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The Propagation of Cod *Gadus morhua* L.

PANEL DISCUSSION

The future of cod farming and the possibility of restocking local coastal cod populations.

Chairman: Dr. J.C. Gamble

Gamble

Good afternoon, ladies and gentlemen, it is my privilege to chair this concluding session of the symposium in which we are all going to have the opportunity to air our views whether for, against or indifferent, on the future of cod farming and the possibility of restocking local coastal cod populations. The discussions will take the following format:

First of all the subject will be introduced by Dr. Victor Øiestad, Institute of Marine Research, Bergen and then the other members of this panel will say a few things about their own particular specialitites. After that the meeting will be open to the audience.

The order of speaking of the other panel members will be: Mr. Ø. Ulltang, Institute of Marine Research, Bergen, Norway; Dr. N. Ryman, Department of Genetics, Stockholm University, Stockholm, Sweden; Mr. P. Solemdal, Institute of Marine Research, Bergen, Norway; Mr. B. Braaten, Austevoll Marine Aquaculture Station, Storebø, Norway; Dr. A. Jones, Shearwater Fish Farming, Abingdon, England.

Øiestad

The main purpose of our activity is to improve the economy in the coastal fishery. Some of the speakers have concentrated on the large offshore cod stocks, such as the North Sea and the Northeast Arctic cod stocks, but for the present discussion, we will consider the local cod stock along the Norwegian

coast. We want to see firstly if it is possible to restock these populations.

The second aim is to improve the recreational value of the Norwegian coast. Fishing in large areas of the Norwegian coast is now not really recreational, but, as we have more and more leisure time, which many people like to use for fishing, there could be a conflict between the fishermen and those just doing it for fun. This conflict might be reduced if we succeed in restocking local coastal waters with cod.

It is a paradox that fishery biologists are so concerned when dealing with the question of restocking or artificial recruitment, yet not so worried when stocks are being depleted. We also know that more or less irregularly most fish stocks produce outstandingly large yearclasses, which might in some way be considered as a type of restocking. I have never heard anyone regretting these strong yearclasses, they only regret that they are so seldom. For instance for the Northeast Arctic cod there have been six years with minimum recruitment. I suppose the dream of most fishery administrators, and probably the fishermen's too, would be a stable high recruitment of important fish stocks.

I assume most of you are familiar with fluctuating stock and recruitment curves. The strategy might be to establish the population we want to exploit at a high level by introducing extra recruits to stabilize the recruitment.

We are now facing a situation where this dream of fishery administrators might be a reality for local cod stocks.

The first condition for the realization of a stable high recruitment is access to large numbers of reared fry. If we really have evolved a method for mass rearing cod fry in a pond we should, within a few years, be able to produce several million cod fry. Depending on interest from the Government and others, it might be increased to some ten millions, perhaps some hundred millions, which according to Dr. Olsen are the numbers required for replacing the natural recruitment of the local cod stocks in the three northern counties of Norway.

There are a number of aspects to be considered if we intend to start a restocking programme in local areas or in a region.

Initially we should consider the optimal size of the fry released, since we are using a fairly large tag we are restricted to a fairly large size of cod fry, furthermore 15-20 cm cod fry are less exposed to predation from other fish. Dr. Riley mentioned yesterday that they had a fairly high return of 1-group cod tagged off The Netherlands coast, approximately 20 percent to date, which might eventually increase to 40 percent 1-group cod are approximately at this size (15-20 cm).

Dr. Blaxter during a meeting in Ostende in 1975 had stressed the importance of the behavior of the released fry. He had indications that laboratory reared fry were very naive and unable to take care of themselves in the open sea. As indicated by Mr. Moksness earlier today, the behaviour of cod reared in basins enabled normal growth and probably a fairly normal survival rate during the ongrowing stage. Furthermore in a pond system the individual cod is exposed to cannibalism and to predation by birds. They should therefore be fairly familiar with the need to evade predation. They can maintain station, as we saw during the videofilm, in the incoming tide water, and so they are familiar with swimming in a stream. They feed on the natural zooplankton, so are able to find their own food. They thus probably get more training than they usually would have in a natural habitat. I think altogether that cod fry produced by this method should be very well adapted for a life in the open sea.

We used a Floy anchor tag on the cod last year and we might consider other methods which we were recommended to look at, such as a mini flag tag produced in Britain. Then we have to find an appropriate release method, and I think that the release method should be more or less like planting a forest. Trees don't eat eachother, but they need some space. And if you are planting pine or spruce in an area where you planted the same pine or spruce some years ago, they will die due to lack of light. The same situation might be for fish. As the fish are very local we should not release cod fry in the same area year after year, but perhaps change to new areas or wait untill the older fish have entered deeper or other localities I hope at least that we will have a special group looking at

this aspect of the programme.

It is easy to imagine that a release of a large population of cod fry would have some impact on the natural population of cod in the area, and also on other fish populations. We know that cod is a clever predator eating mainly fish, and that it might threaten some other valuable fish species in the area. Alternatively it might mainly stick to fish species that are less valuable than cod. There will also be an impact on other food supplies for the cod if you release a large population. The benthic population might in particular have problems with the reproduction. As indicated for the Pacific cod, the large population depleted the shrimp fishery and there might be some effects along the same line destroying the fishery for *Pandalus borealis* in some areas along the Norwegian coast. Certainly we have to monitor the growth of the released cod, and as indicated by Mr. Moksness, the growth pattern in the small release in Flødevigen was the same as for the wild population.

Migration could be a factor particularly when the fish mature. They could migrate to spawn in special spawning places or emigrate through shortage of food. They might perhaps extend the area by migrating to other places with more food. It is very interesting to look at the question whether the fish will recruit to the natural spawning population in the area. I suppose we should use cod from the same area as brood stock and most probably the pond cod are talking the same language as the natural population, so there will be no problems of communication.

The fishing pattern will certainly be looked at closely. As indicated by Mr. Moksness practically all tag returns in Flødevigen were from sports fishermen, and that might be the situation in other parts of Norway, but the tag we intend to use in the future will have more information than the tag used by us in that particular experiment. There was no information about where to send the tag. The future tag used will indicate where to send it and perhaps also the size of a reward. It was also stressed earlier that the genetics of the population should be monitored closely, so as to minimize the diffi-

culties for cod in the future to remain in a defined area.

We should, most importantly, evaluate the tag returns to look at the economy of a coastal ranching programme on cod. As indicated by Dr. Riley we could perhaps have as much as 20-40% return of released cod. Perhaps we should wait till early January to release them as we will have no 0-group mortality! Certainly the carrying capacity of the area should be investigated.

As you will see this activity should demand a new institute at about the same size as the institute we have in Bergen. I doubt that our Government would be willing to pay another 200 people. But nevertheless I think that many fishery biologists would like to participate in such a programme. The number of basic questions in fishery science might have an answer and I hope Norwegian and foreign scientists together will establish a working group on this subject, preferably within ICES. Personally I think we are heading for a new strategy in fishery management. Most human activities are changing rapidly, including the fisheries, and we will always be in a transitional position between yesterday and tomorrow. The culture-based fishery on cod might need some years to prove its profitability. We should perhaps give it these years to find out, and perhaps we might during this period change the approach to a number of questions. For some other species than cod, alternative methods than release of fry might be applicable. Therefore I would recommend that the Government escalates the research on ecological relations in the sea, since we might discover other methods for controlling the population size of main species.

I have proposed a long term aim which is a strategy where man, to a large extent, decides the strength of different species by use of a number of different methods not in use today. This might sound very unprecise and general but the message is that we should be paid to think untraditionally and we should be permitted to test out new approaches to old problems. This will cost money, but there will certainly be a high payback on these investments.

Ulltang

I will during my five minutes now try to summarize very briefly the factors I think should be further studied before a large scale research starts on a regular basis. Some of these factors were already mentioned by Dr. Øiestad, and I will do it very briefly.

Firstly, one of the critical questions which we really do not know the answer of is what happens with the released fish between time of release and the time of recruitment to the fishable stock. How many are dying and further, of what causes are they dying? Will they be rather stationary, i.e. stay at the same locality where they were released? The answer to that question is of importance before one should carry out the release.

Secondly, how will they mix with the natural population? Will they mix with the natural population to an extent that makes it possible or sensible to treat them as one management unit? If the answer is yes the questions are then: What mechanisms are at present regulating recruitment, mortality and growth in the natural population, and how will an input of a significant number of recruits influence these mechanisms? I tried during my talk this morning to illustrate the importance of knowing the form of the yield curve of the natural population for calculating the gain by releasing 0-group fish. I think that this cannot be stessed too much. If you want to be sure of getting enough gain from your production, you need to have some ideas of both the form of the yield curve of the natural population and of where you at present are on that curve.

Probably the largest relative gains could be achieved in rather small local stocks. The problem in those cases I think, will be what effect building up of a cod stock to a much higher new level, will that have on the established ecosystem in the area. Each stock has developed through a very long historic period and established a certain level around which it fluctuates. We do not know how these levels were established, for example we do not know why the cod stock in an area is five times larger than that of the the haddock stock.

But, if by putting artificially produced cod into such an area, you double the cod stock for example, some effects on the rest of the system will have to be expected.

I am, of course, aware of the fact that just by starting to fish the stocks we changed the system. We really do not know to what extent we changed it, because we have no proper data from the earlier periods. But when trying to increase a stock of cod, which feeds extensively on fish, I feel it is unsatisfactory just to answer the question by saying that we already have changed the system. I think this should be further evaluated.

Finally, since I probably have been interpreted to be rather sceptical about the project, I would like to congratulate my colleagues in, for example Austevoll, for the results they have achieved so far in producing the cod fry. I have both now and in my talk this morning mentioned some factors which need careful examination. The point is that some of these factors cannot be studied without a rather large scale release.

Ryman

I am glad for this opportunity to say something about the population genetics of cod. Because of some particular circumstances I was not able, unfortunately, to accept the invitation to give a special paper. I am a population geneticist and I think that I am supposed to give my view on how population genetics data can be used to predict the effect of the release of large numbers of artificially reared cod. This general question reduces into two separate questions. First, what is the effect on the genetic composition of natural populations? Will release of artificially produced fish destroy the resource, for instance through hybridization and destruction of genetically complex population structures? Secondly, what should the released fish look like genetically to provide the best harvest? This further reduces to one single question, I think. Namely, what do we know about the population structure of the Atlantic cod? I want to stress that we do not know everything, but we know a few things, and I would

like to summarize what I feel that we know.

What I want to say is that we usually look at nature in a kind of hierarchical system. At the base we have individuals, which combine into demes or populations etc, upwards, and this is assumed to reflect some kind of an evolutionary relationship. We can now, primarily by the use of electrophoretic techniques, quantify the amount of genetic diversity between different groups of individuals at different systematic levels if we use a large number of randomely selected loci or genes. This permits us to tell how much different various population segments are from one another.

There is only one study of this kind that I am aware of, made by Grant and Ståhl, who estimated genetic distances between and within the two species of cod, Atlantic and Pacific cod. The genetic distances observed between the two species is about what is usually found among true species. There are two samples representing the Atlantic cod from Georges Bank and from the Baltic Sea. It is very clear that, compared to differences between species there are only very small differences between those two samples from each part of the Atlantic Ocean. Recently we have concluded some studies in cooperation with Mork and some other people, just to delineate that branch of Atlantic cod in a little more detail. I will give you some results from that study, too. I want to mention that the next few examples giving genetic distance scales cannot be compared with this one, because those distance scales are based on different sets of loci that have been selected just to provide a better picture of the population structure, not to estimate unbiased genetic distance values.

The range of the populations we have looked at cover the west part of the Atlantic through Greenland, Iceland and some different sampling locations in Scandinavia. It is very obvious, to start with, that the population in the Baltic Sea is the population that deviates most from everything else. The rest of the populations are fairly similar, actually. The Greenland and the Gulf of Main samples cluster, and are different from the rest, but all the other populations give just one single cluster. I think this picture reinforces the previ-

ous one, namely, there are absolutely very small differences in the Atlantic cod. I would like to compare this with some other species and I would like to change into kind of a different scale.

Even if the absolute differences are small, there might be relative differences that are important. I mean, maybe they are not very different on an evolutionary scale. However, the total amount of diversity existing in the species, might to a large extent be distributed between populations, and not within populations. For instance cattle or different breeds of dogs are really not very evolutionarily different, but they are genetically different anyhow in a way that can be utilized by man. There are some statistical ways to decipher the total amount of genetic variability between and within populations.

Let us ignore the statistical part of it. The only thing I want to say is that we can look at the total variation existing in the species, and we separate the components, within populations and between populations. Just to give you some kind of a standard, if we do this in humans we find approximately 90 percent of the variation existing within populations while the remaining 10 percent is between populations, and population groups.

To give some kind of a comparison, I have included four different salmonid species, i.e. the Atlantic salmon, brown trout, rainbow trout and sockeye salmon. I want to compare that with two oceanic species, the Atlantic cod and the Atlantic herring. Let us look at the relative gene diversity within populations. For instance, the first line says that in Atlantic salmon 70,6 percent is found within populations. That should be compared to the 90 percent found within populations in man. It is quite clear that most of the salmonid species, except for sockeye salmon, show very strong amounts of subdivision, that means a small fraction within populations, and a large fraction between populations. That is of course, the basis for our concern about the effects of aquaculture on the genetic structure of naturally reproducing salmonid populations. However, in the Atlantic cod, the situation is quite different. We have essentially very, very little diversity

between stocks, and almost all the variation is found within stocks. In summary, I think this indicates that there are no indications of a very complex population structure, i.e. of a complex genetic population structure. I think that Mr. Jørstad's data from yesterday indicate that there might be a few exceptions within one or a few particular fiords. However, at large, the present data indicate that there is a very small diversity between different stocks of cod. I do not think that releasing large numbers of artificially produced fish will have any large impact on the resource, and the resource I define as the genetic structure of naturally producing populations.

Just a few words about the next question. What should the genetic composition of the released fish be, to maximize harvest? We do not know, actually. But it is clear that the large morphological diversity observed between different stocks is not reflected in electrophoretically detectable genetic differences. And it appears that most of the stock differences are environmentally induced. Mr. Mork's data from yesterday also indicate that selective factors are different at different locations. The only conclusion I can draw from this is that brood stocks should be local, that is, they should be derived from the geographic areas where the artificially produced fish will be released.

Solemdal

I have been involved in laboratory, enclosure and field investigations on cod eggs and larvae since 1968 to study the main factors governing survival and growth. From this work I have learned, at least, one thing: the fluctuations in year-class strength have a multifactor background. In this introduction I will stress the present state of "artificial" production of cod fry, which is a crucial point both for cod farming and restocking. As Dr. Jones pointed out it is necessary to calculate with some degree of certainty the number of fry to be produced. This consistency in production is a must both in commercial farming and restocking projects.

In Norway developments of cod fry production are conducted

along two lines:

1) Intensive rearing of larvae in plastic bags, fed on concentrated natural or/and cultivated plankton organisms.

2) Enclosures, based on natural production and some control of the environment.

According to the need of the commercial farmers for a consistent, reliable number of fry to be produced, I think the bag method seems the most promising because of the greater possibilities for environmental control.

Since this method has been under development for only a few years, many technical problems still have to be solved.

But the results so far, given by Mr. Braaten, clearly show the possibilities of this method.

The enclosure method is more similar to the field situation, though some control of predation etc. is undertaken. As in the field the cod larvae in the enclosure will meet varying conditions from year to year, which leads to the question: "will there be good or bad yearclasses in the enclosure?" If there are, this will be detrimental to farming, since the cod farmers want to plan the number of fry in advance. In addition, unpredictable variations in numbers of cod fry from the enclosures will be undesirable in the restocking context, especially if large yearclasses coincide in the enclosure and in the field. This situation seems to be the case this year.

The results of the enclosure experiments so far are encouraging, especially this year. At the moment only one enclosure is run each season. To get reliable figures of the consistency of this production method and the yearclass variation will thus take a very long time. To reduce time, and also to get a better understanding of the mechanisms ruling the number of cod fry in the enclosure, it would be better to run a number of smaller systems with different types of environmental manipulation, or as parallels. Suitable enclosures already exist here in Flødevigen.

Farming of cod seems to me to be an easy task when the problems of fry production are solved. The success is mostly a matter of economy. Enclosures, artificial and natural diets, medicines etc. can more or less be copied from the salmonid

farming. It will be like raising pigs!

Coming to the crucial question of the possibility of re-stocking local coastal cod populations, I would like to recall a statement by the Norwegian fishery scientist Johan Hjort from his book "Fishing experiments in Norwegian fiords" from 1899, put forward during the quarrel between him and Captain Dannevig about the effects of releasing yolk sac cod larvae into the sea: "At the moment this work should be regarded as a study, and not as the practical result of it". Much can be referred from the dialogue between Hjort and Dannevig (the detailed story is found elsewhere in this volume).

Today the situation is in many ways similar and the citation is still relevant. The release of yolk sac larvae was carried out for a long period before scientific experiments to investigate the effects of release were performed. Now we have the possibility to perform the necessary experiments before a practice is initiated. Therefore, it is time to sit down and plan the experiments which will give the answers for further large-scale practice. Let us not repeat the lesson from earlier times!

To summarize my points:

1. The large-scale production of cod fry will be a reality within few years. The variation in production ("yearclass strength") probably will be less in bags than in the less controllable enclosure method.

2. The farming of cod will be possible when the problems of fry production are solved. The future of cod farming will entirely depend on economic criteria.

3. The present state of cod fry production makes it possible to perform field experiments to obtain information of the effects of releasing fry into different local cod populations.

4. On the basis of the field experiments the usefulness of restocking can be evaluated.

Braaten

I want to make some comments about the intensive rearing of cod, but first some general information.

By January 1983 the Directory of Fisheries had received 115

applications for cod farming from 11 counties in Norway. A Norwegian fish farmer is given licence to breed salmonids in a certain volume of water ranging from 3000 to 8000 m^3. The applications for cod farming represent a total volume of 1.3 x 10^6 m^3, compared to 2 x 10^6 m^3 for the existing salmonid farms. 20 000 tons of cod could be raised easily on such a volume. The production of salmonids was 15 000 tons in 1982.

Some unlicensed cod farms are now in operation which base their production on raising natural stocks of small cod caught in nets and fish traps. The professional fishermen's organization is worried about the increased catches of wild cod for farming purposes and will probably try to stop them by law.

For comparison I want to mention that the farming of Yellowtail *Seriola quinqueradiata* in Japan has for many years been totally dependant on catches of wild fry since they were unable to breed them in captivity. For many years the collection of fry has been considered safe as long as the catch is around 20 million fry per year.

In order to establish an economical intensive fish farm on new species like cod, some basic requirements are needed.

1. Steady supply of fry or small fish. For cod it could be either from wild sources or from culture systems like the enclosed pond.

2. Effective treatment against diseases, like vibriosis. The same strain of *Vibrio anguillarium* which has been shown to cause high mortality in saithe is also attacking cod. A vaccine should be developed as well as antibiotic treatment.

3. Regular supply of cheap raw materials for feeding cod. The diet must fulfil the necessary nutritional requirements for cod. Large amounts of fish waste from processing are dumped every year which could be used in feed production for intensive farming.

The technique for raising cod is basically the same as for salmonids, when the fish has reached the required size for rearing in a net pen. A major obstacle, to make the cod accept a dry pelleted feed, seems to be solved. Experiments in May - June 1983 at Austevoll Marine Aquaculture Station with a new dry pellet has been very successful on cod fry. Growth of the

cod is very fast and cod of 400 g and 2000 g can be produced after 12 and 21 months respectively. High efficiency values were also found and it was possible experimentally to produce 1 kg of cod on 2 kg capelin. For large scale operation a food factor between 3 and 4 can be expected. It is possible to avoid cannibalism by grading and regular feeding of fry since it was not observed among larger cod in optimal feeding and rearing conditions. The optimal temperature for raising cod seems to be near 10°C but good growth has been observed at 6-7°C in large fish.

Maturation was near 100% for two year old cod. Harvesting should therefore be done before spawning because of a substantial weight loss after spawning. It takes almost half a year before a postspawner has regained its prespawning weight.

It is still an open question if cod can be farmed on an economical basis in Norway. The production cost per kg salmon is estimated to 20-25 Nkr. Similar figures have not yet been estimated for cod, but rough estimates indicate 12-15 Nkr per kg. Cod larger than about 100 g seem not to feed more than one large meal every second day. Less work and high efficiency can explain the lower production cost in comparison to salmonids.

The quality of cultured cod differs from the wild fish. The cultured fish should be sold fresh as quality criteria like taste, flavour and consistency will change rapidly when the fish is frozen and stored for substantial periods. A starvation period of several weeks is probably needed before cultivated cod can be compared to wild cod.

Finally, a few words about the release of cod fry in nature. The cod has been chosen as a case study due to its importance in the fisheries. We believe that a similar technique can be used on other species if this is desired. The natural population of cod has been decreasing in the last years. If this situation continues, combined with overfishing and lack of political agreements to conserve the cod stock, a total extinction of the cod stock could be a reality. Faced with such an eventuality, we would have methods to rebuild the stock again.

Jones

I really cannot add much more to what I said this morning, so I'll just recap a little. We have seen that cod can be reared from eggs to fry in large numbers in artificial and natural systems. We have also seen that cod can be grown from fry to marketable size in cages and enclosures at acceptable growth rates and stocking densities. On a technical level then, intensively controlled cod farming would appear to be possible. However, preliminary analysis of the economics of intensive farming based on U.K. costs, indicates that farmed cod would need to command a market price of at least 24 Norwegian kroner a kilo, compared with the current retail price of about 16 Norwegian kroner a kilo, and clearly at this stage it is not profitable. However, one cannot see into the future, and if natural stocks continue to decline, and demand cannot be satisfied, then perhaps one could see a significant strengthening of the retail price of cod.

Before coming to this meeting I talked with some of the larger retailers of cod in the U.K. and their feeling was that it would be very difficult to see a sustainable premium for farmed cod over naturally landed products at this time, and really what we are dealing with is a commodity, where the housewife will buy the cheapest cod available. I think having said that, it is possible that were cheap sources of feed-stuffs exist, such as here in Norway, small and perhaps more significant activities could flourish. Most of the talk from the panel so far has really been about release of fry, and I do hope that someone, at the same time as looking at the economics of sea ranching, will think about comparing this with the economics of intensive farming. We heard this morning that one million released fry could give an additional yield to the natural fishery of about 230 tons. Now, one million fry intensively farmed could give us 1600 tons , about 8 times the quantity. I think the two approaches should be looked at together rather than looking at sea ranching in a separate way. Clearly the overriding consideration is what happens to the artificially reared fry when they are put in the sea, and until one has some idea of the natural mortality, it is going

to be very difficult to answer that question.

meeting is open for discussion but, to try and state
felt was the tenor of the points made by the panel and
s direct the questions along a certain line (which I do
make dominant), I will put a few questions. First
e that we have solved all the problems of rearing
move into the real unknown. What is the strategy
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Gamble

This raises two questions, firstly on the possibility of rearing cod to a 1-group size and secondly, is it fair to apply data obtained from the open coastline of Denmark to a fiordic system as in Norway?

Braathen

Just a brief comment on how to raise cod up to 1-group size. For example in the pond system this year we required 20 tons of dry pellet food to rear them to 15 cm. So it will be quite a large cost to raise them up to 30 cm.

Ulltang

I think Mr. Bagge raised a very important question. During this morning I presented some results of a simulation model were I assumed a rather high predation mortality on the 0-group. The results of the calculations would have been completely different if for example a large part of the mortality on 0-group occured before that time. So it could be the case that the gains would be significantly higher if you just delay the release by two or three months more.

Fridgeirsson, Iceland

While wishing to encourage the work being done on culture and restocking of cod populations I would like to make a comment about yearclasses in large shelf stocks of cod. Dr. Øiestad mentioned that there has not been a good yearclass in the Barents Sea for six years. The same situation exists in Icelandic waters. We have not had a really good yearclass for at least seven years and even 1976, which seemed to be quite a good yearclass according to 0-group, has not shown up in the fisheries. We should be concerned if we think that the brood stock is not producing a good yearclass when conditions indicate is should. However, I think we should be very careful not to force a good yearclass upon nature when it is not needed or when there is no environmental capacity.

With Icelandic cod stocks we are facing a situation where, on top of overfishing and low reqruitment for several years,

the growth rate of cod has fallen drastically in the last few years. I have been wondering, if we had had, in the last seven years, a really enormous cod stock, what effect this would have had on the growth rate of the stock? Maybe it would have led to something worse than the present situation.

Gamble

That is a good point. Should you really try to force a good yearclass on a year in which there is possibly not the capacity for such an enhanced yearclass?

Øiestad

That is one of the aspects we wish to study where repeated large yearclasses are induced in certain regions and their effects evaluated. Hopefully we might learn what the cod will do in such a situation, perhaps there will be migration away from the region to occupy other places. As yet we do not know.

Danielssen, Norway

It seems to me from the release of cod in Flødevigen by Dr. Øiestad and Mr. Moksness that all of the recaptures came from anglers, i.e. sportsmen. This suggests that if cod are to be released at O-group size, most of the recaptures will also be through angling. This raises the question of whether we are releasing cod fry merely to enhance sports fishing. Some further experiments with older cod (30-40 cm) at Flødevigen gave very high recapture values of 60%. Only half were from anglers, the remainder were caught commercially. This consideration should also be considered when designing a release programme.

Gamble

I am still uncertain whether or not we have established that reared cod are as suited to natural environment as are wild individuals. That same doubt arises when such a high proportion were caught by anglers. Were these fish relatively naive? They were used to being fed, in consequence they could have been somewhat more susceptible to this type of predation.

Øiestad

The cod were not fed at all, they had to find their own food in the basin. Concerning the question of naive cod, Mr. Solemdal suggested that laboratory production is a more reliable method. I suppose you know the fate of plaice produced in a laboratory and released in British waters. They were rapidly eaten by predators. Hence I think for coastal ranching purposes we should use enclosure systems for production of fry. They seem to be best adapted to existing in the wild.

Moksness, Norway

Very little has been said about predation at the meeting. Mr. Ulltang mentioned the work done by Daan. I have been rearing cod during the last five years. I cannot remember the exact proportion of cod in these experiments which were eaten by other cod in the same tank, but at least it was as high as 20-30%. Cannibalism has been directly observed in the cod tanks and I think we should not ignore such an important potential cause of mortality when considering the fate of cod released in the sea. We know very little about it.

Gamble

Initially I suggested we assume that we were successful in rearing cod. Nobody, to the present, has said anything about how to choose a site for release and restocking.

Olsen, Norway

Some years ago, when we were discussing the progress and strategy for cod rearing, the Director at the Institute of Marine Research in Bergen stated that we must first solve the problem of rearing cod and producing fry in large numbers before considering other questions. The time will then come when it will be appropriate to think of carrying capacity and the effects of releasing large quantities of small fish on particular local ecosystems.

In my opinion we have now reached that time and I think that this meeting perhaps should conclude with a recommendation that these ecological studies be started rather soon. If

we start at a moderate scale, such as within a Norwegian fiord, then the chances are reasonable of achieving some sort of result in an acceptable time. For instance, regarding carrying capacity or potential growth, mention was made yesterday that cod in fiords were generally smaller than those outside. Maybe, despite the present low fiordic cod populations, the potential is not as much as we would hope for. In Northern Norway, the quantity and quality of food appear to be sufficient, yet growth of cod is small. There are many problems yet to be understood which require answers and which we must start investigating. I ask this meeting to endorse this recommendation that such studies be started.

Gamble

I do not know whether it is in the remit of this particular symposium to make specific recommendations, but I hope that those people who submit research proposals in this field and those who review such proposals will consider the points made at this meeting. I hope that this embodies a recommendation.

You have also raised a very good point. A colleague of mine in Aberdeen, Dr. A.D. Hawkins, has worked extensively on the behaviour and ecology of juvenile cod (0-, 1- and 2-group) in a sea loch (a fiord) on the west coast of Scotland. His results, which are to be published soon, are most relevant to some questions being asked at this symposium. He is, however, a bit sceptical about the proposal to ranch cod in such a locality. He has found, for instance, that the cod in the loch (L. Torridon), although having av high potential growth rate when measured in the laboratory, grew at a much slower rate in one loch. Furthermore the rate was particularly low during winter. He believes that food limitation is a main cause of this; particularly benthic food on which these immature cod feed.

The other highly relevant piece of work done by Hawkins and his group concerns the dispersion of the cod population. Using sonic tags within the fish and hydrophone arrays on the loch bed they were able to show that the cod in L. Torridon occupied specific home ranges of rather limited extent. This

finding implies that only a limited number of cod can occupy the space within the loch. If further cod were added there would not be any space for them. There may also be more cod in the background ready to occupy prime niches within the loch, should any become available.

Thus there may be a defined stocking level which a loch, or fiord, can sustain. I am wondering whether in Norway you have any specific fiordic system in mind for the release experiments. If you do what information do you have about it and what information needs to be acquired before the cod fry are released?

Østvedt, Norway

I think that what is now needed is close co-operation between people working directly on culture and ranching and those interested in natural populations. Much more information is required on natural populations in various Norwegian fiords as well as in other places before we can recommend release of fry as a commercial operation.

Dragesund, Norway

Although there are many things which can be discussed here I agree with the chairman that we should concentrate on specific research strategies. I also agree with Dr. Jones when he suggested that we should compare the two approaches; intensive fish farming and enhancement/sea ranching programmes. It would seem that the commercial fish farmers who are interested staring up with cod will prove to themselves whether this approach is viable. Since we appear to have solved the initial rearing problem the trickiest questions remaining are concerned with sea ranching.

We have learned much from our coastal cod programmes, including indications that the inshore cod stocks are small and that their potential is not large. I think, however, that we are now at a stage where we should release some 0-group fry to look at effects on local cod populations and to get an idea of the percentage recapture of the released fry. I disagree some what with Dr. Bagge since we have results showing a very clear

correlation between the strengths of 0-groups and subsequent yearclasses but this can, of course, vary from place to place. However, I do find Mr. Fridgeirsson's observations on the reducing growth rate of cod in a declining stock to be quite unusual; normally we find better growth rates in smaller stock sizes.

Smith, U.S.

As an alternative to just choosing a particular site for stocking, a better experimental strategy might be to select two populations. Priorities on questions about the effects of stock enhancement might be decided by manipulating one of these two populations for 2-3 years leaving the other as an unaltered control. After this set time the situation could be reversed. This could be a useful strategy which would help to answer certain testable hypotheses and save having to interpret obscure results from a straight stocking experiment. It should precede any major stocking programme.

Danielssen

In support of Professor Dragesund's observations I would like to say that, along the coast here (Flødevigen) there is a close relationship between 0- and 1-group stages of cod. This is a finding from a field experiment described yesterday by Mr. Tveite.

Gamble

One possible danger of embarking on a detailed examination of chosen localities might be that of losing perspective due to the amount of information which will be produced. The objective which should always be aimed for is the cod ranching programme and not the ecology of certain specific localities.

I think another aspect which arises concerning the ranching programme is the economic consideration of who pays for it. Whereas in intensive farming the financial responsibilites are easily defined, those for ranching are much more vague. Who pays for the fry and how is ownership determined?

Øiestad

As long as we are at the experimental stage then the funding will obviously have to come mainly from the Government. I see no problem paying for production levels up to 100.000 fry per year in this manner.

Gamble

Yes, but I was thinking when things were being stepped up to a quasi-operational standpoint when we would be talking about ten million fry. This is a really large commitment in terms of personel and equipment. Presumably you would then need commercial backing.

Jones

One of the things which interests me is just what size the fish will be released at. People have talked about 20-30 cm individuals which weigh about 70 g. If we release one million cod at 70 g that is 70 tons of fish, which will require something like 200 tons of capelin to rear to that size. Obviously we are already into intensive farming before releasing the cod.

Olsen

To return to choice of site; in Tromsø we feel that if a big project is to be initiated then it is very important to gain the goodwill and cooperation of the local fishing community. We also think that one of the main problems will be to control the numbers of predators within the chosen area. These could be, for instance, large cod so it might be necessary to close off the area or otherwise limit the numbers of large fish. Obviously this will need the help and understanding of the local fishermen.

Gamble

Cooperation is the key word here. It can take the form of asking the fishermen to keep out of your research area but someone is going to have to pay for the 70 tons or so of fry. If the objective is to enhance the local cod population and

hence increase the size of the fishery then some form of levy on the returns of the local fishermen might be regarded as another form of cooperation.

Blaxter, Scotland

Could I return to the point that the chairman made about the territoriality of cod, in other words the problem of the carrying capacity of the environment. As far as I can make out the only experiment that might be relevant to this is the release experiment done at Flødevigen in 1977. Do the Flødevigen scientists now have any approximate idea of their input into the fiord, did they increase the population there by 1% or by 10%? This might give us some idea of whether the environment can carry those extra fish.

Danielssen

We have no information on this and so have no idea by what proportion the indiginous population was increased.

Tveite, Norway

During the autumn after the release of the cod we did not get any recaptures in shore seine samples in which we caught about one hundred cod.

Dragesund

A brief comment on the carrying capacity of different fiords. I am quite sure that most local fish stocks are overfished and so the number of fish must have been much higher in earlier years. However, the cod prey organisms are also overfished which could in itself affect the present carrying capacity. Prey species such as sprat and herring are rather scarce now in the fiords. Nevertheless, the potential carrying capacity is higher than the stock size of the present local stocks.

Øiestad

With regard to Mr. Tveite's comment we fished for 1-group cod with a beach seine in April 1977. We recaptured two tagged

cod in a total catch of 200. The tagged fish were from a batch of 700 released in September 1976. It is difficult to calculate the whole population from this 1% return, but at least it indicates that the introduced and wild fish are mingling.

Ulltang

To return to the question of choosing an experimental area for release, I think it most important that an area is selcted where there is data already available on important biological parameters such as species composition, size of stocks and growth of different species. Ideally, data should be available for several years before the recruits are released.

Moksness

Could the total biomass of fish in fiords and inshore coastal areas have remained much the same in that commercial fish species were replaced by other species which were not fished? This could alter estimations of carrying capacity.

Solemdal

I would like to put a question concerning fry production, namely: will there be large and small yearclasses of pond cod? I believe that as yet we cannot guarantee numbers of cod fry but presumably we will have to develop control methods. I also feel that dependence on a single production system is very hazardous since many things could happen which cannot be foreseen.

Øiestad

We have carried out experiments in the Flødevigen basin for six years and we have always been surprised at the similarity between the numbers produced yearly. In the pond system at Austevoll, which is different from the basin at Flødevigen, we have had more variable results. This year when we released cod populations at ten day intervals we obtained 50-70%, 30% and finally 10% survival in each of three successive cohorts. Since we expected 10% to be fairly good survival we feel we

obtained three strong yearclasses. However, in the three preceding years we had fairly bad results. Of course it takes time to learn to monitor and manage such a system but we now think we know how to stock cod larvae. This knowledge will be tested next year using a new pond.

We also are considering using cod which mature later than coastal cod such as those bank cod which enter the Møre coast and which first spawn at five years old. This type of cod could be the correct one to use in intensive culture.

On the point raised by Mr. Ulltang about the need to have several years of data before embarking on a stocking programme; I am afraid that the Institute of Marine Research has been too preoccupied with the more oceanic populations. It might therefore be difficult to find a location which has been studied for a long period except for some areas close to Trondheim and maybe some of the fiords close to Flødevigen.

Gamble

You raise a point which Dr. Ryman mentioned; that of selecting varieties of cod which have advantageous characteristics for rearing. However, could this not create greater problems because the cod are being reared in a much different locality to their normal one? Dr. Ryman recommended that the optimal choice of site would be one where the parental cod were caught and where the culture and release of fry took place.

Ryman

Yes, I think that you should stick to local populations since a problem is that we do not really know the value of characters such as age and maturity; they have yet to be studied.

I have two comments to this discussion. Firstly, Mr. Jørstad's data quite clearly showed that some fiordic cod populations differ genetically from the rest. It is very important to identify these and this should be done before the final choice of experimental area is made. Secondly, if you want cod to mature at five years old, the only thing to be

done is to pick them out. We do not know whether time to maturity is genetically determined or not; the only information we have is that the amount of morphological and behavioural variation we observe does not correlate with electrophoretic data. Hence the best option is to select a fish as similar as possible to the one you wish to produce. I think that you should be as local as possible deriving from the area where the releases will be made. In my opinion there are quite a few different selective forces operating which vary between localities.

Øiestad

We can, of course, obtain brood stock from the area where we intend to release the fry.

Godø, Norway

I have been studying the catch statistics in the coastal area and found that there was a drop in the catches during the last part of the 1960's which can be linked to the decline of the herring fisheries and herring stocks in the area. If we can now observe that cod catches are increased as we see the increase of the herring stocks, it may indicate that the carrying capacity of the system is not too loaded and will accept a build up of cod fry in the area.

Gamble

I think that is an optimistic point to close on. For my part I feel that we are healthily sceptical about the whole cod culture programme but the people at Flødevigen and Austevoll must continue with this work. I would, however, recommend from my viewpoint and from, I hope, many others', that it is vitally important to find out as much as possible about the area in which the releases are to be made before any releases take place.

SECTION VIII

Summing up

by

J. H. S. Blaxter