure 4. Percent total volume and percent frequency of occurrence of food items occurring in 22 feeding Dolly Varden collected from the Afognak River during their emigration, May, 1963.


Percent total volume
Percent frequency of occurrence
Percent
100
90
80
70
60
50
40
30
20
10
0
Snail
Leech
Salmonids
Misc. fish material
Total fish material
Limnephilidae
Hydropsychidae
Misc. Tricoptera
Total Tricoptera
Tendipedidae
Simuliidae
Misc. Diptera
Total Diptera
Misc. insects
Total insects
Misc. material

three monthly intervals. Most of the stomachs were empty; a few contained one to ten adult Diptera (Tendipedidae). It is concluded that the immigrating Dolly Varden feed very little immediately after entering fresh water.

Afognak Lake. During the months of May, June and July, 215 Dolly Varden were collected from Afognak Lake for stomach analysis (Table 1). Results of that investigation show that snails are the most prominent food item with a frequency of 82.8 percent and 44.1 percent total volume (Figure 5). The second most important food item is insects, represented chiefly by the orders Tricoptera and Diptera. Tricoptera, the most utilized order, is represented by three families, Leptoceridae, Phryganeidae and Limnephilidae in order of decreasing frequency. Because of size differences between these families their bulk values change the order of importance to; Phryganeidae, Leptoceridae and Limnephilidae. Although Limnephilidae are the same size as Phryganeidae, both larger than Leptoceridae, their order of importance is not changed by either method of analysis. The reason for this is that the frequency and percent total volume of Limnephilidae are lower than that of the other families. Contributing to the total volume and frequency of Tricoptera is a category which includes unidentifiable remains and minor families. The order Diptera is represented by only one family, Tendipedidae. On the basis of its frequency of 18.6 percent and 0.1 percent total volume, it is felt that

Figure 5. Percent total volume and percent frequency of occurrence of food items occurring in 215 feeding Dolly Varden collected from Afognak Lake, Alaska, 1963.


Percent total volume
Percent frequency of occurrence
Percent
0
10
20
30
40
50
60
70
80
90
100
Clam
Snail
Leech
Salmonids
Sticklebacks
Misc. fish material
Total fish material
Phryganeidae
Limnephilidae
Leptoceridae
Total Tricoptera
Tendipedidae
Total Diptera
Total insects
Misc. material

this order and family represent an incidental food item. Leeches, clams and fish material are respectively the next most important food items of Dolly Varden in Afognak Lake. Although the frequencies of leeches and clams are seven times greater than that of fish material, the percent total volume of the latter is approximately equal to that of the leeches and is twice that of clams. The category of fish material incorporates sticklebacks, salmonids and carrion. The latter item, carrion deposited in the lake by sport fishermen, constituted a volume of 53.2 milliliters in the stomachs of two Dolly Varden, overemphasizing the value of carrion in the general diet. Disregarding the volume of carrion, the amount of fish consumed is found to be 1.8 percent of the total volume.

Bottom samples, taken in the vicinities of the seven gill-netting stations, included six major organisms; clams (Unionidae and Sphaeridae), snails, leeches, Diptera (Tendipedidae), Tricoptera (Leptoceridae and Phryganeidae) and Oligochaeta. Of these items, Oligochaeta were not observed in stomachs of Dolly Varden; it is possible that some of these may be consumed by the char but because of their small size and lack of sclerotization they would be digested rapidly. Of the clams consumed by char, Sphaeridae were the major representatives and only a few, very small Unionidae were utilized. Therefore, only Sphaeridae are considered in these data. Although Phryganeidae are an

important food item of char, they were not abundant in bottom samples. Samples at Station 1 contained one member of this family of Tricoptera. On the basis of ecological distribution in the lake, this organism inhabits aquatic vegetation and detrital materials. Sampling with an Ekman dredge was always hampered by such materials, so little sampling was done in such areas. Because of this limitation in the ability to sample Phryganeidae, no evaluation can be made as to its abundance or distribution in Afognak Lake. Of the remaining organisms collected, Tendipedidae were the most numerous organisms at six of the seven sampling stations. Clams were the most abundant organism at Station 4 but ranked second at all others. The Tricoptera Leptoceridae and snails alternated as the third and fourth most abundant organisms at all stations except Station 1. Leeches were the third most important item at Station 1 but ranked lowest at all the others. The abundance of these organisms in bottom and stomach samples, expressed in percent frequency of occurrence, is presented in Table 3.

The difference in abundance of these organisms between bottom and stomach samples can be clarified by an analysis of their ecology. Tendipedidae is a diversified family of Diptera, members of which occur in large numbers within favorable bottom materials. Consequently, this family was collected in relatively large numbers at all sampling stations. Because these organisms occur primarily in bottom

Table 3. Percent of total number of food organisms in bottom samples and their percent frequency of occurrence in Dolly Varden collected from Afognak Lake, by sampling stations.

Station	Clam	Snail	Leech	Tendipedidae	Leptoceridae	Oligochaeta
1	*10.8	0.5	2.8	66.4	2.8	16.3
	**21.0	57.8	26.3	0.0	47.3	0.0
2	16.5	3.0	1.8	57.9	12.3	8.4
	26.4	91.1	26.4	14.7	41.1	0.0
3	13.3	2.8	0.5	67.4	9.9	5.6
	46.1	87.1	56.4	28.2	25.6	0.0
4	42.9	8.6	1.1	35.4	5.6	5.8
	19.2	65.3	19.2	34.6	42.3	0.0
5	15.8	7.6	1.2	64.7	4.6	5.8
	26.6	83.3	43.3	20.0	66.7	0.0
6	7.6	1.5	0.3	76.5	2.7	11.2
	37.1	82.8	28.5	17.1	31.4	0.0
7	21.4	9.5	1.5	54.4	5.1	7.9
	46.8	84.3	31.2	3.1	25.0	0.0

* Percent of total number of food organisms in bottom samples.
** Percent frequency of occurrence of food organisms in Dolly Varden stomach samples.

materials they are not readily available as fish food unless they are consumed during emergence, during a migration or as part of the materials picked up when a fish feeds on another item which is on the surface of the bottom material. Although the major portion of Tendipedidae consumed by Dolly Varden were the larval forms, the number of adults increased as the summer progressed. But, Tendipedidae remained an item of low importance in the diet of Dolly Varden in spite of its abundance in bottom samples. Sphaerid clams are known to inhabit a variety of bottom types and therefore have a wide distribution (Pennak, 1953). Although clams ranked second in abundance at all but one station, their presence in char stomachs exceeded that in bottom samples. These data suggest that in spite of this organism's relationship to the lake bottom, resting on or just beneath the surface of the bottom materials in a relatively immobile state, it is still utilized by Dolly Varden as a food item. Snails, which largely inhabit and feed upon the surfaces of submerged objects, were not abundant in bottom samples. The difficulty encountered when sampling among submerged objects with an Ekman dredge limits the ability to obtain specimens which are on or among these obstructions. Conversely, such organisms might be easily available as food to Dolly Varden. The mobility of leeches limits the ability to accurately evaluate this organism's abundance; hence it is felt that the bottom-sampling data are not representative of the true

status of this organism. Leptoceridae (Tricoptera) are found in a variety of habitats and may occur in large numbers. Even though these organisms were not present in large numbers among the dredge samples, they are a major item in the diet of Afognak Lake Dolly Varden, indicating that they are widely distributed and readily available as food.

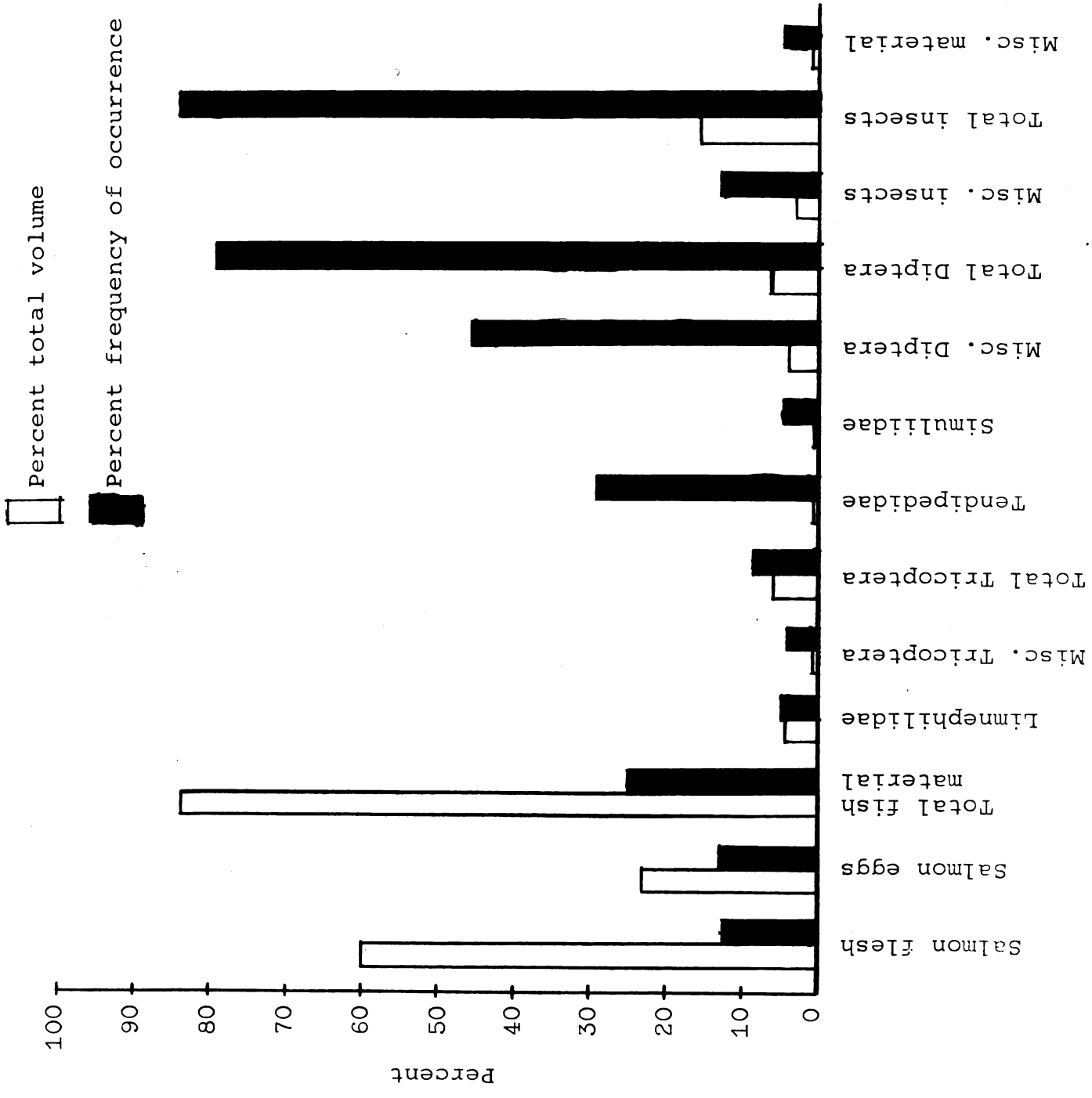
It is difficult to establish a relationship between the abundance of organisms in bottom samples and their use as food by Dolly Varden collected from the lake. The order of decreasing abundance of food items in bottom samples is: Tendipedidae, clams, snails, Leptoceridae and leeches. In stomachs of feeding lake char the order is: snails, Leptoceridae, leeches, clams and Tendipedidae. Possible reasons for this difference might be that: 1) concentrations of these organisms might exist in certain areas of the lake; 2) no concentrations of organisms exist but Dolly Varden feed over wide areas; 3) no concentrations exist but that Dolly Varden are selective feeders; 4) limitations in sampling a lake the size of Afognak did not properly evaluate the abundance of the various benthic organisms.

Hatchery Creek. For the purpose of determining if Dolly Varden actively feed on freshly deposited sockeye salmon eggs, observational data and stomach samples were collected from Hatchery Creek. Dolly Varden were absent from the lake tributaries until early July, just prior to the

movement of adult sockeye into their spawning streams. Because the Dolly Varden is a fall and winter spawner (Lagler, 1956), it is assumed that this was a spawning migration which overlaps that of the sockeye salmon. Ovarial examinations indicated that a large percentage of these Dolly Varden were sexually mature. A large population of these fish persisted in the streams for the remainder of the study.

Of the 24 feeding Dolly Varden sampled from Hatchery Creek (Table 1), 83.3 percent contained insect material (Figure 6). Diptera was the most abundant order, represented by two families, Tendipedidae and Simuliidae. Adult Diptera were difficult to identify in stomach samples because of their fragile nature; consequently they were classified as miscellaneous Diptera. The frequency and volume percentage of adult Diptera was higher than that of immature forms because of the abundance of adults during the time of sampling. The order Tricoptera, represented by Limnephilidae and a few miscellaneous adult forms, furnished only a minor portion of the total insect value, 8.3 percent frequency and 5.9 percent total volume. Members of Lepidoptera and Coleoptera were utilized very little and both orders are considered under miscellaneous insects. In terms of overall utilization, twenty of twenty-four Dolly Varden contained insects. The average volume of this item per feeding fish, was 0.06 milliliters. Large volumes of fish material were

Figure 6. Percent total volume and percent frequency of occurrence of food items occurring in 24 feeding Dolly Varden collected from Hatchery Creek during the sockeye salmon spawning season, August, 1963.


Percent total volume
Percent frequency of occurrence
Percent
100
90
80
70
60
50
40
30
20
10
0
Salmon flesh
Salmon eggs
Total fish material
Limnephilidae
Misc. Tricoptera
Total Tricoptera
Tendipedidae
Simuliidae
Misc. Diptera
Total Diptera
Misc. insects
Total insects
Misc. material

consumed by 6 Dolly Varden. This food item consisted entirely of eggs and flesh from dead spawning sockeye.

Predation

It has been previously noted that Dolly Varden are reported as being predaceous in some systems and not in others. The results of Dolly Varden predation in the Afognak system are presented here. Of the 261 feeding Dolly Varden collected, only 19 contained some form of fish material (7.2 percent frequency of occurrence). This food category includes the items of carrion (including eggs), Salmonidae, sticklebacks and unidentifiable fish remains. Calculations on the basis of percent frequency of occurrence and percent total volume of these items, in Dolly Varden stomachs, are presented in Table 4.

Carrion. Carrion occurred most frequently and constituted the largest volume in the stomachs of Dolly Varden feeding on fish material. Because of predators such as bears and eagles, large amounts of sockeye flesh and numerous eggs were present in Hatchery Creek; these were the only items of fish material present in the stomachs of Dolly Varden collected from that stream. With the abundance of eggs scattered throughout the stream from unspawned dead sockeye, stomach analyses do not afford evidence that Dolly Varden were feeding on freshly deposited eggs. Further, careful observations were made of Dolly Varden approaching

Table 4. Frequency of occurrence and volume of various fish materials in 19 predatory Dolly Varden and in 261 feeding Dolly Varden.

	Salmonid	Stickleback	Carrion	Unidentifable	Total
Incidence*	4	6	9	2	19
Percent frequency in predators	21.0	31.5	47.3	10.5	
Volume (ml)	1.05	11.80	60.20	0.06	73.11
Percent total volume	1.4	16.2	82.3	0.1	100
Percent frequency in all feeding Dolly Varden	1.5	2.3	3.4	0.7	7.2

* Total of these numbers will exceed 19 because some of the fish fed on more than one item.

redds but none were observed feeding on freshly deposited eggs; in all cases the Dolly Varden were driven from a redd by the adult sockeye. Two Dolly Varden collected from Afognak Lake contained salmon carrion--offal disposed of in the lake by sport fishermen. One char was found to contain small fish eggs which might have been those of sticklebacks, but positive identification could not be made. In Afognak River, salmon eggs were found in the stomach of one Dolly Varden. These eggs were from the previous spawning season and it is possible that the writer released them from the streambed while wading during the collection of char.

The high incidence and volume of carrion indicate that the Dolly Varden may be more of a scavanger than a predator.

Salmonidae. Predation by Dolly Varden on salmonids occurred only in Afognak River and Afognak Lake. Three of 22 Dolly Varden collected in Afognak River contained fish material--a total of four pink salmon fry. One fry was present in each of two stomachs and the other contained two fry. During May, one Dolly Varden collected from Afognak Lake was found to contain a single salmonid. No identification of this specimen was possible. During this same month, two other char contained the skeletal remains of one fish each. Identification of these specimens was also impossible; they may have been salmonids. (Confusing these remains with those of sticklebacks is possible but, the

writer found that the pectoral spines of sticklebacks were quite resistant to the digestive processes of char and that they were distinguishable for a considerable time after much of the flesh and smaller bones had been digested.) If these were then the remains of salmonids, the frequency of this item would increase from 21.0 percent (Table 4) to 31.5 percent of those fish consuming fish materials. The frequency of predation on salmonids among all feeding fish would then be 2.3 percent.

Sticklebacks. Six of the 19 Dolly Varden feeding on fish materials contained sticklebacks, and all were collected in Afognak Lake. The number of sticklebacks per stomach ranged as high as 6, with an average of 2.1, for a total of 13. The frequency of this item among char feeding on fish material was 13.5 percent and of the total feeding fish 2.3 percent.

All predation on salmonids occurred during the month of May, the time of their seaward migration. This observation corresponds with that of Foerster (1938), at Cultus Lake, British Columbia. Also, during this month, two Dolly Varden in the lake consumed three sticklebacks. The balance of predation on sticklebacks occurred during the months of June and July. That the predation of Dolly Varden on salmonids decreases during the summer months is supported by the findings of Nelson (1959) at Bare Lake, Alaska.

Considering the role of the Dolly Varden as a predator, on the basis of percent frequency of occurrence, it is noted that both salmonids and sticklebacks were present in equal frequencies. However, seven salmonids--assuming that the remains of the two questionable forms are salmonids--and thirteen sticklebacks were consumed by Dolly Varden; this is a ratio of 1:1.8, salmonids to sticklebacks. If the stickleback is truly a competitor for food with the young sockeye, as noted by Nelson (op. cit.) and Semko (Roos, 1959, page 254), the consumption of sticklebacks by Dolly Varden is of benefit to the young sockeye of Afognak. On the basis of these data, it is suggested that the Dolly Varden of the Afognak system are not serious predators of young salmon and that their role as a predator of sticklebacks may outweigh any detrimental effect they may possibly have on young salmon.

The findings of this study show that the Dolly Varden is not a serious predator of young salmon in the Afognak system during the months of May, June and July. It is possible that they may prey heavily upon the young salmon at two other times: 1) during the fry migration from the spawning streams into Afognak Lake, and 2) during the emigration of the salmon smolts as they enter the Afognak estuary.

SUMMARY AND CONCLUSIONS

The investigation of Dolly Varden feeding habits in the Afognak system has shown that:

1. Snails and insects constitute a major portion of the diet of all Dolly Varden collected from the Afognak system. Insects were the most frequently occurring food item while snails were the highest in percent total volume.

2. Of the three size groups of Dolly Varden, the two smaller groups utilized snails and insects respectively, while the larger char utilized more insects than snails.

3. The size of Tricoptera consumed was found to be proportional to the size of the Dolly Varden. Large char fed primarily on Phryganeidae while smaller char utilized Leptoceridae.

4. Emigrating Dolly Varden are chiefly insectivorous while immigrating char feed very little immediately after entering fresh water.

5. Lake residing Dolly Varden feed primarily on snails and insects. Of the insects consumed, Tricoptera was the most utilized order.

6. There was no correlation between the abundance of food items collected in bottom samples and those present in stomach samples.

7. Although Dolly Varden collected from Hatchery Creek contained a high frequency of insects, they also contained large amounts of sockeye salmon flesh and eggs (carrion).

8. No evidence was found to prove that Dolly Varden actively seek out and feed upon freshly deposited sockeye salmon eggs.

9. The high incidence and volume of carrion in the diet of Dolly Varden indicates that they may be more of a scavanger than a predator.

10. Seven salmonids and 13 sticklebacks were consumed by Dolly Varden; indicating that their role as a predator on sticklebacks may outweigh any detrimental effect they may possibly have on young salmon of this system.

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