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ON THE BIOLOGY OF THE ICELANDIC HERRING STOCKS

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By

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INTRODUCTION

Some scientific investigations on the herring around Iceland started during the 18th century (Ólafsson, 1772), but these were sporadic and a real progress was not made in identification of the stocks and their life history until Danish scientists started their work in Icelandic waters at the end of the 19th century. Judging by his investigations in 1905 Sæmundsson (1906) concludes that there must be two and only two stocks of herring in Icelandic waters, i.e. the spring and summer spawning stocks. In later years Friðriksson (e.g. 1944) put forward his theory concerning the migration of the Norwegian spring spawning herring between Norway and Iceland.

Tagging results have since verified this theory on numerous occasions. In Icelandic waters we are therefore dealing with three herring stocks, i.e. Icelandic spring spawners, Icelandic summer spawners and Norwegian spring spawners.

The object of this paper is to review the biology of the two Icelandic stocks with regard to life history, maturation cycle and fecundity. Absolute abundance estimates are also given.

THE DIFFERENTIATION OF STOCKS

During the feeding periods the whole population complex of the Atlanto-Scandian herring often mixes freely on the feeding grounds in wide areas north and east of Iceland. This was especially noticeable in the period 1957—1962. Results from tagging experiments that have been carried out on the respective spawning grounds show that the three main stocks, i. e. the Icelandic and Norwegian spring spawners and the Icelandic summer spawners, segregate after the feeding period and mixing on the spawning grounds is negligible. Since this paper only covers the two Icelandic stocks, the material has been chosen from pre- and postspawning populations at the south-west coast of Iceland where intermixing with Norwegian herring is very little and therefore the danger of errors, due to uncertainties arising from identification of the stocks, is minimal. The two Icelandic stocks are, however,

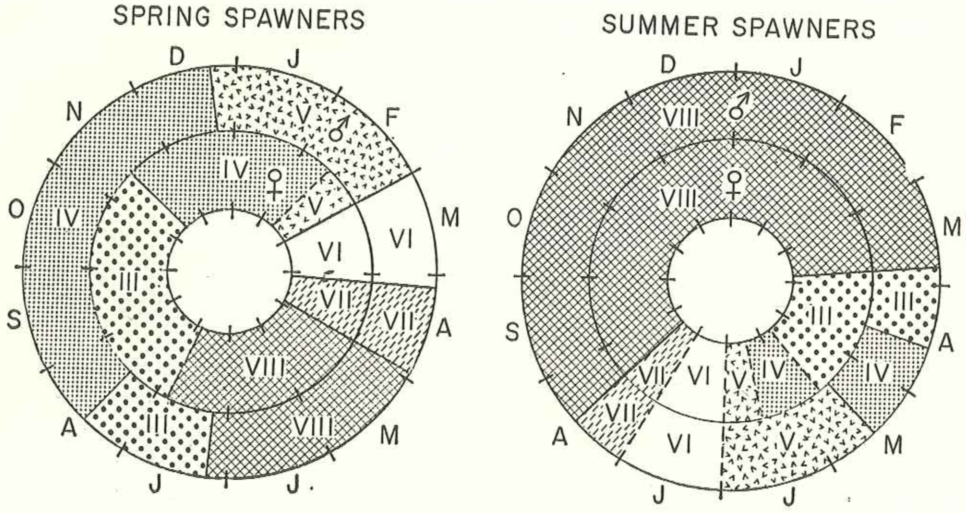

Fig. 1. *Schematic representation of the maturation cycle of Icelandic herring based on data from 1961.*

mixed most of the year with the exception of the two spawning periods. These periods are not entirely separated, in fact stray individuals with running gonads have been reported throughout the year. The height of the spring spawning season is in March and that of the summer spawning in July and early August (Fig. 1). In late April and in May the spent spring spawners are usually found together (in the same shoals) with the prespawning population of the summer spawners. During June the two stocks segregate, the spring spawners migrate to the feeding grounds west or north of Iceland or some part of the stock may migrate in an easterly direction towards the rich feeding areas off the east coast while the summer spawners assemble on the same, but probably more extensive, spawning localities as used by the spring spawners. During August and September spent summer spawners are often found in wide areas, again mixed with the spring spawners.

In the autumn the main part of the adult population is usually found off western Iceland, slowly migrating southward in November and December as the water temperature in this area decreases. In recent years the two stocks, or at least a considerable proportion of them, have remained in coastal waters off the south and southeast coasts until late February when the spring spawners have begun to assemble in the spawning localities. The summer spawners have then disappeared to unknown areas to be ready for yet another intermixing immediately after the close of the spring spawning period.

The two stocks are, however, usually easily distinguished by their different maturation cycle as shown schematically in Fig. 1. The classification of the immature herring has not been attempted and the separation of the Icelandic herring into two stocks for the purpose of growth and density calculations was thus entirely based on maturity analyses of the gonads.

THE FEEDING AND GROWTH RATE

The feeding cycles of the two Icelandic herring stocks are closely connected with their biology and especially their spawning periods. Thus the spring spawners have one feeding period that begins soon after the termination of the spawning, i.e. probably some time during the 2nd half of April, and after that feeding is more or less continuous throughout the summer with varying intensity depending on the quantity of zooplankton, especially that of copepods and euhausiids. Generally very little food is observed in the stomachs after about mid October, but occasionally herring samples appear in the middle of the winter with stomachs full of euphausiids. This winter feeding is, however, very sporadic and of little significance. During the first half of the summer the body and internal fat contents of the spring spawners increase steadily, but during the second half of summer and autumn the fat contents remain more or less constant while there is a rapid development of the gonads (Fig. 1).

The summer spawners also feed intensely during May and June, but their body and internal fat content does, however, not rise significantly and is usually about 12% throughout this prespawning period. Meanwhile there is a sudden development of the gonads as clearly shown on Fig. 1. Feeding is then interrupted during the middle part of the summer by the spawning season, but by mid August, feeding is resumed again. During this period the physiological processes are strikingly reversed because then the gonads remain restive in maturity stage VIII for the next eight months, while there is a gradual increase in the body and internal fat contents until feeding is terminated by winter conditions in the sea.

Thus feeding and the resulting physiological processes in the spring and summer spawners are in striking contrasts:

1. The spring spawners have only one feeding period whereas the summer spawners have two.
2. During early summer the feeding mainly affects the body and internal fat in the spring spawners while only the gonads are affected in the summer spawners.
3. During late summer and autumn there is a rapid development of the gonads in the spring spawners when these are restive in the summer spawners.

The growth curves for the two Icelandic herring stocks were calculated

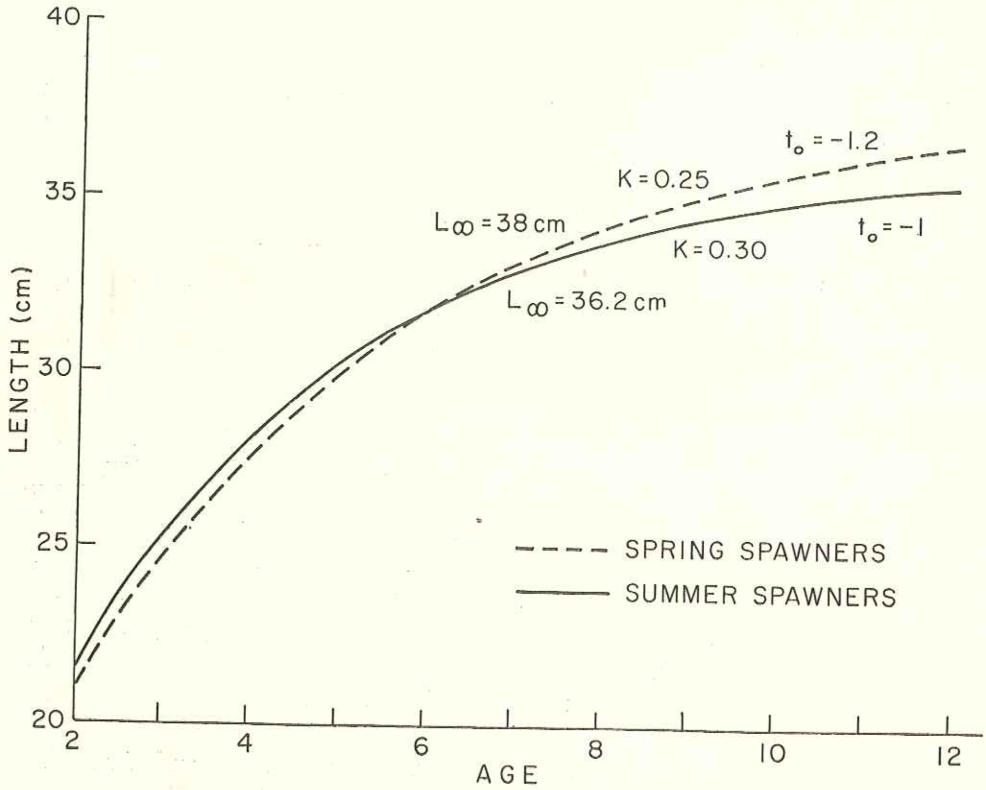

Fig. 2. *Growth curves and growth parameters of Icelandic herring based on data from 1961—1964.*

and are shown in Fig. 2. The data used for these calculations are from the four year period 1961—1964 and the samples were all taken from purse seine catches. The data fit Bertalanffy's growth equation reasonably well with the exception of the younger not fully recruited age groups. The mean lengths of 3 and 4 year old herring lie considerably above the curve, probably due to the fact that the largest fish of each yearclass are recruited first. Fig. 2 shows that 2—5 year old summer spawners have higher mean lengths than the spring spawners, but for the older yearclasses this is reversed. It should be noted that the age of the summer spawners was determined by the number of winterrings. This is in agreement with K. A. Liamin's (1959) observations that most of the summer spawners form a winterring already during their first year of life. Einarsson (1951), on the other hand, considered that the summer spawners did not form their first winterring until their second year of life. Considering the time gap between the hatching in the two stocks (March—July) the larger size of the summer spawners when young was certainly not expected by the present authors. It is well known

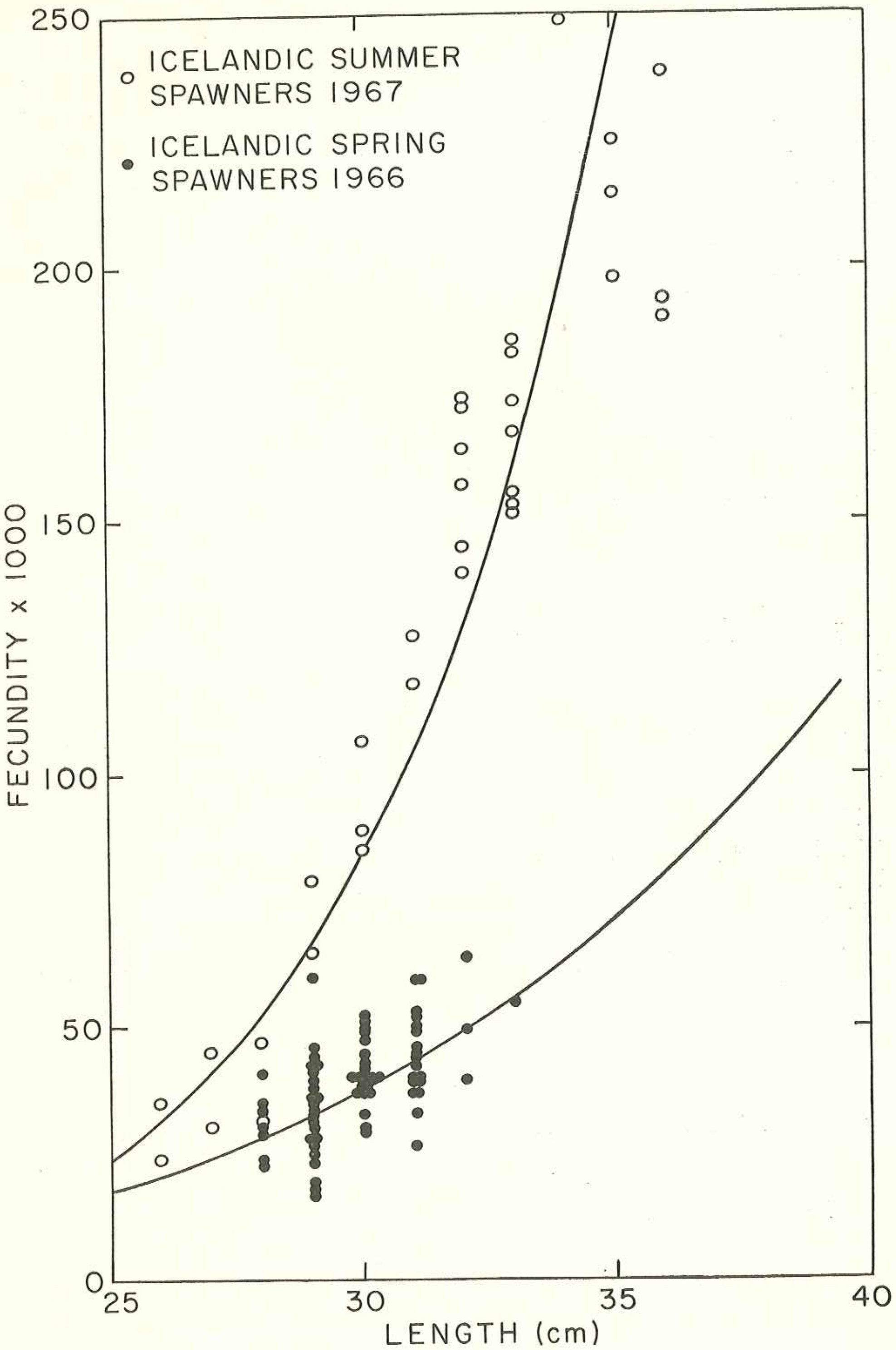

FIG. 3. *The relationship between fecundity and length. Each plot refers to a single fish.*

that the size of the young herring resulting from the summer spawning is much smaller than the fry from the spring spawning at the end of their first winter and after that the immature herring of both stocks are believed to be assembled in the same general localities. The results of the present growth analyses therefore tend to support EINARSSON's view that in the majority of the summer spawners no winterring is formed in the first year of their life.

Clearly this important problem must be investigated in more detail before firm conclusions can be reached.

The higher K and lower L_∞ shown in Fig. 2 for the summer spawners might point to more affinities of this stock to the North sea autumn spawners, whereas the lower K and higher L_∞ of the spring spawners are more in accordance with these parameters found for the Norwegian spring spawners (BEVERTON, 1963).

FECUNDITY

For this study 74 spring spawners were collected from the south coast in November—December 1965 and 33 summer spawners from the south-west coast in July 1967. Length, total weight and weight of ovary were recorded; otoliths and scales were taken for age determination of all fish sampled. The ovaries were preserved in a modified version of Gilson's fluid as used by SIMPSON (1951). The eggs were cleaned thoroughly and counted totally with an automatic fish egg counter (PARRISH, B. B., BAXTER, I. G., MOWAT, M. J. D., 1960). Our thanks are due to Mr. I. G. Baxter of the Marine Laboratory, Aberdeen, for counting the eggs of the spring spawners. The eggs of summer spawners have been counted by the present authors using an egg counting machine of similar type (described by SCHULZ, 1968).

Figure 3 shows the relationship between fecundity and length for the both races of herring. Data were transformed to logarithms and regression lines fitted by the method of least squares, giving for summer spawners:

$$\log F = 6.855 \cdot \log L - 5.199$$

or in the arithmetic transformation:

$$F = 0.000009036 \cdot L^{6.855}$$

and for spring spawners:

$$\log F = 4.1285 \cdot \log L - 1.5182$$

or

$$F = 0.03032 \cdot L^{4.1285}$$

where F denotes the fecundity and L the length.

Because of the different length distribution, Icelandic spring and summer spawners are only comparable over a short range of length, i.e. 28—33 cm. It appears that over that range the fecundity of the summer spawners is significantly higher. There is little or no overlap in fecundity between these two stocks.

In Figure 4 the relationship between fecundity and weight is shown. The relationship appears to be linear and can be expressed by the following equations:

Summer spawners: $F = 718 \cdot W - 91938$

Spring spawners: $F = 189 \cdot W - 7383$

where F denotes the fecundity and W the weight.
From the linear equations, we can derive the rate of increase in fecundity with weight for both races:

	Summer Spawners	*Spring Spawners*
Number of eggs per 10 g	7180	1890

There is a striking difference between these stocks. The increase in fecundity

Table 1.

The relationship between fecundity and age

	Spring spawners			*Summer spawners*		
Age	*Average fecundity*	*Average weight* g	*Frequency (n)*	*Average fecundity*	*Average weight* g	*Frequency (n)*
3	33.070	223	35	67.450	235	2
4	42.270	254	35	88.640	255	10
5	44.550	300	2	160.830	345	11
6	59.350	315	2	136.280	304	5

Table 2.

The relationship between fecundity and length for 3 and 4 years old spring spawners

	Age 3			*Age 4*		
Length	*Average fecundity*	*Average weight* g	*Frequency (n)*	*Average fecundity*	*Average weight* g	*Frequency (n)*
28	32.300	198	5			
29	31.290	221	21	38.620	228	6
30	38.430	239	7	41.840	247	14
31	35.000	255	2	43.760	271	14
32				49.200	270	1

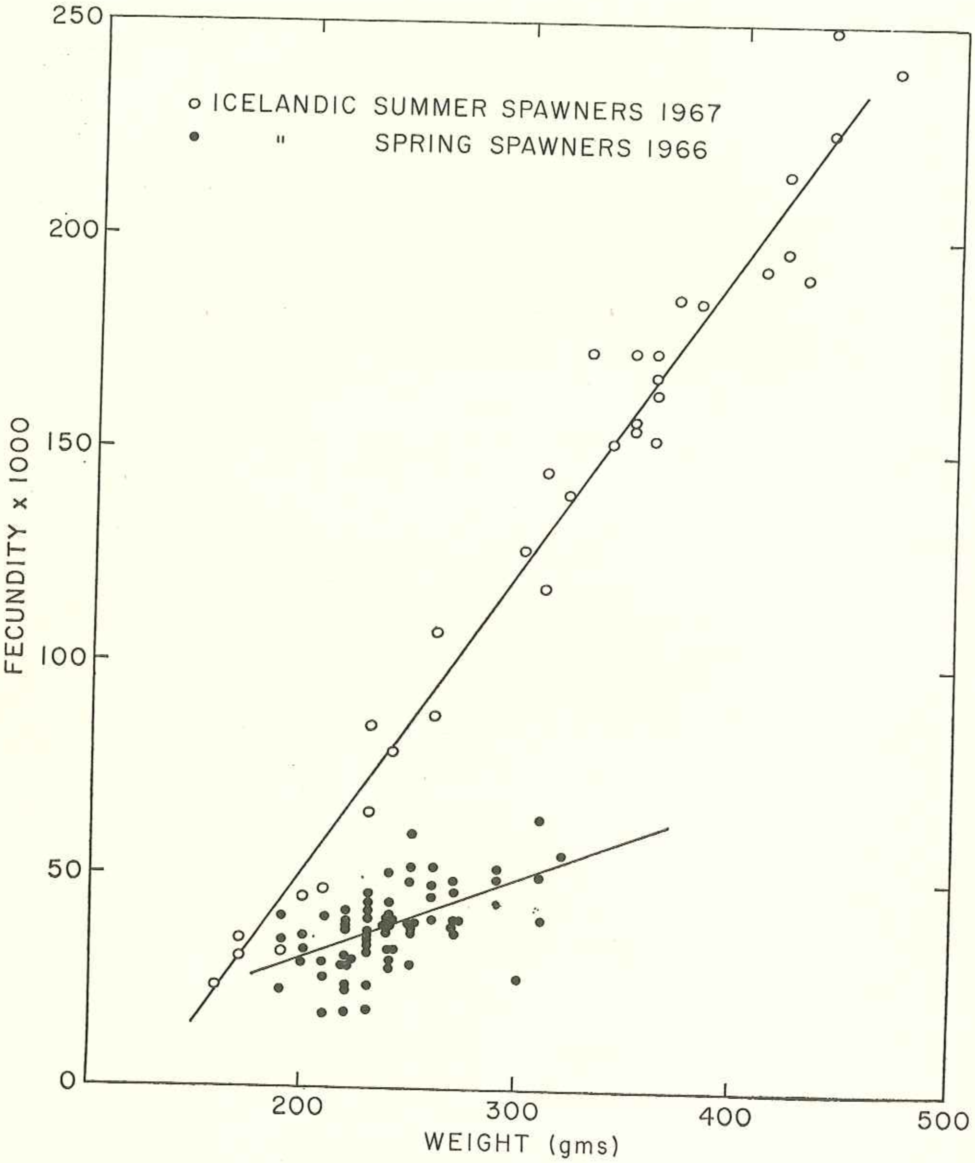

Fig. 4. *The relationship between fecundity and weight. Each plot refers to a single fish.*

of the summer spawners is nearly four times greater than that of the spring spawners.

Figure 5 shows the relationship between fecundity and age. The fecundity also increases with age as expected, but the figures show a wider scatter, especially among the summer spawners.

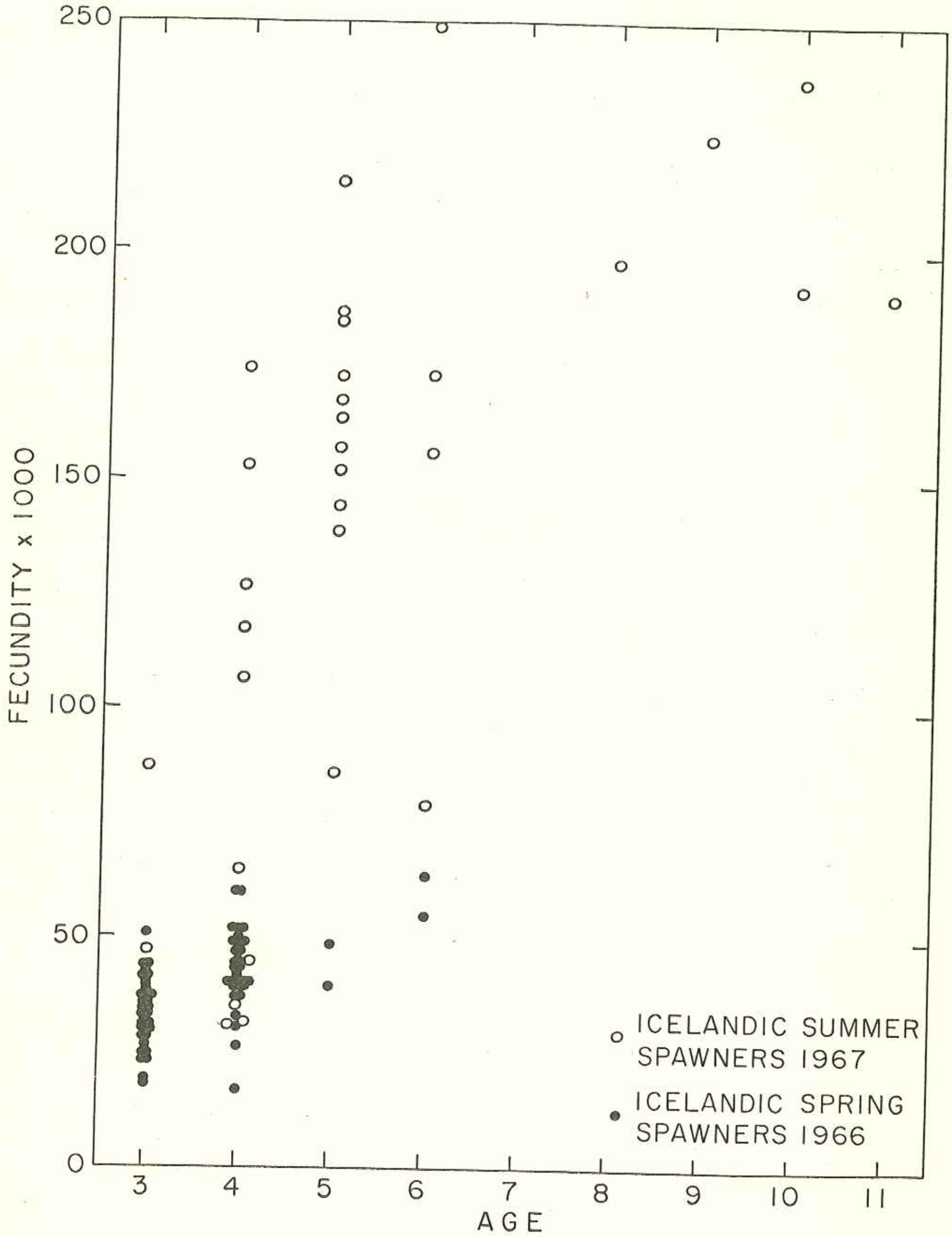

Fig. 5. *The relationship between fecundity and age. Each plot refers to a single fish.*

The increase in fecundity with age for both races is given in Table 1.

Obviously the inverse relationship between fecundity and age in 5 and 6 year old summer spawners is due to the lower average weight in the older fish.

Among the spring spawners two age groups (3 and 4) were well represented. The relationship between fecundity and length for the two ages separately is given in Table 2. Such a comparison was not possible among the summer spawners because of insufficient material. Although an increase in fecundity with age at a given length is indicated, the test of significance failed to show significant differences between the means of fecundity of the 3 and 4 years old fishes at a given length.

An attempt was made to determine whether fecundity is related to the number of times the fish has spawned as well as to its age (Table 3). From the data of Table 3 it seems that the first-spawners are slightly more fecund than the repeat-spawners of the same age and, amongst the repeat spawners, the fecundity increases with the number of times they have spawned. In both cases, however, the differences are not statistically significant.

The only previous worker dealing with fecundity of herring in Icelandic waters was Liamin (1959). He estimated that the fecundity of the summer spawners from Iceland and Faroes ranges from about 55.000 to 294.000 eggs for fish differing in length from 24 to 33 cm (Table 4). In Liamin's paper it is not said, whether length measurements have been made for "total length" or for "fork length". Assuming that these are fork lengths Liamin's estimates agree fairly well with the present counts.

Otherwise the reasons for the difference between these two sets of estimates are not fully understood. Differences of this order can not possibly be attributed to differences in the counting technique nor to differences in fe-

Table 3.

The relationship between fecundity, age and spawning zones

		Spring spawners			*Summer spawners*		
Age	*Number of spawning zones*	*Average fecundity*	*Average weight* g	*Frequency (n)*	*Average fecundity*	*Average weight* g	*Frequency (n)*
3	0	33.750	228	13			
	1	32.670	220	22			
4	0	48.800	250	1			
	1	41.280	254	20	58.980	220	5
	2	43.210	256	14	118.280	290	5
5	2				148.550	325	2
	3				168.560	349	9

TABLE 4.

Fecundity of Icelandic summer spawners.
Comparison of present data to those of Liamin.

Length cm	Present data: Average fecundity	Present data: Frequency	Liamin's data: Average fecundity	Liamin's data: Frequency
27	41.400	2	87.300	2
28	52.700	2	111.800	2
29	66.900	2	138.000	12
30	84.450	3	163.000	9
31	105.300	2	195.000	17
32	131.400	6	212.300	27
33	162.300	7	213.000	7

Please note that Liamin's data are probably based on fork length and his 27 cm group therefore corresponds to our 30 cm group.

cundity from year to year although some moderate changes in fecundity of herring have been described by POLDER & ZIJLSTRA (1959) and for flatfish by BAGENAL (1957).

FARRAN (1938) and BAXTER (1959) pointed out that fecundity and egg size in herring are inversely related and HEMPEL and BLAXTER (1967) showed egg size as a racial character. Because of the high fecundity of the Icelandic summer spawners one can expect very small eggs. For technical reasons it has not been possible so far to measure ripe eggs of Icelandic herrings. It would be of interest to compare egg sizes of spring and summer spawners in order to determine whether there is a characteristic egg size for each of the Icelandic herring stocks.

THE RELATIVE AND ABSOLUTE ABUNDANCE

Prior to 1960 both the Icelandic herring stocks appeared in the drift net catches taken in autumn off the southwest coast in more or less even numbers. (EINARSSON 1956 and unpublished data). Since 1961, however, an ever increasing amount of the population has been made up of summer spawners and by 1967 the share of the spring spawners had shriveled to less than one fifth of the total catch taken off the south and west coasts (Table 5). At the same time there has also been a sharp decline in the abundance of Icelandic spring spawners on the north and east coast summer fishing grounds. This stock, which prior to 1962 accounted for approximately 50% of the catch from this area, has now become quite insignificant and in 1967 it was

TABLE 5.

Year	Total catch Metric tons ISPR	ISUM	% of Catch ISPR	ISUM
1961	37.838	69.747	35.2	64.8
1962	50.809	97.690	34.2	65.8
1963	33.852	122.148	21.7	78.3
1964	39.446	81.554	32.6	67.4
1965	44.032	127.968	25.6	74.4
1966	14.824	53.176	21.8	78.2
1967	14.480	65.520	18.1	81.9

responsible for less than 1% of the total (JAKOBSSON 1962—1967, JAKOBSSON and VILHJÁLMSSON 1968).

Since 1961 tagging experiments on herring caught by purse seine nets have been carried out during the southwest coast spring fishery in late April and May. Using the returns from these experiments in the following year and handling them as done by DRAGESUND and JAKOBSSON (1963) for the Norwegian herring, estimates of the absolute abundance of the herring stocks were obtained. Estimates of F, the instantaneous fishing mortality coefficient, were calculated from the ratios of the absolute estimates and the total catch of both stocks taken by Icelandic fishing vessels. Table 6 shows that F is nearly constant during the 3 year period 1962—1964 while the stock has been reduced by half. In 1965 F increases by same 10%, but comes down again in 1966 to the previous level of 0.38 due to the great reduction in catch. The estimates of F = 0.38—0.48 are considerably heigher than those obtained for the Norwegian herring (ANON 1964) and the reduction in stock size is calculated to be almost fourfold during the five year period 1962—1966. The actual decline, however, is almost certainly even greater than that since in 1962 and 1963 we were only dealing with mature herring, but in 1964 and particularly in 1965 and 1966 a considerable proportion of the material consisted of immatures.

During the last decade great changes in catching technique have taken place in the south and west-coast herring fishery. Before 1959 this fishery was conducted almost exclusively by drift nets in late summer and autumn with landing figures quite stable at around 20—30 thous. tons yearly. After 1959 the drift nets were rapidly replaced by the purse seine and puretic power bloc, and this together with the advent of sonar and a better knowledge of the behaviour and migrations of the herring resulted in a manifold increase in catch in the following years as shown in Table 5. In 1961 the herring season was extended through January to late May and on and after 1963 herring fishery off the south and west coasts of Iceland to more or less

TABLE 6.

Year	*Abundance in thousand tons*	*F (fishing mortality) coefficient*
1962	931	0.42
1963	619	0.38
1964	457	0.38
1965	304	0.48
1966	270	0.38

continuous throughout the year. The depletion of the Icelandic herring stocks thus goes hand in hand with a revolutionary change in fishing technique. The recruitment was at the same time poor and in fact no reasonably good yearclasses have been recruited to either stock since 1956. To be certain the yearclasses from 1961 and 1962 appeared at first to be above average in abundance. Their recruitment to the mature stock in 1965 and 1966 failed, however, to a large extent which was probably mostly due to an exceptionally heavy fishing for immature herring off South and Southeast Iceland in the summer of 1965 and 1966.

The rapid decline and present poor condition of the Icelandic herring stocks, the spring spawners in particular, therefore seems to be effected by poor recruitment during a period of much intensified fishing effort

ÁGRIP

Rannsóknir Bjarna Sæmundssonar, Árna Friðrikssonar o. fl. leiddu í ljós, að við Ísland er um þrjá síldarstofna að ræða, þ. e. íslenzka vorgotssíld, íslenzka sumargotssíld og norska vorgotssíld. Hinn síðast nefndi síldarstofn hrygnir við Noreg, en hinir tveir við Ísland.

Þessir þrír síldarstofnar blandast oft á ætisgöngum sínum, en greinast svo sundur aftur, þegar dregur að hrygningartímanum. Síðari rannsóknir hafa leitt í ljós, að á hrygningarstöðvunum er um svo til alveg aðskilda stofna að ræða. Íslenzka vor- og sumargotssíld er t. d. að finna í sömu torfum allan ársins hring nema í takmarkaðan tíma rétt fyrir og um hrygningu. Vorgotssíldin hrygnir aðallega í marz og byrjun apríl, en sumargotssíldin einkum í júlí.

1. mynd sýnir, að kynþroskastig hrogna og svilja íslenzkrar vorgotssíldar annars vegar og sumargotssíldar hins vegar, eru mjög ólík. Auk þessa eru ýmis önnur atriði í líffræði íslenzku síldarstofnanna mjög mismunandi.

Vorgotssíldin hefur t. d. eitt samfellt fæðuöflunarskeið á ári, en sumargotssíldin tvö. Fyrri hluta sumars fer fæða vorgotssíldar einkum í að auka innylfa- og búkfitu, en á sama tíma þroskast svil og hrogn sumargotssíldarinnar mjög hratt, en fitumyndun er mjög lítil. Vöxtur þessara tveggja síldarstofna er í öllum aðalatriðum mjög svipaður. Þó virðist vaxtarhraði sumargotssíldar vera öllu meiri framan af ævi eins og sýnt er á 2. mynd.

3. og 4. mynd sýna, að hrognafjöldi sumar- og vorgotssíldar er mjög ólíkur, þannig að hinn fyrrnefndi síldarstofn hefur mun hærri hrognafjölda en hinn síðar nefndi. Sé meðal hrognafjöldi reiknaður út miðað við hver 10 g heildarþunga kemur í ljós, að hrognafjöldi sumargotssíldar er 7180 en vorgotssíldar 1890 eða nærri fjórum sinnum lægri.

Stærð íslenzku síldarstofnanna hefur minnkað mjög á árabilinu 1962—1966. Stofnstærðar-útreikningar, sem gerðir eru eftir endurheimtum síldarmerkjum, sýna, að við upphaf framangreinds tímabils voru síldarstofnarnir taldir vera 931 þúsund lestir, en 270 þúsund lestir við lok þess. Hlutur vorgotssíldar hefur farið minnkandi í aflanum, en hlutur sumargotssíldar vaxið að sama skapi.

REFERENCES

Anon, 1964: "Report of the Atlanto-Scandian Working Group". I.C.E.S., C.M. 1964.

Bagenal, T. B., 1957: "Annual variations in fish fecundity". J. mar. biol. Ass. U.K. *36:* 377—382.

Baxter, I. G., 1959: "Fecundities of winter-spring and summer-autumn herring spawners". J. Cons. perm. int. Explor. Mer, *25:* 73—80.

Beverton, R. J. H., 1963: "Maturation, Growth and Mortality of Clupeid and Engraulid stocks in Relation to Fishing". Rapp. Proc. Verb., Vol. 154.

Dragesund, O., & Jakobsson, J., 1963: "Stock Strength and Rates of Mortality of the Norwegian Spring Spawners as Indicated by Tagging Experiments in Icelandic Waters". Rapp. Proc. Verb., Vol. 154.

Einarsson, H., 1951: "Icelandic Herring Investigations". Ann. Biol., Vol. VII.

— 1956: "The Icelandic Herring and Racial Problems". Rapp. Proc. Verb., Vol. 143.

Farran, G. P., 1938: "On the size and number of ova of Irish herring". J. Cons. perm. int. Explor. Mer, *13:* 91—100.

Fridriksson, Á., 1944: "Norðurlandssíldin". Rit Fiskideildar, Vol. 1.

Jakobsson, J., 1961—1966: "Icelandic Herring Investigations". Ann. Biol., Vols. XVIII—XXIII.

Jakobsson, J. & Vilhjálmsson, H., 1967: "Icelandic Herring Investigations". Ann. Biol., Vol. XXIV.

Liamin, K. A., 1959: "Investigations into the life cycle of summer-spawning herring of Iceland", translated in: Spec.. scient. Rep. U. S. Fish Wild. Serv., (327) 166—202.

Ólafsson, E. et al., 1772: "Rejse igennem Island". 1—2. Sorö.

Parrish, B. B., Baxter, I. G. and Mowat, M. J. D., 1960: "An automatic fish-egg counter". Nature Lond. *185:* 777.

Polder, J. and Zijlstra, J. J., 1958: "Fecundity in the North Sea herring". Int. Council Explor. Sea. C.M. 1959, No. 84.

Sæmundsson, B., 1906: "Fiskirannsóknir 1905". Andvari, Vol. 31.

Schulz, H., 1968: "Ein einfaches Gerät zum Zählen von Fisheiern". Ber. wiss. Komm. Meeresforsch., *19:* 226—230.

Simpson, A. C., 1951: "The fecundity of the plaice". Fishery Invest. Lond., Ser. 24, *17:* (5) 27 pp.