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A preliminary assessment of silver hake in sub-area 5

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Catches

After a fairly long period of reasonably stable catches, taken entirely by US vessels - mainly for human consumption, but also for animal food and industrial purposes - catches rapidly expanded from 1962 onwards following the development of the USSR fishery by large factory trawlers; the details are as follows (nominal catch in thousand of tons).

Table I. Annual catches of silver hake from sub-area 5 (thousand tons)

	1959	1960	1961	1962	1963	1964	1965	1966
US	50	47	43	44	40	53	42	41
USSR	-	-	-	42	107	172	281	121
Total	50	47	43	86	147	221	323	162

Migrations - separation of stocks

Little definite information is available on migration patterns, or the existence of separate stocks. Tagging has had only limited success, and has given few returns over more than a few weeks, though a fall-off in returns from inshore grounds has been taken as a sign of movement offshore (Fritz 1959). Analysis of catches in the fish meal fishery off Rhode Island also suggested a movement offshore in winter (Edwards 1966). Extensive movements in a relatively small area would suggest no marked separation of stocks, though Soviet studies (Konstantinov and Noskov 1967) suggest that separate stocks do exist. Morphometric studies suggest two distinct stocks, in the Gulf of Maine and south of C.Cod (Conover etc 1961).

Further studies of this problem are clearly needed, but for the present analysis possible stock difference will be neglected. The ability of the fleets concerned (especially that of USSR) to range over the area would suggest that there is no great difference in the effect of fishing on different stocks, if indeed separate stocks exist.

Examination should also be made of the possible interchange with other areas; in 1965 50,000 tons were caught in sub-area 4 (mostly 4W) and 15,600 tons by USSR vessels outside the ICNAF area to the south. The fact that the area of biggest catches in sub-area 4 were separated from the main fishing area in sub-area 5 both by the deep water north of Georges Bank and by the whole of division 5 X (southern Nova Scotia) suggests that they come from different stocks. The southern catches, taken in second half of March in the area of Hudson Canyon (Konstantinov and Noskov 1966) might well come from the sub-area 5 stock (or stocks) at the end of their winter migration. This would add some 5% to the 1965 catches given above it will not affect the present assessment, but the effect of these catches from outside the ICNAF area might become relatively more important.

Effort and catch per unit effort

Silver hake was not included in the basic effort tables of the ICNAF statistical bulletin until 1965, so these tables cannot be used to produce a series of measures of effort and catch per unit effort. Data of catch per day in the US fishery for human consumption has been given in the US research report to ICNAF. Though lately this fishery has been limited to the inshore grounds, and there are considerable differences between the catch rates on different inshore grounds (Graham 1965), it provides the best presently available index of abundance, and from it a measure of total effort (in US days) has been calculated, as in the table below:

Table 2. Estimates of catch per unit effort and of total effort for silver hake

	1960	1961	1962	1963	1964	1965	1966
Catch per day	17.5	23.8	18.5	17.4	15.1	12.8	12.5
Total catch (000 tons)	47	43	86	147	221	323	162
Total effort (000 US days)	27	18	46	84	146	252	130

This table shows a very clear decline in catch per unit effort, to around 60% of the 1960-61 value. What this decline means in terms of changes in the total population is not certain, since the US fleet does not now work in the offshore area. If the decline in catch per unit effort indeed reflects a decline in population due to increased fishing, then it is probable that the decline in the offshore area where the biggest expansion of effort has occurred has been greater than the decline in US catch per unit effort. Qualitative evidence of the decline in catch per unit effort is also given by Konstantinov and Noskov (1967), who note, concerning the fishery in 1966, that the decrease in silver hake concentrations had continued since 1964. Probably the offshore abundance is now appreciably less than half what it was in 1960.

Age composition

The percentage age composition of USSR catches has been given in the USSR Research Reports from 1963 onwards; these are given in Table 3 below. Figures in brackets are estimated from the other data, to make the total 100%. It is not known whether the figures refer to catches of scouting vessels, the commercial fleet, or both. Data is also given of the average length of hake sampled.

Table 3. Age composition and average length of USSR silver hake catches (per cent)

Age	1962	1963	1964	1965	1966
2	?	?	(3)	7	17
3	37	32	42	52	46
4	51	47	44	33	27
5	8	17	11	6	4
6+	?	3			
Mean length	31.7	30.4	30.5	28.3	28.6

This table shows clearly the decrease in the proportion of old fish, and in the average length which would be expected from increased fishing. The normal estimates of mortality are difficult to apply, since it appears that recruitment is not complete until four years old, and thereafter mortality is very high - estimated by Noskov and Zakharov (1964) as 80%, $Z = 1.46$. This is, as they note, much higher than the $Z = 0.45$ estimated by Beverton and Hodder. But this latter figure based on length data is probably too low, both because it is based on landings, not catches, and because the method used may not be too accurate when the range of lengths within an age group may be as great as the difference in the mean lengths of different age groups. It also appears, from the increasing proportion of 2-year old fish, that there has been a decrease in the age at recruitment, possibly due to changing distribution of the fishing effort.

An index of the change in mortality may be obtained from Table 3, using the ratio of the percentage of 4-year olds in one year to that of 3-year olds in the previous year, as follows:

Table 4.

	1962/3	1963/4	1964/5	1965/6
Ratio	1.27	1.37	0.79	0.52
Z'	-0.24	-0.31	0.23	0.65

This suggests that if the patterns of fishing, and particularly of recruitment (i.e. large recruitment at 4) has not changed, then there has been an increase of mortality coefficient of around 0.9. The fishing mortality coefficient in 1965/66 allowing for the fishing that was already going on before 1962 may, therefore, be estimated as around 1.10. This is about equal to the total mortality estimated above for the old fish present when the intense USSR fishing began, which is probably mostly natural mortality. Two factors, probably acting in opposite directions will affect the indices of apparent mortality in Table 4. Any tendency for earlier recruitment will increase the indices, making them closer to the true mortality. Using percentage age composition, and not measures of abundance, will, if the stock is declining, result in under-estimates of mortality. Neither of these can be quantified. The data are therefore not at all conclusive, but it appears that fishing now (1965/66) accounts for perhaps half or more of the total deaths.

Tagging

Results of tagging experiments in 1957 and 1958 have been reported by Fritz (1959, 1963). Total returns were about 4%, but allowing for poor returns from the fishery for animal food, and for industrial purposes, the actual recaptures can be estimated from Table 1 of Fritz (1959), to have been at least $4.0 \times {}^{7.2}/_{5.0} = 5.8\%$, assuming all tags recaptured in the fishery for human consumption were returned. However, his Table 2 suggests that there may have been incomplete returns even from the human consumption fishery, so that a figure of 6% gives a lower estimate of the recaptures.

These experiments were carried out before the USSR fishery developed; assuming that in recent years the US effort has remained constant, the expected rate of recaptures can be calculated from the ratio of US to total catch, e.g. for 1962 is $6 \times {}^{86}/_{44}$. The resulting estimates are as follows:

Table 5.

	1962	1963	1964	1965	1966
Expected recapture rate	11	22	25	46	29

Though these figures are moderately large, they probably underestimate the fishing rate on silver hake. As Fritz (1959) notes, tagging of both silver hake and European hake has proved difficult, since the fish seem very easily injured, even when special care is taken. Fritz found only about one-third of fish caught by trawl were suitable for tagging. Also he found that the returns dropped off very quickly; from an experiment on Georges Bank all 54 fish recaptured (5% of those tagged) were recaptured within one month, and from an experiment in Ipswich Bay 55 (8.2%) were recovered within 28 weeks, and only one later. The return rate may thus considerably underestimate the true fishing rate, but the estimated returns rates for 1963-66 are sufficiently large to show that the recent fishing rate must be substantial, even though it cannot be estimated quantitatively from the tagging data.

Tagging has also been carried out by Soviet scientists, but gave very few returns,probably due to poor survival at the time of tagging.

Discussion

The evidence considered here shows fairly clearly that fishing is having a significant effect on the stock of silver hake. Although it is not yet possible to make precise quantitative assessments, it seems probable that the fishing effort in the last 3 years has probably approached the level beyond which further increase in fishing would give little increase in average catch. The important question is the extent to which the high catches in 1965 represent a temporary peak, due to fishing out of an accumulated stock, or a catch that can be continued indefinitely - it does not seem to be due to any outstanding year-class, at least as judged from the data in Table 2. This table also suggests that probably two-thirds to three-quarters by numbers of the 1965 catches (nearly all the 2- and 3- year old and many of the 4-year olds) were recruits; thus the 1965 catches did not come from an accumulated stock, and therefore catches might well be continued at not much less than the 1965 level - the decrease in 1966 was mainly due to a drop in effort.

Against this, both the changes in the index of mortality and the tagging data suggest that the 1965 catches represented half, and probably considerably more than half, of the stock. Thus the greatest catch in 1965, that could have been obtained (by removing the entire fished stock) would have been not more than twice the actual catch in numbers and this catch certainly could not have been continued in 1966. Therefore, assuming that the strength of the year-classes in 1965 were of normal strength, the greatest average catch that can be taken from sub-area 5 lies between a value of little below the 1965 catch (say 250,000 tons), and a value less than twice the 1965 catch (say 500,000 tons), and probably in the range 300-400,000 tons.

The US catch per unit effort data show a decline, by 1965, to 60% of the 1960-61 value. Some models, e.g. that of Schaefer (1957) suggest that the greatest sustained catch is taken when the stock has been reduced to half its unfished abundance; other evidence (e.g. Gulland, 1962) suggests that the maximum catch occurs at a rather lower level of stock. On this basis,if the stock abundance is indeed still 60% of the unfished level, further increase in effort beyond the 1965 level should increase the average catch; against this it may be noted: (i) the 1965 abundance was less than the unfished abundance, since considerable US fishing was being carried on; (ii) by 1965 the stock had not completely declined to the level it would reach with sustained fishing at the 1965 effort; and (iii) in the most recent years the US silver hake effort has been on grounds other than Georges Bank, (where most USSR fishing is done) (Graham 1966) and, therefore, the changes in the US catch per unit effort probably underestimates the decline in the stock as a whole. The catch and effort data are, therefore, in reasonably good agreement with the conclusions of the previous paragraph - that the 1965 effort would give an average catch not much different from the maximum.

One important reservation must be made to the above analysis - the common one concerning the relation between stock and recruitment. At the high levels of effort the catches will consist almost entirely of recruits; the catches can consequently only be maintained if the average recruitment is not altered. There is not yet any direct evidence concerning this; in the limit, extreme depletion of the adult stock must reduce recruitment, but because the large silver hake are important predators on small fish (including small hake and haddock) there is the possibility that a not too drastic reduction in the number of big hake could actually increase the number of recruits of both haddock and silver hake.

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