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Trophic Interactions of Oceanic Coho Salmon Introduced into New England Estuaries

by

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Lab. Ref. No. 76-15
10-29-76

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I. Introduction

The National Marine Fisheries Service proposes to assess the ability of large-scale plants of coho salmon (Oncorhynchus kisutch) to generate a coastal marine sportfishery. Annual plants of one million Coho smolt during three consecutive years in the vicinity of Plum Island Sound and the Parker River (Massachusetts) are proposed. Based on the available literature, the potential impact of stocked coho salmon on other species, resulting from oceanic trophic interactions, is considered.

II. Food Composition of Coho Salmon

A. Composition of Coho Salmon Diet

Data on stomach contents of coho salmon (Tables 1a, 1b) is based on samples from the Pacific Northwest from Oregon to Alaska. The five sources cited examined significantly different sample sizes, ranging from 19 to 222 fish. These samples indicate considerable variability in the diet of the coho salmon. Fish make up 20-95% of the coho diet. The proportion of herring varies from 20-93% of the total amount of fish. Sand launce, candlefish and rockfish were also important components of the fish portion of the diet. Amphipods, euphausiids and decapod larvae are the main invertebrate prey.

The composition of the coho's diet varies significantly in different locations and at different times of the year (Pritchard and Tester, 1944). Comparison of diet on the east and west coasts of Vancouver showed marked differences in feeding intensity and proportions of crustaceans to fish (Prakash and Milne, 1958). Heg and Van Hyning (1951) note that sand launce and squid are reported by fishermen to be more important than organized sampling indicated. They suggest that schooling sand launce and squid were simply not present in

the sampled areas. Pritchard and Tester (1944) state that while herring and sand launce are the main dietary components, other fish and invertebrates are also important. In view of this variability, it is doubtful that any one species will be exploited as the main prey of cohos.

Herring have a high thiaminase content which caused nutritional deficiencies in cultured Atlantic salmon whose diet was not supplemented with thiamine. High salinity (30%) resulted in fewer mortalities and increased growth rates, suggesting that seawater may provide enough thiamine to offset the thiaminase of a herring-rich diet (Saunders and Henderson, 1974). If not, salmon would probably limit their intake of herring to avoid a thiamine deficiency.

B. Growth of Oceanic Coho Salmon

Growth data for cohos, from Waddell Creek, California, is reported by Shapovalov and Taft (1954) (Figure 1). Length data is given for cohos of various ages caught at sea. A function relating weight to age was constructed by assuming a cubic length-weight relationship and a weight of 4.5 kg at a length of 650 mm and 24 months old. This function is represented graphically in Figure 2.

There is a great deal of variability in reported lengths of mature cohos, probably stemming from local changes in water temperature and food availability. Elson (1976) gives a range of 3.2-3.6 kg, Hart (1973) reports 2.7-5.4 kg, Novotny (1975) indicates a range of 2-8 kg, and McPhail and Lindsey(1970) report 3.6-5.5 kg. Because the above growth data are from wild salmon, the weight of the fish when they enter the sea as smolts (<20 g) is considerably less than that of the hatchery and saltwater-reared fish to be released in Massachusetts (180 g, NMFS (1975), also see Mahnken and Joyner (1973)). This is expected to give the released fish an advantage in growth of as much as four months over

the wild fish (Survival will also be very high; 12% return on eggs, as opposed to <1% for wild populations). On the other hand, the Californian fish are able to grow throughout the winter because of warmer winter temperatures (Joyner, 1973). Massachusetts fish are expected to cease growth from about January to March. This is indicated for first sea-winter salmon by NMFS (1975). Joyner (1973) indicates that Gulf of Maine temperatures, $<8^{o}$ C, will be too low for growth of coho. It is expected that lack of appropriate food items at low temperatures would be just balanced by reduced metabolic requirements at low temperatures, resulting in minimal growth. While the growth scheme indicated by Figure 2 will to some degree differ from the actual growth of cohos in the Gulf of Maine, it is probably adequate for crudely approximating the consumption of stocked cohos using computational methods to be described below.

When compared to other Pacific salmon, cohos gain weight very quickly. Weight gains in two years at sea are equivalent to those made by chum and sockeye salmon in 3 to 5 years (Gates, et al., 1975). Extremely rapid growth during first summer at sea is noted by several authors including Godfrey et al. (1975).

C. Population Size.

Population numbers were interpolated between release and recapture values using both a linear and an exponential model. One million, two hundred and fifty thousand eggs are expected to produce 1,000,000 smolts 13 months later for release and 144,000 adults are expected to return for spawning after 24 months (NMFS, 1975). Less than 2% are expected to return after 12 months as grilse, or early maturing males. These are not considered in subsequent calculations.

The exponential decline model, $N = 1{,}000{,}000\ e^{-.0807(T)}$ (T is time in months after release and N is the number of fish), agrees with standard methods, and represents higher mortality among the young and small, more numerous fish. The linear model ($N = 1{,}000{,}000 - 35{,}700\ T$) provides a worst case model, as mortality is less for the numerous young fish, consequently, the total food consumption is greater. Because of the lack of data on oceanic population numbers, this is the most adequate manner in which this data can be treated (Figure 3).

D. Models of Consumption

Two models for consumption were used to estimate the total amount of food consumed by a year-class of cohos while at sea. These models also apply to the amount eaten by two consecutive year-classes present together during a given year.

In the first model, increase in weight is assumed to be 20% of the amount consumed. That is, for every 100 g eaten, there will be a weight gain of 20 g. This ratio, known as gross growth efficiency (GGE), is reasonable for salmon in the wild. Novotony (1975) reports a GGE of 20% for cultured mature cohos. Brett (1969) indicated a GGE for juvenile sockeye salmon of 20% over a temperature range of 5-15° C. Brown (1957) reported a GGE of 14-43% for hatchery brown trout and Parsons and Takahashi (1973) expect a GGE of 10-40% for most animals. Because of the changing population size, total consumption is estimated numerically by examining three month intervals (with the exception of December to March of the first winter, and October to November of the second sea year. Consumption for each period is the product of the change in weight and the average population size for that period, divided by the growth efficiency, 20%, ($C = \Delta W x \bar{n} \div GGE$). The total consumption is the sum of the consumption during each of the eight periods.

Several corrections may be necessary to make the analysis more realistic. During the first four months of oceanic life (the first sea-winter), no growth is expected because of the low temperatures (NMFS, 1975). Gross growth efficiency must therefore be zero, as some food is consumed. An alternative method of calculation (#1), is to assume a winter feeding rate of 1%/day (10 g/kg/day). This is reasonable, as will be shown later. This assumption is of minimal effect, as there is little change in total consumption. This same condition may prevail during the second sea-winter, but seems to be balanced by increased weight gain in late summer.

The second important alternative method of analysis (#2) concerns the apparent lack of weight gain during the last five months of oceanic life. Novotny (1975) reports minimal weight gains, and even declines in cultured cohos fed in excess during this period. It is known that coho salmon feed extensively and undergo important gonadal development at this time, therefore, changes in weight may be obscured by changes in the length-weight equation or heavy feeding may result in low growth because a decline in gross growth efficiency. Accordingly, two alternative approaches are considered. In the first (#2a), weight gains equivalent to those of the preceding April to June are assumed for computational purposes for the last five months of oceanic life. In the second (#2b), a reasonable summer feeding rate of 4%/day (40 g/kg/day) is assumed. Number 2B entails an increase of 60% over the earlier model, while estimate #2a entails a negligible increase of only 10%.

Since it is likely that gross growth efficiency diminishes as the fish become larger, more of the intake being necessary for metabolic needs, analysis 2b may be most realistic.

In the second model, consumption is the product of weight, feeding rate (consumption per biomass of predator per unit time), population size and time. This product, numerically approximated with three-month time periods as in the previous model, offers an appropriate method for the calculations of total consumption.

Feeding rates of 4%/day (40 g/kg/day) during the warmer months (April to December) and 1% (10 g/kg/day) during the colder months (January to March) are assumed. At winter Gulf of Maine temperatures, $<8^{o}$ C, no growth is expected (Joyner, 1973). This is substantiated by NMFS (1975) for coho juveniles, and by Brett (1969), for young sockeye salmon fed at rations of 1%.

During the summer months, with temperatures of $8\text{-}14^{o}$ C in the Gulf of Maine, feeding rates of 4% should produce the necessary growth as shown by the growth curve. Slightly higher rates may be in effect for smolts very soon after release, but this seems negligible. Support for a 4% feeding rate comes from Gates et al. (1974) and Warren (1971). They report a 4% feeding ratio for coho fingerlings and juveniles, respectively. Novotny (1971) reports 4% feeding rate as a maximum rate for cultured "small" (.2-.5 kg) cohos, and Brett (1970) reports that the daily cost of living for mature sockeye salmon is 1.5-2.5%, but may rise to 5%. If this feeding rate for cohos is too low in autumn, it may compensate by being slightly high in the early spring. Feeding rate is one of the most difficult measurements to make on a free-living fish, but this approximation seems reasonable.

The product of feeding rate, number of days per period, the average weight of each fish, and the average population size is the consumption during each period. This method corrects for the winter slowdown in feeding. It does

not correct for unduly high early growth, which results in heavier fish for the last part of the oceanic stage. At a fixed feeding rate of 4%, these heavy fish appear to consume an unduly large amount. This model provides an estimate of the upper bound of the total population consumption.

Applying each of the methods discussed above and the linear and exponential population models, the following estimates of consumption were calculated (Table 2).

Table 2. Estimated total consumption.

	Population decline		
	Linear	Exponential	
Gross Growth Efficiency Model	12,785	8,990	metric tons
with alternatives #1,#2a	13,777	9,787	
with alternatives #1,#2b	19,094	13,844	
Feeding Rate Model	23,670	16,634	

III. Location and Movement of Cohos.

Coho salmon in the Pacific Ocean are fish of the temperate continental shelf (Joyner, 1973). Preferred temperatures are 7-12°, although 5-14° C is marginally acceptable. Hart (1973), however, reports oceanic catches of coho as much as 1600 km from shore. Most catches of cohos on the high seas are made in the top 10 m, although they are found somewhat deeper during daylight (Godfrey et al., 1975).

In the Atlantic, smolts released in the Parker River in late autumn would be likely to remain in that area until the water begins to warm in the spring. During the summer and fall they should be present throughout the Gulf of Maine, predominantly from Portland, Maine to the Bay of Fundy. During the

following winter they should be present in the warmer offshore waters from Cape Cod to Portland. Cohos might be found far offshore, so some juveniles may feed in areas far outside of the Gulf of Maine. They are not expected to move south of Cape Cod, due to the presence of a warm frontal zone stretching east of Cape Cod.

IV. Trophic Interaction with Herring

Expected predation by cohos on herring leads to the possibility of competition between the emergent coho sportfishery and the commercial herring fishery. Heavy predation could potentially cause significant reduction in the standing stock of herring.

In an attempt to quantify the amount of herring eaten, three scenarios are examined, showing three possible coho diets.

A - Herring present as 12% of coho diet--approximate minimum recorded in literature.

B - Herring present as 50% of diet. This corresponds to coho diet as seen off British Columbia, and is the expected Atlantic coho diet (Kirkness, 1948).

C - Herring present as 100% of the coho diet.

These three scenarios are compared with the expected total annual consumption of the population. Although the exponential population decline is the more realistic model, the linear decline will also be examined as it predicts greater total consumption.

The greatest conflict between the coho sportfishery and the herring fishery will occur if the cohos remain within the Gulf of Maine (ICNAF Subarea 5Y), and eat only herring. The 5Y herring are fished almost exclusively by the United States so this could lead to reduced U.S. catches. This is the worst case. Should the coho be spread out throughout their maximum range, ICNAF Subareas 4X, 5Y, and 5Ze, or should they consume other food items besides

herring, the impact on the herring fishery will be much less (Table 3).

Table 3. Estimated Herring Consumption (Feeding Rate Model).

	% herring of diet	Population model Linear	Population model Exponential	
A	12%	2.8	2.0×10^3 metric tons	Biomass consumed per year
B	50%	11.8	8.3	
C	100%	23.7	16.6	

Comparing the greatest consumption of herring with the U.S. catch of herring in the Gulf of Maine, ICNAF Subarea 5Y, is the worst case. A comparison with total catch of 4X, 5Y, 5Ze, indicates a less severe impact (Table 4).

Table 4. Average Annual Catch of Herring, 1965-1974 (ICNAF, 1976b)

	SA 5Y	SA 4X, 5Y, 5Ze	
Total catch			
United States	31,299	31,569 metric tons	average annual catch, 1965-74 (almost all 3+ years)
Canada	7,410	114,386	
Others	0	185,922	

In the worst case, cohos with a linearly declining population, eating only herring of catchable size, only in 5Y, could consume 76% of the U.S. catch calculated by the feeding rate model. In a more reasonable scenario, (cohos declining in numbers exponentially, feeding somewhat outside of the 5Y subarea, on herring of various sizes, which comprise only 50% of their diet) as in B, herring could consume 8,300 tons annually, about 3% of the total herring catch in SA 4X, 5Y and 5Ze.

It should also be pointed out that herring are eaten by many other species which occur in far greater numbers than the proposed coho population, such as the cod, pollock, haddock, silver hake, mackerel, and tuna.

V. Competition - Coho vs Atlantic Salmon

A. Feeding Areas.

Atlantic salmon prefer colder, further offshore waters than cohos while in their oceanic phase. While at sea, they are found in the rich, cold arctic waters to the west of Greenland, 2-5° C, although they may return south as far as Newfoundland during the winter. They remain at sea for about three years, then return without feeding to their natal streams during the late summer. (Joyner, 1973). Unlike Pacific salmon, many Atlantic salmon return to sea, and survive to spawn several times. The Atlantic salmon are harvested as they ascend to spawn, largely in North American rivers and streams, although many are harvested in Greenland waters by other countries, predominantly Denmark. Spawning occurs in October and November.

They are not expected to compete with cohos while at sea due to their more northerly positions in the colder waters. When near their natal streams in the summer, they do not feed, so present little problem.

The question of competition by young salmon of both species is well covered by Elson, Carter, and Meister (1976).

The potential impact of coho feeding on young Atlantic salmon cannot be assessed.

B. Diet.

Atlantic salmon feed extensively on fish, including capelin and sand launce on the West Greenland banks. They feed on Paralepis and lanternfishes in the Labrador Sea, and sprat, herring, launce, stickleback and cod in the Baltic (Lear, 1972). These food preferences are similar to those of the coho salmon, but different habitats of the salmon species will lessen direct competition. Both species cease to feed when they enter estuaries prior to spawning (Lear, 1972 and Mallock, 1912).

VI. Competition with Other Fisheries

A. Sizes of Competitive Fisheries.

The total coho catch is expected to be about 690 metric tons per year. This will be a moderate-sized sportfishery. It will be smaller by far than any important commercial fisheries. It is also much smaller than the bluefish and striped bass fisheries which are mainly sport (Table 5).

Table 5. Recorded catches of some Atlantic fishes, 1974 (ICNAF, 1976a).

		SA 5Y	SA4X, 5Y, 5Ze	SA 5+6
Cod	US	6,186	20,062	-
	Others	134	38,364	-
Haddock	US	2,404	24,396	-
	Canada	247	24,004	-
Red Hake	US	375	2,062	-
Silver hake	US	13,636	23,621	-
	Others	0	53,361	-
Bluefish	US	67	68	3,189
Striped bass	US	61	61	4,245

B. Diet of Potential Competitors

Atlantic cod, a commercially important species in ICNAF Division 5Y, eats 69% fish. Herring and other clupeidae are the most important components (25%). Crustaceans and mollusks complete their diet (Table 6a, from Maurer and Bowman, 1975). Because they feed near the bottom, competition with near surface feeding cohos will be lessened.

Haddock rely primarily on polychaetes, crustaceans, and echinoderms, with fish contribution only 2% to their total diet (Table 6b, etc.). Distribution plots show that haddock are more heavily concentrated on Georges and Browns banks than in ICNAF Division 5Y (Grosslein and Clark, 1976).

Silver hake are distributed throughout the Gulf of Maine (as well as farther south) and are commercially important in ICNAF Division 5Y. They depend on fish for 70% of their diet, with herring and mackerel the two single most important species. Crustaceans make up another 25% (Table 6c).

A primary spawning ground of silver hake extends west and north of Cape Cod on the continental shelf in autumn. As noted previously, salmon probably eat proportionately more fish than larvae in the fall, but it is possible that they could affect silver hake recruitment.

Red hake are not fished heavily in the Gulf of Maine. Fish are less important (30%) than crustaceans (52%) in the red hake diet (Table 6d).

White hake, a species taken as by-catch in other hake fisheries of Division 5Y, eat 78% fish. A complete breakdown is not available, but herring are probably not important while mackerel constitute 15% (Table 6e).

Pollock are of commercial importance in Division 5Y, but rely more heavily on crustaceans (66%) than fish (32%) for food (Table 6f).

Atlantic mackerel are much more heavily fished on Georges Bank than inshore. Their diet includes only 4% fish (Table 6g).

Bluefish, an important recreational species depend on fish for 68% of their intake, especially Peprilus triacanthus and Clupeidae, which include the sea herring (Table 6h). Striped bass, another important recreational species is very voracious, feeding on alewife, anchovy, croaker, channel bass, eels, flounders, herring, menhaden, mummichogs, mullet, launce, sculpins, shad, hake crustaceans and mollusks (Bigelow and Schroeder, 1953).

Cod, silver hake, white hake, striped bass and bluefish appear to be the main competitors of a coho stock for fish in the coastal area region of the Gulf of Maine. Crustaceans have been treated less extensively, but would also be affected by coho salmon. The few examples cited indicate that crustaceans are an important component in the diet of many other Atlantic species as well.

C. Prey of Coho

The major prey of Pacific coho salmon, capelin, herring, and sand launce, will presumably also be eaten in the Atlantic. Capelin is an Arctic fish coming inshore to spawn and will not be important to cohos if they stay in the Gulf of Maine (Bigelow and Schroeder, 1953). Herring are found in the Gulf of Maine in large numbers where they are prey of cod, pollock, haddock, silver hake, mackerel, striped bass, tuna, salmon, dogfish and mackerel shark (Bigelow and Schroeder, 1953). This species has been dealt with in more detail above. Sand launce, generally found in coastal waters, are eaten by many of the same species which feed on herring (Bigelow and Schroeder, 1953).

Specific impact of coho on its prey and competitor species cannot be predicted, but it is unlikely that introduction of a relatively small biomass will have serious impacts. If they were to become a large stock due to self-stocking, the situation could easily change.

VII. Possible Effects if Cohos Become Established.

It is expected that after the introduction of cohos, the population will have to be maintained artificially. Should coho become established, the increase of cohos would be at the expense of some other species if food is in fact limiting.

There are excellent indications that should cohos expand to other streams in Massachusetts, north of Cape Cod, or to New Hampshire or Maine, they would be able to spawn closer to the mouths of rivers than the Atlantic salmon, and perhaps inhabit streams that are no longer acceptable to the Atlantics. Elson, et al. (1976) indicate that there could be coexistence between the two species where Atlantics are already found, but that some problems could result, especially in the re-introduction of Atlantic salmon in southern streams.

VIII. Summary

This report assesses the oceanic environmental impact of a large-scale plant of coho salmon (*Oncorhynchus kisutch*) in the vicinity of Plum Island Sound and the Parker River (Massachusetts). The assessment is based on the assumption of 1,000,000 smolt coho salmon migrating from the Parker River estuary to the open ocean at about 13 months of age and weighing 0.2 kg. The oceanic phase of the life cycle lasts for about two years during which time the fish grow to about 4.5 kg.

From 20 to 95% of the diet of the coho salmon of the Pacific Northwest consist of fish. The primary fish species consumed is the herring with sand launce, candlefish and rockfish also forming a substantial portion of the diet. Amphipods, euphausiids and decapod larvae are the primary invertebrate prey of the coho salmon.

Two models of coho salmon consumption were considered. The first model assumed a constant gross growth efficiency (the proportion of consumption reflected in growth) of 20%. The second model assumed a constant feeding rate of 4% and 1% of body weight per day during summer and winter, respectively. These consumption models were combined with exponential and linear population mortality models and other minor modifications to estimate total consumption as from 9,000 to 24,000 metric tons annually. A consumption rate near or below the midpoint of this range seems most likely.

Coho salmon originating in the Parker River estuary will probably spread over the continental shelf from Cape Cod to Nova Scotia. If herring comprised 50% of the diet of the coho salmon (a reasonable percentage according to the literature), then the stocked population could consume about 3% by weight of the annual average catch (1965-1974) of herring from ICNAF Subareas 5Y, 5Ze and 4X. During years of poor herring production or if coho salmon feeding were over a smaller area, the impact might be more substantial.

The potential for competition for food between the coho salmon and cod, haddock, red hake, silver hake, bluefish, pollock, striped bass and mackerel was considered. Coho salmon are most likely to compete with pelagic fish feeding species like the bluefish, striped bass, cod, silver hake and white hake.

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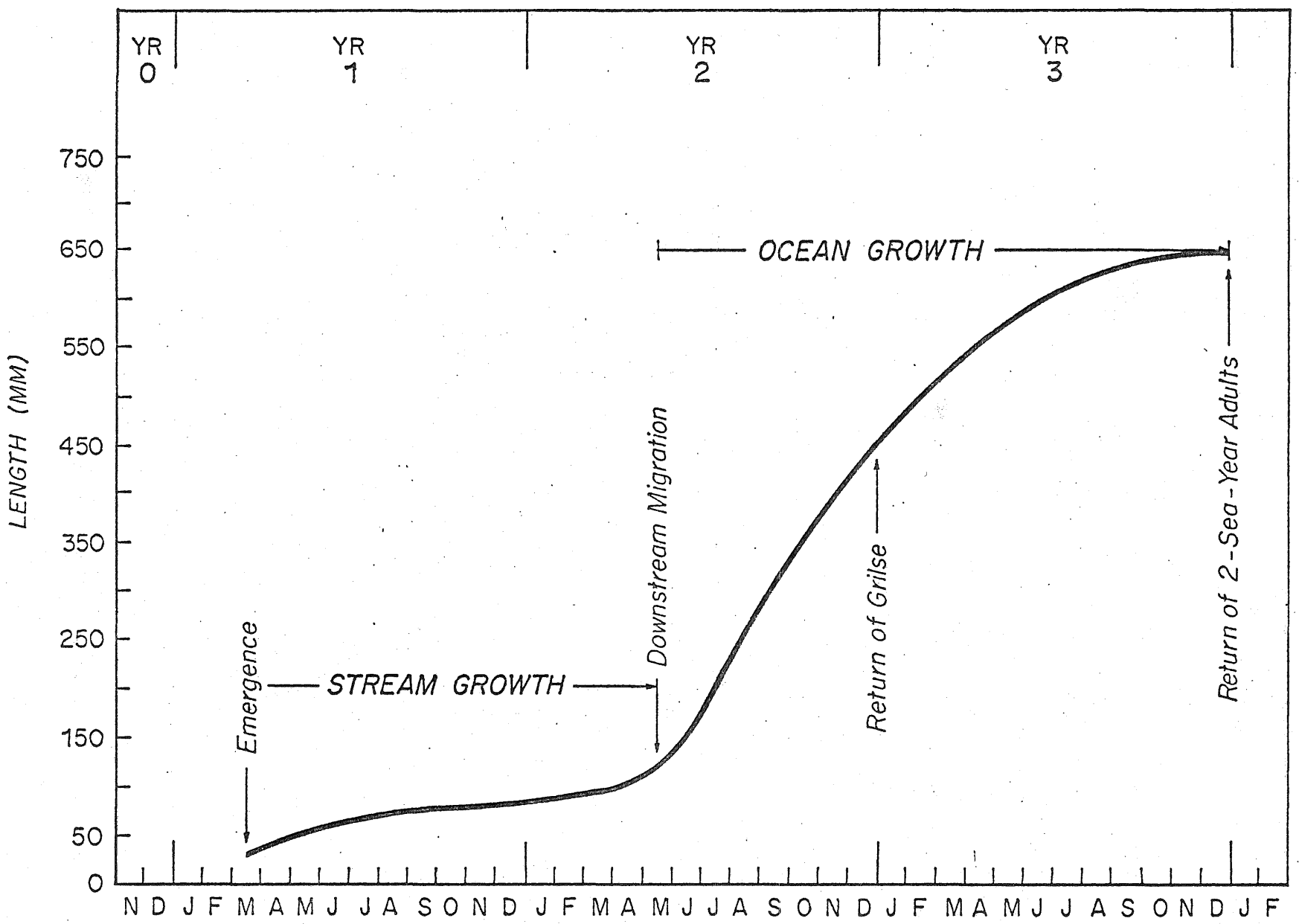

Figure 1. Growth of Waddell Creek, California coho salmon - length.
(fitted by eye to data from Shapovalov and Taft, 1954)

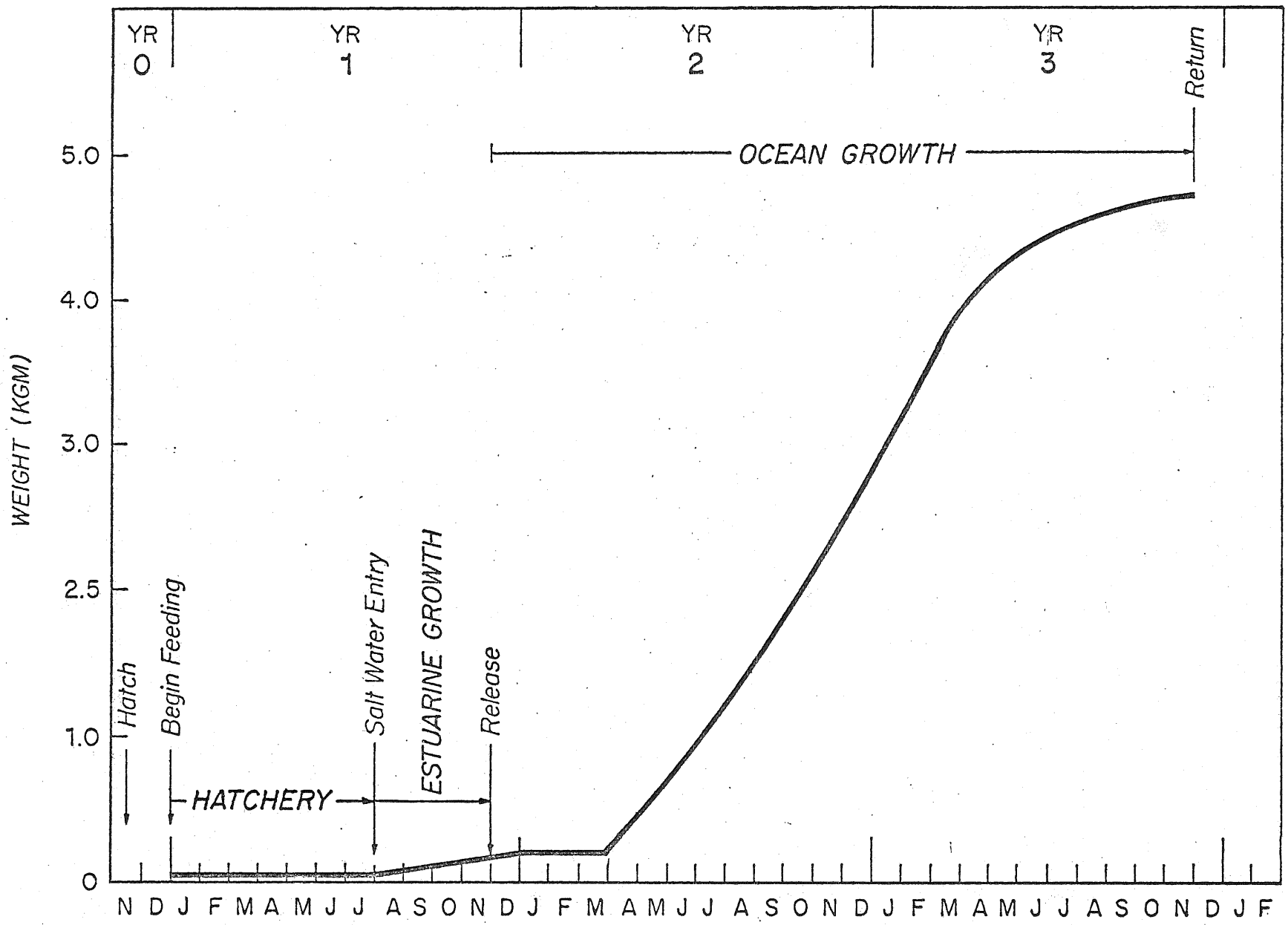

Figure 2. Computed growth of released Massachusetts coho salmon - weight. Growth during first 15 months after the onset of feeding is as described by NMFS (1975).

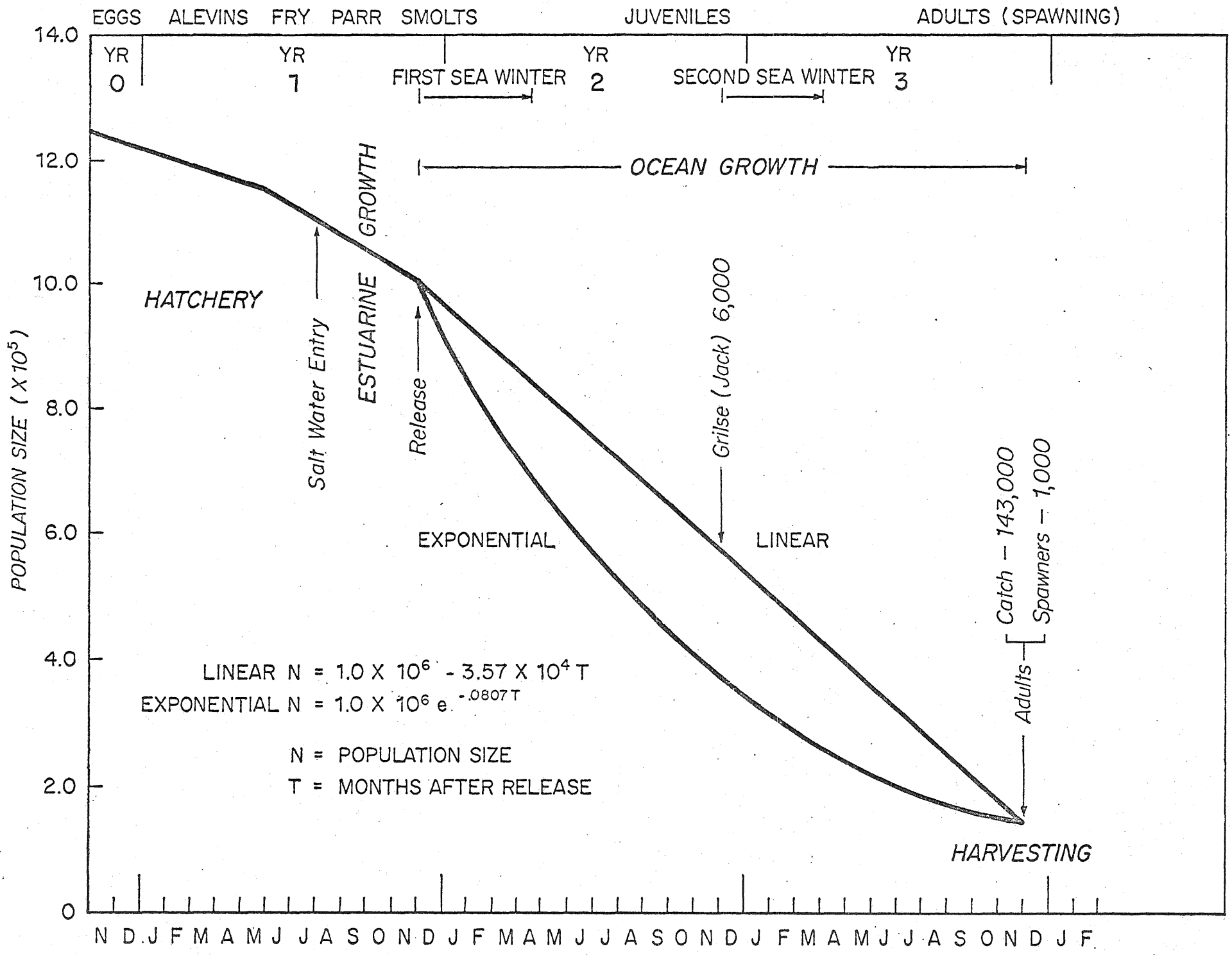

Figure 3. Computed population decline of released Massachusetts coho salmon.

Table 1A. Percent Composition of Diet-Coho and Atlantic Salmon.

Food items	Coho salmon Heen (1957)		Kirkness (1948)			Hoe and Van Hyning (1951)			Prakash (1962)				Lear (1972)
Area	S.E. Alaska	S.E. Alaska	Puget Sound	Puget Sound	Puget Sound	Astoria	Newport	Coos Bay	West Coast Vancouver I.	West Coast Vancouver I.	West Coast Vancouver I.	West Coast Vancouver I.	NW Atlantic Coast and Oceanic Depths
Date	June-Sept. 1957	June-Sept. 1958	Nov.-Feb. 1947-1948	Mar-June 1948	July-Oct. 1948	June-July 1948-1950	June-July 1948-1950	June-July 1948-1950	June 1957	July 1957	Aug. 1957	Sept. 1957	1963-1971
*Specimens/empty	200/	222/	104/19	177/8	186/67	20/4	19/1	28/7					
Herring	18.4 %	17.9	10	12	50	21.6	27.1	18.7	65.4	74.4	87.2	69.7	9.2
Candlefish	-	-	0	24	8	-	-	-	-	-	-	-	-
Sand launce	15.1	14.9	-	-	-	0	0	2.1	1.3	3.5	7.6	4.6	10.3
Capelin	20.4	6.2	-	-	-	-	-	-	-	-	-	-	67.0
Other fish	17.9	17.3	10	3	22	77.4	1.4	38.4	3.0	8.1	1.0	0.9	4.3
Total fish	71.8	55.3	20	39	80	99.0	28.5	59.2	69.7	86.0	95.8	75.2	90.8
% fish of total diet	71.7	55.4	20.4	42.4	87.0	99.0	28.5	63.6	69.7	86.0	95.6	75.2	92.3
Squid	.7	0	-	-	-	-	-	-	-	-	-	-	-
Amphipod	0	7.7	44	8	8	-	-	-	0.2	0.1	0	0	3.1
Shrimp	5.9	.5	11	2	.3	-	-	-	-	-	-	-	-
Euphausiid	0	5.1	-	-	-	0	0	28.5	5.6	0.8	3.4	22.1	1.8
Schizopod	-	-	19	22	.03	-	-	-	-	-	-	-	-
Total Crustaceans	5.9	13.3	74	32	8.33	0	0	28.5	5.8	.9	3.4	22.1	4.9
% Crust. of total diet	5.9	13.3	75.5	34.8	9.1	0	0	30.6	5.8	.9	3.4	22.1	5.0
Larvae	0	1.5	0	19	3	1.0	71.5	14.3	24.5	12.7	0.5	2.3	-
Other	21.8	28.7	4	2	.47	0	0	1.1	0	0.4	0.5	0.4	17.4
% Herring of total diet	18.4	17.9	10.2	13.0	54	21.6	27.1	20.1	65.4	74.7	87.0	69.7	9.3
Total	100.2	99.8	98	92	92	100	100	93.1	100	100	100.2	100	98.4

Table 1b. Percent Composition of Diet--Coho Salmon, British Columbia, 1939-1941 (Pritchard and Tester, 1944).

Organism	Percent by volume 1939	1940	1941
Fish			
Pilchards--*Sardinops caerulea*	-	1.0	5.1
Pacific herring--*Clupea pallasii*	34.1	29.0	12.8
Anchovy--*Engraulis mordax*	-	1.7	6.2
Clupeoid remains (probably mostly pilchard or herring)	-	2.3	13.4
Coho salmon--*Oncorhynchus kisutch*	-	0.6	-
Capelin--*Mallotus catervarius*	1.0	+	-
Lanternfish--*Lampanyctus* sp.	-	1.9	-
Pacific saury--*Cololabis saira*	-	0.5	-
Hake--*Merluccius productus*	-	1.2	-
Whiting--*Theragra chalcogramma* and "cod" remains	+	+	0.1
Rockfish--*Sebastodes* sp.	-	+	22.6
Black cod--*Anoplopoma fimbria*	-	4.3	4.7
Bullhead--*Cottus* sp.	-	-	1.0
Sand launce--*Ammodytes personatus*	41.0	24.0	12.9
Unidentified fish remains	19.6	3.9	2.6
Invertebrates			
Squid(cuttlefish)--Rossia pacifica	-	-	0.6
Goose barnacles	-	0.4	-
Isopods	0.1	-	+
Amphipods	+	12.5	9.0
Red feed (Euphausiids)	0.4	9.1	0.4
Crab larvae	3.8	6.9	8.6
Unidentified crustacean remains	+	-	-
Jellyfish--*Velella* sp.	-	0.7	-
Summary			
Herring	34.1	29.0	12.8
Pilchards	-	1.0	5.1
Clupeoid remains	-	2.3	13.4
Sand launce	41.0	24.0	12.9
Other fish	1.0	10.2	34.6
Unidentified fish remains	19.6	3.9	2.6
Invertebrates	4.3	29.6	18.6
Number of stomachs with contents	45	126	86
Total fish	95.7	70.4	81.4
Total diet	100	100	100
% fish of total	95.7	70.4	81.4
% herring of total	34.1	29.0	12.8
% invertebrates of total	4.3	29.6	18.6

Table 2b. Stomach Contents of Haddock.

ITEMS	wt(g)	% wt
POLYCHAETES	1105.70	16.2
Capitellids	29.30	0.4
Terrebellids	129.34	1.9
Sabellids	108.70	1.6
Nereidiforms	156.60	2.3
Other polychaetes	681.76	10.0
CRUSTACEANS	1254.55	18.4
Amphipods	509.52	7.5
Hyas	25.19	0.4
Paguridae	39.61	0.6
Pasiphaea	76.00	1.1
Axiidae	67.65	1.0
Hippolytidae	18.48	0.3
Pandalidae	77.41	1.1
Other decapods	67.59	1.0
Meganyctiphanes	145.21	2.1
Other euphausiids	55.93	0.8
Other crustaceans	171.96	2.5
MOLLUSKS	252.73	3.7
Pectinidae	16.67	0.2
Nuculanidae	30.84	0.5
Other pelecypods	117.69	1.7
Gastropods	25.34	0.4
Octopods	15.48	0.2
Other mollusks	46.71	0.7

cont'd

Table 2b. Stomach Contents of Haddock (cont'd)

ITEMS	wt(g)	% wt
ECHINODERMS	2523.62	37.4
Asteroids	25.38	0.4
Stronglocentrotus	194.34	2.9
Echinarachnius	64.98	1.0
Other echinoids	202.09	3.0
Ophiopholis	407.59	6.0
Ophiura	557.09	8.2
Other ophiuroids	892.21	13.2
Crinoids	11.67	0.2
Holothuroids	164.05	2.4
Other echinoderms	4.22	0.1
TUNICATES	34.25	0.5
FISH	130.55	1.9
ANIMAL REMAINS	701.96	10.3
SAND AND ROCK	709.01	10.5
MISCELLANEOUS	71.81	1.1
Total	6784.18 g	100.0%

Table 2c. Stomach Contents of Silver Hake.

ITEMS	wt(g)	% wt
POLYCHAETES	12.56	0.2
CRUSTACEANS	1378.22	25.9
Amphipods	20.86	0.4
Crangonidae	73.49	1.4
Pandalidae	284.18	5.3
Pasiphaea	106.91	2.0
Other decapods	34.82	0.7
Euphausiids	713.37	13.4
Other crustaceans	144.59	2.7
MOLLUSKS	111.07	2.1
Cephalopods	111.07	2.1
FISH	3720.51	70.0
Alosa pseudoharengus	222.96	4.2
Clupea harengus harengus	547.69	10.3
Merluccius bilinearis	134.26	2.5
Other gadidae	197.39	3.7
Scomber scombrus	1000.93	18.8
Peprilus triacanthus	81.43	1.5
Other fish	1535.85	28.9
MISCELLANEOUS	93.65	1.8
Total	5316.01 g	100.0%

Table 2d. Stomach Contents of Red Hake.

ITEMS	wt(g)	% wt
NEMERTEANS	13.29	0.5
POLYCHAETES	74.05	2.8
CRUSTACEANS	1374.96	51.5
Amphipods	185.49	6.9
Cancer	137.26	5.1
Hyas	1.41	0.1
Pagurus	69.09	2.6
Munida	254.10	9.5
Munidopsis	12.91	0.5
Other decapod crabs	21.98	0.8
Axiidae	49.66	1.9
Crangon	76.29	2.9
Pandalus	47.38	1.8
Dichelopandalus	183.17	6.9
Other pandalidae	78.05	2.9
Other decapod shrimp	29.88	1.1
Other decapods	17.81	0.7
Cirolana	19.56	0.7
Other isopods	5.54	0.2
Meganyctiphanes	43.15	1.6
Other euphausiids	37.69	1.4
Cumaceans	6.28	0.2
Mysids	1.75	0.1
Other crustaceans	96.51	3.6

cont'd

Table 2d. Stomach Contents of Red Hake (cont'd).

ITEMS	wt(g)	% wt
MOLLUSKS	157.97	0.5
Buccinum	5.55	0.2
Other gastropods	72.13	2.7
Cephalopods	32.60	1.2
Other mollusks	47.69	1.8
ECHINODERMS	14.31	0.6
Holothuroids	12.20	0.5
Other echinoderms	2.11	0.1
FISH	772.54	28.8
Ophichthidae	22.70	0.8
Clupeidae	13.70	0.5
Enchelyopus cimbrius	27.39	1.0
Merluccius bilinearis	4.60	0.2
Urophycis chuss	4.85	0.2
Cryptacanthodes maculatus	27.07	1.0
Scomber scombrus	8.90	0.3
Flatfish	12.86	0.5
Other fish	650.47	24.3
ANIMAL REMAINS	244.13	9.1
MISCELLANEOUS	21.66	0.8
Total	2672.91 g	100.0%

Table 2e. Stomach Contents of White Hake.

ITEMS	wt(g)	% wt
POLYCHAETES	15.47	0.2
CRUSTACEANS	1382.72	17.3
Amphipods	9.40	0.1
Cancer	11.39	0.1
Pagurus	6.02	0.1
Geryon	53.22	0.7
Axiidae	12.94	0.2
Hippolytidae	6.32	0.1
Crangon	19.07	0.2
Dichelopandalus	47.71	0.6
Pandalus	708.42	8.8
Other pandalidae	111.49	1.4
Other decapods	12.80	0.2
Maganyctiphanes	149.42	1.9
Other euphausiids	180.65	2.2
Other crustaceans	53.87	0.7
MOLLUSKS	200.93	2.5
Loligo	43.93	0.5
Rossia	14.56	0.2
Other cephalopoda	139.60	1.8
Other mollusks	2.84	+
FISH	6257.75	77.8
Ammodytes americanus	108.40	1.3
Cryptacanthodes maculatus	59.45	0.7
Scomber scombrus	1199.99	14.9
Melanogrammus aeglefinus	65.32	0.8
Merluccius bilinearis	409.31	5.1
Phycis chesteri	5.46	0.1
Urophycis tenuis	39.43	0.5
Other gadidae	25.58	0.3
Chloropthalmidae	11.60	0.1
Flatfish	125.64	1.6
Other fish	4207.57	52.4
ANIMAL REMAINS	178.51	2.2
MISCELLANEOUS	3.70	+
Total	8039.08 g	100.0%

Table 2f. Stomach Contents of Pollock.

ITEMS	wt(g)	% wt
CRUSTACEANS	6052.03	65.7
Amphipods	14.03	0.2
Pasiphaea	2856.81	31.0
Pandalidae	213.69	2.3
Other decapods	32.64	0.4
Meganyctiphanes norvegica	2076.42	22.5
Other euphausiids	713.74	7.7
Other crustaceans	144.70	1.6
MOLLUSKS	47.35	0.5
Limacina retroversa	40.18	0.4
Other mollusks	7.17	0.1
FISH	2939.80	31.9
Omochelys cruentifer	177.88	1.9
Synaphobranchidae	239.60	2.6
Other anguilliforms	254.52	2.8
Clupeidae	171.04	1.9
Gonostomatidae	35.74	0.4
Myctophidae	230.06	2.5
Melanogrammus aeglefinus	22.35	0.2
Merluccius bilinearis	128.56	1.4
Pollachius virens	2.60	+
Ammodytes americanus	12.76	0.1
Sebastes marinus	6.14	0.1
Other fish	1658.55	18.0
ANIMAL REMAINS	136.87	1.4
MISCELLANEOUS	47.62	0.5
Total	9223.67 g	100.0%

Table 2g. Stomach Contents of Bluefish.

ITEMS	wt(g)		% wt	
CRUSTACEANS	0.49		+	
Isopoda		0.13		+
Decapod shrimp		0.36		+
MOLLUSKS	504.56		30.6	
Loligo pealei		503.63		30.5
Other cephalopods		0.93		0.1
FISH	1130.85		68.4	
Etrumeus teres		83.88		5.1
Other clupeidae		233.31		14.1
Peprilus triacanthus		531.95		32.3
Merluccius bilinearis		10.18		0.6
Strongylura marina		119.50		7.2
Other fish		152.03		9.2
ANIMAL REMAINS	16.08		1.0	
Total	1651.98 g		100.0%	

Table 6a. Stomach Contents of Atlantic Cod.

ITEMS	wt(g)	% wt
POLYCHAETES	611.83	1.3
CRUSTACEANS	9965.275	20.7
Amphipods	215.29	0.4
Cancer	2166.17	4.5
Geryon	1117.35	2.3
Hyas	975.45	2.0
Paguridae	998.43	2.1
Pandalidae	1390.97	2.9
Other decapods	1333.53	2.8
Euphausiids	919.79	1.9
Mysids	161.35	0.3
Other crustaceans	686.945	1.4
MOLLUSKS	3915.41	8.1
Placopecten	1516.88	3.2
Chlamys	536.23	1.1
Gastropods	1185.08	2.5
Other mollusks	677.22	1.4
ECHINODERMS	505.80	1.1
FISH	33074.85	68.8
Clupea harengus harengus	7200.38	15.0
Other clupeidae	4628.47	9.6
Argentinidae	685.43	1.4
Gadidae	1834.87	3.8
Ammodytidae	932.13	1.9
Anarhichadidae	388.33	0.8
Cottidae	707.97	1.5
Scomber scombrus	1344.79	2.8
Sebastes marinus	1135.36	2.4
Limanda ferruginea	837.23	1.7
Fish eggs	2096.41	4.4
Other fish	8702.61	18.1
MISCELLANEOUS	2580.87	5.4
Total	48073.16 g	100.0%

Table 6g. Stomach Contents of Atlantic Mackerel.

ITEMS	wt(g)		% wt	
CRUSTACEANS	75.42		44.1	
Amphipods		0.48		0.3
Crangon		2.66		1.6
Pandalus		1.33		0.8
Sergestidae		0.10		0.1
Decapod larvae		0.81		0.5
Other decapods		0.08		+
Thysanoessa		0.26		0.1
Meganyctiphanes		19.95		11.7
Neomysis		0.74		0.4
Calanus finmarchicus		3.83		2.2
Centropages typicus		12.97		7.6
Temora longicornis		9.14		5.3
Pseudocalanus minutus		10.21		6.0
Other copepods		12.27		7.2
Other crustaceans		0.59		0.3
MOLLUSKS	49.72		29.1	
Cephalopods		0.21		0.1
Limacina retroversa		49.51		29.0
CHAETOGNATHS	0.70		0.4	
ECHINODERMS	0.30		0.2	
ASCIDIANS	7.99		4.7	
Oikopleura		7.54		4.4
Ascidiidae		0.45		0.3
FISH	7.49		4.4	
Merluccius bilinearis		2.75		1.6
Ammodytidae		2.28		1.3
Fish eggs		0.63		0.4
Other fish		1.83		1.1
ANIMAL REMAINS	29.13		17.0	
MISCELLANEOUS	0.11		0.1	
Total	170.86 g		100.0%	