

significant deviation from the "cube law" among older representatives of this species. It is evident that additional data are necessary for clarification of this apparent discrepancy. Comparison of present data with that illustrated by Mansueti and Pauly (1956) is difficult, but there appears to be general agreement, particularly in the 60- to 120-millimeter standard length range.

The condition coefficient,  $K = \frac{W 10^5}{L^3}$ , was

calculated for each standard length class (Table 1). Erratic changes in the magnitude of  $K$  with increasing standard length reflects deficiency in sample size, but the data are shown to indicate the probable range of  $K$  for the species. The mean  $K$  for the sample was 4.25.

The standard length-total length relationship of *T. maculatus* has been determined by calculating the regression equation from the means of 5-millimeter classes. Factors for inter-converting length measurements in both English and metric units together with the regression equation, coefficient of correlation, and standard error are shown in Table 2. Mansueti and Pauly (1956) gave conversion factors, calculated from 12 specimens, for standard to total and total to standard length of 1.22 and 0.82 respectively. It may be seen (Table 2) that in *T. maculatus*, as in many other species, there is considerable change with size in the standard length-total length ratio and that the conversion figures given by these authors are only applicable to a limited length range.

The length-weight relationship and condition factor ( $K$ ) have long been useful tools in the study of fresh-water fishes but have received little attention from workers on marine and estuarine species. The writer (1958) showed significant differences in the coefficient of condition in the spot, *Leiostomus xanthurus*, both seasonally and between "wild" and pond-reared fish. It is here considered that greater application of these relationships is a desirable and necessary step toward more complete understanding of marine and estuarine fish populations.

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## Predation of the Dolly Varden, *Salvelinus malma*, on Young Salmons, *Oncorhynchus* spp., in an Estuary of Southeastern Alaska<sup>1</sup>

### INTRODUCTION

Predation is a source of mortality to young salmon upon their first entry into salt water. Among the predators in Alaska is a char, the Dolly Varden, *Salvelinus malma*, which inhabits many of the same waters as young salmon (Clemens and Wilby, 1949). The purpose of this study was to examine the food of the Dolly Varden when it was associated with young pink (*Oncorhynchus gorbusha*), chum (*O. keta*), and coho (*O. kisutch*) salmon. Field work centered in the estuary which receives Sashin Creek at Little Port Walter near the southeastern extremity of Baranof Island, southeastern Alaska (56° 23'N, 134° 38-39' W). It was conducted from June 2 through August 11, 1958.

### AVAILABILITY OF YOUNG SALMONS TO DOLLY VARDEN

Young of the pink, chum, and coho salmon move into the Little Port Walter estuary during the spring and summer months, in large part from Sashin Creek, its sole tributary. Variations in time of entry and in numbers and sizes of individuals depend, among other things, on the species. In the estuary the young encounter a new environment to which they must adjust. Current, temperature, water chemistry, food, shelter, and variety (and number) of predators are different than in the stream. As they leave the stream mouth, the young concentrate in the upper, least saline layers of water. Schools develop, often mixed among the three species, and are most evident along the shores. Movement apparently may swing alternately toward and

<sup>1</sup>Contribution from the U. S. Bureau of Commercial Fisheries and from the Department of Fisheries, The University of Michigan. Published with permission of the Director, U. S. Bureau of Commercial Fisheries.

away from the creek mouth. Perhaps this movement is a response to tides and their effects on the layering and currents of the fresh-water inflow.

From spring to summer, young salmon leave the original nursery estuary and spread along its adjacent coasts. They are abundant in the shelter of kelp beds and in protected coves. By midsummer the spread includes open water offshore, at least to distances as great as a half-dozen miles to the middle of Chatham Strait, into which the estuary at Little Port Walter opens. Here they are found (in sizes from about 4 to 9 inches) to approximately 10 fathoms (lampara catch). While growing to adulthood, young from Sashin Creek travel at least 120 linear miles into Chatham Strait (Elling and Macy, 1955) with the probability that greater distances are traversed (Pritchard, 1939).

Young of the three species of salmon were available to the Dolly Varden in the Little Port Walter estuary throughout the period of this study, June 1 through August 11, 1958. During this interval young of the pink, chum, and coho salmon were repeatedly observed and frequently collected by beach seine, scale-model salmon trap, tow net, and lampara in this water area. A reasonable assumption is that most of these salmon young entered the estuary from Sashin Creek, its only permanently flowing tributary. The lower 1,800 feet of this stream is accessible to ocean-run salmonids for spawning after they pass through the near-tide-level Sashin Creek weir seasonally maintained by the U. S. Bureau of Commercial Fisheries. Peak periods of entry of young-of-the-year salmon into the estuary in 1958<sup>2</sup> were: for the pink, April 8 to 29; for the chum, April 22 to May 6; and for the coho, May 4 to 13. Young pink salmon remained in the estuary at least until mid-July; young chum, at least until the end of July; and young coho, through August 11.<sup>3</sup>

While in the estuary young salmon appeared to grow rapidly. Apparently, however, they did not attain lengths during the summer months that would render them invulnerable to predation by the Dolly Varden. Upon being passed downstream through the weir into the estuary from March 9 through May 15, the average fork lengths (in millimeters)

TABLE 1.—Mean calculated total lengths of the Dolly Varden from Little Port Walter estuary, Alaska, summer, 1958<sup>1</sup>

Age in years	Calculated length at annuli (millimeters)				
	I	II	III	IV	V
1	85	—	—	—	—
2	91	151	—	—	—
3	95	153	215	—	—
4	88	162	233	304	—
5	96	167	243	318	388
Mean	94	157	230	310	388
Standard deviation of mean	10	15	24	21	17

<sup>1</sup> Based on 20 specimens of each age selected from among the individuals examined for food. The body-scale regression was  $y = 9.998 + 0.1449x$ . From Wright, Asa T., 1960. Age and growth of the Dolly Varden char (*Salvelinus malma* Walbaum) in southeastern Alaska. 18 pp. M.S. Thesis. University of Michigan Libraries. Unpublished.

with little range of variation were: pink fry, 31; coho fry, 32, and fingerlings, 100; and chum fry, 35 (based on measurements by Jerrold M. Olsen). By June 10, young pinks in the estuary were ranging from 38 to 85 millimeters; coho, from 67 to 68; and chum, from 50 to 72. At the end of June, young pink salmon were 38 to 114 millimeters (fork length), coho fry and fingerlings combined 38 to 137 millimeters, and chum, 52 to 115 millimeters. No young of the pink salmon were collected in the estuary after July 1. Young chums were collected as late as July 23 at 131 millimeters fork length maximum and young coho as late as July 31 with a maximum fork length of 143 millimeters. These lengths are mostly within the range which the Dolly Varden can eat, as shown at the lower limit by the sizes of herring fry ingested (Table 1, average total length 34 millimeters, ranging from 18 to 62 millimeters for 322 specimens) and, at the upper limit, by the Pacific sand lance (139 millimeters total length of largest specimen eaten). However, the largest sand lance was eaten by a Dolly Varden only 386 millimeters in total length, whereas the largest Dolly that we collected was 476 millimeters in total length (1,152 grams), and the species attains at least 914 millimeters (36 inches, 20 pounds; Carl and Clemens, 1948) in more southerly waters. There are no Alaskan records of this size.

#### FOOD OF DOLLY VARDEN

Food habits of 183 adult and subadult individuals of the Dolly Varden collected with other fishes by the authors in the Little Port Walter estuary in 1958 were examined. The

<sup>2</sup> Weir counts by Jerrold M. Olsen.

<sup>3</sup> Lagler, Karl F. (1959) Field report on 1958 studies of early saltwater life of the pink salmon, Port Walter region, Baranof Island, Alaska. Juneau, U. S. Bur. Comm. Fish., 33 pp. (offset).

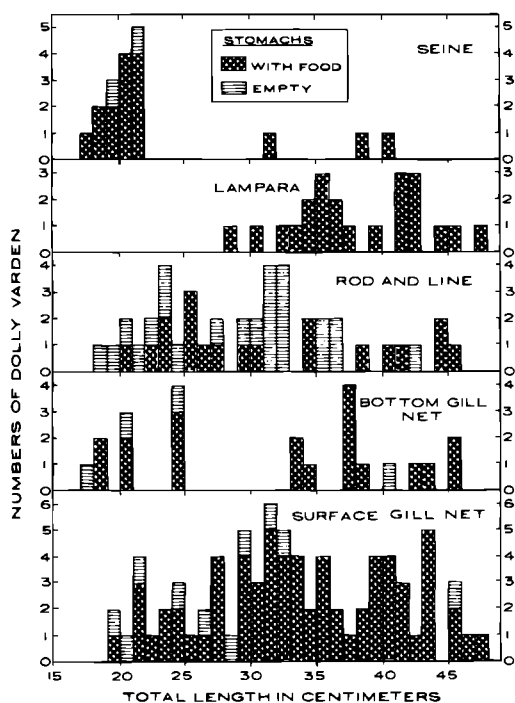


FIGURE 1.—Relationships among method of collection, size of the Dolly Varden captured, and presence or absence of food in stomachs.

char were captured by various methods (Figure 1): 54 percent by gill net; 10 percent by beach seine; 12 percent by lampara net; and 24 percent by rod and line. In June, 51 percent of the total were taken, and in July 45 percent. The remainder was caught during the first 9 days of August.

Of the 183 stomachs of the Dolly Varden examined, 40 were empty (Figure 1). The 143 individuals with food ranged in size (respectively, fork length and total length in millimeters and fresh total weight in grams) as follows: smallest 148, 168, 45; mean, 309, 329, 430; largest, 452, 476, 1,152. Age groups represented were yearling through 5-year-old (Table 1).

The principal foods by volume were capelin (78.8 percent), Pacific sand lance (7.1 percent), polychaete worms (4.7 percent), and Pacific herring (4.0 percent) (Table 2).<sup>4</sup> The frequency of occurrence of the various items was: capelin (49.7 percent); sand lance (18.9 percent); herring (16.1 percent) (Ta-

TABLE 2.—Stomach contents (1,386.3 milliliters) of 143 Dolly Varden char, from Little Port Walter estuary, Alaska, summer, 1958

Food item	Approximate number of individuals of food item	Percentage of total volume of food	Percentage frequency of occurrence
Capelin	275	78.8	49.7
Sand lance	111	7.1	18.9
Herring	328	4.0	16.1
Salmon young	5	1.0	2.8
Fish remains	47 <sup>1</sup>	2.3	25.9 <sup>1</sup>
Crustaceans	1,183	2.0	11.8
Polychaete worms	32	4.7	5.6

<sup>1</sup> Includes a trace (less than 0.1 milliliter) of a lipid in one stomach.

ble 2). Crustaceans occurred in 11.8 and polychaetes in 5.6 percent of the stomachs.

The capelin (*Mallotus villosus*) composed more than three-fourths of the volume of stomach contents of the Dolly Varden in the estuary and was found in nearly one of every two specimens studied. Total lengths of the capelin when alive could be measured or restored by estimation for 239 of the specimens in the stomachs of the predator; for these the mean was 97.2 millimeters, and the range 47 to 116 millimeters. This size range practically coincides with that of most of the adults of the species taken from the same estuary by seine and gill net (67 to 116 millimeters total length). The mean total length of the individuals of the char that had eaten the capelin was 381 millimeters, and the range, 261 to 476 millimeters.

The mean total length of the prey specimens of the Pacific sand lance (*Ammodytes hexapterus*) was 70.5 millimeters, and their range, 34 to 139 millimeters. Dolly Varden in which they were taken averaged 291 millimeters and ranged from 182 to 462 millimeters, total length. Specimens of the sand lance that we collected by seine and gill net during the same interval ranged from 48 to 159 millimeters, total length.

Since the Pacific herring (*Clupea harengus pallasii*) was eaten as larvae, it represented only a small part of the food but was present in about one of every six char. The average was about 14 larvae in each of their 23 predators (range, 1 to 51). As might be expected, the specimens of Dolly Varden that contained these small herring tended to be smaller than those feeding on the capelin or sand lance; their average total length was 248.2 millimeters; range, 186 to 420 millimeters.

Various small crustaceans, mostly shrimp, were eaten in small quantity (2.0 percent of

<sup>4</sup> Identifications were based primarily on Wilimovsky (1958), Provisional keys to the fishes of Alaska. Juneau, U. S. Fish and Wildlife Service Fishery Research Laboratory, 113 pp. (offset).

total food volume) with about the same frequency (16.1 percent) as larvae of the herring. Included were Mysidae and Euphausiidae (382 individuals, Eumalacostraca), Gammaridae (21, Amphipoda), and crab larvae (780, Brachyura; Decapoda). As for the small herring, a very few (6) of the predators accounted for most of the numbers consumed. The average total length of the 19 specimens of the Dolly Varden that had preyed on crustaceans was 249.1 millimeters, and the range, 187 to 450 millimeters.

Polychaete worms composed 4.7 percent of the total volume of food. They occurred in only 8 char. One char (434 millimeters, total length) contained most of the bulk as well as the specimens of the worms (25 worms, 45.6 milliliters in volume), in addition to one sand lance (3.0 milliliters).

Young salmon were available to the Dolly Varden in the estuary throughout the study period, although sampling of the char was after the seasonal peak of downstream migration of the young salmon and doubtless after some estuarine out-migration had occurred. Their remains were identified in only four (2.8 percent) char. This evidence does not, however, remove the Dolly Varden from concern as a significant predator of young salmon (Rounsefell, 1958). The Dolly, generally in smaller sizes than we sampled in the estuary, along with other known fry predators (Pritchard, 1936), including coho fingerlings, the introduced rainbow trout (*Salmo gairdneri*), and sculpins (*Cottus* sp.), inhabits Sashin Creek and doubtless preys upon the young as they emerge from the gravel and work their way downstream (as shown elsewhere by Pritchard, 1936). Furthermore, our sampling did not include the numerically changing aggregation of the char at the outfall of Sashin Creek into the estuary. This aggregation seemed to be well located for taking young salmon at the tidally variable point of their first contact with salt water. Here the concentration of both prospective predator and prey occasionally was relatively high. Unpublished field observations by Remo Riciputi at this site in 1959 showed a small school of about nine adults of the rainbow trout to be present at the Sashin Creek outfall, but no Dolly Varden. From April 10 to May 29, 1959, 232 adults of the Pacific herring were taken about the stream mouth. Whether or not they were predaceous on the young salmon was not determined.

#### FOOD OF ASSOCIATED FISHES

Late spring and early summer fish inhabitants of the Little Port Walter estuary and adjoining waters include numerous species sufficiently large and carnivorous to be potential predators of young salmon. Examinations of stomach contents of a few adults of each of the following fishes proved to be negative for salmon: Pacific cod (*Gadus macrocephalus*); walleye pollock (*Theragra chalcogrammus*); Pacific halibut (*Hippoglossus stenolepis*); kelp greenling (*Hexagrammos decagrammus*); rock greenling (*Hexagrammos superciliosus*); and black rockfish (*Sebastes melanops*).

The hair seal (*Phoca r. richardii*) also occurs in the Little Port Walter estuary and adjacent bays. The numbers to be seen were never large in 1958, approximating about two per hour by an observer afloat along shore in a small outboard motorboat. The contents of the stomachs of three specimens examined were made up of remains of the Pacific herring.

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