1. INTRODUCTION

The pike-perch is a notable object of fishing in the lake district of Finland, and along the coast of the Gulf of Finland. According to the fishing statistics of 1959 (HEIKKINEN 1960 p. 151) the catch in the lake district was 739 tons, and in the sea coast area 253 tons. With an increase in the number of fishermen, and with an increase in the effectiveness of fishing, a question of the appropriateness of regulations limiting the fishing of the pike-perch has become ever more timely. In this investigation an attempt has been made to clarify certain characteristics of the pike-perch stocks of the Gulf of Finland in order to bring out new points of view to form the basis of more appropriate regulations concerning fishing. Tagging of fishes has been used as the primary method of investigation for finding out about the areas of migration of the stocks, as well as the growth and the mortality of individual fishes. Data obtained from the taggings have been supplemented, among other methods, by means of scales investigations.

There are in existence few literature references on taggings of pike-perch. HENKING (1923) has, during 1914-1916, tagged a total of 377 pike-perches in the Stettinscher Haff, and outside of it, in the Baltic Sea. From these taggings 78 tags were recovered. The purpose of the tagging was to clarify the migrations of the pike-perch between the Stettinscher Haff and the Baltic Sea. In order to investigate the migrations of the pike-perch in Lake Mälare, in Sweden, a total of 200 pike-perches were tagged in 1943.

10 tags were recovered (SVÄRDSON 1948). PUCE (1952) carried out during the years 1946-1949 in Väner, Sweden, a tagging on a total of 482 pike-perches. 107 tags were recovered. The principal purpose in this tagging was also a clarification of the migrations.

Two taggings of pike-perch have been carried out on the coastal waters of Finland. In 1938 136 pike-perches were tagged in the Gulf of Viborg, and 20 individuals in Virolahti (AALBERG 1952). One of the individuals tagged in Virolahti had swum to the Gulf of Viborg, from where it was picked up 38 days after the tagging.

In 1956 an tagging experiment was carried out with tag-hooks to be attached to the gil cover. Altogether, 30 individuals of the 247 tagged ones were recovered. Of these 26 individuals were obtained within a month from the tagging, 3 individuals within the second month, and one tag 10 months after the tagging. A fisherman, who donated the pike-perches for the investigation in queastion reported having later come across pike-perches with a depression scar in the gil cover in the spot where the tag would have been. The tags apparently were torn off within a short time.

On the basis of data on catches, and age-determinations from scales SEGERSTRÅLE (1936, 1938 and 1949), and HALME & HURME (1952) have earlier delved into queastions regarding the pike-perch stocks of the northern coast of the Gulf of Finland.

2. MATERIAL AND METHODS

Data regarding the regional occurence of the pike-perch stocks in the coastal waters of Finland have been gathered by going through the queastionaire forms of the 1959 fishing catch statistical survey. In these forms the locality and the amount of the catch are included. The causes for the local differences in abundance of the coastal pike-perches have been investigated by comparing the data obtained as explained just above with data obtained from literature regarding the nature of the environments.

The data regarding the migration area on the migrations, the rate of growth, and the mortality of the pike-perches of the Gulf of Finland, of Sea Saaristomeri (Archipelago Sea), and of the Åland Islands is based on taggings done in 1958, 1959, and 1960. The tag that was used is designed by CARLIN (1955), which has been used on a large scale in salmon taggings. The tag is composed of a rectangle, about 5 mm x 15 mm, cut from stiff cardboard, to the one side of which has been written, in capital letters, in drawing ink the nationality insignia (SF) and an identifying number, and to the other side of which has been printed the text: "Mail to: Fish Research, Helsinki. Mention the place, the date, the length, the weight, the sex. Include scales. Reward." The tag is covered with a celluloid coating. The tag is attached onto the fish by means of thin stainless-steel wires. The tag is attached to the base of the caudal dorsal fin.

Altogether 2350 pike-perches were tagged in Karhula, the waters in the vicinity of Helsinki, in the Bay Halikonlahti, in Kakskerta,

and in Ödkarbyvik of the Åland Islands. From this tagging 670 tags have been returned. The taggings and the tag returns in various regions are presented in Table 1.

Table 1. Tagged lots of pike-perch, and tags returned.

Tagging			Tags returned	
Locality	Date	NO. tagged	NO. returned	%
Karhula, Pitkäsaari	26.6.1958	52	15	28,8
	13.5.1959	129	63	48,8
		181	78	43,6
Helsinki, Suomenlinna	14.6.1958	100	31	31
-"- Laajalahti	3-15.6.1958	335	88	26,3
-"- -"-	19.5.-27.6.1959	483	149	39,9
-"- -"-	15.6-28.8.1960	78	22	28,2
		996	290	29,1
Halikonlahti, Petässaari	17.6.1959	239	89	37,2
Kakskerta	10-17.6.1958	400	90	22,5
-"-	25.6.1959	184	17	9,2
		584	107	18,6
The Åland Islands, Ödkarbyvik	14-18.6.1960	350	106	30,3
	Total	2350	670	28,6

The location of the tagging places may bee seen in Fig. 1.

The tagged pike-perches have been caught, with the exception of those from the Åland Islands tagging, with a large bagnet. In the Åland Islands the pike-perches were caught with a seine. The writer has, himself, tagged the lots on the coast of the Gulf of Finland. In the Åland Islands the tagging was done by the fishing officers M. Westling and H. Moliis.

In connection with the tagging the length of the pike-perches was measured, and, with a few exceptions (the 1958 lots of Karhula and Helsinki), the fishes were also weighed. The scale samples were ta
the lai
in Hels

For eac
The dat
punched

Siv. 5
Fig. 1

3. THE OCCURENCE OF PIKE-PERCH IN THE COASTAL WATERS OF FINLAND

The pike-perch (Lucioperca lucioperca L.) is, as far as its over-all area of habitat in Europe is concerned, an eastern fish. The natural distribution area includes, according to BERG (1949 p. 1021) the River Elbe and the inland water systems which empty into the Baltic Sea, the Black Sea, the Sea of Azov, the Caspian Sea, and into Lake Aral.

In the waters emptying into the Baltic Sea the pike-perch has, according to LÖNNBERG (1898, p. 796) spread only to those areas which have, in the ancient times, been situated within the bounds of Lake Ancylus. The most northern lakes in which the pike-perch is met are Lake Kemijärvi, and Lakes Vietonen, Raanujärvi, and Miekojärvi, which belong to the inland water system of River Tengeliönjoki,all in Finland. These stocks of pike-perch have been taken by NORDQVIST (1903, p. 22) to be relicts of a larger distribution are, which has existed in the warm Ancylus period following the last glaciation.

In the Baltic Sea the pike-perch is met principally in the southern and the central parts. It forms abundant stocks along the southern coasts of the Baltic Sea, for instance in Saaler Bodden, in Grosse Jasmunder Bodden, in Kleine Jasmunder Bodden (SCHLUMPBERGER 1962, p. 712), in Stettiner Haff (HENKING 1923, p.20), in Frisches Haff (FILUK 1962, p.705), and in Kurisches Haff (MARRE 1933, p. 310). In Esthonia the Bay of Pärnu is known as a good pike-perch fishing area (ERM 1961, p. 280). On the other hand, there is little of the pike-perch along the northern

coast of Esthonia (SILLAMAA 1936, p. 425). The abundance of the pike-perch in the Bay of Kronstadt in the 1920's and the 1930's has been described by SEGERSTRÅLE (1939 pp. 500-505). According to AALBERG (1962 p. 3) the Bay of Viborg has been long known as an good pike-perch water. ALM (1964 p. 430) mentions the existence of the pike-perch in the eastern aechipelago to the north of Småland up to the coast of Västerbotten. Except in the closed bays of the coast the pike-perch lives also along the open sea coast in the southern part of the Baltic Sea, according to HENKING (1923 p. 26) and SCHLUMPBERGER (1962 p. 719).

An overall survey of the occurence of the pike-perch in the coastal waters of Finland has been presented by JÄRVI (1932, p.103). According to this, pike-perch stocks are met in the coastal waters of Turku, in a very few bays along the southern coast (for instance near Porvoo), and in the Åland Islands in bays named Ödkarbyvik and Saltvikfjärd. Further, it is mentioned that pike-perches are, reraly, met near Uusikaupunki. According to SEGERSTRÅLE (1949 p.. 89-91) the pike-perch stocks of the waters in the vicinity of Helsinki and of the bays to the east of Porvoo may be said to be quite old. AALBERG (1962 p.3) mentions the pike-perch to have been a rare fish in the waters in the vicinity of Hamina before 1930, but that it became common there in the beginning of the 1930's.

3.1. The areas of occurence according to ~~fishing~~ catch statistics.

Of the prevailing abundance of the pike-perch in various parts of the coast data are obtained from the catch statistics gathered in 1953, 1959, and from 1962 to 1968 (LIEDES 1954 p. , HEIKKINEN 1960 pp. 146-151, and unpublished material in the Bureau of Fisheries Investigations). The division into regions is shown in Figure , and the obtained catches are presented in Table . The regional catches reflect the abundance of the pike-perch, for due to its great commercial value it is being fished effectively in all regions where it is to be met. Because of the manner of getting the statistics the data on the regional catches are not quite reliable - the catches are taken down according to the home locality of the fisherman, and in this way fishes caught by him elsewhere get to be attributed to this locality, unless the person filling the queationaire mentions from where the fishes have been caught. This probably explains, among other similar cases, the nonzero figures from areas 2 and 3 for the years 1963 and 1968, though the pike-perch is missing from these regions with the exception of a few wanderers.

According to the statistics the most abundant stocks are the ones in areas 10, 11, 12, and 13. In addition, pike-perches are caught regularly also from areas 5, 7, and 9. Thus, the pike-perch is met in the coastal waters of Finland principally along the coast of the Gulf of Finland and in its archipelago, though it is met also along the coast of Bothnian Sea, in Merenkurkku and in the Åland Islands.

Upon inspecting the differences among the various years it may be noted that the catches have remained relatively constant in most pike-perch areas. In Archipelago Sea (area 10) the pike-perch appears to have become somewhat more common in the 1960's. The same development is to be seen more clearly in area 12. On the other hand, on the coast of Gulf of Finland between them (area 11) the most abundant catches have been caught in the beginning of this ~~century~~ decade.

In order to create a more detailed picture of the occurence of the pike-perch in the coastal waters of Finland the queastionaire forms of the statistical survey of 1959 have been gone through with respect to the professional and the semiprofessional (with fishing as a sideline) fishermen, and the data regarding the pike-perch have been collected from these queastionnaires. In the statistical survey forms the catch from half a years is reported. Figure has been drawn with dots of different sizes, depending on the size of the catch, in those places to which the catches have been reported. For the sake of improving clarity a part of the points have been left out from those places where the dots overlap.

The occurence of the pike-perch may be seen to be centered at certain parts of the coast, and, on the other hand, ~~xxxx~~ there are areas between these where the pike-perch is missing. Starting from the eastern border of Finland small numbers of pike-perch are met in Virolahti. From the region between Virolahti and Hamina there are, on the other hand, no reports of caught pike-perches. From west of Hamina there begins a region of continnous ~~incidence~~ occurence,

which continues, with a few small exceptions, up to the waters of Helsinki. The most abundant catches have been made in bays that extend deep into the mainland along this section of the coast. From west of Helsinki pike-perches have been caught from two different areas, from the Bay of Pikkala (see Fig.), and, on the other hand, from northeast of Hanko. Between these areas the pike-perch is met only as individual fishes, which do not appear in the catch statistics. Further west, a more abundant occurence of the pike-perch is encountered in the waters to the south of Salo, extending past the erchipelago of Turku up to the waters south of Uusikaupunki. Southwest from Turku the habitat of the pike-perch extends fairly far from the shore, amidst the islands. From the coast of Bothnian Sea small catches have been reported from near Rauma and from the waters in front of Pori. Between Pori and Vaasa there is a long stretch of coast where the pike-perch is a ratery. In Bothnian Bay there are, according to the catch statistics, two separate stocks of which one is in the area northeast from Vaasa, and the other in the bay waters to the southwest from Kokkola. In the second of these the stock is, however, rather small. North of Kokkola individual fishes are obtained now and then from as fas as Tornio.

Upon comparing literature references (JÄRVI 1932, SEGERSTRÅLE 1949 and AALBERG 1962) regarding the earlier occurence of the pike-perch with those regarding its present occurence in the coastal waters of Finland it seems that especially in the Gulf of Finland the pike-perch has become more common, beginning with 1930. This fact has already been noted by SEGERSTRÅLE (1949 p.91). He writes: ".... it may further be mentioned that the pike-perch

has become a much more abundant fish in the coastal areas of Finland during the last fifteen years, as well as in waters from which no pike-perches, or very few of them, were gotten in the boyhood years of old fishermen."

This process seems to have continued, on the basis of catch statistics, still in the 1950's and the 1960's in the Gulf of Finland (in areas 11 - 13). Also in Archipelago Sea (area 10) the catches have increased continuously.

It is not possible to say for certain whether the process referred to above is a permanent increase in the stock due to some environmental factor having become more advantageous, or a temporary increase caused by periodic changes in the stock. Certain changes in the quality of water, to be treated in Chapter 3.25, are in evidence, and the process of the pike-perch getting more common may be connectable to these.

3.2. Factors influencins the occurence

3.21. The geomorphological character of the coast

An archipelagic region, characteristic of the coasts of Finland, has clearly formed in the region of the Gulf of Finland. Its width varies in general within the bounds 10 - 20 km from the outermost rocks to the tips of the inland bays. As an example of the general character of the archipelago, and of the depth relations, a figure describing the coast in the Helsinki region is presented. Near the outer rocks the depth of the water is about

30 m., and from this the depth decreases fairly linearly to the shore. HÄYRÉN (1921) has proposed a division of the archipelago into four regions: 1. the sea region, 2. the outer archipelagic region, 3. the inner archipelagic region, and 4., the edge of the sea. SJÖBLOM (1968 pp. 13 - 14) divides the coast into three regions: the archipelago, the edge of the sea, and the open sea.

The archipelago is at its widest in Archipelago Sea between the mainland and the Åland Islands. This area extends from Hanko to Uusikaupunki. The area is characterized by narrow straits extanding deep into the mainland. These are relatively deep.

Along the coast of Bothnian Sea the archipelagic region is weakly developed, or is missing. The same is true of the coast of Sea Perämeri. The archipelagos in the vicinities of Vaasa and Kokkola are an exception to the openness of th coast of the Gulf of Bothnia.

Upon inspecting the map of the abundance of the pike-perch (Fig.), prepared on the basis of the catch statistics, one may note that the presence of the archipelago apparently is an acconmodating factor for the pike-perch. In general, the pike-perch stocks are to be met only in relatively closed archipelagos. This is to be seen for instance in Bothnian Sea, where there are only two clear inner archipelagos, and in both of these the pike-perch is to be found. On the other hand, in some closed bays of the coast the pike-perch is almost an unknown fish. Such an area is, for instance, the archipelago to the west of Hanko. The closedness of the archipelago is apparently only one of many factors which affect the ~~accomodability~~ occurence of the pike-perch.

3.22 The influence of the rivers

The dependence of the occurence of the coastal pike-perch stocks on the water brought by the rivers may be considered on the basis of Figure . In it the most important discharge points of the rivers on the coast, and the main river flow rates according to GUSTAFSSON (1963), have been marked on the map of the occurence of the pike-perch. From the figure it may be seen that the occurence of the pike-perch is centered about those parts of the coast which receive river water. Along the coast of the Gulf of Finland this may be seen clearly. Areas poor in pike-perch, and in which the influence of river waters is also small, are, for instance, the watered region between Virolahti and Hamina, certain parts of the coast between Helsinki and Hanko, and the region to the west of the Hanko peninsula. In Bothnian Sea and Bothnian Bay pike-perch stocks are to be met at the mouths of only a few rivers, so that in these parts the effect of the water brought by a river alone does not create the prerequisites for the accommodation of the pike-erch along the coast. This may also be seen from the fact that the pike-perch is to be found in the Åland Islands in such bay systems that the influx of fresh water is very slight.

Changes in the quality of the coastal water caused by the river waters are treated more in detail in Chapters 3.24 and 3.25.

3.23 Temperature

The annual temperature distributions of the coastal waters in different areas are shown as the smoothed (monthly averages) temperature curves from Seivästö, Tammio, Harmaja, Lohmi, Säppi, and Ulkokalla, published by GRANQVIST (1938) (Figures ; the locations of the observation stations in Fig.). The temperature conditions at these stations represent the conditions in the open sea, or at the edge of the open sea. The summer temperature of the surface water is, in the eastern part of the Gulf of Finland, at the observation station of Seivästö, notably higher (the calculated maximum temperature of the surface water 18.3°C) than at the mouth of the Gulf of Finland, at the observation station of Harmaja (the maximum temperature of the surface water 15.3°C). At the observation station at Lohm, for Archipelago Sea, the surface water is warmer (the maximum temperature of the surface water 16.9°C) in the summer than at Harmaja. In Bothnian Sea, at the observation station of Säppi (the maximum temperature of the surface water 15.1°C) the water is, on the average, a little cooler than at Harmaja; and further, in Bothnian Bay, at the observation station of Ulkokalla, (the maximum temperature of the surface water 13.6°C) the water is clearly cooler than at Säppi.

In the archipelago there are great temperature differences between the edge of the sea and the inland bays. As an example of the temperature differences prevailing between the various coast-parallel regions Table is presented. This Table has

been prepared on the basis of data from the year 1968 of the Waters Pollution Laboratory of the City of Helsinki. The location of the observation stations is presented in Fig. . Station 87 is situated in a mainland coast region (according to the division of HÄYREN (1921)), station 94 in an inner archipelagic region, station 68 in an outer archipelagic region, and station 125 at the edge of the sea. From Table may be seen that in the spring, after the ice has melted, the water warms up considerably faster in an inland bay (station 87) than at stations further out. In May the differences in the surface temperatures between stations 87 and 125 are about 5 degrees. During June-August the temperature of the water in the bays is continually a few degrees higher than that of the surface at the edge of the sea. In the beginning of September the situation becomes reversed. In a shallow bay the cooling of the water occurs faster than at the edge of the sea, in deeper water. Freezing-over occurs also considerably earlier in the bays than in the outer parts of the archipelago.

In the waters in front of Helsinki a upwelling phenomenon, caused by the winds and the Coriolis-acceleration, causes often, according to the investigations of SJÖBLOM (1967 and 1968), a displacement of the cold sea water into the archipelago. In addition, great changes in the level of the water surface cause strong exchange of water in the archipelago.

The pike-perch may be taken to be a fish predisposed toward relatively warm water. According to information collected by

DEEDLER & WILLEMSEN (1964, p. 3:16) the most advantageous growth temperature for the pike-perch is 19-22°C, and figuerlings choose to move, in tests with a choice, into water of temperature 24-26°C.

The temperature conditions along the coast of Finland may be compared with conditions in Lake Kemijärvi, where the pike-perch lives at its northern-most. According to temperature data (Fig.) presented by SIMOJOKI (1956) the average maximum surface temperature for a year is 18.1°C, and at a depth of 10 meters, correspondingly, the temperature is 16.5°C. Equally warm surface water is to be found in the Gulf of Finland in the open sea, and at the edge of the sea only in the easternmost part of the Gulf, at the observation station of Seivästö (Fig.). SEGERSTRÅLE (1936 p. 501) has investigated the occurence of the pike-perch in the eastern part of the Gulf of Finland, and observed that the pike-perch is to be met there along the open coast. Elsewhere in the Gulf of Finland the occurence of the pike-perch is limited to the archipelagic region. The same is ~~true~~ true of Archipelago Sea and the Gulf of Bothnia (Fig.). As the cause of this may probably be taken the coolness of the water in the open sea. In the inner parts of the archipelago the water warms up in the summer to reach considerably higher temperatures than in the open sea, as has been indicated in the foregoing, and this fact probably establishes the prerequisites for the occurence of the pike-perch in the coastal waters of Finland. The lack of the pike-perch along the southern coast of the Gulf of Finland (SILLAMAA 1936) probably is caused, in part,

by the low temperature of the water in the summer, as a protective archipelago is missing. On the other hand, in the southern part of the Baltic Sea considerable amounts of pike-perch are gotten from the open sea in the Pommern Bay (SCHLUMPBERGER 1962 p. 719), but there the temperature in July-August is 18.0-19.0°C in the surface water, and in the water near the bottom (at a depth of about 15 meters) about 16.0°C (WIKTOR J. &K. 1962 pp. 115-121).

In the development of the pike-perch stocks the temperature is most influential in the maturing of the eggs, the determination of the time of the breeding season, and the development of the fingerlings during the first summer. If the breeding season, due to the coldness of the water, is moved far into the summer the fingerlings may in the fall be too small and weak to stay alive over the winter. According to information collected by DEELER & WILLEMSEN (1946 Table V) the breeding of the pike-perch begins, in general, when the temperature of the water is about 12°C, independently of the geographic locality. In Central Europe and in Southern Russia the breeding season of the pike-perch generally occurs in April-May, and in Turkey, begins as early as in February. The breeding of the pike-perch in Southern Finland begins in the end of May, but usually it takes place in June. In Lake Kemijärvi the pike-perch breeds in the end of June, and in some years the breeding is delayed until July. According to the temperature measurements of SIMOJOKI (1956) (Fig.) the temperature of the water in Lake Kemijärvi rises to values suitable for the breed of the pike-perch (12°C) after the middle of June. The breeding season of the pike-perch in the waters about Helsinki occurs approximately at the same time as in Lake

Kemijärvi. Thus, it may be argued that the pike-perch lives in in the coastal waters of Finland in marginal areas as far as its temperature acconmodability is concerved. Though the temperature in a breeding bay of the pike-perch, in Bay Laajalahti, has reached, in the beginning of June, for instance in 1968 (Table station 84), already 18.0°C in the surface water, and 14.7°C at the breeding depth, the coldness of the water further out in the archipelago, where the pike-perches are before breeding, causes the delay of the breeding season.

The influence of the temperature on the growth of the pike-perch will be discussed when inspecting data obtained as a result of fish taggings, in Chapter 5.2.

3.24 The Salinity

The Baltic Sea with its bays forms a typical brackish water region. VÄLIKANGAS (1933) and SEGERSTRÅLE (1957) have published general surveys regarding the effect of the salinity on life in such a region. The salinity in different parts of the Baltic Sea is revealed in Fig. . Great seasonal variations in the salinity are to be noted, as well as smaller, long-period changes. The annual changes are different in different parts of the Baltic Sea. At the observation station of Tammio, at the edge of the sea in the eastern part of the Gulf of Finland, for instance, the salinity has in 1958 (KOROLEFF 1962 p. 81) varied in the surface water within the bounds 0.00-5.38 per mil, with the average at 3.74 per mil.

At its lowest the surface salinity is in Tammio in the late winter, when river waters spread under the ice far out into the open sea, and at its highest in the early winter. In the bottom waters the variations are not as great as in the surface water. In 1958 the salinity of the bottom waters (20 meters) has varied within the bounds 4.13-6.44 per mil.

In the region of Sea Saaristomeri, at the observation station of Lohm, the annual variations in the salinity are generally slight. For instance in 1958 (KOROLEFF op.c.p. 55) the salinity of the surface water has been regularly between 6.00 and 6.85 per mil (with the average at 6.76 per mil), not taking into account observation 1. IV, for which the salinity was exceptionally 0.34 per mil. In the bottom water, at a depth of 50 meters, the salinity at the Lohm observation station has varied in 1958 within the bounds 6.00-6.85 per mil, so that there is no essential difference between the water from the bottom and that from the surface at the Lohm observation station.

As an example of the salinity conditions at the breeding place of the pike-perch in the Gulf of Finland region Table has been prepared which presents a collection of salinity observations, obtained by the Waters Pollution Laboratory of the City of Helsinki in 1968 at station 87, 4, and 125 (the location of the station in Fig.). Station 87 is located in the center of a well-know pike-perch breeding bay, the Bay Laajalahti, in which the augment of fresh water is quite small excepting the fresh water included in the large amounts of municipal sewage

discharged into the bay in recent years. Station 4 is situated in a pike-perch breeding bay similar to Bay Laajalahti, namely in Bay Vanhankaupunginlahti. The latter differs, however, from the former in that River Vantaa discharges into the latter's tip. The average flow rate in this river is, according to GUSTAFSSON (1936 p. 6) 16 m^3/s. Station 125 is located at the edge of the sea, and reflects the variations in the salinity at the outer border of the archipelago.

In Bay Laajalahti the decrease in the salinity is to be noted clearly only in the late winter in the surface water under the ice. Upon getting to the breeding period in the latter half of June the salinity has, however, reached already 4.63 per mil even in the surface water, and the difference between this and the value at station 125, at the edge of the sea, is about 1 per mil. During the early development of the fingerlings, in the beginning of July, the salinity is already above 5 per mil.

At Bay Vanhankaupunginlahti the donditions differ from those at Bay Laajalahti to the extent that as River Vantaa floods in the spring, the whole mass of water of the bay becomes non-salty all the way to the bottom (the salinity on April 25 0.08 per mil) in the end of April. After the spring flood has passed, however, fresh water is puched into the bay, so that at the time of the breeding of the pike-perch the salinity conditions are very similar to those in Bay Laajalahti. According to the investigations of GRANQVIST & BUCH (1921), and of WITTING (1922) in the years 1919-1920 the salinity in Bay Vanhankaupunginlahti has been in the early summer lower than nowadays, when the City of Helsinki

takes, except during floods, almost all of the water of River Vantaa into its municipal water system. During the aforementioned years 1919-1920 the salinity in Bay Laajalahti has been much higher than nowadays. The changing of the salinity in the archipelago outside of Bay Laajalahti and Bay Vanhankaupunginlahti is shown in Fig. , which has been prepared on the basis of observations made by the Institute of Marine Research during July 27 - August 3, 1961.

As a fresh-water fish the pike-perch, in its accommodabilidity to new areas in the brachis water regions, is limited by the salinity.

Regarding the ability of the pike-perch to withstand the salinity of water KUDERSKIJ (1958 b, p. 82) presents that in Lake Aral the pike-perch is to be met in water of salinity greater than 10 per mil, and in the northern part of the Caspian Sea in water of salinity up to 13 per mil. Further, the pike-perch is being fished in the Sea of Azov in areas where the salinity is, according to ZENKEVITCH (1963), as great as 14 per mil.

On the other hand, DEEDLER & WILLEMSEEN (1964 p. 2:1) mention that pike-perches which happen to wander from the Dutch system of inland waterways into the Waddensee, which contains brachis water, die there without exception. The salinity of Waddensee varies between 12 and 29 per mil. In the southern part of the Baltic Sea, in the Pommern Bay, to where some pike-perches migrate, according to the observations of HENKING (1923 pp. 20-30), from the Stettin Lagoon the salinity is, according to the observations of J. & K. WIKTOR (1962 pp. 121-129), in the bottom water about

7 per mil, and has varied, during the years 1957-1958, within the bounds 6.5 - 7.8 per mil.

In the coastal waters of Finland where the pike-perch is to be met the salinity usually does not exceed the value 6.5 per mil. On the basis of the literature data presented in the foregoing it may be assumed that salinity is probably not along the coast of Finland the factor limiting the distribution of the pike-perch. This is true of older fingerlings and of mature fishes. On the other hand, detailed observations regarding the maximum salinity in which the breeding of the pike-perch will succeed, are sparse.

The pike-perches living in the Caspian Sea and the Sea of Azov migrate up the rivers, and into the mouths of rivers, for the breeding, and similarly, the pike-perches living in the Pommern Bay probably do their breeding mostly in the less-salinated Stettin Lagoon. On the other hand, in Bay Laajalahti, from where salinity data have been presented in the foregoing, the influence of fresh water is not appreciable, and the pike-perches have to do their breeding in water of salinity about 4.5 per mil, and, at times, higher. Yet, Bay Laajalahti is a long-known breeding area. In the foregoing (see Fig.) it has been noted that ~~along~~ the occurence of the pike-perch along the northern coast of the Gulf of Finland is limited mostly to these areas which receive river discharge. If this is due to the lowering effect of the rivers on the salinity, the greater abundance the pike-perches is to be connected of the river openings with the fact that the breeding of the pike-perch in these areas succeeds better than in other parts of the coast.

3.25 The turpidity and the pollution of the water

It is generally known that the pike-perch prefers lakes with turpid water. This is clearly revealed also in the investigation of JÄRNEFELT (1949) regarding the fish fauna of 284 lakes in Southern and Central Finland. In that investigation it is noted that the pike-perch is to be met as a varity in a few clear-watered oligotrophic lakes, and in a few weakly dystrophic lakes, but commonly in eutrophic, mixotrophic, and, especially, argillotrophic lakes.

According to JÄRNEFELT (1949 p. 225) the pike-perch is to be most commonly met in lakes in which the transparency is < 1.8 meters. In lakes where the transparency is greater than this the pike-perch is rare, and is to be met only if the average depth of the lake exceeds 4 meters.

The eye of the pike-perch has been especially adopted to see in the dim. According to WUNDER (1936 p. 122) the retina of its eye contains a layer formed of guanin-crystals (tapetum lucidum), which reflects light, and wakes seeing in the din easier.

WOYNAROVICH (1960 pp. 81-82) has noted, that direct sunshine causes, within a few hours, the death of a fry, and that the effect of continual dimmed light of about 400 luxes on the fingerlings is unusual moving about and "light-blinded dress", which leads into the death of these fingerlings as the feeding-phase begins.

Further, WOYNAROVICH has observed that as the fingerlings grow

their negative photothrophy becomes ever clearer. The "light-blindness" disappears later, and a developing, about one month old, fingerling can see fairly well in sunlight, and its eyes can adjust to excess light.

On the basis of these observations of WOYNAROVICH (1960) it may be assumed that excessive light at the breeding localities can destroy the developing fry, and that this may go on to cause the pike-perch to be missing from too clear waters. On the other hand, it is clear from the above-mentioned investigation that older pike-perches are negatively photothropic and thus avoid regions with too clear water.

Turpidity of the water, which prevants the light from pevetrating deep into the water, is apparently, on the basis of the foregoing, one of the most important prevequsites for the occurence of the pike-perch. Turpidity is caused by rivers suplying clay-colloidal water along the coasts. On the other hand, polluted water brought by the rivers, or discharged directly on the coast, decrease the light transmissivity of the water, and cause plankton turpidities.

In the southern and the southwestern parts of Finland clay is the prevailing loose mineral (see, for inst., the Atlas of Finland p. 4). The rivers coming from these areas are, as is generally known, especially during spring floods, very clay-turpid. In Chapter 3.22 it has been noted (Fig.) that pike-perch stocks are concentrated in these parts into regions near the mouths of rivers. It may be assumed that the turpid-water region, brought into existence by the rivers, is of decisive importance in causing this.

There is not available a single thorough general studies study of the turpid-water regions along the coasts of Finland. In connection with certain local pollution studies measurements regarding the turpidity and the transparency have been made, however.

In the eastern part of the Gulf of River Kymi causes, according to observations by the Institute of Marine Research (Fig.), a turpid-water bulge reaching into the archipelago. The turpidity is in this case caused principally by the effects of polluted water.

In front of Helsinki (Figures) a turpid region extends approximately to the outer edge of the archipelago. Also in this case the turpidity is caused principally by pollution of the water. This is clearly brought out in pictures which show maps of the pollution of the bottom, and the regional distribution of the ~~basic industries~~ primary production along the coast of Helsinki in 1968. These maps have been prepared by the Waters Pollution Laboratory of the City of Helsinki.

In the region of Archipelago Sea (Fig.) the lowering of the transparency is in part caused by clay colloids, and in part by pollution of the water (especially in the vicinity of the city of Turku). The turpid-water region is limited to within the archipelago, and the distribution area of the pike-perches (Fig.) also falls in this region.

In front of Pori the polluted river water discharged by River Kokemäenjoki causes a turpid-water region, according to RYHÄNEN (1962 a and b). In this area these is, according to the map of the occurence of the pike-perches (Fig.),a weak pike-perch

stock. Before River Kokemäenjoki became polluted the pike-perch was a very rare fish in these waters.

It is not possible to estimate what significance the coastal waters getting polluted has had on the pike-perch becoming more common, of which was mentioned in Chapter 3.1, as ~~overall~~ general information regarding the pollution situation in the archipelago is lacking. It is, however, probable that the regional coastal turpidization caused by polluted discharge waters, and the growth of the ~~basic industries~~ primary production, have improved the accommodation of the pike-perch.

3.25 Discussion

A map (Fig.) has been prepared on the basis of the returned queastionnaire forms of the fish catch statistical survey to describe the occurence of the pike-perch in the coastal waters of Finland. It is possible to see on the basis of the map that the pike-perch favors those parts of the coast in which there is a wide archipelagic belt, and, on the other hand, those parts of the coast which receive river discharge water. Regarding the occurence of the pike-perch in the lakes it is known that it is principally a fish of the open expanses, so that the closedness of the archipelago is not, as such, a ~~mix~~ decisive factor. In the Gulf of Finland and in the Gulf of Bothnia the temperature of the surface layer is, in the open sea, in the summer so low on the average that nowhere in the lakes is the pike-perch to be met in so cold conditions. On the other hand, it is possible to note

that in finnish coastal waters, where there is a wide archipelagic belt shielding the coast, the temperature in the bays is appreciably higher, and also the temperature in these bays gets warmer much faster than does the noter in the open sea. It may be presumed that the effect of the archipelago, favoring the occurence of the pike-perch, is caused principally by the fact that the archipelago hinders mixing of the waters of the bays and of the open sea, and brings about temperature conditions in the bays favorable to the pike-perch. Probably, the success of the reproduction of the pike-perch is dependent on the relatively high temperature of the water in the bays. In addition, the warm water influences the growth of the pike-perch favorably, as is presented in Chapter 5.21.

The occurence of the pike-perch is concentrated into those parts of the coast which receive river discharge water. The most important effect of the river waters, from the vienpoint of the pike-perch, probably is the turpid-water region brought into being by them along the coast. The turpidity of the coastal waters is increased in same rivers and in the vicinities of municipalities by pollution. The effect of the rivers in lowering the salinity may also cause regional occurence of the pike-perch in the coastal waters of Finland. In other parts of the distribution area of the pike-perch (for instance in the Caspian Sea, in the Sea of Azov, in Lake Aral, and in the southern part of the Baltic Sea) the pike-perch has been observed to live in considerably more salin waters than those to be met in the areas of habitat of the pike-perch in the Gulf of Finland

and in the Archipelago Sea. This is true of mature individuals, and more developed fingerlings. There is no accurate information available as to how high the salinity of water may be for the reproduction of the pike-perch (the development of the fertilized eggs, and the survival of fry during the first weeks) to succeed. The occurence of the pike-perch in the regions at the mouths of rivers may be caused by the fact that in these areas their breeding succeeds more often than in other parts of the coast, due to the lower salinity at the mouths of the rivers.

4. THE REGIONAL GROUPING OF PIKE-PERCH STOCKS, AND THE MIGRATIONS ACCORDING TO TAGGING RESULTS

4.1 The migration area

In the tag attached to a pike-perch the request is made, among others, to report the location where the fish has been caught. A majority of those returning tags have done this. A number of the tags have, however, come back by way of fish stores, and in these cases the tag-find logation is usually not known. In some cases it has not been possible to locate on a map the reported location of a find. Of 670 returned tags 593 have made it possible to locate the place of finding on a map. Data regarding the location of finding, obtained from taggings in different years and in different areas, have been marked onto the maps (Figures 16-20).

As a general feature, upon inspecting Figures 16-20, may be seen the fairly even distribution of the pike-perches in the surroundings of the place of tagging. In all areas the pike-perches have stayed within the island belt. The area of migration extends from inland bays out to the fringe of open sea, and, in the directions along the coast, even farther by distance. The centering of tag finds to ceptain locations to an extent beyord direct change may be associated with a tendency for the pike-perches to preter some areas for staying, but, on the other hand, it may be caused by regional differences in the effectireness of fishing.

In the tagging area of Karhula (Fig. 16) a lot of pike-perches have been caught in the vicinity of the place of tagging. The

region of migration extends out to the sea as far as to the coastal waters of the Island Kirkonmaa. In the directions along the mainland coast, the pike-perches have clearly moved more in the eastward direction than toward the west, where the polluted water of the River Kymijoki, and the associated pollution of the waters surrounding Kotka, may form a factor limiting migration. In the east individual pike-perches have been caught from Virolahti, and one pike-perch has migrated all the way to the far end of the Gulf of Finland, to the outlet region of the River Neva.

Of the fish tagged in Laajalahti and near Suomenlinna (Sveaborg) (Fig. 17) the majority have been caught from the waters surrounding Helsinki. Toward the open sea the finds most distant from the shore are from the line: Harmaja - Katajaluoto - Rysäkari. In the east the of area of fairly general migration for the pike-perches of Helsinki extends as far as to the waters south of Porvoo, around Emäsalo. Individual fishes have also been found in Pernajanlahti, about km to the east from the place of tagging, and at the opening to the Bay Ahvenkoskenlahti, about km to the east from the place of tagging. To the west of the place of tagging several tag finds have been made in the Bay Pikkala behind Porkkala, one in the Ingo archipelago, and an uncertain find as far as in the Vaasa (see Figure 3) archipelago.[x)]

In the tagging at Halikonlahti (Fig. 18) the pike-perches have kept mainly to the narrow bays opening toward the south and toward the

---

x) The tag SF 5893, attached to a pike-perch in Laajalahti on June 12, 1958, has been reported by a fisherman living in Iskmo to have been found on September 10, 1959 in a "pike" by the Lillöre-Rock in Iskmo.

west. In the south the area for normal migration extends to the waters surrounding Särkisalo, and in the west to the western outlet of the Bay Halikonlahti. Four tags have been come across outside the Bay Halikonlahti. Of these two have been found at the fringe of the outer archipelago, to the southwest of the Island Kemiö from the waters of Hiittinen and Dragsfjärd, one to the south of Kemiö, by Taalintehdas, and one from the northern part of the Bay Paimionlahti.

The pike-perches tagged in Kakskerta (Fig. 19) have spread evenly into all directions in the narrow open channels of the arcipelago. The eastern bound for the living area of this stock appears to be formed by the Bay Paimionlahti and by the Paimionselkä ecpanse, from which there are a few tag finds. In addition, one pike-perch has swun into the Bay Halikonlahti. In the south the most distant tag finds are fran the southern archipelago of Parainen. In the west the migrations extend to the southern and western parts of the Airisto expanse, and in exceptional instances, to the west of Rymättylä. As the northern bound for the migration area may be taken, for the pike-perches of Kakskerta, the waters close to Naantali.

In the Åland Islands (Fig. 20) the migration area of the fishes tagged in Ödkarbyvik is limited to the bays and expanses within the group of islands. The principal part of the pike-perches has been caught in Ödkarbyvik, in Färjsund, and from the Lumparnselkä Expanse. Three finds, somewhat separated from the rest, have been

made at the boundary of the archipelago area in Teili, in the channel northeast of Lumparland, and in the vicinity of the city of Mariehamn.

Data regarding the distance of the catching sites of the pike-perches from the tagging site have been collected into Tables 4 and 5. With the place of tagging as a center circles with radii increasing by 5 km. for each circle, up to a radius of 50 km., have been drawn on a tagging chart. The number of tag finds in different tagging lots has been calculated within each area between two circles (Table 4). From these, the cumulative counts from the tagging place outward, and the corresponding cumulative percentage, have been calculated (Table 5).

In the Karhula tagging area more than half (55.2 %) of all the finds have been made at a distance below 5 km. from the tagging place, and within a distance of 10 km. 85.5 % of the pike-perches have been caught. Some individuals have swum farther in the direction along the shore, one as far as 165 km. from the place of tagging. The tag find in queastion, made in the territory of the U.S.S.R. near the city of Sestorjetski, corresponds to the longest uscertained migration distance in connection with this investigation.

The pike-perches tagged in the tagging area of Helsinki, near Suomenlinna (Sveaborg) have mostly (85.7 %) kept to within a distance of 10 km. from the place of their release. Some have extended their migration eastward in the direction along the shore up to a distance of 30-40 km.

Upon inspecting the taggings at Laajalahti as a whole it may be

noted that the migration area is larger than, for instance, with the tagging lots of Karhula and Suomenlinna. The lot of 1960 forms an exception to this, for with this lot all the tag returns are from places less than 15 km. distant from the tagging place. The more extensive material from the taggings of 1958-1959 shows that a large part (about 80 %) of the pike-perches keep to within 15 km. of the place of tagging, but, on the other hand, fairly general migrational activity may be found to a distance of 25-45 km. in both, the eastward and the westward, directions.

The migration area of the pike-perches of Halikonlahti extends fairly generally as far as 30 kilometers from the place of tagging. Also, the pike-perches of the tagged lot of Kakskerta have migrated within a larger area than, for instance, the fishes tagged in Karhula.

The returns data obtained from the tagging cappied out in the Åland Islands appear rather clearly to be divided into two groups. On the one hand plenty of pike-perches have been caught within a radins of 10 kilometers from the place of tagging, and, on the other hand, from a distance of 20-25 kilometers.

Taking all the material as a whole it may be said that the pike-perches of Suomenlahti migrate usually to a distance of ten kilometers from the place of tagging, for more than 2/3 (67,6 %) of the tags have been returned from places within 10 kilometers. Not very seldon, however, the pike-perches have migrated to distances of 35 kilometers. From distances less than 35 kilometers 96.6 % has been caught. Pike-perches found at distances greater than 35 km, 20 in number altogether, may be taken to be rovers

which have wandered outside the normal migration area of the lot. These long-distance wanderers are pike-perches which are respersible for the fact that pike-perches are occasionelly found in areas outside their usual habitat througkout the entive coastal regions of Finland, as data received, among other places, from Kalajoki (HEUSALA 1933, s. 176) and from the waters outside of Oulu (ANON. 1934, ss. 131-132) indicate.

Differences among various regions may be noted in the extant of the area of migration. In part the differences probably are caused by the location of the place of tagging. The normal area of migration of the pike-perches consists of the archipelago from the shallow bays cutting into the mainland out as far as to the edge of the open sea. Whan the place of tagging is located on the border of a populated area, as is the case with the taggings of Laajalahti and Halikonlahti, the distances of migration become, on the average longer than in connection with taggings which have been made further out in the archipelago, as, for instance, with the taggings of Karhula and Suomenlinna.

The differences among the various areas, as far as the migrational habits of the pike-perches are concerned, are caused by, in addition to the locality of the tagging, by the character of the archipelago and by the quality of the water. In the archipelago of relatively open coast (the taggings of the regions of Karhula and of Helsinki) the migrational distances remain shorter than in an archipelago characterized by narrow open expanses and straits (the taggings of Halikonlahti and Kakskerta). On the other hand migrations extending far in the directions along

the coast are more common in connection with an open coast than in connection with other types of coast. The extent of the area of migration also characterizes the extent in the archipelago of the area with water of physico-chemical properties favorable to the pike-perch. This question has been delved into in Section 3.4.

In the taggings carried out by HENKING (1923, ss. 21-29) it was found that the pike-perches wandered out from the Stettin Lagoon to the Baltic Sea, and pike-perches tagged in front of Swinemünde in the Baltic Sea had completed migrations of as long a distance as 25 kilometers along the coast, while a part had swun into the narrows separating the Stettin Lagoon from the Baltic Sea, the distance being below 10 km. The migrations in the Stettin Lagoon tagging which have extended the furthest have reached distances of 30-40 kilometers from the place of release after tagging, and, in general, the places of finding are at distances of 10-20 km. from the place of tagging. The area of migration of the pike-perches tagged by HENKING is approximately of the same magnitude as that noted in this investigation for the pike-perches of Suomenlahti.

Of the 200 pike-perches tagged in Kungör of the Lake Mälaren by SVÄRDSON (1948, ss. 173-174) 10 were picked up again. Of these one had swun to a distance of about 70 km. from the place of tagging. Two others were found fairly far (distances of 60 km and 40 km). The rest had stayed within a distance of 15 km.

In a tagging carried out in the Lake Vänar PUCE (1952) observed 48 km as the longest distance between the place of tagging and the

place of catching. In general, the pike-perches had stayed near the places of tagging. From Dettern, which is a well-known spawning bay, a part had migrated to adistance of about 7 km from the mouth of the bay to a location near the wide, open water, and the rest had been caught from the Bay Dettern, and fron its immediate vicinity. Also in case of a tagging at Vålösund the majority were caught in the immediate vicinity of the place of tagging. A few had migrated to a distance of 10-20 km. and two even further. The area of migration of the pike-perches of the Lake Vänarn appears, on the basis of these data, to be less extensive than that of the pike-perch stocks of the northern coast of the Gulf of Finland.

4.2 The Migrations

Upon inspecting the material as a whole it may be concluded that the pike-perches have been distributed fairly evenly around the place of tagging. Their migration has not, however, been random wandering. Upon comparing to each other data regarding places of catching from different years and different seasons certain differences may be noted, which give cause to the supposition that pike-perches partake in regular migrations.

4.21 Differences by years

Taggings have been carried out in Karhula, Laajalahti and Kakskerta in 1958 as well as in 1959. A small-size tagging has been carried out, in addition, in 1960 at Laajalahti. In Halikonlahti and in the Åland Islands a tagging has been carried out only during one year.

In Karhula (Fig. 16) the pike-perches from the tagging of 1958 have clearly remained within a less extensive area than from that of 1959. Especially, only fairly few fishes have partaken in the migrations westward. Only fairly inadequate results are obtainable from the comparison, since only 16 tags have been gotten back from the tagging of 1958. In Kakskerta (Fig. 19) the situation is reversed, for the area of migration of the pike-perches tagged there in 1959 has been less extensive than the corresponding one in 1958, and migration southward seems to be lacking altogether. This result is possibly influenced by the fact that there are only 17 tag returns from the lot of 1959.

From the taggings of Laajalahti (Fig. 17) relatively far-reaching migrations may be noted to have taken place from the lots of 1958 and 1959, but from the lot of 1960, on the other hand, from which there are only 18 returns, the pike-perches have stayed in a small area seaward from the place of tagging.

Several pike-perches from both, the tagging of 1958 and the tagging of 1959, have been found in the waters to the south of Porvoo, from westw..of Emsalö and from the archipelago of Sibbo (Sipoo). The migration east appears to be fairly regular in character for the pike-perches of the Helsinki region, for pike-perches from Suomenlinna have also been met in the waters of Emsalö. Unusual in the tagging of 1959 is that in that year several pike-perches went westward by the Porkkalanniemi to the waters of Obbnäs and Pikkalanlahti. Out toward the sea the migrations have extended as far as to the line Harmaja - Katajaluoto - Rysäkari, and no clear differences may be noted between the results from the various years in this respect.

The differences in the character of the migrations among the various years are probably mainly caused by differences in the temperature of the water and in the nature of the sea currents. One possibility is also that the migrations of the animals that the pike-perches feed on is reflected in the migrations on the pike-perches.

Unusual, and relatively clear, has been the migration of pike-perches westward past the Porkala peninsula. The first find was made on May 13, 1959 in the archipelago of Ingo westward from Obbnäs. Further, tags were found: on Sept. 6 by the Obbnäs peninsula, on Sept. 7 from Pikkalanlahti, on Sept. 18 from Obbnäs, on Oct.29 from Pikkalanlahti, and on Dec.2 from Porkala. It appears that strong migration westward had occurred at the end of August and the beginning data from the end of August till September (Fig.46) a very strong drop in the temperature may be noted during the period August 23-28. The temperature on the coast at Kaivopuisto in the surface water dropped from 20.7°C to as low as 5.4°C as a result of the prevailing strong winds from the west and from the northwest. It is possible that the sudden cooling of the water has caused the migration.

Upon inspecting the currents of the sea (unpublished observation, Merentutkimuslaitos (the Marine Research Institute)) an unusually uninterrupted current from west towards east may be seen to have occurred about the turn of August into September in 1959. In the surface water the current begins already on Aug. 30, but reaches deeper (15 and 30 m) on Sept. 1, and continnes uninterruptedly in the surface waters until Sept. 9, and deeper down, interrupted by

short currentless periods, until Sept. 12. The observations end on Sept. 15, when the lightship m/s Helsinki was replaced by a stationary lighthouse.

It could be assumed that this continuous current caused the westward migration, for just near the end of this current period two pike-perches were found from west of Porkala, and still one on Sept. 18, and two later in the autumn and approaching the winter.[x] Then, the pike-perches would have swun counterstream, and the migration in question would have been of an active character, and not of passive transport with the stream, of which type JÄRVI (1959, p. 286) assumes the migration of salmon in part to be.

The surface stream along the northern coast of the Gulf of Finland goes principally from the east to the west (JURVA 1951, Fig. 11). Upon inspecting the taggings made in the Helsinki waters and in Karhula (Figures 16 and 17) it may be noted that far-reaching migrations have clearly been stronger in the eastward direction than in the westward. Also in the former movement the fish would have moved countercurrently as has been presumed to have been the case in the migration of the pike-perches in the autumn of 1959 to the west of Porkala.

---

x) The pike-perch found on Aug. 13 in the Ingo waters does not fit this theory very well, for no noticeable continnous current from west to east is/in the first half of August, the current then having been mainly from east to west.

4.22 Seasonal Migrations

For clarifying the seasonal habitats the tag finds have been classified by the seasons in Figures 21-24. The year has been divided into three parts: I-IV, V-VIII, and IX-XII. In the period from the beginning of May to the end of August. May and June have been, in addition, grouped separately. In May the pike-perches move to the spawning areas, and spawning takes place in June. July and August are the most important growth months. In September-December the migration to the wintering areas takes place, and the tag finds from January-April reveal the wintering habitats. During the last-mentioned period the coasts of the Gulf of Finland are, in general, covered with ice.

4.221 The Migrations in the Tagging Area of Karhula

Of the pike-perches tagged during two years at the shore in Pitkäsaari three have been caught during June (Fig. 21) from the surroundings of the place of tagging: from the mowth of the River Summajoki, from the waters next to Hamina and from a location to the east of Kirkonmaa. In June of the next year two pike-perches have been caught from places outside of Rakila, to the southeast of Hamina, and one from a place about 5 km. east of the place of tagging. During the spawning season, thus, pike-perches tagged in Karhula have been caught from a rather extensive area, and it appears that in the tagging lots there are fishes from more than one spawning area.

On the whole the pike-perches have kept in May-August closer to the place of tagging both during the first year and during later years. However, there are some exceptions which indicate that the migrations begin in this area already during the summer months. Thus, in July a pike-perch has been caught almost 50 km. east of Virolahti, and another in August already from a basin of the River Neva near the city of Sestroryetsky. The westward migrations have been small.

One fish has been caught west of Kotka, from the strait between Mussalo and the city. Furthest out to the sea, two pike-perches have been caught from the western side of Kirkonmaa.

In the autumn and in the early winter pike-perches have been met on the average slightly further out from the shore than during the summer months, but during the former period the same kind of long-distance migrations have not been observed as during the summer. Several tags have been found near the place of release upon tagging, but, in general, slightly further from the shore than during the summer months. During the second autumn one tag has been found from a place about 20 km to the southwest, from the eastern side of Kannissaari, and two more from the vicinity of Kotka. During the winter months, proper during January-April, tags have been found from the same areas as during the summer and the autumn.

The pike-perches of Karhula do not appear to have clearly different habitats during the various seasons. In the autumn and in the winter the pike-perches stay a little further from the shore than

pike-perches of the Helsinki area. However, for them, too, the habitats in the autumn and in the winter are somewhat further from the shore than during the summer months. A part of the fishes wander as far out as to the outer archipelago, and this happens, in part, already during the late summer. Apparently due to the nature of the coast, no clearly-defirable migrations in the directions along the coast have been observed. One pike-perch, however, has moved to Paimionlahti.

4.224 The Migrations in the Tagging Area of Kakskerta.

From the taggings at Kakskerta a lot of pike-perches have been gotten back already in June (Fig. 23), in which month the tagging was carried out (on June 10 and 17, 1958, and on June 25, 1959). In two weeks the fishes have been time to spread out nearly into all directions. The greatest part (12 fishes) have, however, directed their movement toward the mainland, to the straits between Hirvensalo and Kuusisto, or have remained in the vicinity of the place of tagging. A part have migrated to the south, to the straits of Pargas (3 fishes), and one has been met in the southern part of Airisto.

The summer fishing of pike-perch in the archipelago of Turku is efficient. In July-August a lot of tags have been gotten from the same areas as already in June. A part of the fishes have, however, migrated further: to the vicinity of Ruissalo, to the south of Parainen, and to Paimionselkä (the Paimio Expanse).

From the autumn there is a small number of tag returns (4 finds)..

Of these two are from the vicinity of the place of tagging, one from the northern tip of Airisto, and one from the southern part of the Bay Paimionlahti, from the vicinity of the Island Atu.

During the winter two tags have been gotten from the summer-habitat of the pike-perches, one from Kuusistonsalmi and one from north of Pargas. On the other hand, a lot of tags (10) have been returned from the shores of the Airisto Expanse. One pike-perch has even swun to the west of Rymättylä. It seens that the pike-perches have wandered into deeper waters for the winter, just as in Helsinki.

The tag returns from May following the first tagging are in part from the waters near Kakskerta, but, on the other hand, there is one from the vicinity of Naantali and one from Paimionlahti. During June of the same year there are two unexpected finds from Nauvo and from a location to the west of the Paimio Expanse. The other tags from the second summer have been found from fairly near the place of tagging, and approximately from the same areas as during the previous summer.

During the second autumn two pike-perches have been found from the southern parts of the archipelago, one from east of the Island Attu and another from the eastern parts of Nauvo. During the winter of the same year one has been found from the harbor-area of Turku, one from north of Naantali, and three from the southern tip of Airisto.

There are no tag finds from the third year, but from the fourth year there is one find from the strait of Hirvensalo, about 5 km. to the north of the place of tagging. Overall, it may noted, that

the pike-perches spend, in general, the spawning period and the summer in the narrow straits surrounding Kakskerta. During the autumn and the winter a lot of pike-perches have been met in the shore areas of the bigger expanses, such as the Airisto Expanse and the Bay Paimionlahti, and to the latter connected Paimio Expanse, so that it may be concluded that these pike-perches, too, have a tendency to move for the winter into deeper waters farther out in the archipelago. During the spawning period pike-perches have been caught from a rather large area. Possibly the lot tagged in Kakskerta has come from several spawning stocks. Another possibility is that all the pike-perches do not spawn every year and wander, during a non-spawning year, in areas further out in the archipelago.

4.225 The migrations in the tagging area of the Åland Islands.

From the tagging done in Ödkarbyvik in June 14-18, 1960, from the first summer there is only one find, from an expanse about 15 km to the south, in Lumparn (Fig. 24). Similarly, there is one find from the autumn from the same archipelagic expanse. On the other hand, from the period January-April there are a lot of tag returns, especially from April. A large part of these are from Lumparn, but there are several also from the Strait Färjsund between Lumparn and Ödkarbyvik, and one from Saltvik. In May a few pike-perches have still been found in Lumparn and one in the vicinity of Mariehamn, but many at the place of tagging and one in Färjsund.

Also during the following June several tagged fishes have been met in Ödkarbyvik, one in Färjsund, and one in Lumparn.

Further, during July-August tags have been returned from Ödkarbyvik and from Färjsund, and several from Lumparn. In addition, one

tag has been reported as haring been found in Teili.

From the second autumn there are finds from Lumparn (2 finds), and one from Färjsund.

From the third summer (June-August) there are tag finds only from Ödkarbyvik.

The pike-perches tagged in Ödkarby appear to have a clearly-definable annual migration rhythm in their movements between the spawning bay and Lumparn. After the spawn the pike-perches move gradually to the south, so that already in August a part of them have reached Lumparn. The autumn and the winter they spend in Lumparn, but a part go only half-way, to Färjsund, to winter there. The return to the spawning bays begins in April and continues in May. During the spawning month only one pike-perch has been met outside the Bay Ödkarbyvik. Out as far as to the open sea the migrations of the pike-perches of Ödkarbyvik reach only quite exceptionally.

4.23 The nature of the migrations.

4.231 The spawning migrations.

The migration of fishes from one location to another during various seasons can be classified into spawning migrations, search-for-feed migrations (feeding migrations), and wintering migrations. During the spawning migrations the fishes move from the wintering habitats to the spawning places. According to NIKOLSKI (1957, pp. 401-402) the pike-perches of the Sea of Azov

gather already during the winter months, in December and in January, to the month areas of the spawning rivers Don and Kuban, and the ascent to the spawning places begins in March-April. The spawning places of the pike-perch are situated on the flooding river plateau above the delta of the Don and the lagoon of Kuban. Also the close relative of our pike-perch, the American pike-perch, Stizostedion vitreum vitreum (Mitchill), has been found to have, on the basis of extensive taggings, a clear spawning migration, as the fishes ascend the rivers in the spring to spawn. The same fishes have been observed to come to the same spawning places from year to year (comp. for inst, CARBINE & APPLEGATE 1946, CROWE 1962, RAWSON 1957, OLSON & SCIDMORE 1962 and FORNEY 1963).

On the basis of the returns data with respect to taggings carried out in the Gulf of Finland it may be deluced that also the pike-perch of our coastal waters has a clear spawning migration. This becomes apparent especially from the tagging of Laajalahti and Ödkarbyvik, which were carried out at known spawning places ans which, each, included fishes from one spawning population. The results from the tagging of Karhula, Halikonlahti, and Kakskerta are less clear and more difficult to interpret. This is probably in part caused by the heterogeneity of the material, as the tagged lots included individuals from more than one spawning population, and in case of the lots of Karhula and Kakskerta, also by the fact that the tagging was not carried out at the spawning place.

On the basis of the tag returns it seens that migrating of the pike-perches of Laajalahti toward the spawning places begins in

April. From May there are tag finds only from the immediate vicinity of Helsinki. The pike-perches have apparently returned to the archipelago from their migrations which reach as far as to the archipelago of Sibbo and to the waters south of Porvoo, since there are no finds data from there from the summer months, though there are such data from many months of the autumn and the winter. The spawning of the pike-perch in Laajalahti takes place usually during the second half of June. It is not possible to say, on the basis of the tag returns, when the fishes gather in Laajalahti, for due to there being a closed season as regards fishing in June there are only a few tag finds from this period. To a great part the pike-perches arrive in Laajalahti probably as late as in June, since in May-June, 1959, when fishing for the tagged pike-perches, the catches improved continuously toward the end of June, at which time the spawn took place.

The gathering of pike-perches into Ödkarbyvik takes place approximately at the same time as the above-presented spawning migration of the pike-perches of Laajalahti. From the wintering area, from the Lumparn Expanse and from Färjsund, several pike-perches have been caught as late as in May, but also from the vicinity of the spawning place. In June several tagged fishes have been met in the immediate vicinity of the place of tagging. The spawning migration appears, thus, to take place mainly in May, but it contienues into June.

After reaching sexual maturity the pike-perches spawn generally every year. On the basis of the taggings of Laajalahti and the Åland Islands the pike-perches may be assumed to come to the same

spawning places from year to year. A few finds made in June of the year following the tagging year far from the place of tagging, from the tagging lots of Karhula and Kakskerta, among others, give reason to doubt the conclusion that all the pike-perches return to the earlier spawning places..

4.232 Feeding migrations.

After a spawning which has taken place in shallow bays in the end of June the pike-perches spread out to feed and begin their annual growth. As will be presented later, in Chapter 5.21, all the annual growth occurs during a fairly short period in July– September, and the most important growth month is, according to the tagging results, August.

After the taggings carried out in May and June the pike-perches have spread out fairly evenly into the surroundings of the place of tagging. It can be assumed that at this stage the movement of the fishes is not of the nature of a migration in a certain direction, but, rather, of can ainless wandering in search of food. The tag finds made during the summer have occurred mainly in the inner archipelago region, and the mainland coast, in accordance with the geographical division according to HÄYREN (1948). The migration area does not then, in general, reach out to the outer archipelago region, but longer migrations may be observed in the directions along the coast. Most clearly this becomes apparent with the taggings of Helsinki and Karhula

Feeding migration reaching out to the open sea is probably

prevented along the northern coast of the Gulf of Finland by the coldness of the water in the outer archipelago region, which property has been discussed in Chapter 3.4311. By its nature the pike-perch, living in lakes, is a habitant of the open expanses. In the southern part of the Baltic Sea, where the temperature of the water is higher, pike-perches are met in the summertime in the wide expanses. In the tagging carried out on June 12, 1915 by HENKING (1923, p. 21) it was clearly observed that the pike-perches had voyaged during the summer to the open expanses of the Baltic Sea. Similarly FILUK (1962, pp. 705-706) observes that the pike-perches from Frisches Haff move, after the water has warmed to a temperature of 20°C and during a strong thickening of the water due to the presence of algae, into deeper waters, and, in part, out to the Baltic Sea. Not before the autumn is more pike-perch gotten from Frisches Haff again.

It is well-known that the pike-perch avoids regions of clear water. The bounding of the sedimented-water region by the outer archipelago belt, for instance in the Helsinki water area, can, in part, prevent the pike-perches from traveling to the open expanses during the summer. SEGERSTRÅLE (1949, p.89) has cited observations by fishermen, according to which pike-perch fingerlings are occasionally caught from deep water from nets for Baltic herring during June-July at the outer bound of the archipelago from the waters in front of Helsinki and Porvoo, among other places. These pike-perches are 15-20 cm in length, but there are 30 cm long ones among them. They are from 1 to 3 years old. SEGERSTRÅLE has noted that they have mainly eaten mysis. According to these observations the yong pike-perches appear, at

least in part, to stay in the outer archipelago in relatively cold water during the growth period, and this, according to SEGERSTRÅLE, is caused by the abundance incidence of feed animals. To what extent the locations of the habitats of older pike-perches are dependent during the growth period on the prevalence of their feed animals, mainly the smelt (Osmerus eperlanus), has not been clarified in connection with the present investigation.

4.233 The wintering migrations.

The pike-perches which are on a feeding migration are carried during the summer ever farther from the spawning places. The real move to the wintering waters takes place during September-October. The winter is spent by the pike-perches according to the tag returns in the deep basins of the inner and the outer archipelago. The freatest part moves from the vicinity of the coast toward the open expanses, but a part carries out rather long migrations during the winter in the directions along the coast. These migrations, for instance in the case of the pike-perches of Laajalahti, extend regularly as far as to the waters south of Porvoo.

As one reason for the wintering migration away from the shallow bay waters into the deep basins of the archipelago may be assumed to be the changes in the temperature gradient during the autumn. Chapter 3.431, dealing with temperature, makes it apparent that during the summer months the water temperature of the inner archipelago is clearly higher than the temperature in the open sea. During the late summer the difference gradually disappears,

and generally during September the situation is reversed as the bay water cool down faster. During the early winter the water of the open sea is warmer than the waters near the coast. Assuming that the pike-perch moves during various seasons generally always to such locations where it finds warm water, it is possible to understand why the autumn migration into the deep basins of the archipelago takes place.

Principally the streaming water along the northern coast of the Gulf of Finland moves from east to west (comp. for inst. JURVA 1951, p. 132). The wintering migration of the pike-perches of Laajalahti is generally directed toward the east, and, thus, in the countercurrent direction. As exceptions to this, several tagged pike-perches were met west of Porkala in the autumn of 1959. It may be that the unusually continuous current from west to east during the period August 30 - September 12, 1959 caused this move to the west.

The wintering migration and the winter habitats of the pike-perches of the northern coast of the Gulf of Finland appear to depart to some extent from those observed elsewhere. Of the pike-perches tagged on September 14, 1915 by HENKING (1923, p.27) in the Baltic Sea in the vicinity of Swinemünde a part were caught during the autumn from the vicinity of the place of tagging in the Baltic Sea, but a quite large part had swum, by February, into the narrows leading into the Stettin Lagoon. HENKING notes that pike-perches have a migration out to the Baltic Sea during June-July, and in the autumn, during October-November, a migration back to the Stettin Lagoon. Accerding to NIKOLSKI (1963, p. 257) certain semimigration fish species move into the outflow branches of rivers for wintering. Thus, the pike-perch has such a wintering

migration from the Caspian Sea into the lower branches of the Volga.

4.234 Intermixing of the pike-perch stocks.

According to the tagging results the pike-perches appear to return from year to year to the same spawning locations. In this way the spawning fishes and their offspring form a separate population for the bay in question. During feeding and wintering migrations the spawning populations of the various bays get intermixed, as the pike-perches carry out long migrations along the coast. A small part of the tag finds have been made so far from the tagging place that it must be assumed that the fishes in queastion have spawned in some other spawning location than in the one from where they were caught prier to tagging. On account of such wanderers the stocks of the various spawning bays ar continnously crossed to some extent with each other. Thus, it is hardly possible to find racial dirrefences among the various spawning populations in the Gulf of Finland and in the Saaristomeri. Separate stocks are formed by the pike-perches living in the Åland Islands and in the northern part of the Gulf of Bothnia, respectively.

4.3. Data regarding the migration speed

Into Table 6 have been collected some tagging and returns data, on the basis of which the average distance moved during 24 hours has been computed. Data regarding fishes whose migration speed

has been greatest have been chosen into the table. The distance has been measured along the straightest possible path of moving. Upon inspecting the results it should be taken into account that the taggings have been made before the spawning in the vicinity of the spawning places. Only after the spawning period do the pike-perches leave the spawning areas to feed. During the feeding migrations the speed of journeying in a certain direction is apparently still relatively small, for during the growth period of the summer the biggest part of the pike-perches have kept, to the inner parts of the archipelago. Not before the autumn does the migration out to the deep basins of the archipelago, and, on the other hand, along the coast, take place. Therefore, it is difficult, on the basis of Table 6, to make conslusions regarding the journeying speed in connection with a migration in a certain direction. For finding the journeying speed during the wintering migrations it would have been necessary to do the taggings in the late summer, and, on the other hand, for estimating the journeying speed during the spawning migrations, at the wintering locations during the late winter.

The greatest migration speed has been observed in connection with a tagging carried out in 1956 by the Varsinais-Suomen Kalastajaliitto (the Fishers Union of Finland-Proper), in which one pike-perch (No A 8) had swum from Kakskerta to the archipelago of Luvia, the distance having been about 150 km. On this basis the average journeying speed is obtained as 4.1 km/day. Some other pike-perches have been observed to move from place to place with a speed of 1.8 - 2.6 km/day, but generally the speed is lower. Usually the distance covered in a certain direction during 24 hours stays on the average under 1 kilometer. During the summer

the pike-perches appear to move from place to place only a few hundred meters during 24 hours.

5. The growth

5.1. The growth on the basis of the scales investigation.

In connection with a tagging scale samples have been taken from the pike-perches. The size and the usability of the scales for the age determinations varies from part to part in the fish. In connection with this investigation the scale samples have been taken from a location between the dorsal fins, below the lateral line. In this region the scales are relatively big, which facilitates the interpretation. The sample-taking area has been chosen/after comparing with each other the scales taken from various parts of the body.

A close relative of our pike-perch, the American pike-perch, Stizostedion vitreum vitreum (Mitchil), has been subjected to an investigation by PRIEGEL (1964 p. 199) with respect to the first development of the scales on growing, young pike-perch. He observed (Figure 25) that the first scales form in the tail, on the lateral line. From here the scale cover spreads towards the tail, and at the same time towards the head, along the lateral line. An American pike-perch of 45 mm length has a fully-developed scale covering.

between the size of the scales and the size of the fish. SCHINDOWSKI & TESCH (op.cit.) have presented the ratio in question as a firstdegree, and as a third-degree, curve.

The scale samples in this investigation have been taken from a different spot than in the above-mentioned references. For this reason it has not been possible to use these reterences when calculating the length of fishes of various ages on the basis of the scales. For the purpose of calculating the correction factor the radius of the anterior sector of the scale along the center-line of 584 pike--erches has been measured. The fishes have been divided, according to length, into groups differing from each other by 2 cm., and within these groups the average length of the fishes and the corresponding average radies (x10) of the scales has been calculated (Table 7). By means of regression analysis a linear equation has then been calculated to represent these results:

$$l_t = 4.42 + 1.012\ r\ (x\ 10), \text{ where}$$

l_t = the over-all length of the fish, cm.,

r = the radius of the scale, mm.

From Fig. 26 may be seen that the points fall fairly well along the line. On the basis of these measurements, thus, there would not see to be reason to calculate, for instance, a third-degree curve as SCHINDOWSKI & TESCH (op.cit.) have done. When comparing the curve presented by SCHINDOWSKI & TESCH with the line of Fig. 26 it may be observed that in this investigation the scales of the pike-perch have been relatively somewhat larger. This is particularty true with respect to small pike-perches. Inspecting

ever larger oues the difference may be seen to disappear gradually.

5.11 The Growth in Different Tagging Areas

In Table 8 are presented the distribution of the tagged lots of pike-perch into various age-groups and the average lengths within the age-groups. In addition, for Table 9, the average weight within the age-groups has also been calculated.

The tagged pike-perches have mainly been from 4 to 6 years old. There are a few 3 years old ones, and a few 7 years old ones and older. In the lots tagged at Kakskerta and at Halikonlahti there have been more older pike--erches. The oldest tagged pike-perch has been, according to the scales-analysis, 11 years old.

According to the age determinations 4 years old pike-perches are, on the average, 31,2 cm. long, 5 years old ones correspondingly 34,5 cm, 6 years old 37,6 cm, and 7 years old 41,8 cm. Among the various regions may be noted differences, which, however, there is no reason to inspect more closely, for the information given in Tables 8 and 9 reagarding the growth of pike-perches gives an incomplete and misleading picture. This results from the following reasons, among others:

1. From the many lots of fish used for the tagging, pike-perches greater than the low linit (37 cm.), fixed by the fishing lows, have been removed. Pike-perches gotten in such a wanner are the ones delivered for tagging by fishers as the lots

vicinity of, or from paths leading to, spawning localities. Along in the tagged lot is a small number of pike-perches which would not have been mature for breeding during the summer when they were caught, but, in general, the tagged material is composed of sexually mature individuals. It is generally true for fish that the fast-growing individuals in some year-class reach spawning maturity sooner than the slow-growing individuals in the same year-class. This is the case with respect to, among other species, the dwart whitefish of the Lake Inari (TOIVONEN 1960, p. 32). A board general survey of this question has been presented by ALM (1959). Of the Gulf of Finland the males reach spawning maturity as 4- or 5-years old, the femaler generally not before the age of 6 years. It is probable that those individuals which are not yet mature for spawning (for instance among the 4 years old) do not yet take part in the spawning migration, and, thus, a wrong impression about the size of the individuals in the year-class is possible obtained.

In connection with the tagging it has not been possible to determine the sex of the pike-perches with certainty, and for this reason the growths of the males and the females cannot be presented separately. According to the investigations of SVÄRDSON and MOLIN (1966, p.2) the difference in growth between the sexes is quite small, but the females do grow a little faster than the males.

A better picture about the growth of the pike-perches of the Gulf of Finland is given by Table 10 (formed on the basis of the growth tables for various areas, presented as Appendix I), in

which the corrected lengths, calculated on the basis of the growth zones of the scales, is presented. In this way, among other results, more correct values for the lengths of 3- and 4-years-olds is obtained. Later, the growth curve obtained by means of the scales investigation will be compared with the data regarding the growth of the tagged fish for the purpose of estimating the sources of errors associated with the various methods.

Upon comparing growth data from various areas with each other small differences become apparent. However, there appears to be no clear tendency in the data to change with locality when inspecting the data, for instance, from the eastern part of the Gulf of Finland westward. The data material is to such a degree unrepresentative that the differences which are observed may be caused by this.

5.12 Comparison of the obtained growth data with data from the literature regarding the growth of the pike-perch.

Some data from the literature regarding the growth of the pike-perch have been collected into Table 11, where is also given the average growth of the pike-perches tagged in connection with this work, the average having been taken from all areas combined.

The rate of growth of the pike-perch of the Gulf of Finland has been investigated by SEGERSTRÅLE (1938, p. 104) and HALME & HURME (1952, p. 109). According to data regarding the scales, collected in connection with the taggings for the present work,

the growth of the pike-perches corresponds well to the length data on pike-perches from Kuokkala (SEGERSTRÅLE, op.cit.) up to the age of four full years (Fig. 27). From this age onward the pike-perch from the far end of the Gulf of Finland grows faster.

The growth curve for the pike-perch from the waters in the vicinity of Porvoo (SEGERSTRÅLE, op.cit.) is based on a relatively small (105) number of observations, collected over several years, which probably explains the scatter of the data to both sides of the curve for the tagged pike-perches. As a whole the growth of the pike-perches of the Porvoo vicinity correspond to a great extant to the rate of growth of the pike-perches of this investigation.

The growth of the tagged pike-perches agrees less well with the growth of the pike-perches of the waters around Helsinki as presented by HALME & HURME (op.cit.). Especially large is the difference in growth with 3- and 4-years old ones. With older age-classes the difference diminishes so that an 8-years old pike-perch among the tagged ones is only slightly bigger than a pike-perch of the same age caught from the Helsinki waters in 1950 by HALME & HURME.

The rate of growth of the pike-perch in various parts of the Baltic Sea is shown in Fig. 28. Data is given from the Stettin Lagoon (NEUHAUS 1934, p. 609), Kurisches Haff (MARRE 1933, p.316) Frisches Haff (FILUK 1967, p.142), and from the Gulf of Pärnu (ERM 1961, Table 3).

The growth is fastest in the Stettin Lagoon, where the pike-perch

has already reached a length of 30 cm. after two months of growth, and a length of 55,8 cm. after four months.

The growth rate is slower in Frisches Haff and in Kurisches Haff than in the Stettin Lagoon. In the two former the growth rate is approximately the same. A 4-years old pike-perch from them is as long as a 3-years old one from the Stettin Lagoon, and an 8-years old one from the former as long as a 5-years old one from the Stettin Lagoon.

Upon inspecting the growth rate situation further north, in the Gulf of Pärnu and along the northern shores of the Gulf of Finland, a slower rate may be seen to prevail, so that a 9 years old pike-perch from the Gulf of Finland is approximately of the same length as a 7 years old one from the Gulf of Pärnu, a 6 years old one from Frisches Haff and a 4 years old one from the Stettin Lagoon.

In Figure 29 the growth rate of some lake pike-perches is shown in comparison with the growth rate of the pike-perch of the Gulf of Finland. In general, it may be observed that the growth rate slows down in the northward direction. Fastest is the growth rate in Lake Raselm in Rumania and slowest in Lake Toften in Sweden. The growth rate of the pike-perches of the Gulf of Finland corresponds very well with that of the pike-perches from the latter lake. Local differences in the growth rate naturally exist depending on the trofia-degree of the lakes, the depth conditions, and the differences pertaining to the species and quantities of feed-animals, but the weather conditions appear, however, to be the most determining factor influencing the growth rate.

Data regarding the growth of pike-perch are available from Lake Tuusula, Lake Hiidenvesi, Lake Rautavesi, and Lake Kemijärvi, which data are all presented in Table 11. In addition, JÄRVI (1938) has published observations regarding the growth of individual pike-perches in Lake Nilakka, Lake Vesijärvi, and Lake Lohjanjärvi, and BROFELDT (1915, p.114) data regarding the growth of pike-perches in Lake Tuusulanjärvi.

A comparison between the growth rates of Finland's lake pike-perches and pike-perches from the northern coast of the Gulf of Finland shows (Fig. 30) that faster-growing than the coastal pike-perch are the pike-perch stocks of Lake Tuusulanjärvi and Lake Rautavesi, and slower-growing are the pike-perch stocks of Lake Hiidenvesi and Lake Kemijärvi. However, it must be taken into account that the given growth rate of the pike-perches of Lake Hiidenvesi is based on the lengths computed on the basis of the growth zores of the scales, which lengths have not been corrected; and that the samples have been taken in mid-summer, when the growing season has not yet ended (comp. JÄÄSKELÄINEN 1930, pp.28-29). As a result, the growth rate of the pike-perch of Lake Hiidenvesi is probably greater than what is shown in Table 11. In general, the pike-perches of the northern coast of the Gulf of Finland must be regarded as slow-growing, though, according to the growth classification based on the growth of the pike-perches of Fennoscandia (the Scandinavian peninsula and Finland) presented by VALLEN (1944, p.2), these pike-perches should be regarded as average-growing.

5.2 The growth with respect to the location of tagging.

In the tags which are attached to the pike-perches the finder is requested, among other things, to report the length and the weight of the fish he has caught. Most fishermen have fulfilled this request. The obtained data are, however, in some cases inexact and even unreliable. Such reports which give an estimate for the length of the weight have been discarded when handling the growth data. Similarly have been discarded data which give an impossible value for the ratio between the length and the weight i.e. the value departs too far from the length vs. weight curve. These measures have been taken to improve the reliability of the results. In connection with handling the length data a difficulty has been that there are two methods of measurement in general use in this connection in our country. In accordance with the fishing laws the length was measured, during that period when the taggings for this investigation were done by using the so-called "fork-length" (l_f). Today, generally, in fish research the greatest possible length is used (the length from the tip of the nose to the tips of the longest fin bones in the caudal fin, when that fin is compressed to be as narrow as possible). This method of measurement has been adopted into the fishing laws in a measure from the year 1964. This measure of length (l_t) is being used with all the length data in this investigation. In many tagged-fish reports it has been indicated how the length of the fish has been measured. Sometimes the reporter has been questioned afterwards as to what method of length measurement he has used. In some cases it has been

necessary to resort to the formulas computed for the ratio between the length and the weight, and to the corresponding curves:

$$w = 0{,}0236\ l_t^{\ 3{,}203}$$

$$w = 0{,}0366\ l_f^{\ 3{,}385}$$

In these: w is the weight of the fish, g;

l_t is the overall length of the fish, cm;

l_f is the fork-length of the fish, cm.

The foregoing formulas have been computed on the basis of measurements with 113 pike-perches from Laajalahti.

In case of many fishes both the fork-length and the over-all length have been measured. In connection with some taggings (Laajalahti 1959) a so-callet standard length (the length from the tip of the nose to the end of the scale covering) has also been measured. When, upon inspecting the returns from a tagging, there has been uncertainty as to the method of length measurement that has been used, the weight has been employed for determining, on the basis of the length-weight curves, which method of length measurement is probably in queastion. On this basis the increase in the length and in the weight, that have occurred since the tagging, has been calculated. In those cases in which the fork length has not been measured during the tagging the reported fork length has also been changed into the over-all length according to the formula $l_t = 0{,}67 + 1{,}044\ l_f$, which is based on the previously mentioned measurements with 113 pike-perhhes from Laajalahti.

There have been a total of 670 tag returns. In connection with these the length has been reported of 481 pike-perches and the weight of 338 pike-perches.

5.21 Seasonal Variations in the growth

For clarifying the seasonal growth pattern the growth data have been tabulated in time increments of half a month after a tagging, during the period June-September, and then, after September, in time increments of a month. From these the averages have been calculated (Table 12). The results are also presented in Fig. 31.

From the tagging month of June there are very few tag-returns data since the fishing of pike-perch is then prohibited by the Finnish fishing law.

No appeciable increase in length and in weight can be detected. The differences with respect to the measurements made during the tagging occur probably as a result of the incxactness of the observations.

In July numerous tag-finds have been made. A slight increase in length may be observed: in the first half of the month on the average 0,8 cm. and in the second half 1,3 cm. During this month quite a large number of reports have still been received which give the same value for the length as was gotten during the tagging. The growth of many pike-perches had, thus, not yet begun. Many fishes may be observed to have become lighter. This

results from the decrease in weight in connection with the spawning. Also in the average weight during the first half of July a decrease may be noted. During the latter half of the month the average increase in weight is only 5 g. For overcoming the decrease in weight caused by the discharge of the sexual secretions the pike-perch of Suomenlahti appears to need the whole month of July.

In August extensive growth occurs: The average increase in length relative to the tagging length of the pike-perches caught during the first half of August is 1.9 cm., and, during the latter half, 3.4 cm. The weight has also increased, though there are few observations regarding this. The increase during the first half is, on the average, 88 g., and during the latter half, 79 g.

In September strong growth still continues. The average increase in length for the individuals caught during the first half of the month is 5.1 cm., and during the latter halg 5.5 cm. Especially fast has been, during September, the increase in weight. During the first half of the month the fishes which have been caught, have, on the average, experienced in increase of 164 g, and during the second half, an increase of 244 g.

The average increase in the length of the fishes caught during October is slightly greater than the corresponding value for the latter half of September. Thus, slight growth still occurs during October. The average increase in weight during October is, on the other hand, smaller than the corresponding value during the latter half of September. The increase in weight appears, thus, to have come to an end at the time about the change of the

month from September into October.

From November on, no growth may be noted in the increase in length and in the increase in weight. In May the values are still at the same level as in October. It is possible that a small decrease in the weight occurs from March on. In the weight reports of the fishermen there are, however, such large inaccuracies that no certain conclusiens regarding this may be drawn.

During the period from May of one year to June of the next year the length may be seen to have increased on the average by 1 cm. and the weight by about 100 g. On the whole, it appears that the annual growth of pike-perches occurs during a quite short period. Before the spawning time the pike-perches grow somewhat in length already at the end of May and during June. The main growth in length begins, however, in July, and strong growth continues in August and September. The increase in length that occurs during the second half of July (1.3 cm) comprises 23.2 % of the whole annual growth (5.6 cm., when computed on the basis of the growth data from November to May). The value for the total annual incremental growth in the second half of August (3.4 cm) is 60.7 % of the annual growth, and the same value in the second half of September (5.5 cm) 98.2 % of the increase in length during the growth period. No length growth may be onserved during the period November-May.

The increase in weight occurs somewhat differently. The increase in weight upon the approach of the spawning time is revealed by the observations during the second May-June period following the tagging. The pike-perches which have spawned appear to need the

whole of July for bringing their weight back up to the pre-spawning level. The annual increase in weight occurs mainly in August and in September. Possibly the growth continues slightly still in October. The weight during the winter remains constant, possibly decreasing during the late winter.

Observations regarding the annual growth pattern of the pike-perch have earlier been made, among others, by HENKING (1923, p. 23), SEGERSTRÅLE (1936, p. 503), and MÄÄR (1947, p.13). HENKING notes, on the basis of a tagging, that the growth is quite slight in March-April. Similarly, from November until April the growth appears to have stopped almost completely. Thus, of the 10 months during which the fishes have been away, only 3 months remain, during which growth has been observed, namely September, October and June.

SEGERSTRÅLE (op.cit) mentions that the growth of sexually immature individuals (the pike-perch of the coast of Karelia reaches sexual maturity at the age of 6-8 years) in 1936 has begun in the end of June, when, on the other hand, the growth of sexually mature individuals has begun in the beginning of July.

According to the diagram presented by MÄÄR (op.cit.) the growth of those pike-perches of the Gulf of Pärnu which are living their second summer takes place mainly during a short period in June. Also during the period from September till June the pike-perches have been observed to grow a little.

These observations of SEGERSTRÅLE, HENKING and MÄÄR are quite well corroborated by the just discussed observations regarding the annual growth pattern of the pike-perch of the Gulf of

Finland, which observations have been mainly made regarding spawning-mature individuals. The fishes observed by MÄÄR were mainly 1-year old ones, and also the fishes tagged by HENKING were, to a great extent, young ones. On the other hand, it must be taken into account that the spawning of pike-perch in the Stettin Lagoon takes place already in May, and along the coast of Gulf of Finland not before the second half of June.

It seems probable that among the factors influencing the growth pattern the temperature of the water in which the pike-perch lives is of central importance. The dependence between the temperature and the rate of metabolism has been investigated by MOLNAR and TÖLG (1962). They have delved into the digestion of 8-10 cm long bleaks by 25-30 cm long pike-perches by means of x-rays. The emptying of the stomach lasted in various temperatures as follows:

Temperature (^{o}C)	5	10	15	20	25
The duration of the emptying of the stomach (h)	257	157	83	45	28

On the basis of these results the following formula has been computed:

$$y = 473.15 \times 1.12^{-x}$$

y = duration of the emptying of the stomach (hours)

x = temperature (^{o}C)

With a decrease in temperature the rate of digestion is greatly decreased. At a temperature of 20^{o} the emptying of the stomach lasts about 2 days, but in water at 0^{o}C already as long as 20

days. The rate of growth naturally deponds on the rate of digestion.

The need for a relatively high temperature appears in a pike-perch in that, according to data collected by DEELDER and WILLEMSEN (1964), the most andvantageous temperature for grawth is 19-24°C for the pike-perch, and that fingerlings in experiments that present choices, move into water of a temperature in the range 24-26°C.

Upon inspecting the harmonically smoothed temperature curves from the observation station at Harmaja (Fig. 45), drawn on the basis of values presented by AHLNÄS (1962, p. 14), it is noted that the maximum temperature in the surface waters occurs at the turn of July into August. Deeper down, the maximum temperature occurs ever later, so that at a depth of 10 m. the maximum temperature of the summer ocuurs during the latter half of August, and at a depth of 30 m. during the turn of September into October.

On the basis of these observations it is easily understandable that the growth is concentrated in August-September. The beginning of the growth is retarded in the case of the sexually mature individuals due to the decrease in weight caused by the smapwning.

5.22 The growth of the scale and the formation of the annulus

FREIDENFELT (1922, p.50) has investigated the formation of the annuli in a pike-perch. He has noted that the first, second, and the third thickening of the stria are formed on the scales principally in the spring, or in the early summer; the fourth and the fifth principally in the midsummer, this development continning as long as till the autumn. Yet, the time it takes for the various zones to develop can vary appreciably, both in the positive, and in the negative, direction.

The time of formation of the annulus has been investigated by camparing a scales sample taken during the tagging with a scale taken from the same fish in connection with a recatching. For making the comparing easy the scales have been photographed (appendix, Fig's. 32-42). The location of the annuli have been marked with crosses on the scales, and on the scales of recaught fishes the location of the edge of the scale upon the original tagging has been marked with two crosses.

The taggings have been made in May-June before the spawning-time. Upon inspecting the sample scales taken at that time it may be observed that no clear annuli are to be seen along the edges of the scales. The annulus is, in general, formed by a thickening of the strium pattern, or by broken stria. As an exception to the above, some pike-perches tagged in June (for inst. Fig.32) carry on their scales, already at the time of the tagging, signs of the formation of an annulus.

No growth may be observed on the scales of pike-perches recaught

during June. From the previous annulus there is left, for instance, in both scales of pike-perch № 10721 (Fig.33) the same number of growth stria (23), and in a later sample there is no annulus along the edge.

In this scales of fishes recaught in July, after the spawning, the formation of the annulus is not yet in evidence (Fig. 34), for the edge of the scale is similar to what it was in a sample upon tagging. On these bases it seens evident that the annulus is not formed in the pike-perch in connection with the spawning, but only as growth begins. Pike-perches caught in the end of July have formed a clear annulus, and their growth has begun (Fig. 35).

The region of growth in the scale which has formed in pike-perches caught in August is yet relatively narrow (Fig. 36). The growth of the scale continues on in September (Fig. 37) and possibly weakly still in October (Fig. 38). In November the region in a scale formed between the time of the tagging and the time of the recatching is already approximately as broad as the growth region formed during the previous year (Fig. 32).

The pike-perches caught during the winter (Figures 39 and 40) have clearly in their scales a summer's growth region, but no sign of a now annulus. This is the situation also in a pike-perch which has been away almost exactly a year (Fig. 41). However, it is possible to note, upon inspecting samples taken during the winter and scales samples from June, that all the stria on the edge of a svale do not continue as far as to the etoined area of the fin posterior. The now stria, formed during

the summer, on the other hand, circumscribe the whole of the anterior sector of the scale. Following these incomplete stria is one of the surest ways to determine the location of an annulus in uncertain cases.

In a pike-perch which has been in the sea for two growth periods between the tagging and the recatching it is clearly to be seen that a new growth region has formed in the scales during both growth periods (Fig. 42).

On the basis of the foregoing the growth of a scale and the formation of an annulus can be described as follows. When the growth of the pike-perch and the growth of the scales come to an end in October-November a region formed by relatively broad stria is left along the edges of the scales. The outermost strium is most often not continuous, and some other stria near the edge do not extend to the etenoid area of the fin posterior. In the summer the growth of the scale appears to begin no sooner than in July, after the spawning. At that time continuous stria, which extend to the etenoid area are formed. In many cases the stria are, in the beginning, closely spaced, being later spread apart from each other. Broadly spaced stria of this sort are formed until the termination of the growth. The growth regions of the various years can be seprated from each other as a boundary between the broadly-spaced stria, formed in the autumn, and the closely-spaced stria, formed in the middle of the summer, but also on the basis of the discontinuity and the shortness of the las strium formed in the autumn.

5.23 The annual growth

In the foregoing, in studying the annual growth pattern, it has been noted that the increases in the length and in the weight for the pike-perches of the Gulf of Finland occur only during the summer months of July through October, including the latter. The growth of these sexually mature, tagged individuals begins in July, and in October growing is already quite slight. During the winter and the spring (from November until May) no growth may be observed. For enumerating the growth that has taken place during the growing period the increases in the length and in the weight have been calculated from the tag-returns data of November through May. On the basis of these data the average increases in the length and in the weight, divided into groups according to length- and age-classes, the geographical area, and the year of tagging, have then be calculated. The division into length-classes has been made so as to prevent possible errors in the age-determinations from hindering the comparing of the growth among various areas and various years.

5.231 Differences in growth in various length- and age-classes

The average growth by length-classes, with the various areas combined, shows that with an increase in length the annual rate of growth (length growth) gradually decreases (Table 13). This may be seen also in Fig. 43. The dependence between the increase in length that occurs during a growth period ($l_{n+1} - l_n$) and the

and the average length of the fishes upon tagging in the various classes.

For comparing the growth data obtained by scales analyses with those obtained by taggings Fig.47 has been drawn. In this figure the growth curve obtained on the basis of the scales analyses has been drawn. On this curve the average length of the pike-perches from the classification by length has been marked, as well as the average growth in these length-classes during the first growing period following the tagging. From the figure may be seen that the growth of the tagged pike-perches has been, in length-classes 27-30, 30-33, and 33-36, faster than that of the corresponding 4-5 years old pike-perches. In length-classes 36-39 and 39-42 the growth has been of the same magnitude as in the growth curve. From this onward, the tagged pike-perches have grown slower than what the growth curve drawn on the basis of the scales analyses would predict.

In Fig. 48 a growth curve is drawn on the basis of scales analyses, and in Table 15 the growth of each age-class during the first, the second, and the third growing period following the tagging is presented. The 4- and 5-years old have grown faster during the first growing period than would be predicted by the growth curve; during the second growing period, on the other hand, slower. For 7-years old the rate of growth has been slightly slower than the values shown by the growth curve. The 8-years old ones, on the other hand, have followed the direction of the growth curve.

The growth can also be investigated by frawing the so-called Walford-line (WALFORD 1946). For it the length of the fish at the age is marked on the x-axis, and on the y-axis the length at the age n+1; or, on the x-axis the length upon tagging, and on the y-axis the length upon recatching (after the growing period). In addition, a 45^{o}-line is drawn on the figure. The growth of a fish slows down, in general, with age. Thus, the curve drawn through the datumpoints approaches, the 45^{o}-line. An intersection with the 45^{o}-line represents the greatest, theoretical length, l_{∞}, for the fish, at which condition the annual increase in length =0.

In Figure 49 the length results (the material from Table 10) obtained on the basis of scales analyses are shown forming a Walford-diagram. In the same figure the average growth data from a tagging, classified by length-classes (the material from Table 13), have been included.

A linear regression line has been computed for these points, which are based on taggings data.

This equation,

$l_{n+1} = l_{\infty}(1-k) + kl_{n}$ (RICKER 1958, p.194),

in which

$l_{\infty} = \frac{l_{1}}{1-k}$ (ROUNSEFELL & EVERHART 1953, p.319)

is for the pike-perches of the Gulf of Finland:

$l_{n+1} = 9,0 + 0,905\ l_{n}$.

From this:

$l_{\infty} = \frac{9,0}{1-0,905} = 94,7$ cm.

Correspondingly, a growth equation has been computed on the basis of the scales analyses for the age-classes 1-7:

$l_{n+1} = 7.6 + 0.918\ l_n$

From this: $l_\infty = 92.7$ cm.

Upon inspecting the Walford-diagram drawn for the growth of the pike-perches of the Gulf of Finland one notes that the dashed line connecting the scales-analyses points is situated at the beginning below the "tagging-line", but intersects this line at the points $l_6=37.9$ and $l_7=42.9$, and beyond this the former line is situated above the latter. Thus, it appears that, according to taggings, the pike-perches have grown faster than what the values obtained on the basis of the scales-analyses would indicate, up to the age of 6-7 years. From this age on the inverse situation appears to prevail.

What causes these differences? Before, in Chapter 5.11, it has been stated that the errors in the growth curve bases on scales analysis result from the following causes:

1. from many of the tagged lots of fish the big pike-perches have been picked out;
2. the selectivity of the catching devices causes errors, especially in 4-years old pike-perches;
3. the material is sparse as far as older age classes are concerned;
4. there are possibly errors in the scales-analyses.

In the growth data computed from the tag returns there are, among others, the following weaknesses:

1. the measurements carried out in connection with the recatching are inaccurate;
2. there are differences in growth from year to year, and the material to be treated here is based on taggings during anly two years;
3. the tag possibly causes changes in the rate of growth.

These factors may lead into getting an erroneous result for the general rate of growth, but they should not, on the other hand, affect the growth differences between the various size- and age-classes.

When comparing the growth data obtained by scales analysis with that obtained by tagging ones attention is caught especially by the fact that the differences in length between the age-classes 4-6 years are clearly smaller than what the values obtained in the tagging indicate. According to scales analysis the length growth (29.1 - 34.0) of a 4-years old is 4.9 cm., whereas according to the equation ($l_{n+1} = 9.0 + 0.905\ l_n$) developed on the basis of the tagging a 29.1 cm. long pike-perch grows to the length of 35.3 cm. (the growth is 6.2 cm.). A 5-years old, 34.0 cm. long, pike-perch grows, according to the scales analysis to the length of 37.9 cm. (the growth is 3.9 cm). On the basis of the taggings the value of 39.8 (the growth is 5.8 cm) is obtained as the length of a 6-years old. It is probable that the reason for these three age-classes (4-6) being squeezed into a narrower spread of values than that indicated by tagging is caused, firstly, by the fact that of the 4-years old only the individuals larger than the average are along in the lets, due to

the selectivity of the catching devices, and thus the average of the age-class is too large. On the other hand, the average of the 6-years old is too small, for if individual fishes longer than 37.2 cm. are picked out of the lot to be tagged the individual fishes larger fhan the average remain out of the 6-years olds' sample.

On the basis of the foregoing it appears that there are, in the growth curve obtained by means of scales analysis, errors caused by the data, and possibly by the age determination. Especially, the lengths in the older age-classes in it are too large. On the basis of the age-classes 1-7 the growth equation

$$l_{t+1} = 7.6 + 0.918\ l_t$$

has been determined. If 35.0 cm is taken as the length of a 5-years old pike-perch, values for the length and for the weight on the basis of Table 17 are obtained for 3-11 years old fishes. In this determination the weights have been computed according to the length-weight equation of Chapter 5.2.

Table 17. The lengths and the weights of 3-11 years old pike-perches computed on the basis of the growth equation.

Age, years	3	4	5	6	7	8	9	10	11
Length, cm	24,2	29,8	35,0	39,7	44,0	48,0	51,7	55,1	58,2
Weight, g	100	224	375	562	781	1032	1310	1610	1900

These values fit also fairly well the growth data obtained by means of the taggings.

By means of the Walford-diagram it is also possible to inspect the general process of growth in a pike-perch. According to the scales analysis the annual increase in length is almost the same

for the 7-9 years old ones as for the 1-3 years old ones. No clear slowing down of growth with age would thus occur. This is seen on the Walford-diagram in that the "scales-analysis curve" has the same slope as the 45^{o}-line. According to the taggings, on the other hand, the growth gradually slows down. Upon inspecting the growth curves shown in Figures 21-30 it may be perused that all growth curves except the one obtained in connection with this investigation bend towards right, and, thus, that the growth slows down with age. The growth of the American pike-perch (Stizostedion vitreum vitreum) has been found in some investigations (comp. RICKER 1958, p. 185) to continue unaltered from year to year. In another case (CARLANDER & WHITNEY 1961, pp. 133-134) the growth of the American pike-perch has been noted to slow down until the age of 5, and to continue from there on unaltered until the age of 10. In this work the material for pike-perches older than 7 years is scarce, and thus, little reprentative. The danger for erroneous interpretation in scales analysis increases also considerably the older the inspected fishes are. Thus, the length data for 8-10 years old pike-perches, obtained on the basis of scales analysis, cannot be held very reliable. On the other hand, it should be taken into account that some big pike-perches have grown faster than the growth equation computed on the basis of the taggings would indicate. In this case the growth could not, in any case, be represented by a straight line on a Walford-diagram.

The greatest size of a fish can be computed theoretically on the basis of the Walford-diagram. The terminal size of 95 cm. results from the equation obtained on the basis of the taggings, and the

maximum size of 93 cm. from the equation computed an the basis of the scales analyses (for 1-7 years old fishes). The biggest tagged pike-perch (in Halikonlahti) weighed 3.4 kg. and was 69.6 cm. long. The fishermen of Laajalahti report having caught in earlier years individuals which weighed up to 5 kg. The length of such a fish is obtained on the basis of the length-weight formula as about 80 cm. In the material of HALME & HURME (1952, p. 108) from the waters of Helsinki there is an individual the length of which has been 83 cm. and the weight 6.25 kg., and the age of which has been determined as 15 years.

6. MORTALITY

Calculations regarding the changes in the size of a certain pike-perch stock that take place during a year (survival and mortality) can be made by making use of the known of various age-classes (ratios of representation) portions in a large sample/population, or data obtained from a tagging. Both of these methods have their weaknesses. In this work both methods of calculation have been used, and sources of error have been sought by comparing the two results with each other.

6.1. Mortality on the basis of age-classes

For calculating the survival rate, s, and from it, the annual mortality rate, a, randomly taken pike-perch samples have been used, in whic proportions ratios of representation of the various age-classes are believed to correspond to those prevailing generally. A large part of the tagged lots were composed of fishes donated by fishermen, and marketable sizes were missing from these lots. Such lots could not be used in this connection. Samples, which have been internally age-classified, and which are originally random, are the sample of 1958 from Kakskerta, the sample of 1959 from Halikonlahti, and the sample of 1959 from Laajalahti. In the last-menfiened sample there were fishes released by fishermen. These fishes have been removed when calculating the survival rate.

In Table 18 the total count of the pike-perches in various age-

class from which a part is selected away by the selecitivity of the catching device (the fyke net) must be excepted. For this reason the 4-years old pike-perches have been left out. In addition, in the sample of Halikonlahti, the count of the 5-years old ones does not correspond to reality, and, therefore, there the calculation has been done only with respect to the 6-years old, and older, pike-perches. When calculating the survival rate the total count in two consecutive age-classes are compared with each other by dividing the count in the second age-class by the count in the first. From a sample consisting of several consecutive age-classes the survival rate is obtained by using the formula proposed by RICKER (1958, p. 41), in accordance with which also the survival rates for this investigation have been calculated from the head countc in the age-classes:

$$s = \frac{N_2 + N_3 + N_4 + \ldots + N_r}{N_1 + N_2 + N_3 + \ldots + N_{r-1}}$$

in which N = the head count in an age-class,

s = the survival rate.

From this the annual mortality rate is obtained by means of $1 - s = a$.

Table 18. The head counts in various age-classes in different regions, and the annual mortality rates (a) calculated from them.

Region and year	Age-class 4	5	6	7	8	9	10	Annual mortality age-classes	a
Laajalahti 1959	62	246	60	2	1	-	1	5-8	0,80
Halikonlahti 1959	4	84	84	44	10	2	3	6-10	0,58
Kakskerta 1958	116	195	55	17	3	1	-	5-9	0,72
The total	182	525	199	63	14	3	4	5-10 6-10	0,65 0,70

At Laajalahti the annual mortality is clearly lower than at Laajalahti. In its age distribution the sample differs from all the other samples used for the calculation, and thus is not quite comparable with them. There the head counts in the older age-classes are bigger than elsewhere, which fact also would indicate lower mortality. The annual mortality rate calculated on the basis of the age-classes 6 to 10 is 0,58. On the other hand, the value a = 0,73 is obtained on the basis of the age-classes 7 to 10.

At Kakskerta the value 0,72 for a is obtained on the basis of pike-perches of 5 to 9 years of age.

For all the areas combined, the value of 0,65 is obtained for

the mortality of the 5 to 10 years old, and, correspondingly, a = 0,70 for the 6 to 10 years old.

The mortality may be inspected by taking the logarithms of the head counts of the various age-classes, and by drawing the dashed line (Fig. 50) connecting them. The line should be straight if the mortality stayed the same from age-class to age-class.

In the Laajalahti sample the decline from age-class 5 to age-class 6 is less steep than that from age-class 6 to age-class 7. For the Halikonlahti stock the decline is quite slight between the age-classes 6 and 7. On the other hand, the decline between the age-classes 7 and 9 is smooth, and the calculation carried out on the basis of the age-classes 7 to 10 (a = 0,73) probably gives the best picture of the mortality of pike-perches oflength above the legal minimum for fishing. On the other hand, the sample gotten from younger pike-perches apparently is not representative. The decrease in the population of the Kakskerta pike-perches is rather regularly smooth. Between the age-classes 6 and 7 the decline is steeper than between the age-classes 5 and 6.

Combining all the material, a diagram is antained, in which the decline begins as very slight between the age-classes 5 and 6, and continues as steeper, and continues even up to pike-perches of 8 and 9 years of age. The rise of the line between the ages 4 and 5 and the slow decline between the ages 5 and 6, and the steeper decline taking place from there on reflects, probably, to some extent the changes in the effectiveness of fishing. It seems that only after the age 6 does fishing meet the pike-perch stock with full effectiveness, and, thus, the mortality calculations

should be made starting with the age-class 6. In this way 0,70 is obtained as the value for the annual mortality rate for all the data material. The mortality of the pike-perches of Laajalahti is clearly greater than either one of those of the pike-perches of Halikonlahti and Kakskerta.

In order that the correct picture regarding mortality be obtained on the basis of the age distribution it is assumed, according to RICKER (1958, p. 45) that:

1. The mortality rate is the same in those age-classes for which the calculations have been made.
2. Since the survival rate and the annual mortality rate complement each other ($a = 1 - s$), and since the latter is composed of the mortality caused by fishing and by natural causes, this means that both causes must remain the same from age-class to age-class.
3. There are no changes in the mortality with respect to time.
4. The obtained sample is representative of the age-classes in question.
5. The age-classes in queastion possessed the same head count as they reached the size when fishing began to tax them.

The validity of assumption 1 has been examined above by means of Fig. 50. It may be noted that the mortality varies also for various age-classes in the case of fishes of fishable size. On the other hand, the variations may be caused by variations in the head count for different age-classes, thus departing from assumption 5. It is well-known that variations in the local populations of pike-perch are great (comp. for inst. HENKING 1923, SEGERSTRÅLE 1938 and FILUK 1967), which come out as

variations in the size of the pike-perch catch. As to of what magnitude have been the variations in the head count in those age-classes with which this investigation is concerned, it is not possible to estimate, lacking, amoung other things, long-term, reliable size-of-catch data. Thus, there is no certainly with respect to the reliability of assumptions 2 and 5. The calculations for the mortality have been carried out at the various regions on the basis of the sample for only one year, and thus it is not possible to estimate differences in the mortality during different times (assumption 3). When doing the mortality calculations those age-classes have been left out in connection with the size of the net eye of the fyke net has been such as to have caused selectivity. Otherwise the fyke net probably gives a representative sample of the various age-classes, and thus, assumption 4 probably is valid with respect to those age-classes for which the calculations have been made. Since it is not possible to check the validity of most of the presumptions, a mortality calculation, done on the basis of the age-distribution, gives only a rough estimate for the value in queastion.

6.2. Mortality on the basis of the taggings

For calculating the survival rate the tag returns have been classified by the month from the various regions (Table 19). Usually the date has been given on the tag reutrns, but there are such returns data, which have, for instance, reached this investigation by way of a fish store, and for which the exact date of the find is thus not known. The month of the find, however

can be fixed even for these.

On the basis of Table 19 Table 20 has been prepared, in which is shown how many pike-perches from the various areas and the various years have been gotten during the first year, the second year, etc., after the tagging. If, for instance, the tagging has been done in June, those tags which have been found up to the end of May of the calendar year following the month of tagging have been included in the returns for the first year. Moreover, of the pike-perches gotten during the month of tagging, during the next year, it has been determined whether they have been gotten before or after the date of the tagging, and in this way they have been split between the two different years. In this table have also been indicated the percenage of all tags returned, and the values of the survival rate and the annual mortality rate in the samples for the various years have been calculated. When calculating the survival rat the following formulas of RICKER (1958, pp. 111-128) have been used:

$$s = \frac{R_2}{R_1} = \frac{R_3}{R_4} = \ldots = \frac{R_n}{R_{n-1}} \quad \text{(RICKER's formula 4.1)}$$

This formula has been used if there are tag returns data only from two years following a tagging. If there are tag returns data from more than two years the following formula (RICKER's formula 4.2) has been used:

$$s = \frac{R_2 + R_3 + \ldots + R_n}{R_1 + R_2 + \ldots + R_{n-1}}$$

If a tagging has been done in the same region during two consequtive years the following formula (RICKER's formula 5.2) has also been used:

$$s_1 = \frac{R_{12} M_2}{M_1 (R_{22} + 1)}$$

In these formulas

s = survival rate

s_1 = survival rate during year 1 (during the period from the tagging in year 1 until the tagging in year 2)

M = the number of tagged fishes

M_1 = the number of tagged fishes in the beginning of the first year

M_2 = the number of tagged fishes in the beginning of the second year

R_1 = the number of tag returns during the first year after a tagging

R_2, R_3, etc. = the number of tags returned during later years

R_{11} = the number of tag returns during the first year from a tagging in the first year

R_{12} = the number of tag returns during the second year from a tagging in the first year

R_{22} = the number of tag returns during the second year from a tagging in the second year.

Upon inspecting the survival rate values fairly great differences among the different regions, and with the use of different formulas, are noted. It appears that RICKER's (1958) formulas 4.1 and 4.2 give more reliable values than formula 5.2. This is due to the fact that the tagged lots have not been comparable with each other in different years. Thus, in Kakskerta the percentage returned for different years is quite different, and on the basis of formula 5.2 too large a alue for s, s = 0.40, is apparently obtained. In this case the percentage returned during the second year is clearly smaller than during the first year. The situation in Karhula is reserved, for there the percentage returned during the first year was smaller than during the second year. The value of s obtained than by using formula 5.2 is smaller than the value obtained by using formula 4.1. The same situation is revealed by the calculations for s for the years 1958 and 1959 in Laajalahti.

It must be taken into consideration that when calculating the survival rate value according to formulas 4.1 and 4.2 the total number of the tagged fishes is in no way taken into account. The calculation is done on the basis of the number of returned tags in the various years. In this way such error-causing factors, among others, as that a part of the tagged fishes possibly die within a short period after their tagging from injuries suffered during the catching and the tagging, and that all tags are not spotted in connection with a catching, and that all spotted tags are not returned, are avoided. It may be assumed that in different years the same percentage of the spotted tags are returned.

Data regarding the number of returned tags from different years may be examined by drawing diagrams for the logarithms of the quantities of Table 20 (Fig. 51). From these it may be seen that in the waters of Kakskerta and Helsinki (Laajalahti and Suomenlinna) the points fall almost on the same straight line, and, thus, the value for the annual mortality has remained steadily the same during the years following the tagging. On the other hand, in other regions (in Karhula, Halikonlahti, and in the Åland Islands), and also in the data material as a whole, it may be noted that at first the decline is less steep, and then becomes steeper; i.e., the value for the annual mortality is, at first, smaller, and later increases. This is apparantly caused by the fact that the mortality changes with respect to an increase in size.

In Table 21 the recaught pike-perches have been divided into groups (separated by 4 cm) on the basis of the length observed upon tagging. It may be seen from the table that in the length group 25-29 cm the ratio $\frac{R_2}{R_1}$ is, in all regions, clearly bigger than that ratio in other length groups. By combining the data from the various regions, o.46 is obtained in this size-group as the value for the survival rate. In many regions less tagged pike-perches have been obtained during the first year than during the following year. This is caused by the fact that fishing is not directed during the first year at these small fishes at full effectiveness. The same is true, to same extent, with respect to the next larger size-group. Actually, the value for the survival rate can be calculated only from those fishes, which already upon tagging are of the minimum size (37 cm) fixed by the

fishing law, or bigger. The formulas used for calculating the survival rate require that the tagged fishes are already upon tagging fully vulnerable to the effects of fishing.

For this reason the tagging does not give a reliable picture regarding the mortality of the pike-perches of Karhula, since almost all the pike-perches have been, upon tagging, of less than full size. For clarifying this mather Table 22 has been prepared on the basis of Table 21. In Helsinki and in Kakskerta fishing is directed strongly already during the first year following the tagging at fishes of less than full size. This is revealed, with respect to the length groups 29-33 cm and 33-37 cm, in the values of $\frac{R_2}{R_1}$, which, for the pike-perches of Helsinki, are even smaller than for pike-perches safisfying the legal minimum size.

The value for the annual mortality for the pike-perches of Halikonlahti increases with respect to the size, and for pike-perches of the legal size is as follows: ($a = 0.77$, and $a = 0.85$). For the pike-perches of the Åland Islands the mortality remains fairly low ($a = 0.61$), even for pike-perches satisfying the legal limit. In this respect, for them, there is clearly a departure from the pike-perches of the coast of the Gulf of Finland.

If all the observations from the coast of Finland are combised, it is noted that with an increase in size the value for the annual mortality gradually increases. The differenme in the mortality of the individuals below the legal limit in size, and those above it, is not, however, very great, since for those below the legal limit the value of a is 0.82, and for those satisfying the limit 0.85.

In the following will be discussed which variables may be consistered to describe best the survivality in various regions.

The pike-perches tagged in Karhula have been, with a few exceptions, below the legal limit in size, and, thus, not well representative for the calculations. It may be assumed that the annual mortality (a) for them is greater than 0.67.

In the waters of Helsinki there is intensive fishing directed at young pike-perches, and for this reason the value a = 0.86, calculated from all the material, may be considered more realistic than the value a = 0.80, obtained for the individuals satisfying the legal size limit.

In Halikonlahti the annual mortality rate appears to decrease with an increase in size, approaching the legal limit. In this case the value a = 0.82 probably best describes the mortality of the pike-perches of legal size.

In Kakskerta it is difficult to estimate what is the mortality of the pike-perches of legal size. From the tagged pike-perches of the legal size 28 have been gotten back during the first year, during the second year none at all, and during the third year 1. Moreover, quite different values for s have been obtained from taggings in different years: from the tagging in 1958 0.20, and from the tagging in 1959 0.13. In this situation it is probably best to use the value a = 0.82, obtained on the basis of combined results for the various years. This value is the same for the pike-perches of Halikonlahti.

In the Åland Islands there are no clear differences in the mortality of the pike-perches of size below the legal limit, and

of those of size satisfying the limit. Thus, the value a = 0.62 computed on the basis of all the material is probably most realistic.

6.3. A comparison between the values fo the mortality obtained on the basis of the age-distribution and on the basis of the taggings.

In the foregoing (Table 18) the values for the annual mortality for the pike-perches of Laajalahti, Halikonlahti, and Kakskerta, have been computed on the basis of the age-distribution. On the other hand (Tables 20 and 22) the corresponding values for a have been computed on the basis of the taggings.

By calculating on the basis of the head count in different year-classes from the sample from Laajalahti the value a = 0.80 is obtained. This value is the same as the one obtained, on the basis of the taggings, for the pike-perches satisfying the legal limit. On the basis of all the material from the taggings the value for the survival rate of a = 0.86 has, however, been obtained. The difference in these values of a, obtained in different ways, is 0.06.

From the sample of Halikonlahti there is obtained, by taking into account the various year-classes, the values a = 0.73 and a = 0.58, from which the first is probably more realistic. By means of the taggings the value a = 0.82 has been obtained. The difference between the values 0.73 and 0.82 is 0.09.

In Kakskerta, on the basis of the age-distribution, the value a = 0.72 has been computed. On the basis of the tagging, on the other hand, the value 0.82 is obtained. The difference between these is o.10. All the values calculated above indicate that estimates for the annual mortality based on the age-distributions give lower values than the calculations on the basis of the taggings. The factors which may be presumed to be causing this will be discussed in the following.

Consideration in the foregoing has been directed at the possible errors involved in the calculation of the mortality on the basis of the age-distribution. As a result of this consideration it is noted that systematic errors may be involved, but the estimation of their magnitude is difficult due to the lack of necessary data, as for instance data regarding the variability of the birth-rate from year to year.

In trying to define the types of causes for errors RICKER (1958, p. 86) has listed the following assumptions which are usually implicit in the treatment of the results of a tagging:

1. the natural mortality is the same for the tagged and for the untagged fishes;

2. the vulnerability to fishing of the tagged fishes is the same as that of the untagged fishes;

3. the tag does not get torn off the fish;

4. all the tags are spotted, and that of all the spotted tags a report is made.

There is reason to delve into the validity of these assumptions.

There is some mortality, for the tagged fishes, in departure from what assumption 1 would call for. Mainly this occurs during a short period after a tagging. Especially on connection with the tagging at Kakskerta there are tag returns with which it is reported that the fish has been found dead, or in bad condition, from shallow water by the shore. These find, have been made during a few days after the tagging, and within a radins of a couple of kilometers from the place of tagging. The number of pike-perches dying soon after a tagging may be large, for gulls catch quickly the fishes on the shore and floating on the surface of the water. Thus, not nearly all the dead pike-perches are found. It is possible that the low over-all percentage of returns, especially in 1959 in Kakskerta, is caused by the great mortality immediately after the tagging. It was not possible to make observations of the fishes in Kakskerta after taking them from the catching devices. Rather, the fishes were tagged immediately upon pulling in the fyke net, and were consequently released. In other regions the fishes have been kept in large, net-walled observation sumps for a few days before the tagging. Then, it has been possible to leave those fishes which have been injured during catching without a tag. At Laaja-lahti a part of the fishes have been kept, additionally, in the sump for one day for the purpose of observing mortality.

The mortality occurring during a short period after the tagging does not, however, cause any error in calculating the value for the survivality, for the total count of the tagged fishes is not taken into account in the formula which has been used. The mortality in queastion does, however, cause on error when

calculating the mortality caused by fishing, as will be shown later.

It is difficult to estimate, is the mortality of the tagged fishes later, after weeks and months, greater than that of untagged fishes. If such an effect exists, it is probably of the same order of magnitude during different years, and, thus, probably does not cause a systematic error in the calculation for the survivality and the mortality.

In departure from assumption 2 the tagged fishes get caught in the catching devices slightly more easily than the untagged ones. This is true of catching devices operating on the net-eye principle. The tag has been attached in the pike-perches about in the middle of the rear dorsal fin, in the base of the fin in such a way that the wires of the tag encircle, in general, one of the bones of the fin. At this point the pike-perch is already clearly thinner than at the front of the forward dorsal fin, at which location the fish usually gets caught in a net eye. Such a pike-perch which would have passed through the net, but is caught due to the wires of the tag, and then gets tangled up in the net, naturally increases the representation of the tagged fishes in the total catch to values higher than their fraction before any catching. The increase in the fishing vulnerability caused by the tag can be taken to be the same during various years, so that it probably does not cause an error in calculating the value for the survival rate. The error appears in the calculations fo the fishing mortality, but in the direction opposite to that caused, for instance, by an unnaturally great mortality among the tagged fishes.

In assumption 3 is set forth the presumption that the tag does not get torn off the fish. This does not, apparantly, quite correspond to reality. This conclusion is drawn from the fact that occasionally a tag without a fish is found in a catching device. In the material of this investigation, there is one report of such a find. The tags which have become turn off the fishes do not always remain stuck to the catching devices, and then these tags are not found. It is also possible for tags to get lost as a result of having been attached carelessly to the fish: the manner of attachment being such that the wires of the tag do not encircle a bone in the fin. Then, namely, the tag may be lost as a result of an infection in the fin. As to how many tags may get forn off is shown by the observations of SVÄRDSON and ANHEDEN (1963, p.112) for the sea trout, when using the same tag as in the pike-perch taggings of the present investigation. Tagged sea trout fingerlings were released into the River Verkå, from where they migrated into the Baltic Sea. As the trouts returned into the river for spawning they were taken into a fixed catching device, where the same person who had tagged the fingerlings inspected every trout. He could see a scar in some fishes in the place where the tag would have been. Thus, from such fishes the tag had been torn off. On the basis of these observations 40 % may be taken to be the percentage of tear-off loss. The tear-off percentage may be as high as 67-77 % during a year according to observations made by HOLMBERG and LINDSTRÖM (1967) with respect to a lot of lake trouts (Salvelinus namaycush). This big the tear-off perwentage cannot be in connection with the present pike-perch investigation. It is

understandable that the tags can become torn of from small lake trouts and trout fingerlings, but in this investigation the tagged fishes are generally bigger than 30 cm in length, and to fishes of that size the tags can be attached much more sturdily.

It is, however, probable that the difference appearing in the survivality as gotten by means of the age-distribution, on the one hand, and the taggings, on the other, is caused by tags having been torn off. As tags are being torn off continnously, less tags are gotten back in later years than would be expected, and this leads into too small a value for s. For this reason it is probable that the value of s gotten on the basis of the age-distribution represents the real circumstances better.

Different tags become torn off in different ways. This is clearly shown by the investigation carried out in Kakskerta in 1956 with hooks attached to the chin, that have been described in Chapter 1. Due to tear-off of tags only 29 tags, of which the last 10 months after the tagging, were gotten back from a tagged lot of 246 pike-perches.

All the found tags are not returned, as is assumed in assumption 4. It is very difficult to estimate how large a percentage of the tags are not returned. The error caused by this does not, however, affect the calculation of s, for it may be assumed that the same fraction remains unreturned every year. On the other hand the error naturally lowers the estimate for the fishing mortality.

6.4. Mortality due to fishing, and natural mortality

In the foregoing, calculations have been presented for the total mortality (a). On the basis of the taggings it is possible to go on to calculate the value for the mortality due to fishing (u), and the value for the so-called natural mortality (v).

When calculating the annual mortality decrease due to fishing the formula presented by RICKER (1958, p. 112) has been used:

$$u = \frac{R_1 + R_2 + R_3 + \ldots + R_n}{M\,(1 + s + s^2 + .. + s^{n-1})}$$

where

u = the value for the mortality due to fishing,

R_1 = the total count of the tags returned during the first year after the tagging,

R_2, R_3 = tag returns during later years,

M = the number of tagged fishes,

s = the value for the survivality.

For comparing the annual total mortality, the fishing mortality, and the natural mortality in different regions Table 23 is presented. This table has been calculated, based on taggings, from the combuned values in Table 20 for the various regions.

Table 25. The mortality and the survivality in a stock of M fishes, which stock have been tagged in the beginning of year 1, and in which the value (u) of the decrease caused by fishing, the value (v) for natural mortality, and the value (a) for the total mortality, as well as the value for the survivality, all remain constant during five years.

The year	1	2	3	4	5
The original stock of tagged fishes	M	Ms	Ms^2	Ms^3	Ms^4
Tag returns	Mu	Mus	Mus^2	Mus^3	Mus^4
Natural mortality	Mv	Mvs	Mvs^2	Mvs^3	Mvs^4
Total mortality	Ma	Mas	Mas^2	Mas^3	Mas^4

Table 26. The mortality and the survivality in a lot of 393 pike-perches (above 37 cm in length) from the coast of the Gulf of Finland, in which lot, according to the tagging, s = 0.15, u = 0.32, v = 0.53, and a = 0.85. In parentheses the obtained tag returns R_1, R_2, and R_3.

The year	1	2	3	4	5	Altogether
The original stock of tagged fishes	393	57,2	8,4	1,2	0,2	
The returns	(125)	(19)	(2)	(0)	(0)	(146)
Natural mortality	209,9	30,6	4,5	0,7	0,1	245,8
Total mortality	335,7	49,0	7,2	1,0	0,16	392,16

Table 27. The mortality and the survivality in a lot of 393 pike-perches (above 37 cm in length) from the coast of the Gulf of Finland, in which lot, s = 0.15, u = 0.32, v = 0.53, and a = 0.85.

The year	1	2	3	4	5	6	Altogether
The original stock of tagged fishes	393	98,2	24,6	6,2	1,6	0,4	
The returns	137,6	34,4	8,6	2,2	0,6	0,15	183,55
Natural mortality	157,2	39,3	9,8	2,5	0,6	0,15	209,55
Total mortality	294,8	73,7	18,4	4,7	1,2	0,3	393,1

Upon comparing with each other Tables 26 and 27 it may be noted that by using uncorrected values for the mortality and the survivalrate the expected catch from 393 pike-perches would be 147.4 fishes (146 tag returns), but by using corrected values the expected catch would have been about 184 fishes.

Data in the literature regarding the annual mortality values for the pike-perch are quite sparse. WIKTOR (1962, pp.700 and 728-729) has calculated 58 % as the annual total mortality of the pike-perches of Oderhaff (Stettiner Haff), of which figure, according to his estimate, the share due to natural mortality is about 8-10 %, and the share due to fishing, therefore, about 50 %. When comparing these values with those gotten for stocks in the Gulf of Finland, attention is caught especially by the great difference in the values for the natural mortality. The share

of fishing mortality in total mortality is greater in Oderhaff than in the Gulf of Finland.

For the whitefish along the coast of the Baltic Sea in Middle-Sweden DAHR (1947, p. 69) has calculated, baes on taggings, 33 % as the annual decrease due to fishing. 50 % has been gotten as the total annual mortality (for the tagged fishes 67 %). The share of natural mortality is thus 17 %. For the whitefishes of the Åland Islands WIKGREN (1962,pp. 19-20) has calculated the annual decrease caused by fishing to be 30 %, the annual natural mortality to be 45 %, and the annual survivality 25 %. The natural mortality for the whitefish of Luvia has been found to be 59 %, the fishing mortality 17 %, and the survivality 24 %. The mortality figures obtained for the whitefish correspond approximately to those observed for the pike-perch.

Survivality values, considerably departing from those presented above, have been observed by BYLUND (1962, pp.26-27), based on the age-distribution, for the bream of the Åland Islands. On the basis of the age-classes 11-16 the value $s = 0.764$ has been calculated. The survivality value has been observed to decrease appreciably with an increase in age.

6.5. The changes occurring in a pike-perch stock during a year.

In the foregoing the annual growth and mortality of the pike-perch have been studied. By taking into account the changes in growth occuring during a year, and, on the other hand, the effectiveness of fishing during different seasons it is possible

to carry out calculations for the changes in the total number and in the total weight of a stock that take place during a year.

On the basis of taggings the annual growth of the pike-perch has been found to take place during a relatively short period from the middle of July till the first half of October. This may be taken to be true only of spawning-mature individuals. Most of the tagged pike-perches are in this category.

In Table 19 the tag returns by the month are presented. Along the coast of the Gulf of Finland fishing is practiced during the various months of the year approximately the same way in different regions. In the Åland Islands the effectiveness of fishing during different seasons is, however, unlike that just mentioned. Table 28 presents the distribution of tag returns to the various months of the year from the taggings in the Gulf of Finland, and, on the other hand, from the tagging in the Åland Islands, as well as the percentagewise distribution of the effectiveness of fishing during a year.

Table 28. The tag returns from the coast of the Gulf of Finland and from the Åland Islands by the month, and the percentagewise distribution of the effectiveness of fishing into different seasons.

The region	The month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
The coast of the Gulf of Finland	28	36	16	23	79	41	149	37	48	47	43	17
		together, 154 returns 27,3 %				together, 275 returns 48,8 %				together, 135 returns 23,9 %		
The Åland Islands	3	-	9	46	22	10	9	3	-	-	2	2
		together, 77 returns 72,6 %				together, 22 returns 20,8 %				together, 7 returns 6,6 %		

On the coast of the Gulf of Finland approximately 50 % (48.8 %) of the yearly catch is taken during the summer season, from June till the end of September. During the autumn season, from October till the end of January. the catch is about 25 % (23.9 %), and during the winter-spring season also about 25 % (27.3 %). Thus, one half of the annual catch is taken during the summer season, and one quarter during both, the autumn and the winter, seasons.

In the Åland Islands most of the catch is taken during the winter-spring season, especially in April-May, for 72.6 % of all tag returns are from the period February to May. During the summer season, from June till the end of September, about 20.8 % of the annual catch is taken, and during the autumn season, only 6.6 %.

Not much is known about seasonal variations in the natural mortality. Possibly the mortality during the spawning season is unusually large. This is suggested by the observations of LAVROVSKI (1963, p. 80) for the pike-perch of the Kurisches Haff. Also, the mortality due to bacterial infections may be more usual during the warm summer season than during other seasons. On the other hand, the cold water in the winter may lead into starring for the pike-perches, and, thus, into greater than normal mortality. These factors have not, however, been closely studied, and in the calculations for the annual variations in the pike-perch stock the natural mortality has been taken to be evenly distributed among different seasons.

For calculating the changes in the total population of a stock that occur during a year as a result of mortality it is necessary to use the so-called instantaneous mortality rates. These are: the instantaneous total mortality (i), the instantaneous mortality rate due to fishing (p), and the instantaneous natural mortality rate (q). The values of the instantaneous mortality rates are related to each other, and to the annual mortality rates given in the foregoing, as follows (RICKER, 1958, p.25):

$$p + q = i$$

$$i = -\log_e(1-a)$$

$$a = 1 - e^{-i}$$

$$\frac{i}{a} = \frac{p}{u} = \frac{q}{v}$$

After calculating, on the basis of the age-distribution or a tagging, the value for the survival rate (s), and on the basis of a tagging the mortality due to fishing (u), the annual mortality (a = 1-s) and the natural mortality (v = a-u) are obtained from these. The value of the instantaneous mortality (i) is most conveniently gotten from a table presented by RICKER (1958, pp.271-278), when the value of a is known. The value of the instantaneous mortality due to fishing is given by the relation $p = \frac{ui}{a}$. Moreover, the relation q = i-p can also be made use of.

Table 30 clarifies variations occurring in the pike-perch stock from year to year, and during different seasons. The data cover 10000 3-years old pike-perches, and the decrease in this stock

from season to season on from year to year until these fishes are 11 years old. This table may also be taken to be a summary over chapters 5 and 6, which deal with growth and mortality. The average lengths, weights, and mortality values from Table 29 have been used for the different age-classes in Table 30.

Table 29. The average length, weight, and the estimated mortality values in different age-classes among the pike-perch stocks of the Gulf of Finland.

	Age, years								
	3	4	5	6	7	8	9	10	11
The length, cm	24,2	29,8	35,0	39,7	44,0	48,0	51,7	55,1	58,2
The weight, g	100	224	375	562	781	1032	1310	1610	1900
s	0,60	0,35	0,30	0,25	0,25	0,25	0,25	0,25	0,25
u	0,0	0,25	0,30	0,35	0,35	0,35	0,35	0,35	0,35
v	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40
a	0,40	0,65	0,70	0,75	0,75	0,75	0,75	0,75	0,75
p	0,0	0,40	0,51	0,66	0,66	0,66	0,66	0,66	0,66
q	0,51	0,65	0,69	0,74	0,74	0,74	0,74	0,74	0,74
i	0,51	1,05	1,20	1,40	1,40	1,40	1,40	1,40	1,40

The length and weight data are from Table 17. The mortality values have been gotten from Tables 22 and 24 by estimating, keeping the natural mortality values the same from year-class to year-class (v = 0.40). Fishing has been taken not to take any

toll among the 3-years olds, and thus $u = 0$. From this the value of u is estimated to change so that for 4-years olds it is 0.25, for 5-years olds 0.30, and for 6-years olds 0.35. 6-years old, and older, pike-perches are taken to be fully of fishable size, and u to remain constant (0.35).

In Table 30 in column 6 g = the instantaneous rate of growth. If W_t is the weight of a fish at time t, and W_o its weight at time $t = o$, the value of relative growth is h:

$$h = \frac{W_t - W_o}{W_o}$$

On the other hand:

$$h = e^g - 1 \text{ (RICKER 1958, p.31),}$$

and

$$g = \log_e (h+1)$$
$$= \log_e (w_t/w_o), \text{ when } t = 1.$$

In Table 30 the year has been divided into two parts: into the period from the beginning of June till the beginning of October, and from the beginning of Oktober till the beginning of June of the next calendar year (columns 1 and 2). During the summer period, in June-September, the whole annual growth is taken to occur (column 6). The natural mortality is taken to be distributed evenly over the whole year. Then the summer period, whock is 1/3 of the whole year, gets the share, $q/3$, of the whole annual natural mortality. According to the taggings about one half of the decrease in population due to fishing occurs during the summer period. Thus, the decrease caused by fishing is $p/2$. During the other parts of the year, from the beginning

of October till the beginning of June of the next year no growth is taken to occur. During that period, then, $g = 0$. The decrease due to natural mortality is, during the autumn-winter period, 2/3 of the value of q, and, correspondingly, the decrease due to fishing 1/2 of the value of p. Columns 6-8 have been calculated on the basis of the feregoing.

In column 9 the quantity $g - q - p$ has been calculated. Thus, from the instantaneous growth value have been substracted the value for the instantaneous natural mortality and the value for the instantaneous fishing mortality. If the resulting quantity is positive there is a net increase in the total weight of the stock. If, again, the quantity is negative, there is a not decrease in the weight of the stock. From the value of Column 9 the weight-change factor (Column 10) has been obtained by using the table of RICKER (1958).

In Column 11 the weight of the stock is presented, and in Column 12 the population of the stock during different seasons and years starting with 10000 3-years old pike-perches, whose total combined weight is 1000 kg. At the end of each period the weight of the stock is obtained by multiplying the population at the beginning of the period by the weight-change factor, and the remaining population from the remaining total weight by dividing by the average weight of the fishes (Columns 11 and 12).

For calculating the catch during different periods the arithmetical averages of the total weight of the stock and the populations at the beginning and at the end of the period have been calculated. The total weight and the population of the catch

are obtained by multiplying remaining population by the appropriate value of p.

Upon inspecting the changes taking place in the stock, as presented in Table 30, it is noted that the total weight of the stock is at its maximum when the pike-perches are 3 1/3 years old. From this point on the total weight of the stock decreases continuously except for a slight increase that occurs in the summer of the fourth year. When the fishes are 7 years old the total weight is about 125 kg, and when they are 10 years old the total weight is only 4 kg according to this calculating procedure.

The decrease in the population takes place in such a way that the population of the stock decreases during the autumn-winter season of the fifth year to a count below 1000 from an original of 10000 3-years old individuals. The population dips below the count of 100 upon reaching the age of 7 years, and below the count of 10 at the age of 9 years.

According to Table 30 the share to become claimed by fishing from the 10000 3-years old ones is 2623, whose combined weight is 1104 kg. This catch is distributed among the various age-classes as shown in Table 31.

Table 31. The portion of the catch caught at different ages.

The catch	The age-classes							Combined
	4	5	6	7	8	9	10	
kg	513	331	175	58	19	6	2	1 104 kg
%	46,5	30,0	15,9	5,3	1,7	0,5	0,1	100 %
the head count	1 611	676	253	63	15	4	1	2 623
%	61,4	25,8	9,6	2,4	0,6	0,2	0,0	100 %

During the fourth year, when fishing begins to take a toll from a pike-perch stock, already 46.5 % of the weight of the catch and 61.4 % of the total number of the catch are caught. During the fifth year the corresponding figures are 30 % and about 25 %. During the sixth year the same figures are 15.9 % and 9.6 %. During these first three years 92.4 % of the total catch by weight is obtained, and 96.8 % by the head count. The proportion of 7-years old fishes, and older, in the catch is, thus quite small.

7. SUMMARY

The occurrence of the pike-perch in the coastal waters of Finland, in the Gulf of Finland and in the Gulf of Bothnia, is local. On the basis of the catch reports of the fishermen the pike-perch may be taken to form separate stocks. Along the coast of Selkämeri (the southern part of the Gulf of Bothnia) sparse stocks are to be met in the waters of Rauma and Pori. In Perämeri (the northern part of the Gulf of Bothnia) there are two separate pike-perch stocks. The pike-perch occurrences are centered about those parts of the coast where rivers discharge. The decrease in salinity effected by the rivers is perhaps not, however, of decisive importance as far as the fitness of the local circumstances to the pike-perch is concerned. The turbidity caused by the river water in the sea is probably a more important factor. On the other hand, the width of the archipelago region and the spacing between its islands are decisive factors for the adaptation of the pike-perch to the locality. The temperature of the water in the bays of the archipelago, and in those sticking deep into the mainland, in which both the temperature is higher than that in the waters of the open sea, may be a decisive factor as far as the increase in stock is concerned.

A comparison between literature data and data regarding the present-day occurrence shows that the pike-perch has become common along the coast of the Gulf of Finland during the past decades. This may have been caused by the pollution and the conseguent turbidation of the coastal waters.

The migrations and the area of migration have been studied by means of taggings carried out during the years 1958-1960 in the Gulf of Finland and the Åland Islands. From the 2350 pike-perches tagged in Karhula, the waters near Helsinki, in Halikonlahti, in Kakskerta, and in Ödkarbyvik in the Åland Islands, there are a total of 670 tag returns.

In the sizes of the migration areas of the pike-perches of different regions there are differences which probably are caused by the nature of the coast and the location of the place of tagging. When the coast is relatively open, as in Karhula and in Helsinki, the average migration area is less extensive than in an archipelago in which there are narrow, long straits, as in Halikonlahti, Kakskerta, and in the Åland Islands. Cambining all the material, about 37 % of all the tags have been found within a region inside a circle of radius 5 km. Within a circle of radius 10 km there are about 68 % of all tag finds, within one of radius 20 km about 88 %, and within one of radius 30 km about 94 % of all those returned tags for which the location of the recovery is known. Only 0.8 % of the tag returns are from locations at distances above 50 km from the place of tagging. Of the five long-distance-migrator pike-perches (making up the 0.8 % just mentioned) one had swum from Karhula to a basin of the River Neva near Leningrad, the straight-line distance covered having been about 160 km. Of the fishes tagged in Laajalahti one had swum to the mouth of the Bay Ahvenkoskenlahti, another to the Bay Pernajanlahti, and a third, according to a report of questionable reliability as fas ar to the archipelago of Vaasa

in the Gulf of Bothnia. One of the pike-perches of Valikonlahti has been met sowth of the Island of Kemiö, next to the open sea, at a distance of over 50 km from the place of tagging. No migrations across the Gulf of Finland, or mixing between the stocks of the Åland Islands and the archipelago of Turku, have been observed in connection with the taggings.

A seasonal migration rhythm is to be noted in the movements of the pike-perch. Most clearly this rhythm has become apparent from the taggings in Laajalahti and in the Åland Islands. After spawning in Laajalahti the pike-perches of that region spend the summer months in the inner archipelago. The migration to the basihs of the outer archipelago, and, on the other hand, the migrations along the coast take place during the fall and the early winter. The pike-perches of Laajalahti migrate then fairly generally as far as to the waters of Porvoo. These wintry migrations may be called wintering migrations. The return to the spawning localities takes place in April-June. Also the pike-perches which have migrated to the waters of Porvoo apparently return to the waters of Helsinki for the spawning season, since no fishes tagged in Laajalahti have been met in the waters of Porvoo in the summer, but such fishes have been met there again during the following winter.

The pike-perches which do their spawning in Ödkarbyvik have a similar migration. They migrate in the fall to the Lumparn Expanse for wintering and return to the spawning locations in April and May.

In other regions the habitat locations of the pike-perches during

different seasons do not depart from each other as dearly, though migration into deep waters is to be noted in all regions.

Migration rates have been calculated for the pike-perches on the basis of the shortest distance between the place of tagging and the place of the find, and the time elapsed between the tagging and the find. The greatest rates of migration thas observed have been 2-3 km/day. The rates are usually in the range 0.3-0.7 km/day.

The growth of the pike-erches of the Gulf of Finland has been studied by taking scale samples from the tagged fishes, and also on the basis of growth data gotten in connection with the taggings As the tagged pike-perch lots contain only fishes in the age-range 4-10 years, the length of the pike-perches during the younger years has been calculated on the basis of the width of the growth zones in the scales. In this case the lengths of the scales have been converted into the length of the fish by using the formula $l_t = 4.42 + 1.012\ r\ (x10)$, in which l_t is the over-all length of the fish and r is the radius of the scale.

The growth data obtained by means of the scales investigations have been compared with research done elsewhere regarding the growth of pike-perches. As a result it is possible to state that the pike-perches of the northern coast of the Gulf of Finland are the slowest-growing of all observed pike-perch stocks.

The growth of pike-perches has been studied also by calculating the increase in the length and in the weight that have occurred between the tagging and the tag recovery.

The annual growth of spawning-mature pike-perches of the Gulf of

Finland appears to take place during a relatively short period. The pike-perches tagged in the first part of June do not appear, upon re-examination in the first part of July, to have experienced any growth. The growing begins in the second half of July, and continues strongly during August and September. In October the growth is already quite slow. No growth may be observed during the winter, since as late as in May the annual incremental increases in length and in weight are still at the same levels as in October. During the end of May and the beginning of June slight increase in length may occur.

Scule samples taken upon tagging have been compared with scale samples taken upon the tag recovery. The appearance of the so-called annulus seems to occur not before July, upon the beginning of the growth of the pike-perch. At this time a zone composed of several closely-placed stria appears, and later, as the pike-perch grows in August and September, a broader zone composed of less closely-spaced stria appears.

The annual growth of pike-perches has been studied by calculating the incremental increase in the length and in the weight that pike-perches caught during the period November-May have experienced during the annum prior to the November. The whole annual growth may, namely, be taken to have occurred already by November. Differences in growth for pike-perches of various sizes and ages have been studied. Similarly, differences in growth between various regions and different years have been studied.

As the size of the pike-perch increases the annual length growth

slows down gradually. This slowing-down of the growth may be represented by the equation

$$l_{n+1} = 9{,}0 + 0{,}905\ l_n,$$

in which l_n is the length of the fish at the beginning of the growth period and l_{n+1} the length of the fish upon the termination of annual growth. The corresponding changes in weight may be calculated by the equation

$$w = 0{,}0236 \times l^{3{,}203}$$

in which w is the weight of the fish (g), and l the length of the fish (cm).

Differences in growth among different years may be clarified especially on the basis of the taggings done in 1958 and in 1959 in Laajalahti. In connection with these it has been noted that the pike-perches have grown faster in 1958 than in 1959. This difference in the growth rate has been found to be statistically significant. The difference in the growth rate has been assumed to have been caused by differences in the temperature of sea water. At the observation station of Harmaja the temperatures of the water were in the summer of 1959 clearly higher than during 1958, till as late as the end of August, when, in 1959, a rapid cooling-down of the water occurred. From this time on the water was clearly colder than normal in 1959, while in 1958 the water was warmer than normal until December. In the foregoing it has been noted that August and September are the most important months as far as the growth of the pike-perch is concerned. It may be assumed that the rapid cooling-down in the end of August in 1959 caused the annual growth to remain smaller than in 1958.

Differences in growth among the various regions have been observed The general tendency is for the growth rate to decrease from the eastern parts of the Gulf of Finland westward. In the taggings carried out in the same years it has been possible, in part, to find statistically significant differences among the various regions. It may be assumed that the differences are caused by temperature, and not, for instance, by differences in salinity among various regions.

By comparing the growth data obtained in a tagging with the results of the scales investigation it is observed that the results disagree with each other to some extent. The 4-years and 5-years old pike-perches have grown faster during the year following the tagging than the growth curve drawn on the basis of the scales investigation would indicate. The 6-years old ones have grown approximately as the growth curve would dictate. The growth of the 7-years old ones has been slower than what the growth curve would predict. The differences between the results of the scales investigation and the results of the tagging are assumed to be caused by the fact that the lots of pike-perch used in the age determinations have not always been representative samples. This may result from the selectivity of the catching devices, and, on the other hand, from selection by the fishermen. The material regarding older pike-perches is also so limited that errors may result. The danger for erroneous interpretation in the age determinations increases the older the fishes are the age of which to be determined.

Calculating the growth equation for the 1-7 years old ones on

the basis of the average lengths obtained in the scales investigations results in:

$$l_{n+1} = 7,6 + 0,918\ l_n$$

Using this formula, and taking, on the basis of random samples, 35 cm as the length of a 5-years old pike-perch, the values below are obtained as the lengths and the weights of 3 to 11 years old pike-perches. These values corroborate the values obtained on the basis of the taggings.

Age, years	3	4	5	6	7	8	9	10	11
Length, cm	24,2	29,8	350	397	44,0	480	51,7	55,1	58,2
Weight, g	100	224	375	562	781	1032	1310	1610	1900

These figures may be taken to represent the average growth of the pike-perch along the coast of the Gulf of Finland.

The values for the annual mortality for the pike-perch stocks of the Gulf of Finland have been studied on the basis of random samples, and, on the other hand, by means of taggings. The value for the annual mortality (a), calculated on the basis of the populations of the various age-classes, varies, being 9.80 for the pike-perches of Helsinki, 0.73 for the pike-perches of Halikonlahti, and 0.72 in Kakskerta. The corresponding values of a, based on the taggings, are: 0.86 in Helsinki, 0.82 in Halikonlahti, and 0.82 in Kakskerta. The differences in the value for the survivality, as based on the age-distribution, and on the taggings, have been assumdd to have been caused mainly by the tags getting loose.

Calculations have been carried out on the basis of the taggings for the decrease in the pike-perch stock caused by fishing. The effectiveness of fishing varies considerably from place to place. Fishing is estimated to decrease annually the pike-perch stock of individuals of legally fishable length by 28 % in Helsinki, by 34 % in Halikonlahti, by 17 % in Kakskerta, and by 22 % in the Åland Islands. For the combined regions of the coast of the Gulf of Finland the following changes may be estimated to take place annually in the population of the pike-perches of fishable size: 73 % die, and of this figure 26 % is the part due to fishing. The mortality due to other reasons (= natural mortality) thus accounts for 47 %.

Taking into account the results with respect to growth and mortality Table 30 is presented as the result for a calculation for the changes in the total weight and the total population of a selection of pike-perches from stocks from the coast of the Gulf of Finland, starting with 10000 3-years olds.

The decrease in the population is calculated to take place so that the population decreases from the original 10000 3-years old pike-perches to a count below 1000 fishes during the early winter of the fifth age-year. The count of 100 the test stock reaches upon reaching the age of 7 years, and further, the count of 10 pike-perches at the age of 9 years.

Starting with the test lot of 10000 3-years old pike-perches the changes in weight occur, according to a formula, so that the total weight of the test stock is at its greatest upon the termination of the fourth growth period (about 187 kg). From

this value the total weight decreases continnully, excepting a slight increase which occurs during the fifth growth period. At the age of 7 years the total weight of the test stock has been calculated to be about 125 kg, and at the age of 10 years about 4 kg.

Fishing has been calculated to claim 2623 fishes, whose combined weight has been obtained as 1104 kg, from the lot of 10000 3-years olds. Pike-perches of ages from 4 years to 6 years have been calculated to account for 96.8 % of the head count of the whole fishing catch, and 92.4 % of the weight of the whole catch.