CHANGES IN STOCK ABUNDANCE

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The purpose of the session was threefold:

a) to describe changes in the abundance of demersal fish stocks;

b) to identify and study the main factors leading to the changes in abundance; and

c) investigate how knowledge on these factors can be utilized in order to arrive at more reliable assessments, rational management, and harvesting.

Three of the eight papers assigned to this section dealt with pollock stocks in the northeast Pacific. Bakkala, Wespestad, and Low described the historical trends in abundance and current conditions of walleye pollock in the eastern Bering Sea. Results from cohort analysis indicated that the stock increased from less than 5 million metric tons in the early 1960's to more than 13 million metric tons in the early 1970's due to good recruitment. In the period 1975-1980 the stock size was 8-10 million metric tons, while the abundance in recent years appeared to decline because of poor abundance of most year-classes since 1978. However, different measures of abundance showed somewhat conflicting trends in stock abundance in most recent years.

The authors discussed several possible explanations for the observed fluctuations: cannibalism, survival during the very early stages of development of the larvae, and the possibility that the pollock had taken up a niche in the ecosystem vacated by other species. Regarding cannibalism, it could be assumed that the virgin stock in the early 1960's was dominated by older fish which through cannibalism could have limited the size of recruiting year-classes. As the fishery developed in the early 1960's, the abundance of old cannibalistic fish decreased, resulting in higher survival of young fish, an increasing stock in the latter half of the 1960's, and a maintenance of the overall population abundance at a relatively high level in the 1970's. The authors stated that the results from the cohort analysis did not fully support this explanation. Older age groups appeared to be less abundant in the population in the early 1960's than in the late 1960's when the population was increasing in abundance. Yet, the hypothesis that reduced mortality due to cannibalism was a significant factor behind the population increase in the 1960's should not be rejected because the reliability of the catch at age data from the earliest period is uncertain. Dwyer et al. (in prep.) point out that, although cannibalism might be a significant factor regulating the abundance of pollock, it is likely that environmental conditions during the early stages of development are also important in determining the abundance of year-classes.

There appeared to be some correspondence between positive sea temperature anomalies in the eastern Bering Sea and strong year-classes of pollock, but the pattern was not consistent.

Another possible explanation for the increased abundance of pollock in the 1960's is that they have taken up a niche in the ecosystem vacated by Pacific herring and Pacific ocean perch, species which both showed a major decline in abundance in the eastern Bering Sea in those years. The magnitude of this decline (about 2 million tons) was much less than the increase of the pollock stock (about 8 million tons) but, since Pacific herring and Pacific ocean perch feed primarily on small pelagic crustaceans while pollock are also cannibalistic, there may not be a direct relationship between gains and losses of biomass.

The apparent decline of pollock abundance in recent years may be caused by poor initial survival of year-classes in combination with increased predation on young fish by the strong 1978 year-class of pollock and the extremely abundant 1977 year-class of Pacific cod.

Alton, Nelson, and Megrey described changes in the abundance, composition, and distribution of pollock in the western Gulf of Alaska. The pollock in that region is considered a stock separate from those of the adjacent regions of the Aleutians, Bering Sea, and eastern Gulf of Alaska. Survey estimates of relative abundance, as well as total landings, indicated that the stock increased substantially in abundance between the early 1960's and the early 1970's. Analysis of catch at age data showed another strong increase in abundance in the late 1970's from a total biomass of 0.8 million tons in 1977 to 2.5-3.5 million tons in 1981-1982. The catch at age data indicate that the stock abundance has been declining since 1981-1982 and these findings are supported by the results of hydroacoustic surveys.

The increase in stock abundance and its recent decline are attributed to changes in recruitment. Successful year-classes spawned in 1967, 1970, and 1972 contributed to the increase in abundance in the early 1970's; the rapid rise in abundance after 1978 was the result of 5 strong consecutive year-classes (1975-1979). Weak year-classes spawned in 1980 and 1981 are contributing to the recent decline in stock biomass.

The authors discuss two processes which may have been important for the observed changes in abundance: Species replacement and density dependent control of recruitment. The increase in pollock abundance in the area in the early 1970's occurred during and after a period in which exploitation caused a major reduction in the stocks of Pacific ocean perch, a species which feed on similar prey as pollock. The increase in pollock biomass in the early 1970's was approximately the same as the reduction in the biomass of Pacific ocean perch a few years earlier. However, the secondary increase in pollock biomass in the area in 1978-1981 did not coincide with or follow comparable reductions of the abundance of competing species. Yet, the possibility of species replacement cannot be rejected since information on the total biomass of rockfishes in the area during the period is lacking.

The possibility of density dependent controlled recruitment is discussed by the authors. The fact that the weak 1980 and 1981 year-classes were produced when the stock size was at its maximum could indicate such a control, and this would agree with Megrey (Session 3) who indicated that the stock of pollock in the western Gulf of Alaska had Ricker type spawner-recruit relationships. Recent results from acoustic surveys indicating that the 1984 year-class is extraordinarily abundant could be interpreted as further support of a density dependent recruitment control in this stock, since the 1984 year-class emerged from a parent stock well below the high level of 1981-1982.

The distribution of pollock catches in the western Gulf of Alaska, as well as the catches of other species (Atka mackerel and Pacific cod), has shifted westward during the past 7-8 years.

This regional shift is probably related to greater availability of fish, which in turn is related to prey availability since the mentioned species feed on the similar organisms.

Strickland and Sibley discussed potential effects of water transport on the walleye pollock fishery in the Gulf of Alaska. The paper focused on the spatial distributions of the various stages of pollock within the region and how these distributions might be related to the main patterns of the currents. The transport in the western Gulf of Alaska is characterized by two strong westward flows: The Kenai current which is a coastal current over the shelf and the Alaska stream which has its highest speeds over the edge of the shelf. Freshwater runoff in the central and eastern parts of the Gulf, seasonal changes in the distribution of prevailing winds, tidal currents, bottom contours, and the formation of semipermanent eddies, reversals, and counter currents will modify the transport and the seasonal and spatial distribution of water masses. Thus, the transport mechanisms for the spawning products of pollock, as well as the environmental conditions for the commercially exploited stages, may vary from year to year. It would be useful to compare time-series of pollock recruitment and maps of juvenile distribution against data on interannual variability of the environmental parameters mentioned above. Such studies might throw light on the extent to which yearly variations in the transport of larvae may protect the juveniles from predation and cannibalism. Likewise, further research is necessary to fully reveal the processes that control the abundance, spatial and temporal distributions of prey, and their relevance for affecting pollock distribution and recruitment.

In the northwest Atlantic, Cohen studies some factors affecting the recruitment of Georges bank cod and haddock. He focused on testing the hypothesis that predation on juvenile gadoids is a major factor controlling recruitment variability. A series of cruises to study the abundance and distribution of bottom settled young-of-the-year cod and haddock and the food habits of their predators was carried out in 1984. Although the results yielded some evidence of predation by fish on young demersal gadoids, the figures obtained did not seem large enough to account for the high level of mortality postulated for the past larval period by previous authors. Cohen concluded that if predation mortality determines year-class strength, it would appear that in 1984 it took place earlier in the juvenile phase while the prerecruits were still pelagic.

The author also used time series on haddock recruitment, temperature, spawning biomass, and potential predators to test the hypothesis. Transfer function models using temperature and spawning biomass as input and numbers of one year old haddock as output were fit to the data. In addition, multiple regression of cod and haddock recruitment with the abundance of potential predators was done using a series of bottom trawl survey data. The author concluded that the results of the statistical analysis were of little predictive or diagnostic value in understanding the environmental and biological factors affecting recruitment. A significant correlation of haddock recruitment with June temperature and of cod recruitment with predator abundance was obtained, but it is possible that these correlations may be the result of chance.

Macer and Shepherd discussed the effect of species and technical interactions on the assessment of North Sea gadoid stocks. At present scientific advice on the long-term strategy for North Sea gadoids (cod, haddock and whiting) is based on single species yield per recruit models. In the paper, results from these models are compared with those from a model which incorporates predation mortality, technical interactions, and a stock-recruitment relationship. Predatory interactions between the three main North Sea gadoid species (cod, haddock and whiting) were simulated. These three species are taken, both in a directed fishery and as bycatch in industrial fisheries, and interactions between these two fisheries were also modelled. The model consisted of a set of conventional age-structured yield per recruit models, with the addition of stock-recruitment relationships and predation mortality. The data required are conventional and obtained from ICES assessment working group reports, apart from the parameters which are used to calculate predation mortality. Predation is taken to be proportional to predator and prey biomass, with mortality rates being modified by prey size preference and prey species preference.

A run with constant recruitment and no predation was made first, and in the following runs predation was introduced. Succeeding runs explored the effect of changing prey size preference in whiting and of changing the mean weight of 0-group haddock. Finally, the effect of introducing a stock-recruitment relationship in cod was examined.

The results confirmed previous work in showing that inclusion of predation has an effect on prediction of the steady state situation in North Sea gadoids. However, although there can be little doubt about the direction of the changes, their magnitude is uncertain. The model includes only three species and two fisheries, and the functional feeding relationship used is probably an oversimplification. In addition, the values adopted for the predation mortality coefficients were derived from a preliminary attempt at such an analysis. Nevertheless, the results show that the current advice on managing North Sea gadoid stocks based on single species yield per recruit considerations is incomplete. The advice is to reduce fishing mortality towards F_{max}. However, in the present work F_{max} is predicted to be higher than the present level of F, in some cases by a factor of two. Fishing mortality in all three stocks is at historically high levels and it is not inconceivable that one or more of these stocks could collapse due to recruitment failure if F were to double. Hence, as pointed out by Shepherd (1984), work on species interactions may be of limited value in the context of management without equivalent work on stock and recruitment relationships and the processes determining recruitment.

Sunnanå studied the 0-group abundance of northeast Arctic cod in relation to temperature and length measurements in the period 1969-1984. The data included area-stratified abundance indices, corresponding mean lengths, and three sets of mean values of sea temperature in each stratum; at the surface, at 50 m depth, and the mean value for the 0-50 m depth layer. The author used cluster analysis to investigate the relationship between density of 0-group cod, temperature, and mean length. In the theory of cluster analysis there are two distinct cases discussed--clustering of variables and clustering of cases. The present analysis was based on clustering of cases, the so-called K-means clustering.

The main results of the work were that the variations in the temperature distribution at the time of sampling could not explain the variations in 0-group abundance (year-class strength). No clear relationship between 0-group abundance, temperature, and length was found. The larger fry were always found in areas far to the north and east, at the greatest distance from the spawning grounds, thus indicating that the age of the fry is probably more important than temperature in determining the length of the fry at sampling time.

Sunnanå, Bax, and Godø described and discussed the results obtained using the ecosystem model--NORFISK--for studies of fish stocks off western Norway. NORFISK is a biomass based ecosystem simulation model which is designed to simulate biomass variations and interactions of important fish species in Norwegian waters. In Norwegian waters many of the stocks show distinct seasonal migrations and the various age groups occupy different geographical regions. The model was, therefore, modified to have geographical resolution and the unit of biomass was allowed to be a stock component. Hence, it was necessary to simulate recruitment between the different stock components, as well as migration between geographical areas.

A pilot study was carried out at Møre, a restricted area on the Norwegian coast.

The interaction part of the model relied on food consumption tables, i.e. the percentage of each prey group present in the stomachs of each biomass group. The prey groups are the same as the biomass groups. Data were available from literature and from a stomach sampling program in the area.

The stock components used in the simulation were adults, juveniles, and eggs/larvae. Migration in and out of the pilot study area were given as fixed amounts of biomasses entering or leaving the area.

Results of repeated runs, changing input biomasses and parameters, were given for Møre. The model seemed to give rise to stable biomass combinations well within reasonable levels. It also appeared that the demersal fishes played a more important role in stabilizing the system than did the pelagic fish biomasses. This may be because the pelagic species are feeding on plankton which is not a limiting factor in the pilot system, while the demersal fish are eating each other and also will be more dependent on biomass fluctuations of other prey stocks. Saithe and other demersals seem to be strongly dependent on each other, whereas cod may shift between demersal food and herring. It was clearly demonstrated that the interactions depended upon the food composition tables. Migratory biomasses staying in the area for a short period did not influence the stability of the system.

Mehl, Nakken, Tjelmeland, and Ulltang described the construction of a multi-species model for the Barents Sea with special reference to the cod-capelin interactions. The fish stocks in the Barents area are presently assessed by single species models where growth, natural mortality, maturation rate, and recruitment are input parameters estimated from long-term means or recent observations. The main weaknesses with these models are that, although changes in important population parameters can be taken into account when they are observed, they can not (or can only partially) be explained or predicted by the models. Multispecies models can potentially explain more of the variations observed in critical population parameters such as growth, natural mortality, and recruitment. Specifically, the multispecies model for the Barents Sea will be used for studying questions like the following: To what extent is recruitment and natural mortality of capelin dependent on the size and composition of the cod stock? Is there a relation between stock size of herring and the recruitment to the capelin stock? To what extent is growth of cod dependent on the size and composition of the capelin, herring, and shrimp stocks? Is the size of the shrimp stock partially determined by the size of the cod stock? What effects has predation by marine mammals on the commercially important fish stocks?

The model includes two main components; a migration model and a food consumption model. The migration model describes the time-varying geographical overlap of species and size (age) groups. The sea is partitioned into eight regions and migration is described by matrices, giving the fraction of a given species and age group migrating from one region to another in the course of a month, estimated from survey data and from the overall knowledge of fish migration in the area. Migration matrices for both cod and capelin are established.

Individual food consumption is estimated from stomach content data and gastric evacuation rates. A stomach sampling program provides detailed data on stomach content weights, composition, and prey size preference for the different predator age groups per quarter. Combination of the estimates of individual food consumption and the estimates of the abundance of predators and prey obtained from the migration model gives the time varying total consumption of prey groups. Preliminary results on stomach contents of cod are given in the paper. These results show large individual, area, and year to year variations as found by other investigations. The general trend is that crustaceans (krill and shrimp) are the dominant food of the smaller fish, while the bigger cod feed mainly on fish.

Although stomach content data are presently collected from cod, haddock, and herring, and all fish species and shrimp found in the stomachs are registered, only capelin and cod have so far been explicitly incorporated in the model. In future the work will be extended along two lines:

1. Species not presently included in the stomach sampling program, but which generate a significant predation mortality on the important commercial species have to be taken into account.

2. In addition to cod and capelin, important species-like haddock, herring, polar cod, and shrimp should be included in the model.

DISCUSSION

In the discussion following the presentation of papers, Bakkala stated that all available information indicated that the pollock populations in the eastern Bering Sea and the Gulf of Alaska were two separate stocks, and he focused on the similarities which were observed in their development. According to virtual population analysis, VPA, the biomasses in both stocks increased considerably during the period when the fishery developed, apparently as a result of good recruitment from a number of strong year-classes. In recent years both stocks tend to decline. He asked the question: "Is there something in the method of VPA that generates an artificial increase in abundance when catch at age data from a rapidly developing fishery are used?" Francis and Megrey stated that the underlying assumptions for the application of VPA should be carefully examined. In a number of cases some of the basic assumption might be violated, particularly in the case when data from a rapidly developing fishery is used. Nakken said that systematic errors in a VPA-series usually would originate from errors in the catch at age matrix, and hence, the historical catch at age data series ought to be scrutinized. Ulltang agreed and stated that basically there are two main factors which may lead to systematic errors in the VPA-results; these are errors in the applied natural mortality rate and errors in the catch at age data used. He doubted that errors or time/age dependent changes in the natural mortality would generate changes in stock biomasses like the observed ones. The chairman, Jakobsen, supported Nakken and Ulltang in that errors in catch data probably were the most likely reasons for wrong VPA-results, and he referred to a period for North Sea saithe when that had been the case. Macer mentioned that the increase in stock size of pollock in the 1960's coincided with a similar increase in stock sizes of North Sea gadoids, the so-called gadoid outburst.

Cohen referred to the patterns of occurrence of good year-classes and the possible explanations for the observed changes in stock biomasses. Both competition and replacement were discussed by the authors. He would expect variations in growth rates and maturity rates when stocks changed dramatically as a result of competition, and he wanted some further comments on that from the authors, particularly regarding the competition between adult pollock and Pacific ocean perch (POP). Alton said that in the Gulf of Alaska the two species fed on the same prey, mainly nectonic organisms. Gunderson stated that since the POP was a very minor part of the fish biomass in the eastern Bering Sea, it was probably also of minor importance as a competitor with pollock. Livingston agreed to that. She also commented on some results from stomach content analysis showing that cannibalism appeared in pollock. However, the observations did not cover sufficient areas to assess the effects of cannibalism on the recruiting year-classes. Dragesund would like to know the possibility for estimating year-class strength in pollock at the 0-group stage, similar to what has been done in the Barents Sea. He had noticed that 0-group pollock in the Bering Sea seemed to be distributed over a smaller area than the older age groups. This is contradictory to what has been observed in the Barents Sea where the 0-group as a rule is distributed over wider areas than are the older fish. Bakkala and Nelson answered that the 0-group surveys on pollock had been carried out for only a few years and that large year to year differences had been observed in the geographical distribution of the 0-group. The distribution area may well be larger than indicated by the results obtained so far.

Alton commented on the spawning areas and shift in distribution of pollock in the Gulf of Alaska. The major spawning site is in Shelikof Strait. Since 1977/1978 there has been a westward shift in the fishery from the Kodiak region to the Shumagin region. In 1981-1983 approximately 75 per cent of the total catches came from the Shumagin area. There has also been an increased fishing on Atka mackerel, a species which feeds on the same prey as pollock. Dragesund asked if there was a correspondence in the occurrence of strong year-classes in the Bering Sea and Gulf of Alaska. Alton replied that there was correspondence for some year-classes. Jakobsen asked if any tagging had been carried out in order to throw some light on the question of stock separation in the region. Alton said that tagging had been attempted in the Bering Sea but not in the Gulf of Alaska. The Bering Sea tagging had taken place on a small scale and yielded little success, but he was optimistic concerning the possibility to tag pollock from midwater trawl catches under certain circumstances. Nakken asked for comments on the seasonal distribution patterns of the adult fish. Alton outlined this for the Gulf of Alaska; in January the fish gather into Shelikof Strait for spawning. Spawning occurs in March-April and then the fish disperse into the Kodiak and Shumagin regions as far west as Fox Island. The main fishing in the Shumagin area takes place during the feeding season in May-October. Bakkala mentioned that in the Bering Sea no pronounced seasonal movements seemed to occur. There is a tendency of a shift towards the outer shelf (deeper waters) and southward during winter associated with the cooling of the water masses.

Megrey commented on the technique used in Cohen's paper. In the past, environment dependent spawning stock/recruitment models have been approached by applying parametric multiple regression techniques. Cohen used a time series technique and Megrey wanted to know if others had used the same technique with success. Cohen answered that the time series and transfer function approach had been applied by several investigators and that some very promising results had been obtained in lobster. Regarding recruitment, he believed that a series of factors were involved in the Georges bank area, including physical processes on both smaller and larger scales, as well as starvation, predation, and spawning stock/recruitment mechanisms. The figures he had used for one year old haddock recruits in his work were based on figures for three year olds estimated from VPA. Discards at sea of young fish and misreporting of catches could lead to errors in the age one estimates.

Macer commented on the main results arrived at and the difficulties faced by the multispecies approach taken by Shepard and himself. Such models are very demanding of data, particularly food consumption data. The chief difficulty lies in feeding relationships. The size preferences might be quite different from the actual size distribution of prey found in the stomachs. Another weakness is the mean weight of the 0-group fish, which constitute a major part of the prey. These fishes grow rapidly and an annual mean weight will probably be difficult to establish. Mean weights should, thus, be established on a monthly or quarterly basis. There are also area differences in growth rates which have not been considered. Despite these weaknesses, there is no doubt that multispecies approaches have to be considered in the future. The results arrived at are quite different from those obtained with single species models, and add considerably to the understanding of how fish stocks interact, fluctuate, and can be harvested and managed. At present data are collected from five fisheries for nine species and fed into the model, and preliminary results of this exercise will be available in the autumn of 1985. Francis was concerned that the significant impact on recruitment in most cases takes place long before the fish recruit to the fishery. Hence, recruitment should be monitored through surveys and given as input to the assessment models. How does this compare with the stock and recruitment relationships used in the model? Macer replied that there is a difference between the long term and steady state relationship between stock and recruitment and the year to year variation. "What we are trying to do with stock and recruitment relationships is to sort out the 'signal' from the 'noise'. Now we are concerned with the noise and once we have sorted out that, we will get an idea of the signal, and then we can proceed."

In a comment on Sunnanå's paper, Bergstad expressed his surprise that no relation between the temperature and mean length of 0-group cod was found. Using the same set of length data as Sunnanå, Bergstad indicated a correlation between mean length of 0-group cod and the sea temperature at the Kola meridian in the Barents Sea. He also commented on the paper by Mehl et al. According to his opinion, it would be important to include krill and perhaps copepods in the model. Nakken agreed to that.