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REPORT FROM THE SYMPOSIUM ON SEA RANCHING OF COD AND OTHER MARINE FISH SPECIES. ARENDAL, NORWAY 15-18 JUNE 1993

by

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ABSTRACT

Recent ranching experiments aimed to enhance the stocks of cod on the Norwegian and Danish coasts have led to disappointing results. The young stages were reared before releasing as juveniles. The use of tags and genetic markers showed that, although emigration was minimal, long-term enhancement of the stock did not occur. It appears that the "carrying-capacity" of the inshore areas is limited, leading to density-dependent mortality. Considerable insight has been obtained on fjordal ecology; this suggests that releases on a more open coastline might be beneficial. In addition the enhancement of sport fishing needed to be evaluated.

Ranching of Pacific salmon by releasing reared smolts has also been disappointing. Some enhancement did occur but the fish were smaller and the catch dominated by the releases. Japanese flounder and Texan red drum stocks have, however, been enhanced by ranching.

INTRODUCTION

In 1982 the Flødevigen Marine Research Station celebrated its centenary, and in that connection arranged an international symposium on the Propagation of Cod in 1983. In earlier years the main objective of the Flødevigen Hatchery was to increase the natural population of the local cod stocks in the area by release of large numbers of yolk-sac larvae. However, these releases were never been proved to have any significant effect on the size of the natural cod population (Tveite, 1971). At the 1983 symposium, the first results of releasing of artificially reared 0-group cod were presented by scientists from the Flødevigen Marine Research Station (Moksness and Øiestad, 1984). The panel discussion at that Symposium, focusing on the future of cod farming and the possibility of restocking local coastal cod populations, concluded that sea ranching should be examined in more detail and, in addition, the vital importance of collecting as much information as possible about the release area before a release took place was identified.

There has been an increasing international interest in the enhancement of local marine fish stocks over the past decades, with Japan as one of the leading nations with experience back to the sixties. In the Pacific about 30 marine fish species have been identified for sea-ranching but in the Atlantic less than 10. Based on the information given at the 1983 Symposium (Dahl et al., 1984), and the success at that time to produce large numbers of juvenile cod in meso- and macrocosms, the Institute of Marine Research in Norway started an enhancement programme on cod in 1985. The Norwegian Fisheries Research Council decided to start a large sea-ranching programme on cod in 1987, and in 1991 the Norwegian government initiated an even larger sea ranching programme which included cod, lobster, salmon and Arctic charr. In the past ten years, three extensive sea ranching projects on cod have therefore been conducted along the length of the Norwegian coast. In addition, similar projects on cod and flatfish have been undertaken in other Nordic countries. The main objective, like that one hundred years ago, is still: can sea ranching of marine fish be a future means of increasing fish stocks?

The size of such populations, the annual fluctuation in yearclass-strength, the level of juvenile mortality and its causes, population genetics and the natural ecosystem in the release area have been identified as important parameters to quantify when evaluating sea ranching of marine fishes. In addition, the economic consequences have to be examined before a final conclusion can be made. The main objective of the 1993 symposium was to: "..... present, discuss and evaluate the current knowledge on stock enhancement of marine species in general and cod in particular. Special attention will be paid to the ecological effects of large scale release and the potentials and limits of stock enhancement".

GENERAL COMMENTS

Two types of ranching have been described at this Symposium. These are:

1) restoration of depleted stocks to their "historic" level.
2) enhancement of stocks above their "historic" level.

These stocks may be of localised non-migratory fish depending on local sources for food, or high seas migrants foraging in the open sea.

Among the localised species this Symposium has been dominated by the cod (as befits the venue in Arendal and Norway) but we have heard about work on turbot, red drum, and ling cod as well as Japanese red sea bream, black sea bream, flounder and rockfish; of these, cod, red drum and flounder are the most fully documented. This work has been done with the purpose of enhancing local stocks and any intention of attempting to increase major offshore fisheries has been abandoned since the last meeting in Arendal in 1983.

We have also heard about Canadian, Japanese and U.S. efforts to enhance Pacifif salmon stocks on a huge scale. The apparent attraction of this strategy is that smolts can be produced easily (if expensively) in large numbers and released without a subsequent feeding problem. The results have been most disappointing. On the American side the Lake Michigan chinook fishery was initially enhanced (but has collapsed recently although it is still above the historic level). The Alaskan pink salmon fishery has also been improved by large-scale releases but these artificially reared fish now dominate the catch. On the Japanese side the chum salmon fishery has been greatly enhanced but now, although the fish are more numerous, they are smaller. This means that density-dependent effects are occurring on offshore feeding grounds.

Achievement with cod

To return to the cod, it is worthwhile listing the achievements over the past 10 years. These are:

1. Successful large-scale production of 0-group cod.
2. Release of cod in four areas in Norway (Tromsø: 80,000, Rørvik: 40,000, Bergen: 500,000 and Risør: 40,000) and cod also released in the Danish Limfjord.
3. Good comparisons made of the diet of wild and reared cod.
4. Successful marking by external Floy tags, by use of alizarin or oxytetracycline to mark otoliths and vertebrae and by genetic markers.
5. Recapture success allowing comparisons of growth and mortality of reared vs. wild cod.

6. Biomass estimates by echo-integration and mark-and-recapture methods.
7. Manipulation of feeding behaviour and distribution of cod by the use of sound stimuli to locate feeding stations.
8. The beginnings of an understanding of the nature of carrying-capacity of habitats.
9. A deeper knowledge of fjordal ecosystems from the Tromsø area to the Skagerrak.
10. Useful results from modelling, suggesting, in particular, the importance of advected food sources.

Main findings with cod

From the positive aspect, it has been shown that:

1. Reared cod have a high growth rate, a high condition factor and liver index. On release they are larger than their wild counterparts. In some case this year's 0 gp may be nearly as big as last year's wild 1-gp. However, the high condition factor allows them to withstand a period of poor feeding after release.
2. After release the reared cod revert towards the wild fish in terms of diet, feeding efficiency and anti-predator behaviour, in just a few weeks.
3. Reared and wild cod have similar growth rates in the sea and tend to remain in the same locality, although some cod released in the Danish Limfjord moved considerable distances, but they belonged to the North Sea cod stock. Norwegian cod from local stocks released near the open coast also tended in some areas to move greater distances laterally.

From the negative aspect:

1. Released cod are more liable to recapture, probably because they are larger than the wild fish.
2. There is no evidence that released cod have enhanced the local stock at a stage when they recruited to the fishery, although they augment the stock in the first few months after release. This means that, in some circumstances, year-class strength is still labile after the 0-gp stage.
3. There is evidence of density-dependence and low pre-recruit survival when the abundance of 0-gp is high.

Other species

These have not been so well documented at this meeting but wild stocks of red drum have been restored and even enhanced by releases to 150% above historic levels, at least to the sub-adult stage. Japanese flounder releases have also augmented the wild stocks by 25%.

Work on other species shows some similarities and differences to cod. For example, red drum and turbot remain close to the release point, although turbot released offshore move greater distances.

Genetics

Genetic work on the Norwegian cod stocks seems to show little difference along the coast as judged by gene frequencies and isozyme patterns. Nevertheless the following criteria are being adopted:

1. Local broodstock should be used to produce fry at each release point (although this has not yet been practiced).
2. A broodstock of 50-100 each of males and females should be used to maintain genetic diversity.
3. Rare alleles can be used (after selective breeding) to mark cod and red drum. It is not clear, however, whether rare alleles might be linked to characters giving reduced fitness (the reason why they are rare?).

Casrrying-capacity and diet

Carrying-capacity has been used rather inexactly at this meeting and this point will be taken up later.

First it is desirable to summarise the finding on the diet of cod:

1. Cod are opportunists, taking benthic and pelagic food including their own species. (One paper reported 119 species in cod stomachs).
2. The diet changes with age of the fish.
3. The diet changes with season because cod move to different parts of the fjord (as a result of temperature effects or because advection brings in different amounts or types of prey on a seasonal basis.
4. Overlap with species (such as whiting) competing for prey varies from place to place and season to season.

5. Cohort competition between reared and wild 0-group cod may influence the degree of cannibalism.

Estimation of the total biomass available is very difficult in such a dynamic trophic situation. It clearly has not been done, and that is one of the notable gaps in this symposium. It requires the monitoring of the relevant resident benthic and pelagic prey, and the extent of advected prey.

It may be that only the empirical approach is realistic - to release varying numbers of cod in different trophic situations and see how they grow and survive. In this respect it seems worthwhile releasing cod in more open areas where advection may indeed suddenly increase the carrying-capacity of the environment. It is relevant to mention here that the enhancement of red drum stocks may also be due to their dependence on pelagic advected food.

It also seems a valid recommendation to release cod and other species only every 2nd or 3rd year to reduce the extent of cannibalism following any enhancement of the wild population.

At this point it is desirable to discuss the definition and philosophy behind the term "carrying-capacity". It might be said that the carrying-capacity is that stock, which, feeding at the maximum conversion rate of food to flesh, gives the maximum sustainable yield. It seems pointless to enhance the numbers of a fish population if density-dependent effects immediately start to operate, unless there is some particular reason to opt for numbers rather than total yield.

Is it a false premise to assume that some areas are <u>not</u> being used to their full capacity? If there is spare capacity, is the reproductive potential of the cod stock not sufficient to take up the excess food by producing a good year-class? Alternatively, will not other fauna move in or grow faster to take up the spare capacity?

Some earlier experiments on plaice juveniles are woth mentioning (see Danielssen *et al.* 19181). Fish were released on to the beaches in Loch Ewe, Scotland to augment the existing population; in other experiments juvenile plaice were used to stock small basins at Arendal. Over a 3-month period the numbers fell by about one half to one tenth. It seemed that the populations were being regulated, by some unknown means (presumably a mixture of predation and food limitation) to an appropriate density for the habitat. It may be quite exceptional for a fjord to contain a fish biomass below its carrying-capacity. Most likely fjords are fully stocked or overstocked so that density dependence is close to operating, or even in operation.

A case has been put by several authors that the existing stock, not only of cod but of other species, should be managed to give a maximum sustainable yield. Apart from

regulating the level of fishing the maximum sustainable yield might be manipulated by an "interventionist" approach. For example:

(1) Some cod could be removed to see whether the growth rate of the remainder increased.
(2) Predators could be removed.
(3) Competitors for food could be removed.
(4) Extra cover or habitats, such as arfiticial reefs, provided.

It might be useful to summarise before continuing:

(1) it seems that salmon ranching is something of a failure and certainly not viable economically.
(2) there is no evidence that ranching of cod, as presently practiced, is likely to enhance the biomass except in places of extreme depletion (although it must be admitted that this end point has not been very well studied to date).
(3) ranching of red drum off the Texas coast and flounder off Japan have led to enhanced stocks.

The failure of salmonid ranching in some parts of the Pacific seems to be linked to the failure of the environment to carry more fish. In general, reared individuals merely replace the wild stock. Density-dependent factors sometimes seem to be operating and the problem is compounded by the difficulty of managing a multi-species fishery. It may be that the best thing to do is to manage the wild stock properly and close at least some of the hatcheries, although this would be economically painful in the short term because the number of returns would fall and harchery workers would lose their jobs.

The present failure of localised cod enhancement also seems to be linked to density-dependence affecting mortality rates. There is not enough information to say why the red drum and Japanese flounder experiments are successful, although it seems significant that the evidence suggests that red drum juveniles are dependent on advected pelalgic prey. Breaching of the offshore islands in the Gulf of Mexico, leading to a better connection with the ocean, improved year-class strength probably as a result of increased advection both of red drum larvae and their food.

Although at the start of the symposium it seemed doubful whether we would see any coherent themes running between migrant and non-migrant species, we can see now that carrying-capacity and density-dependence are valid concepts in the ocean as well as in enclosed areas. Advection of pelagic prey and the accessibility of enclosed areas to advection are also a common link between species.

Economic and social factors

Only a few biologists think much about the financial yield from their research. Research on stock enhancement is expensive initially. It should be aimed to yield success in a reasonably short term to help repay the initial investment costs. However, many enhancement programmes might only yield profit on an immediate year-to-year basis, ignoring the initial investment.

Profit is not the only criterion. Employment, coastal settlements and infrastructure and tourism require fish stocks. It is a political decision whether such social aspects are subsidised by the state. Although it is becoming increasingly necessary for biologists to show that they are providing value for money, how can they quantify the social spin-off from their work?

Another factor is that additional useful information on general ecology and fjord management and insight into the management of wild stocks is obtained as spin-off from enhancement experiments. This cannot easily be quantified, but should be appreciated by the administration. At a biological level, social factors such as the requirements of sport fishing may play a role in the philosophy underlying enhancement. It may, for example, be desirable to produce more small fish for angling rather than aim for a maximum sustainable yield.

Yet another feature of stock enhancement is whether it mainly benefits the nationals of the country doing the work. This is likely to be so in local enhancements but less so with enhancement of high sea migrants.

Main gaps and suggesstions for the future

1. Cod should be released on more open-coast sites where advected food is more readily available, although dispersal along the coast might be greater.
2. Release of cod should be tested before weaning when they are cheaper to produce, available in larger numbers and will not have to re-learn to feed on natural food. The release of smaller fish, with lower resistance to starvation, will have to be carefully matched to the availability and size of the prey.
3. Whatever the species, work should be done to estimate the trophic carrying-capacity of habitats by measurements of the relevant biomass of benthic, pelagic and advected prey. This will help to develop models and judge the level of enhancement possible, but it will be a long and boring task.
4. Territorial and dominance hierarchies should be studied in cod and other species to assess the degree of partitioning of the habitat.

5. Methods of release should be perfected to reduce stress and mortality. Points to consider are pre-conditioning, distribution of release, depth of release, time of day, reduction of initial predation and presence of cover.
6. There seems little point in large-scale releases of salmon smolts except to maintain stocks such as those of the Baltic where interference with the normal paths of migration has occurred.

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APPENDIX

The following contributions were presented at the meeting. The symposium was summed up by Professor J.H.S. Blaxter. Previewed manuscripts will be published in Aquaculture and Fisheries Management in spring 1994.

Bailly, D.: What can the econom ist say about sea-ranching of cod today?

Berg, E. and T. Pedersen: Estimation of stock size of cod (*Gadus morhua* L.) in an enhancement area by acoustic and tagging-recapture methods.

Berg, E., P. Kanapathippillai, T. Pedersen and J. dos Santos: Dynamics of growth and sexual maturation of wild and released cod (*Gadus morhua* L.) in a North Norwegian fjord.

Blom, G., J.T. Nordeide, T. Svåsand and A. Borge: Application of fluorescent chemicals to tag otoliths of cod (*Gadus morhua* L.).

Bradford, R.G. and J. Gagné: Dynamics of juvenile cod concentrations in the northern Gulf of St. Lawrende, Eastern Canada.

Clarke, W.C.: Temperature conditioning of marine broodstocks.

Danielssen, D.S. and J. Gjøsæter: Release of 0-group cod on the southern coast of Norway in the years 1986-89.

Folkvord, A., O. Dragesund, A. Johannessen, O. Nakken and G. Nævdal: A conceptual framework for enhancing and stabilizing recruitment of marine fish stocks.

Fosså, J.H., J.T. Nordeide, A.G.V. Salvanes and O.M. Smedstad: Impact of released cod on the ecosystem in Masfjorden.

Fukusho, K: Mass larval rearing of finfish for sea ranching in Japan.

Gotceitas, V., S. Mercer and J. Brown: Substrate selection by juvenile Atlantic cod in the absence and presence of a predator.

Grimes, C.B., J.J. Isley and A.W. David: Identificaiton of hatchery reared Red Drum using discriminant analysis of otolith banding patterns.

Hammer, C.: Effects of endurance swimming on the growth of whiting: a comparisom with litterature data on salmonids.

Hansen, L.P.: Development of sea ranching of Atlantic salmon towards a sustainable aquaculture strategy.

Harada, Y. and Y. Matsumiya: A theoretical study on the resource enhancement effect of stocking.

Hilborn, R. and J. Winton: Ocean ranching of Pacific salmon: lessons from history.

Hop, H., J. Gjøsæter and D.S. Danielssen: Dietary composition of sympatric juvenile cod (*Gadus morhua* L.) and juvenile whiting (*Merlangius merlangus* L.) in a fjord of southern Norway.

Howell, B.R.: The fitness of hatchery-reared fish for survival in the sea: A review.

Iglesias, J. and R. Rodrigueq-Ojea: Fitness of hatchery-reared turbot (*Scophthalmus maximus*) for survival in the sea: First year results on feeding, growth and distribution.

Johannessen, T.: Distribution and growth of juvenile cod (*Gadus morhua*) on the Norwegian Skagerrak Coast in relation to habitat.

Jørstad, K.E., O.I. Paulsen, G. Nævdal and S. Thorkildsen: Genetic studies on released and recaptured cod in a fjord system.

Kanapathippillai, P., T. Pedersen, J. dos Santos and E. Berg: Feeding habits of cod (*Gadus morhua* L.) in a high latitude Norwegian fjord cod enhancement area.

Larsen, L-H. and T. Pedersen: The first release of artificially propagated cod in North Norway - Status on recapture, migration and mortality after a five year period.

Larsson, P-O. and J. Pickova: Rearing experiments with Baltic cod (*Gadus morhua*) for stock enhancement release.

Leth, N.K.: Feeding and growth of juvenile cod (*Gadus morhua* L.) and bull-rout (*Myoxocephalus scorpius* (L.)) in a North Norwegian cod enhancement area.

McCarty, C.E., McEachron and W.P. Rutledge: Beneficial uses of marine fish hathceries: The Texas experience.

Midling, K. and V. Øiestad: Fjordranching with conditioned cod.

Nicolajsen, H.: Recapture, migration and growth of reared turbot released in the Limfjord, Denmark in 1989.

Nordeide, J.T., J.H. Fosså, A.G.V. Salvanes and O.M. Smedstad: Enhancement experiment in Masfjorden - effect on cod production.

Nævdal, G.: Genetic aspects in connection with sea ranching of marine fish species.

Olla, B.L., M.W. Davis and C.H. Ryer: Behavioural deficits of hatchery-reared Pacific salmon: Potential effects on survival following release.

Pedersen, T. and S. Løken: Production of cod juveniles for enhancement of local coastal cod stocks in Northern Norway, an overview.

Richardson, J.: Alaskan salmon sea ranching: Economic success or disaster in the making?

Rogers, S.I.: The benthic ecology and carrying capacity of a flatfish nursery ground and the implications for the enhancement of natural sole (*Solea solea* L.) stocks.

Sakurai, Y., H. Yoshida and T. Nishiyama: Artificial propagation of Pacific cod and walley pollock in Japan.

Salvanes, A.G.V., D.L. Aksnes, Fosså, J.H. and J. Giske: Carrying capacities of coastal areas.

Salvanes, A.G.V., J. Giske and J.T. Nordeide: A life-history approach to habitat shifts for coastal cod and optimal timing of jcod releases for extensive mariculture.

Sandberg, P. and R. Oen: Economic consequences of large-scale Sea Ranching of Cod in Norway.

Smedstad, O.M., J.H. Fosså, J.T. Nordeide and A.G.V. Salvanes: Enhancement of cod in Masfjorden - an overview.

Steingrund, P. and A. Fernø: A comparative study of the predatory behaviour of reared and wild cod (*Gadus morhua*).

Støttrup, J.G., R. Nielsen, C. Krog and K. Rasmussen: Results on the extensive production of North Sea cod and their growth and distribution subsequent to release in the Limfjord, Denmark.

Svåsand, T.: Status of the cod enhancement programme in Norway.

Wespestad, V.G., G. Bargman and D.E. Hay: Opportunities for the enhancement of the Ling Cod (*Ophiodon elongatus*) in Puget Sound and Georgia Straits.

Yoseda, K.: Recent progress in research on mass seed production of the Pacific cod in Japan.