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ECONOMIC CONSEQUENCES OF LARGE-SCALE SEA RANCHING OF COD IN NORWAY[1]

by

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Abstract

Two different management models for sea ranching of cod are outlined. These differ by timing of recapture. The mathematics for determining the "break-even" cost of producing cod juveniles is presented. Data from two sea ranching projects in the western part of South Norway and data for wild cod in North Norway indicate that these costs must be significantly reduced if sea ranching of cod is to be profitable for Norwegian fishermen. We also assume that cod from a sea ranching project can be harvested as a supplement to a traditional catch of wild cod at lower costs than if cod must be taken in a unilaterally targeted catch operation.

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Introduction

One reason for fluctuating fish stocks is recruitment. Several years with too low recruitment may lead to lower fish stocks than an ecosystem can sustain. Consequently, catches may be lower than they could have been if recruitment was at a steady (and higher) level. To solve the problem of underutilizing the ecosystem, sea ranching has been launched; by taking care of the recruitment process (producing fish juveniles) it may be possible to increase fish stocks and subsequently, catch levels.

Such an undertaking is ambitious, and one is forced to ask whether the expected higher revenues (as a result of sea ranching) will cover the costs of producing juveniles and of catching the fish. If this is so, there may be willingness to undertake a sea ranching project. If the costs of producing juveniles is higher than the expected higher profit from the project, economic reasoning leads to the conclusion that sea ranching should not be initiated.

In this note, we will look closer at the economics of sea ranching of cod in Norwegian coastal waters. Since fishermen are the beneficiaries of such projects, they are the most likely group to cover the costs associated with the production of cod juveniles. What are these costs?

Mass production of cod juveniles for sea ranching has, to date, been financed by government fisheries research budgets. A considerable part of the expenditure on the production of cod is directly "research-related" expenditures, that could have been reduced in a plain commercial production of cod juveniles. It is therefore difficult to assess what the commercial costs in production of cod juveniles would have been, but some guidelines have been given by the Institute of Marine Research (IMR) (Svåsand, 1993a). Under varying assumptions about necessary level of investments, IMR suggested possible future cod juvenile prices in the range from NOK 3.6 to NOK 9.9. These costs are based on extensive production of cod juveniles in a land-locked basin outside Bergen, Norway.

Given these vague estimates of possible future costs for producing cod-juveniles, we ask what price fishermen will be willing to pay for cod juveniles in order to increase their harvest rates.

Materials and Methods

Let us start out by explaining how we calculate what price fishermen from an economic point of view will be willing to pay for cod juveniles in a sea ranching project. This price will vary as a consequence of how the process of recapture is organized. We will sketch two possible management models.

Management model 1

In this model, sea ranching is supposed to be a supplement to a traditional catch of wild cod. The cod juveniles are released in fjords, and recruit to the fishery in the same manner as wild cod. This means that they will be fished at all ages during their life span. The fishing pattern of wild cod will determine the fishing pattern of released reared cod. Using methodology of

Virtual Population Analysis (VPA), outlined in (Hamre, 1980), the expected present value of a sea ranching project according to Management model 1 will be as follows:

$$E[PV] = -C_r R + \sum_{t=1}^{t=n} C_t W_t (P - C)(1+r)^{-t} \qquad (V1)$$

where

$C_t = E_t * N_t (1-e^{-zt})$, $E_t = f/z$,

$z = f + m$ and $N_t = N_{t-1} * e^{-zt}$

Symbols:

$E[PV]$	=	Expected present value of the project
C_r	=	Cost of producing and releasing one cod juvenile
R	=	Numbers of juveniles released
t	=	Years after release
C_t	=	Recatch in number of individuals in year t
f	=	Fishing mortality
m	=	Natural mortality
N_t	=	Survivors in number of individuals in year t
W_t	=	Average weight per individual in catch in year t
P	=	Cod-price (NOK/kg)
C	=	Catch-cost (NOK/kg)
r	=	Discount rate

The expected present value of sea ranching of cod will be positive if the discounted profit generated by recatch of the cod is higher than the cost of producing the juveniles. The price fishermen will be willing to pay for cod juveniles (the critical juvenile price) will depend on the attitude towards risk. A risk-neutral investor will not pay a higher price for juvenile than:

$$C_r = [\sum_{t=1}^{t=n} C_t W_t (P - C)(1+r)^{-t}]/R \qquad (V2)$$

A risk-averse investor will demand a lower price than the right hand side expresses. For the sea ranching projects, we will fit fishing mortality to recatch numbers as shown in table I and II below. Fishing mortality is expressed directly for wild cod from the project from North Norway in table III.

Management model 1 has the disadvantage that it does not take care of the cod's growth potential as there will be fishing pressure on the cod during most of its life cycle. The model has, however, the advantage that when reared cod enters the catch of wild cod as a supplement, the cost of catching this (reared) cod will be limited. The fishermen need not adjust behaviour as a consequence of the released cod. They will perform the same catch operation and simply experience higher catch levels. Catch cost for the reared cod may therefore be low, and in our calculation we will use an interval ranging from a level covering variable to nil costs per kg cod.

Management model 2

The idea of the second management model is to take care of the cod's growth potential by prohibiting fishing pressure until the cod has reached an optimum weight (Sandberg, 1988). When the fish has reached this weight, heavy fishing pressure will be released. The expected present value of a project under this regime is found as follows:

$$E[PV] = -C_r R + C_T W_T (P - C)(1+r)^{-T} \qquad (V3)$$

where

T = Number of years from release until recatch

The other symbols are described under Management model 1.

For a risk-neutral investor, the critical price (the cost of producing and releasing one cod juvenile) is found as follows:

$$C_r = [C_T W_T (P - C)(1+r)^{-T}]/R \qquad (V4)$$

The advantage of this management model is that the growth potential is safeguarded. This is done by postponing catch until the released cod has reached an optimum catch weight. A disadvantage relative to Management model 1 is that the expected harvesting costs will be higher. Management model 2 does not take cod from sea ranching project as a supplement to catch of wild cod. The model prescribes a harvesting sector unilaterally built for catching

cod from sea ranching projects. When asking what fishermen will be willing to pay for cod juveniles under this management model, one should therefore calculate with higher harvesting costs than in model 1. In our calculation we will use harvesting costs ranging from a level covering total to variable costs[2].

In Management model 2 we have presumed that it is possible to avoid fishing pressure until the fish has reached an optimum weight, without fixing any costs for the enforcement to achieve this. Our calculations will therefore tend to overestimate the profitability of the projects.

Having described our method of finding the "break-even" price for the cod juveniles, or the price fishermen will be willing to pay for the cod juveniles, we proceed to a description of data used in our analysis.

Biological data

Biological data (growth, natural mortality and fishing mortality) is derived from two sea ranching projects in South Norway and an analysis of wild cod in North Norway. All cod juveniles are released as 0-group, at an age of approximately 6 months.

[2] *When releasing fishing pressure with the aim of catching the entire remaining biomass in an area, catch costs pr kg will be likely to increase during the catch operation as the density of fish will decrease. In our analysis we have used a constant catch cost pr kg. This will tend to overestimate the profitability of the project.*

Project 1

The first project is the sea ranching project of the Institute of Marine Research's in Austevoll, south-west of Bergen. Table I shows weight at age and numbers of recaptured cod from the 1983-release of cod outside Heimarkspollen in Austevoll.

Table I. Mean weight at age and numbers of recapture of 16.079 cod released outside Heimarkspollen in Austevoll in the autumn 1983. Mean weight in kg is estimated from 2.114 observations. Numbers of recapture are estimated from 2.465 observations, inflated with a factor of 1.23 due to misreporting and tag loss). (Source: Svdsand 1991, 1993b)

Age in years	Mean weight (kg)	Recapture
1 (incl 0)	0.42	945
2	0.95	1267
3	1.88	524
4	2.91	194
5	3.32	63
6	4.45	27
7	6.55	13

The release of cod outside Heimarkspollen in Austevoll proved to give a high return rate, approx. 19%, and good growth. The fishing pattern is however non-optimal, as much of the fish is caught very young. The fishing pattern reflects the fact that cod from this sea ranching project was taken as a supplement to catch of wild cod.

Project 2

The second project is the sea ranching project of the Institute of Marine Research's in Masfjorden. Table II shows weight at age and numbers of recaptured cod from the five releases during 1985 - 1989.

Table II *Mean weight at age and numbers of recapture of 31.332 cod released in Masfjorden during the years 1985 - 1989 (project P85, P86, P87, P88H and P89H). Mean weight at age was estimated from 3732 observations of wild cod during 1984 - 1987. Observations of wild cod were used instead of observation of released cod because the number of the latter was too limited to give a good estimate. In addition, no significant differences were found, as in project 1, in the growth of released and wild cod in Masfjorden. Numbers of recapture were estimated from a recapture of 1.463 individuals inflated with a factor of 1.23 due to misreporting and tag loss. (Source: Fossd et al 1993, Nordeide 1993).*

Age in years	Mean weight (kg)	Recapture
1	0.23	1171
2	0.55	429
3	0.97	159
4	2.92	36
5	3.22	5
6	...	...
7	...	...

... *Data not available*

The sea ranching project in Masfjorden has so far given a lower return rate than the project outside Heimarkspollen in Austevoll. The corresponding weight at age is also lower in Masfjorden than in Austevoll.

Project 3

The third project is the survey of wild coastal cod in the northern part of Norway (fjords from Malangen to Varangerfjorden) undertaken by the Norwegian Institute of Fisheries and Aquaculture Inc.

Table III Mean weight at age and fishing mortality for wild cod outside the coast of North Norway. Fishing mortality is calculated in the same way as in ICES when managing the North East Arctic Cod stock with the exception that coastal cod recruits to the fishery at different age than North East Arctic Cod. A possible error in these figures is that we could not eliminate the fishing mortality caused by trawl. Under current management regime, the use of trawl in coastel waters is forbidden (Source: Sunnand, 1993).

Age in years	Mean weight (kg)	Fishing mortality
1	...	...
2	...	...
3	0.950	0.020
4	1.600	0.110
5	1.900	0.210
6	2.400	0.320
7	2.850	0.380
8	3.100	0.420
9	3.950	0.520
10	4.400	0.520
11	5.300	0.520
12	6.500	0.520
13	7.700	0.520
14	8.900	0.520
15	10.000	0.520

Table III shows weight at age and expected fishing mortality if this cod were subject to an expected fishing pressure on wild cod. We use this data to sketch the growth and fishing mortality for reared and released cod. In so doing, we presume that the released cod grows and recruits to the fishery in the same manner as wild cod. Natural mortality for all three projects is shown in Table IV.

Table IV Natural mortality used in the calculations. The relatively high mortality rate before the cod has reached an age of 2 years corresponds to what Svåsand found in Heimarkspollen in Austevoll (Svåsand 1991). A natural mortality of 0.2 pr year from age 2 and older corresponds to what is usually used in management of wild cod.

Age (years)	Natural mortality	Survivors
0.5	1.5	1000
2.0	0.2	223
3.0 etc ->	0.2	183

Economic data

Economic data (cod prices and harvesting costs) is taken from the Directorate of Fisheries. Table V shows total Norwegian landings of cod, corresponding total values and average prices of cod for the years 1989 - 1991.

Table V Total landings, total values and average prices of cod in Norway in the years 1989 - 1991. Source: Directorate of Fisheries.

Cod	1989	1990	1991	1989-91 average
Quantity (in tonnes)	186.353	125.182	161.400	157.645
Value (in 1000 NOK)	1.263.243	1.131.044	1.610.100	1.334.796
Average price (NOK/kg)	6.78	9.04	9.98	8.47

In our calculation we will use the average price for the period 1989 - 1991, but we also calculate with one higher and one lower cod price.

Table VI shows harvesting costs pr kg fish for vessels from 13 to 20.9 m, separated on boats from South-Norway and from Finnmark. In our calculation we use average harvesting costs for the period 1989 - 1991.

Table VI Total and variable costs for two different groups of vessels. Source: Directorate of Fisheries.

Region	Group of vessel	Total costs NOK pr kg	Variable costs NOK pr kg
Finnmark	13-20.9 meter length (No 1)	6.7	3.9
Southern Norway	13-20.9 meter length (No 7)	7.3	4.6

There will naturally be a time lag between the expenditure on cod juveniles, and the income from the increased catches of cod. We use a discount rate of 4% to make these cash flows comparable.

Results

Project 1

Based on data from the sea ranching project of the Institute of Marine Research's outside Heimarkspollen in Austevoll, we find the following break-even prices for cod juveniles.

Table VII Sea ranching outside Heimarkspollen in Austevoll. Break-even prices under different cod prices. In model 1, harvesting costs vary between variable costs and nil costs. In model 2, harvesting costs vary between total costs and variable costs (se table VI).

Management model	Cod price A 6.0 NOK/kg	Cod price B 8.5 NOK/kg	Cod price C 11 NOK/kg
	Break-even price of cod juveniles (NOK/recruit)	Break-even price of cod juveniles (NOK/recruit)	Break-even price of cod juveniles (NOK/recruit)
Model 1	+0.3 -> +1.2	+0.8 -> +1.8	+1.3 -> +2.3
Model 2	-0.5 -> +0.5	+0.4 -> +1.4	+1.4 -> +2.4

The table shows that with a cod price of 8.50 NOK/kg, the break-even price of cod juveniles in Management model 1 will range between 0.8 and 1.8 NOK, depending on level of harvesting costs. Under Management model 2, the corresponding break-even price will vary between 0.4 and 1.4 NOK.

With a cod price of 8.50 NOK/kg, the higher harvesting costs in Management model 2 outweighs the economic significance of the biological more optimal fishing pattern in this model. As the fish becomes more valuable however, the value of the biologically more optimal fishing pattern will outweigh the increased harvesting costs.

Project 2

Based on data from the sea ranching project of the Institute of Marine Research's in Masfjorden, we find the following break-even prices of cod juveniles.

Table VIII *Sea ranching in Masfjorden. Break-even prices under different cod prices. In model 1, harvesting costs vary between variable and nil costs. In model 2, harvesting costs vary between total costs and variable costs.*

Management model	Cod price A 6.0 NOK/kg	Cod price B 8.5 NOK/kg	Cod price C 11 NOK/kg
	Break-even price of cod juveniles (NOK/recruit)	Break-even price of cod juveniles (NOK/recruit)	Break-even price of cod juveniles (NOK/recruit)
Model 1	0.0 -> +0.1	+0.1 -> +0.2	+0.2 -> +0.3
Model 2	-0.4 -> +0.4	+0.4 -> +1.1	+1.1 -> +1.9

Tables VII and VIII show that break-even prices of cod juveniles under Management model 1 are significantly lower in Masfjorden than in Austevoll. This corresponds to the difference in recapture percentages. In Management model 2, the break-even price is also lower in Masfjorden than in Austevoll, which corresponds to slower growth. This slower growth makes it optimal to catch the fish at a higher age, and natural mortality has then reduced the numbers of surviving fish further than in Project 1.

From the project in Masfjorden, break-even prices in Management model 1 are significantly lower than in Management model 2. The reason for this difference is the low recapture percentage which might be connected to the existing fishing pattern in Masfjorden.

Project 3

Based on weight at age and fishing pattern from the survey of wild coastal cod in North Norway undertaken by the Norwegian Institute of Fisheries and Aquaculture Inc., we find the following break-even prices for cod juveniles:

Table IX Sea ranching in Northern Norway. Break-even prices under different cod prices. In model 1, harvesting costs vary between variable and nil costs. In model 2, harvesting costs vary between total costs and variable costs.

Management model	Cod price A 6.0 NOK/kg	Cod price B 8.5 NOK/kg	Cod price C 11 NOK/kg
	Break-even price of cod juveniles (NOK/recruit)	Break-even price of cod juveniles (NOK/recruit)	Break-even price of cod juveniles (NOK/recruit)
Model 1	+0.3 -> +1.0	+0.8 -> +1.4	+1.2 -> +1.8
Model 2	-0.1 -> +0.4	+0.3 -> +0.9	+0.8 -> +1.3

Table IX shows the result of a theoretical sea ranching project in North Norway based on the assumption that released cod grow, die and are harvested in the same manner as wild coastal cod. The table shows that with a cod price of 8.50 NOK/kg, the break-even price for cod juveniles will be lower in Management model 2 than in Management model 1. Again this shows that at this cod price, the higher harvesting costs in Management model 2 outweigh the value of the biological more optimal fishing pattern. As mentioned earlier, enforcement costs are not included in the above analysis. Inclusion of such costs would lower break-even prices calculated above.

Discussion

As mentioned in the Introduction, the biomass of wild fish stocks fluctuates from year to year, depending among other things on the success of recruitment. Fluctuating size of fish stocks may lead to varying catch levels. Artificial rearing of cod with subsequent release in fjords is therefore a logical answer to even out the effect these variations have on fishermen's income.

It is, however, important to analyse the reasons for low catch rates. If low catch rates are caused by overexploitation, it seems easier to reduce fishing pressure than to start a sea ranching project in order to rebuild fish stocks.

To avoid sea ranching in areas with no capacity for a larger fish stock, it is also important to know the carrying capacity of the ecosystem.

However, the data we have used indicate that the price fishermen will be able to pay for the cod juveniles in a sea ranching project will be low. The main reason is high mortality of cod in its early life stages and a moderate price of cod.

The price of juvenile cod must therefore fall significantly below what IMR has reported to be a realistic price level in the future (NOK 3.6 - NOK 9.9). Releasing cod with such a price will lead to economic loss for the fishermen.

We have assumed that harvesting costs will differ between the two management models outlined above, being highest in Management model 2. Under these assumptions, the value gained in the model with the biological more optimal fishing pressure will be offset by higher harvesting costs. This indicates in economic terms that sea ranching projects where the recapture of fish is taken in a biological non-optimal pattern, as a supplement to catch of wild cod, may not always be worse than a sea ranching project with a biological optimal fishing pressure with higher harvesting costs.

If it is realistic to lower production costs of juvenile cod significantly, sea ranching of cod may be profitable in the future. Further studies in order to achieve this would then be interesting. Being laymen in the field of biology, we would also like to point out the possible joint interest in research fields of production of cod juveniles for sea ranching on the one side and studies of recruitment process for wild stocks on the other.

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