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Feeding of salmon and sea trout and their food resources in the Baltic Sea

by

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Our investigations on the feeding of salmon and sea trout were conducted in 1959-1975. 214 salmon /1,196.7 kg/ and 252 sea trout /962.6 kg/ were examined during this period. After determination of the species the examined ungutted fish were measured and weighed, following which the stomach contents were weighed and species composition determined. In this manner an attempt was made to determine the quantity and quality of the food ingested. The date and assumed time of day of feeding were recorded. Unfortunately it was impossible to identify all sprats and herrings found in the stomachs due to the extent of digestion. Thus these two species were combined and classified as clupeoids. It seems, however, that greater quantities of sprat are ingested. Only in winter, when sprat remains at greater depths, is herring ingested more often. Further observations show that salmon feeds more intensively in spring than in autumn. In the spring an average of 11.9 g of food per 1 kg of live weight was found in the stomachs of salmon, whereas the figure for autumn was only 5.4 g. It seems that in spring, salmon have much more food at their disposal than in autumn and winter. Thus in winter, having only

a small quantity of food available, the salmon readily grasps of hooked bait and in this manner is easily fished.

The total food intake found in the stomachs of the all examined salmon amounted to 9,137.8 g. That is 42.7 g for one salmon with an average weight of 5,592 g and for 1 kg of salmon live weight - 7.6 g of food. This can be assumed as the mean weight of a single meal. According to our observations during a period of 24 hours salmon feeds intensively twice: first early in the morning and the second time at dusk. Thus it eats twice in 24 hours, the global weight per 1 kg of salmon body weight is about 15 g on average. The qualitative composition of food seems to be little varied. The basic food are clupeoids, which, according to our investigations, constituted 87.5% of the food mass. The following species occupied successive positions:

garfish /Belone belone/ - 5.0%,
cod /Gadus morhua callarias/ - 2.5%
sand eel / Ammodytes sp./ - 2.4%
roach /Rutilus rutilus/ - 1.3%
smolts / Salmonidae/ - 1.1%
stickleback /Gasterosteus sp./ - 0.1%
crustecea /Gammarus, Grangon/ - 0.1%.

The presence in the food of such species as garfish, sand eel and roach indicate that salmon feed in inshore waters. Data on the amount of food ingested and the rate of increase of salmon body mass enable the determination of the feeding index, i.e. the amount of weight units of food required to ensure an increase in salmon weight unit. For this end, basing on the investigations on age, length and weight of salmon caught in the years 1966 - 1975, their rate of growth in

successive years of their marine life, was determined. /Table 1/

Salmon growth in the sea — Table 1

Years of marine life	Range of growth min. max. cm	Mean length cm	Mean weight g	Weight increase g
1	24.0 - 67.5	41.2	690	665
2	41.0 - 96.0	65.0	2740	2050
3	63.0 - 123.0	88.3	7450	4710
4	75.0 - 129.0	108.6	13500	6050
5	110.0 - 130.0	118.4	18250	4750

The mean length of smolts migrating to the sea is 14.5 cm and their weight - about 25 g. Comparison of the figures given shows that in its first year of marine life salmon increases its weight about 27-fold. In its second year of life, as compared with the previous, the weight increases threefold, and in the third - slightly over twofold. In the next years the weight increase diminishes.

The subject of our investigations constituted mainly salmon in their third year of life, when their mean annual weight increase is 4,710 g with a day's intake of 15 g of food per 1 kg of live weight of the salmon; to reach the weight increase in mass of 4,710 g., the annual food intake should be 25.8 kg. From the relation of the weight of food ingested to the weight increase, it results that the salmon feeding index is about 5.5 %. Basing on an index so determined attempt was made to calculate the total demand of food

by salmon inhabiting the sea. According to our calculations the mean annual salmon catch in the Baltic in the years 1966-1975 amounted to 2,215.8 tons. The catch included 6 age groups, the weight, number and quantity of food taken up by these fish being presented in Table 2.

Table 2

Marine age groups	%	Weight of fish caught /t/	Mean weight of salmon g	Number of salmon ~~extracted~~ caught	Weight of food ingested /t/
A 0+	0.01	0.2	1500	133	1.10
A 1+	19.81	438.9	3918	112,021	2413.95
A 2+	54.43	1,206.1	4141	291,258	6633.55
A 3+	22.04	488.4	6971	70,062	2686.20
A 4+	2.97	65.8	9400	7,000	361.90
A 5+	0.74	16.4	10750	1,526	90.20
A0+ - A 5+	100.00	2,215.8	4584	482,000	12186.90

As can be seen, most salmon are fished in their third year of marine life /group A2+/. Salmon one year younger and older constitute a considerable part of catches / groups A1+ and A3+/. Thus three age groups of salmon are the main food consumers in the sea. Alongside the fish which were object of fishing, those salmon which died natural deaths and were not extracted by fishing, were also food consumers. According to Carlin /1962/, about 80% die in their first year of marine life. In the second year natural mortality decreases significantly, but may amount to about 5% of the fish. Taking these two values / 80% and 5%/ as the basis for further calculations

the approximate mass of food taken in by these fish can be determined. Swedish specialists defined the annual production of salmon smolts - natural and artificial - as the mean for 10 years to be 4.7 million individuals. According to Carlin, about 3.8 million fish from this number died during the first year of life. These fish were also feeding until they were eliminated from the stock, as the result of natural mortality. To simplify calculations on the mass of food utilized by these fish it is assumed that they fed for only half a year reaching the mean weight of 250 g. In this manner the total weight of fish eliminated from the stock in the first year was about 950 tons. Applying the feeding index of 5.5 it was calculated that in order to reach such a weight, these fish could ingest about 4,702.5 tons of food /250-25/x3,800 000 x 5.5/.

In the second year natural mortality eliminated abou 45,000 individuals / 5% / from the stock of 900,000 juvenile salmon. Again for simplification it was assumed that these fish fed for a half of a year reaching the mean weight of 1,370 g. At that time the weight increase of a single fish could be 680 g. and that of all the eliminated fish -30.6 tons. Continuing calculations in the above manner /30.6 x 5.5/ the weight of food utilized by fish eliminated from the stock, could reach about 168.3 tons in the second year. Salmon which migrated to rivers for spawning should be added to those utilizing the food. In fact, because of the lack of statis - tical data on fish migrating to the rivers of Sweden, Finland and the USSR the quantity and mass cannot be determined. Even so, taking accepting a substantial error, it can be

assumed that their total weight was about 700 tons. With the feeding index of 5.5 these salmon could utilize about 3,850 tons of food. From our calculations it follows that over the period of a year all the salmon took up 20,913.7 tons of food, including 18,955 tons of clupeoids. The salmon eliminated from the stock due to natural mortality had utilized about 4,876.8 tons, i.e. 23.3%. In some respects that food can be treated as lost.

Investigations on the feeding of sea trout were carried out similarly to those on salmon. Research material came primarely from fishing in the open sea, as sea trout stop feeding in the Gulf of Gdańsk and other fishing grounds off the coast. 252 sea trout weighing a total of 962.6 kg were examined, the stomachs containing 6,738 g. of food. According to this, 26.7 g. of food fell to each sea trout with a mean weight of 3,820 g. and 7 g. of food per 1 kg. of live weight. As in the case of salmon, this amount was assumed as the mean amount of a single meal. As sea trout feeds intensively twice in 24 hours, one day's food intake is 14 g. per 1 kg of body weight. The qualitative composition of sea trout food is similar to that of salmon. There is, however, a smaller quantity of clupeoids but more other species of fish and crustaceans. This is indicated by figures which characterize the weight share of particular food components: clupeoids /Clupeidae/ - 77.0%; garfish /Belone belone/ - 9.6%, sand eel /Ammodyted tobianus/ - 4.3%, gobies /Gobius sp./ - 0.4%, sticklebacks /Gasterosteus sp./ -0.3% and crustaceans /Crustacea - mainly Crangon crangon/-4.6%.

In order to determine the feeding index the mean length /16.3 cm/ and weight /40 g/ of smolts were first defined, and then the growth of sea trout in the consecutive years of marine life / Table 3/.

Table 3

Growth of sea trout in the sea

Years of marine life	Range of growth min. - max. cm	Mean length cm	Mean weight g	Weight increase g
1	26.0 - 66.0	44.7	980	940
2	45.0 - 82.5	64.4	3,450	2,470
3	63.0 - 99.0	82.0	7,280	3,830

The figures in the Table show that in the first year of life sea trout increases its weight 24.5 times; in the second year - 3.5 times, and in the third - slightly over twofold. These data indicate that sea trout grow somewhat slower than salmon in the sea.

Most of the sea trout examined for the contents of food in the stomachs were in their second year of marine life, when the mean annual weight increase was 2,470 g. With a day's food intake of 14 g per 1 kg of sea trout live weight, the annual food intake should be 12,620 g. for a weight increase of 2,470 g. It results from the relation of food intake to the weight increase that the feeding index of sea trout is about 5.1. Thus it is somewhat less than that of salmon. It would indicate that sea trout utilize food slightly better than salmon. Applying a feeding index so determined, let us attempt to define the

total food demand of a stock of sea trout feeding in the sea. Unfortunately there are no statistical data on sea trout catches in the Baltic. Attempts were therefore made estimate them on the basis of various data available. In this manner the mean annual sea trout catches in 1966 - 1975 were estimated at 118.5 tons. Our investigations indicated that these catches were composed of 5 age groups. Their weight, number of fish and weight of food taken up by these fish are presented in Table 4.

Table 4

Marine age groups	%	Weight of fish caught /t/	Mean weight of sea trout /g/	Number of sea trout caught	Weight of utilized food /t/
A 0+	0.37	0.44	1587	277	2.24
A 1+	26.26	31.13	3291	9456	158.76
A 2+	57.26	67.86	3781	17945	346.08
A 3+	15.15	17.95	4546	3949	91.54
A 4+	0.96	1.12	7042	159	5.71
A 0+ -A4+	100.00	118.50	3820	31786	604.33

Most of the sea trout were caught in their third year of marine life /A 2+/. Fish in their second year of marine life constituted a comparatively numerous group / A 1+/. Over 600 tons of food were taken in by fish in all the age groups of which the catches were constituted. However, those sea trout, which were eliminated from the stock as the result of natural mortality and also the adult fish which migrated to the rivers, should be included among those utilizing food.

There are no special investigations on natural mortality of sea trout in the sea. As sea trout lead a life similar to that of salmon, we assume after Carlin that in the first year mortality attains 80%, in the second - 5%. The adopting of these values enables a rough calculation of the food mass, taken in by juvenile sea trout prior to their elimination from the stock. The annual natural and artificial production of sea trout smolts in the last decade was estimated at 350 000 individuals. Natural mortality resulted in a loss of about 280 000 individuals in the first year. To simplify calculations it was assumed that these fish fed for six months reaching a mean weight of 300 g., their total mass thus being 84 tons. Applying the feeding index of 5.1 it was calculated that in order to reach this mass they had presumably taken in 428 tons of food. About 3500 fish died as the result of natural mortality in the second year. Their mean weight increase was about 1700 g. Thus the amount of food taken in by these fish was / 3500 x 1700 x 5.1/ about 30 tons.

It was estimated on the basis of Polish catches that the mean mass of sea trout entering the rivers in 1966-1975 was about 40 tons. Again, basing on the feeding index it was calculated that to reach this mass, these fish took in about 204 tons of food in the sea. On the basis of the above calculation it follows that the sea trout which were the object of fishing in the sea and rivers, utilized 808 tons of food in the sea. On the other hand, fish eliminated from the

stock due to natural mortality, took in about 458 tons of food. Thus 1266 tons of food were required to produce 158.5 tons of fish caught. Food intake, which can be defined as a natural loss, constitutes a considerable part of this amount /36.2%/.

In the years 1966-1975 the mean annual catch of salmon and sea trout in sea and rivers amounted to 3074.3 tons. According to our calculations during the process of production of this mass, 22 180 tons of food were utilized, including 19 970 tons of clupeoids. The question arises as to how large is the biomass of clupeoids constituting the food base for salmonids in the sea?

According to the ICES Working Group on the Assessment of Pelagic Stocks in the Baltic in the area of the Baltic from the Arcona Basin to the Gulf of Finland in the years 1970-1977, the mean annual biomass of sprat in all age groups amounted to 1553.1 thous.tons. Most of the sprat 832.8 thous.tons / 53.6%/ inhabited the Gdańsk and Gotland Basins. According to the same source in the area from the Belts including the Gulf of Bothnia the herring biomass amounted to 2408.3 thous.tons. Herring occur mainly in the areas of the ~~Gulfs~~ Basins of Bornholm, Gotland and Bothnia / 1915.7 thous.tons - 79.5%/. Hence the total biomass of clupeoids was 3,961.4 thous.tons. From the comparison of data concerning the intake of clupeoids by salmonids and their biomass in the Baltic it results that salmonids utilize barely 0.5% of the biomass of these two species. The data on cod are also interesting, as these fish feed on the clupeoids. Załachowski /1977/ estimated the biomass of juvenile cod /0-II age groups/ to be 161.698 tons and adult fish-feeding mainly on fish - to be 320,346 tons. The mean total cod biomass in the years 1972 - 1974 amounted to 482,044 tons.

According to the author the annual food intake by cod in all the age groups was 2,180.5 thous. tons, including 670,678 tons of clupeoids. It would thus appear that of the total biomass of clupeoids, cod utilizes 16.9%. Therefore cod are the main predators of clupeoids.

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