A Report to the Joint Standing Committee
on Marine Resources regarding:

THE ECONOMICS OF FISH STOCK ENHANCEMENT

In accordance with the requirements of P.L. 1993, Ch. 194
"An Act Creating the Groundfish Study Hatchery Commission"

By

The Groundfish Hatchery Study Commission

Submitted: January 1994

THE ECONOMICS OF FISH STOCK ENHANCEMENT

A report on Phase I of a study for the Maine State Legislature in accordance with the requirements of H.P. 211, L.D. 273, Bill, "An Act Creating the Groundfish Hatchery Study Commission".

Introduction

In response to an initiative by the Maine Fisherman's Cooperative Association the 116th Legislature passed an act creating a 13 person commission to investigate the feasibility of enhancing the groundfish stocks off the coast of Maine. The commission consists of representatives from the fishing, scientific, business, and environmental communities as well as a commissioner's designee from the Department of Marine Resources. The commission is to undertake a study in two phases. In Phase I, to be completed by January 1994, the commission is to investigate the economic feasibility of producing hatchery-raised fish in the State at a production level that will affect the fishery. If the economic report is positive, the Joint Standing Committee on Marine Resources will approve the initiation of Phase II. This phase, to be completed by January 1995, will determine the need for one or more hatcheries and the appropriate methods for revitalizing localized schools of groundfish, and the tendency of groundfish to return to their breeding areas. In addition the commission will determine the impact of introducing hatchery-raised groundfish into the groundfishery.

Commission Members and Meeting Report

A list of the Groundfish Hatchery Study Commission members is appended to this report.

The commission was appointed by the Commissioner of the Department of Marine Resources in August. They formally met on September 21st to review the statuary charge of the Commission, to review a trip report on a recent symposium (June 1993) on sea ranching of cod in Norway, and to discuss the commission's goals and objectives and to establish a time line and work assignments. At that meeting it was decided that an economic model should be constructed to investigate the variables that would determine the factors controlling the success or failure of a hatchery operation. On October 26th, the University of New Hampshire Sea Grant Program sponsored a workshop entitled "Cod Sea Ranching: Identifying the Next Step" where a commission progress report was presented. The report from that workshop is appended to this document. A second meeting of the full commission was held on November 19th to review the economic model and discuss the data needs for the final Phase I report. A draft report was prepared and circulated to all commission members immediately after the new year and this final draft represents a consensus of the entire commission membership.

Commission Recommendations

It is the opinion of the Groundfish Hatchery Study Commission that Phase II of this project should continue. The economic model presents encouraging survival rates for hatchery-raised fish which would be sufficient to recapture the investment in an enhancement operation over a projected ten year time span.

The model determines the break-even point for a hatchery operation based on the return to the groundfishery as additional landed value accrued to the fishery in the course of normal operations. It does not consider any multiplier effects that would come from an increased harvest and expenditures on such things as nets, boat repair, and other items directly related to this economic gain. In an Input:Output model of Maine's fishing industry, by Briggs, Townsend and Wilson (see Marine Fisheries Review, January 1982) additional fish landings result in an added benefit to both the harvesting sector and processing sector. The multipliers for incomes generated from additional landings are 1.32 for harvesters and 1.33 for processors. In other words, a successful hatchery operation would have a net positive effect on the infrastructure of the fishing industry which suggests that our hatchery survival rates could be lower than our model requires for a break-even operation.

The potential for stock enhancement through a fish hatchery is not only being recognized by the state of Maine but also by the federal government. The recently established Northwest Atlantic Fisheries Reinvestment Program recognizes the potential for restoring the depleted New England groundfish stocks through aquaculture and hatchery programs. Similarly, the latest list of Saltonstall-Kennedy Fisheries Development Program priorities recognizes the same need. Both of these programs are potential sources of federal funding. Completion of Phase II of this Groundfish Hatchery Study Commission's report should put Maine in an advantageous position for securing financial support for developing a hatchery program.

Phase II of this project will give the commission the opportunity to explore, and recommend development of, research programs that would address increasing the survival of released fish. The cod sea ranching symposium in Norway and the workshop at the University of New Hampshire (see attached) both point to the need for understanding the biological potential of the ecosystem for sustaining released fish, and the need for distinguishing these fish from their wild counterparts. Our economic model projections are based on the best biological information available. It should be recognized, however, that further research on fish habitat will not only enable us to empirically evaluate hatchery success but also develop a positive, rather than restrictive, management strategy for the Gulf of Maine. This management approach will, if successful, allow our fishermen to continue harvesting fish without the devastating consequences the industry is currently experiencing.

The Economic Model

The economic model determines the break-even point of a groundfish hatchery where the landed value of fish caught in the fishery equals the hatchery costs of rearing these fish prior to their release in the environment. The potential economic gain from a hatchery program is expressed in terms of survival of fish from birth through capture at a marketable size.

Input parameters for the economic model include: 1) knowledge of the timing of critical life stages (eg. hatching time, time of first feeding for larval fish, length of the time a groundfish lives in the water column prior to settling to the bottom) 2) rate of natural mortality for all critical life stages 3) weight at age 4) catch at age 5) price per unit weight of harvested fish (landed value) and 6) hatchery and other production costs. For our modelling investigation these input data were taken from the scientific literature or were based on experience of commission members. For example, price, catch at age, and weight at age data are published by the National Marine Fisheries Service while hatchery operation costs were supplied by commission members who have extensive experience raising salmon. Critical life stage information and natural mortality were based on discussions with National Marine Fisheries Service personnel and/or the scientific literature.

The least well known life stage information concerns the expected survival rates of the fish following their release from the hatchery. Consequently the model is run by making an initial estimate for the required survival rate through to adulthood, when the hatchery production costs would be recovered by the fishery. The costs and benefits are accumulated and the original estimate is refined until a break-even hatchery survival rate is achieved. Whether this survival rate is realistic is a judgement based on our knowledge of the biology of the particular groundfish species and is essentially a biological judgement.

For the purposes of this report the commission decided to focus on the Atlantic cod and minimize hatchery operation costs by "keeping it simple". Cod was selected because it is the "bread and butter" species of the Maine ground fishing fleet and "keeping it simple" is interpreted as releasing the fish from the hatchery at the earliest time that would maximize larval survival. For this investigation two release strategies were employed. In the first case, fertilized eggs were released while the second strategy involved holding the larvae until the yolk sac was absorbed and they were about to start feeding on wild food. The model could be run through to later life stages for release and even through the aquacultural production of an adult, market size, fish. Although Atlantic cod does not, on average, have as high a market value as either haddock or witch flounder it does have a high growth rate and is a "robust" fish. There is also extensive scientific literature on cod which makes the input for the economic model more realistic.

Model Input Values

1) Knowledge of the timing of critical life stages.

Atlantic cod experience several major changes in their life habits as they grow into marketable fish. First they are fertilized eggs that develop into yolk sac larvae. Following this stage they begin to feed and become true pelagic larval fish. Finally they settle to the sea floor where they take on the characteristic behavior of adults. Fish at each of these stages experiences different levels of natural mortality which, obviously, has a major impact on the success of hatchery production. Hatching and development are temperature dependent and variable in nature. In a hatchery we are able to maintain an optimal temperature for development and therefore we have assumed that the fish remain in a particular stage for a fixed period in this model. Cod remain as eggs and yolk sac larvae for three weeks. They then are pelagic larvae until they are five months old when they settle out of the water column and essentially become adults.

2) Rate of natural mortality for all critical life stages.

Egg mortality is assumed to be 25% of the total production in the first week in the hatchery. This 25% assumes the level of mortality the eggs would experience under hatchery conditions prior to release. In the second strategy, when fish are in the hatchery until they have absorbed their yolk sac, an additional 25% of the fish are assumed to die prior to release. Mortality of pelagic larvae is reported in the scientific literature to be about 5% per day until they are five months old. Natural mortality then continues at a high but essentially unknown rate for the remainder of the first year of life. For both release strategies we have assumed a natural mortality rate in excess of 95% over the first year following release in the environment. The accepted natural mortality rate (M) for adult fish is 20% per year and, in the model, this value is applied to fish following their first year.

3) Weight at age

Weigh at age data has been collected by the National Marine Fisheries Service for the Gulf of Maine stock, NAFO Division 5Y, for the period 1982-1991. These data are published in: "The Report of the 15th Northeast Regional Stock Assessment Workshop" Northeast Fisheries Science Center Reference Document 93-06, issued in February 1993. The average year class weights were calculated over this ten year period and these values are: Age 3 = 3.78lbs, Age 4 = 5.99lbs, Age 5 = 9.59lbs, Age 6 = 14.00lbs, Age 7 = 19.12lbs, Age 8 = 23.86, Age 9 = 29.45lbs, Age 10 = 32.91lbs

4) Catch at age

For the model it is assumed that fish recruit to the fishery at age three and 48% of the entire stock is harvested each year. Fishing mortality rates are reported in the Northeast Fisheries Science Center Reference Document 93-06 as instantaneous rates. Prior calculations by commission members have converted these rates into an equivalent yearly mortality rate. The yearly mortality rates were then applied to the model by summing the 8 year catch period, age 3 to age 10, and dividing to gain the average catch rate expressed above.

5) Price per unit weight of harvested fish

Three price categories of cod were established and the landed value for these size classes at the Portland Fish Exchange were used in the model. They are $0.60 per pound for scrod, $0.80 per pound for market cod, and $1.00 per pound for large cod. These numbers are fixed for all model runs. In other words, they are not adjusted for season, or for inflationary increases, or potential price increases or decreases as cod become more or less abundant over time.

6) Hatchery and other production costs

Hatchery costs are considered in two ways. First, there is the up front cost of producing fish based on estimates from our commission members experience operating hatcheries in Maine. In the two hatchery release strategies these estimated costs ranged from $0.005 to $0.04 per fish. Second, there is the cost of borrowing the money to produce the fish and the associated interest rates for these loans were estimated to range from 5% to 20% for borrowing money over a ten year period.

Model Results

Two hatchery release strategies are presented below, and in the accompanying tables annd figures, and represent early release of larval fish rather than trying to grow fish in a hatchery for a prolonged period.

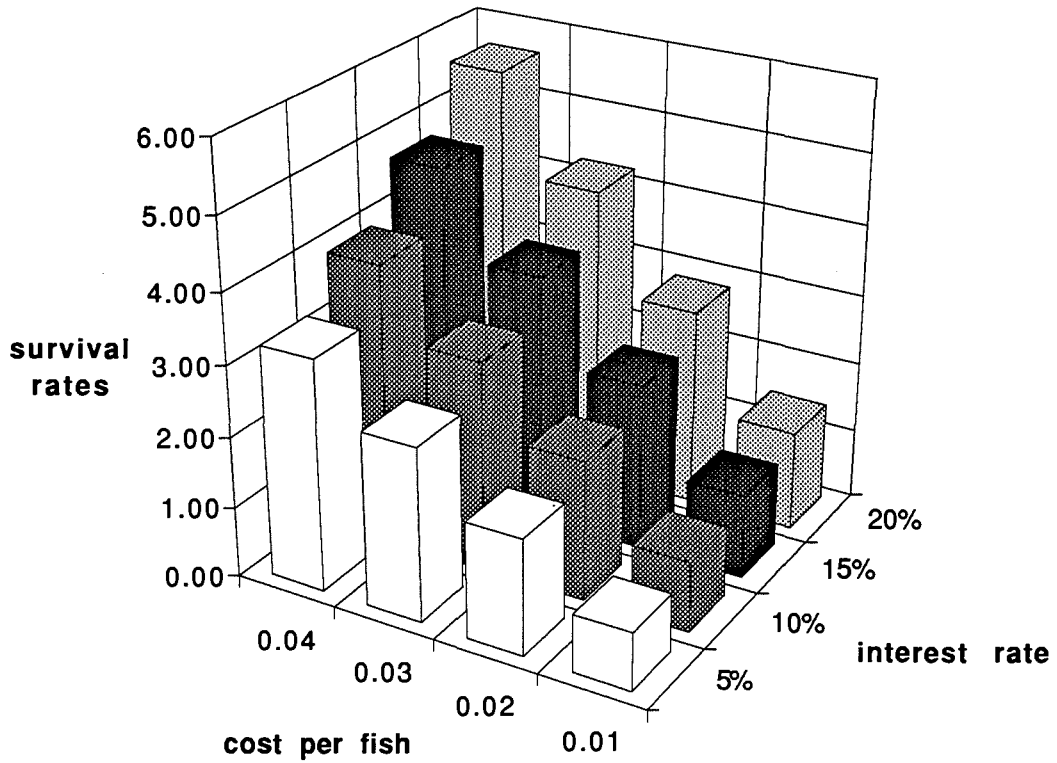
In the first example, fertilized eggs are released after one week in the hatchery. In this case it is assumed the cost per fish could range from $0.005 to $0.02 and the interest rate was variable from 5% to 20%. At the lowest cost per fish ($0.005) and the lowest (5%) interest rate 3 fish out of every thousand released would have to survive up to the age just prior to their recruitment into the fishery (age 3) for the hatchery operation to recover its costs over a ten year period. In other words, it would require a 0.31% survival rate for the state to recover its investment in a hatchery. In contrast, at $0.02 per fish and a 20% interest rate it would require a 2.10% survival rate.

In the second example, the fish are kept in the hatchery an additional two weeks, until they have almost absorbed their yolk sac and are about to become truly pelagic larval fish. The interest rates would remain the same but the cost per fish increases to a range of $0.01 to $0.04 per fish due to the additional time the animals are held in the hatchery. In this case the least expensive ($0.01 per fish and a 5% interest rate) combination would require that 8.2 fish out of every thousand released survive, or a 0.82% survival rate. On the high end ($0.04 per fish and 20% interest) the survival rate increases to 5.61% or 56 fish out of every thousand released.

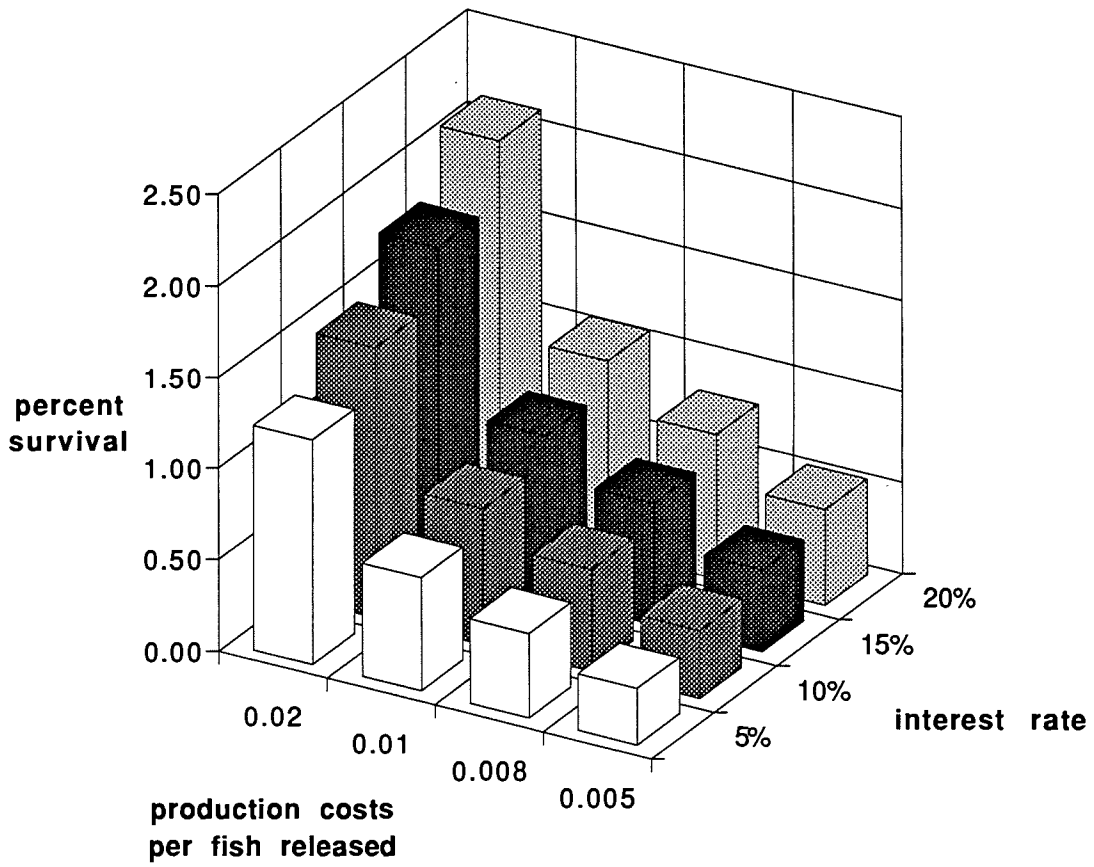
These calculations were all based on a hatchery employing a staff of three with 50 six foot diameter tanks. Each tank can hold between 5 to 10 million eggs. For the first strategy, production would be phased over a period of time so that hatched fish are ready for release almost weekly for up to a three month period. A facility of this sort should be able to produce far more hatched eggs than its maximum one time capacity of 50 million. For the purposes of this estimate of feasibility, costs are based on "batches" of 50 million eggs. Under the second strategy, holding the larvae until they have absorbed their yolk sac, the same staff of three and similar tank capacity would produce fewer 'batches' for release over the three months, since yolk sac absorption would take an additional two weeks, but this time would be offset by an increased larval survival rate.

In the hatchery, fifty tanks initially holding 5 million eggs each, would produce 574,672 adult fish at the break-even level assuming a survival rate of 0.31%. If the hatchery released fertilized eggs, at two week intervals for three months, the total annual production would potentially be 3,448,037 fish. Actual survival of this number of fish is questionable since they would all require suitable habitat and food. Nevertheless, this level of production could substantially enhance the Gulf of Maine landings.

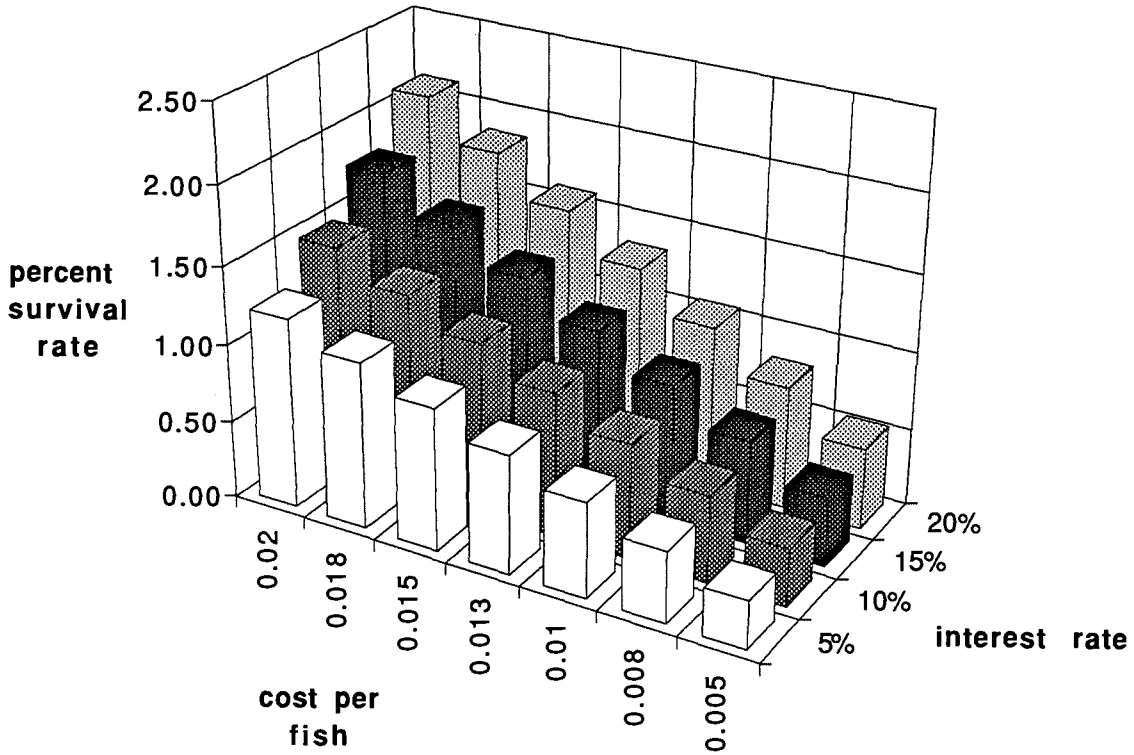
BUTTON-UP HATCHERY
percent survival to age three
required for break-even



EGG RELEASE HATCHERY:
percent survival to age three
necessary for economic breakeven



EGG RELEASE HATCHERY:
percent survival to age three
necessary for economic breakeven



PERCENT SURVIVAL RATES TO AGE 3
NECESSARY FOR ECONOMIC BREAK EVEN
By hatchery cost per fish and interest rate

Straight Egg Release Hatchery

		Cost Per Fish			
		0.02	0.01	0.0075	0.005
Interest Rate	5%	1.23	0.61	0.46	0.31
	10%	1.48	0.74	0.56	0.37
	15%	1.78	0.89	0.67	0.44
	20%	2.10	1.05	0.79	0.53

Button Release Hatchery

		Cost Per Fish			
		0.04	0.03	0.02	0.01
Interest Rate	5%	3.27	2.45	1.63	0.82
	10%	3.96	2.97	1.98	0.99
	15%	4.74	3.55	2.37	1.18
	20%	5.61	4.21	2.81	1.40

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8/2/93

MEETING REPORT

COD SEA RANCHING: IDENTIFYING THE NEXT STEPS

A workshop held:

October 26th, 1993
New England Center
Durham, NH

Sponsored by the University of New Hampshire/University of Maine Sea Grant Program

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Cod Sea Ranching: Identifying the Next Steps

Executive Summary of the Workshop

In order to evaluate prospects for the enhancement of natural stocks of cod and other groundfish in the Northwestern Atlantic, we require considerably more fundamental information about the aquaculture of the fish and the dynamic processes of the ocean ecosystems into which they will be released. There are four topics of immediate concern: aquaculture of the fish up to the release size, understanding the processes controlling juvenile survivorship of cod, understanding the ecosystem dynamics in the release area in order to assess the carrying capacity for cod, and development of the means to assess the impact (on wild populations and on the ecosystem) of the release of hatchery-raised fish. A fifth consideration is the evolution of the programmatic infrastructure and multi-agency coordination of funding that will be required for any program of stock enhancement of groundfish.

All working group reports indicated a need for time, money, and personnel, and several specified that committed leadership was of fundamental importance. We will also require methods to evaluate the success of the enhancement efforts. A further point of agreement is the call for full participation in this effort by all constituent groups: fishermen, the fishing industry, the scientific research community, the fisheries agencies, and government representatives. Any effort toward stock enhancement of cod in the Northwest Atlantic must be coordinated regionally, to ensure that all political and geographic entities are full participants.

Introduction to the Cod Sea Ranching Workshop

This workshop was designed to evaluate the prospects for stock enhancement of groundfish in New England. Several groups have suggested that we could reverse the trend of declining stocks of groundfish in New England using a strategy based on aquaculture of groundfish for release. The sea ranching of cod and other groundfish calls for the release of cultivated individuals into the sea, where they must fend for themselves in the natural ecosystem. When they are sufficiently large, they can be caught again. In the case of cod, the goals of sea ranching include the enhancement of natural stocks through release of aquacultured individuals.

The UNH/UM Sea Grant College Program is not an advocate for this particular idea or any given approach. We at the UNH/UM Sea Grant College Program organized this meeting to provide a forum for the exchange of ideas and information. With this goal in mind, we encouraged participation by diverse interest groups: research scientists, administrators, politicians, fishermen, and seafood processors. These groups were all able to provide their perspective on the prospects for enhancement at the meeting.

The speakers for the morning session covered a range of ideas, opinions, and information that exists today. The speakers were encouraged to provide factual information that would be useful in the decision-making and planning processes. They were also encouraged them to give their summary views - i.e., their opinion - based on their experiences. These summaries by people directly involved in fisheries and aquaculture are particularly useful in evaluating the information, some of it contradictory, that surrounds the issue of sea ranching.

A primary objective of this meeting was to identify those questions that must be answered in order to evaluate prospects for stock enhancement of groundfish. For example: sea ranching has two components. The first is rearing of the species to the appropriate stage for release. This in itself requires considerable technical and scientific expertise: manipulation of the reproductive process, optimization of diet, control of disease, and regulation of growth. Design of the release strategy is also critical, including: size at release and seasonal timing and geographic siting of release. Determination of these and other parameters requires genuine understanding of the ecology of the ecosystem into which the release is made. In both these areas - aquaculture and ecosystem dynamics - we must identify those issues that are central to an evaluation of the prospects for stock enhancement of groundfish.

During the afternoon, we held a plenary brain-storming session to identify and prioritize topics that are critical to an evaluation of stock enhancement. We called this session, "What Do We Need to Know?". From this listing, we identified a small number of high-priority topics that became the focus of working groups. Each group considered the following questions:

Introduction to the Cod Sea Ranching Workshop (continued)

What are the steps to implementation?
What are the obstacles to implementation?
What resources are needed?
Who should be involved?

Any consideration of prospects for stock enhancement will require a regionally coordinated, multi-faceted approach. An important goal of this meeting was to spot opportunities for collaboration. The final element of this list, "Who should be involved?",was aimed at building partnerships that will be essential for the rational consideration of prospects for stock enhancement of cod and other groundfish in the Northeast U.S.

Ann Bucklin, Director
UNH Sea Grant Program

BRAIN-STORMING SESSION: WHAT DO WE NEED TO KNOW?

1. What controls the survivorship of juvenile cod?

-What defines the "survival window"?
-Where/when/how variable is survivorship?
-What is the mortality/life table for cod: where is the rise in slope of mortality curve? (Can we afford to determine this?)
-What are habitat requirements for survival? (consider food and prey species abundances and substrate availability)
-What are the effects of predators?
-How can you measure or tag survival and survivorship? (consider: visible tags, color polymorphism, diagnostic pigmentation)

2. When, where, and how should release of cod be done?

-What is the economically best size for release?
-What is the critical age?
-How many larvae/juveniles should we release?
-How can we use evidence from other species?
-Can we provide suitable benthic habitat?
-What is the best artificial habitat for juvenile cod?
-What is the target survivorship?
-Are there differences between raised/wild fish?

3. How do we raise the fish prior to release?

-What is the best feed for post-yolk sac juvenile cod? (consider: nutrition and economics)
-How can we manage disease control during culture? (consider: inoculation)
-How many fish can you use for broodstock? How many <u>should</u> you use?
-How many larvae or juveniles can you produce?

4. What management issues are associated with release of reared fish?

-Will enhancement speed recovery?
-How can we sustain yield, not just enhance current stocks?
-Who owns the fish? (consider: common ownership, retention of ownership with fish tagging)
-How can we prevent small stocked fish from suffering mortality associated with being caught and discarded by harvesters?

4. (con't) What management issues are associated with release of reared fish?

-What approach would be better than stock enhancement?
    -Aquaculture of fish with no release
    -Stronger management practices
    -Predator removal
    -Reduction of fishing pressure
    -Scientifically based fishing strategies
    -Encouragement for fisherman to participate in scientific studies
-How is enhancement to be paid for?
-How do we show tangible results?

5. What aspects of ecosystem dynamics will determine successful enhancement?

-What caused stock decline? (consider: over-fishing, pollution, disease, climatic change, noxious dinoflagellate blooms)
-Can you impact natural populations?
-What is the carrying capacity for cod of the ecosystem?
-How is the carrying capacity for cod affected by other species?
-Sensitivity of ecosystem?
-What are critical environmental factors? (consider: ocean circulation, meteorology, climate, event-scale environmental issues, biological-physical linkages, food web dynamics, species composition)

WORKING GROUP REPORT
ISSUE: AQUACULTURE

Working Group Chairs: Terry Bradley, Larry Buckley, Linda Kling

What are the steps to implementation?

The first step in any aquaculture process is to understand the criteria for broodstock selection and the methods of their collection. A primary need is to master techniques for the manipulation of spawning of the species in captivity. Also, the genetic consequences of broodstock selection - including inbreeding and drift - need to be taken into account in designing an appropriate strategy for controlled breeding.

The next critical step is to develop techniques to ensure successful larval rearing, including ensuring acceptable levels of mortality and production of healthy fish. Several types of systems should be considered for this process, including: enclosures, ponds, and land-based, circulating, or recirculating systems. We should also, at an early stage, assess locations for hatchery sites, especially with regard to water quality.

A primary factor determining success at this stage is food; we will need to consider both artificial and natural feeds for both economic and biological reasons. Timing of weaning from any artificial feed will also have considerable impact.

Timing of release, whether by age or size of the fish, will be critical in determining both post-release biological processes and the economic costs of rearing. Optimization of the timing of release will require consideration of a complicated mix of factors, and will be critical to the overall effort.

Determination of feasibility should be done at smaller scales than that eventually anticipated for production. Thus, much consideration must be given to the challenge of scaling up from pilot to production scales.

What are the obstacles for implementation?

The foremost obstacle to successful aquaculture of groundfish, based on previous studies with cod and other groundfish, and on the first principals of marine aquaculture, is disease. For any new system, the possible hurdles imposed by pathogenic organisms are essentially unknown. Also, numerous technical and economic problems associated with spawning and rearing of cod on a large scale need to be overcome.

Discharge from hatcheries is always a primary concern when any community considers siting aquaculture activities nearby. Pollution of coastal environments resulting from commercial aquaculture is a very real danger; questions concerning the impact on environmental quality must be resolved immediately. There are also potential legal hurdles

in the siting of hatcheries in natural areas, such as ponds, because of environmental quality concerns.

What resources are needed?

Additional sources of funding will be required to bring into effect the aquaculture of groundfish. Special facilities require significant investments up front. Identification of the sources of these investment dollars is critical. Without a doubt, production-scale aquaculture of groundfish will require a commitment from the Federal and State Governments. Such a venture will be dependent upon the committed support of the fishing community and industry.

Securing the support of the disparate groups needed will require excellent public relations, to ensure that aquaculture activities are viewed in a positive light by the public.

Who should be involved?

First and foremost, aquaculture efforts will require a committed leader: a charismatic, hard-driving individual who can spearhead this effort. Active participation by representatives of the constituent groups is essential, including: aquaculturists, fisherman, and local communities. Throughout the process of bringing this effort into reality, the academic and applied research community will need to provide advice and guidance.

WORKING GROUP REPORT
ISSUE: POST-RELEASE SURVIVORSHIP

Working Group Chairs: Terry Bradley, Larry Bradley, Linda Kling)

What are the steps to implementation?

The first requirement for determination of post-release survivorship of groundfish is a monitoring program. The program should be regional in extent and may be either nearshore or offshore. Particular stations should be selected for periodic data collection. Station locations should be selected based on available information on fish densities. Information gathered should include fish abundances (using trawls and acoustic backscatter assessment) and plankton abundance (by net tows and acoustic backscatter assessment).

In addition to the monitoring program, a suite of ecosystem measurements is essential to understand how release of reared fish may impact the ecosystems into which they are released, and vice versa. Study of the population and stock structure of cod and other groundfish should be continued, in order to estimate probable dispersal patterns of the fish. Ecosystem-level studies should be instituted to determine the carrying capacity of the ecosystem in the areas targeted for release. The goal is to determine whether actual densities are significantly below carrying capacities, thereby providing the opportunity for successful enhancement. The community structure and species abundances of benthic habitats in the release area should be monitored closely; benthic habitats may provide a significant portion of the prey species for groundfish, and may therefore be significantly impacted by significant increases in fish abundance in the release area.

It is essential that we understand the physical oceanography, especially patterns of ocean circulation, in the release area. Although such studies are outside the purview of any stock enhancement program, such studies must be encouraged, and their results made available to the people responsible for designing any release program.

It will be essential to discriminate between wild and hatchery-reared fish, for biological, economic, and policy reasons. In biological terms, it will be essential to know whether the reared fish do as well as natural stocks, in terms of survivorship and physiological health. Predation on released juveniles should be monitored closely. For economic reasons, it will be essential to determine impact of any enhancement program and to enable retention of "ownership" of reared fish, if this becomes legally possible. Sensible policies regarding fishing and ownership of mixed reared and wild fish can only be drawn up if it is possible to discriminate the fish on the basis of their origins.

What are the obstacles for implementation?

Any program aimed at assessing the survivorship of post-release groundfish will be labor-intensive and costly. A carefully-designed monitoring program, circumscribed by the immediate goal of assessing survivorship, may be feasible.

A further obstacle is our limited understanding of the community and physical dynamics of any potential release area. Both the biology and the physics are likely to be very complicated. There may also be some difficulty in understanding the implications of existing data in terms of the questions asked above. How do we assess carrying capacity of an ecosystem for a particular species? How can we determine how it might have changed over time? These questions will be difficult to answer using existing data.

What resources are required for implementation?

Design of a field monitoring effort will require use of existing data bases from a variety of sources. Data should be sought from previous programs in the anticipated release area from any source.

Field monitoring programs require significant funding; funding sources will have to be coordinated at the regional level to enable an adequate effort with sufficient geographic and temporal coverage. Such coordination will require organization of research and monitoring efforts, and the enlisting of at least several interested funding agencies.

A leadership group will have to take charge, and demonstrate long-term commitment to the field monitoring effort.

Who should be involved?

The monitoring effort should be targeted at the regional level, with involvement of interested researchers, groups experienced in marine monitoring programs (including environmental consulting firms) and program managers from several funding agencies, including EPA and NOAA.

WORKING GROUP REPORT
ISSUE: HABITAT AND ECOSYSTEM DYNAMICS

Working Group Chairs: Geir Dahle, Hunt Howell

What are the steps to implementation?

An ecosystem-level research program is potentially enormously costly. In order to minimize cost and avoid repetition or duplication of effort, we should first identify programs and data bases that already exist for the Gulf of Maine. Some of these databases will be highly relevant for evaluating prospects of groundfish stock enhancement. We should identify gaps that may exist in these data bases and design a sampling regime appropriate to fill gaps.

Using available data and carefully designed field programs, we should determine the temporal and spatial distribution of cod and other finfish species in the Gulf of Maine. An early goal should be the definition of the carrying capacity of cod and other groundfish and the development of techniques to measure it.

What are the obstacles to implementation?

The most significant obstacle to a program designed to understand the ecosystem dynamics of the Gulf of Maine as a potential release area for ranched groundfish are limitations of all critical resources: time, money, and personnel.

Other important obstacles are our limited understanding of the population dynamics of many species, including the species targeted for enhancement. There is currently limited information on the critical ecological processes that determine population dynamic phenomena, such as: predator-prey relationships, food web dynamics, and energy flow through the system.

What resources are needed for implementation?

An ecosystem level study of the Gulf of Maine will require time, money, a coordinated team of scientists, and considerable facilities (e.g. vessels, laboratories, and equipment).

Who should be involved?

An ecosystem level study of the Gulf of Maine should include active participation by academic researchers, the fishing industry, state and regional aquaculture organizations, and state and federal agencies associated with fisheries.

WORKING GROUP REPORT
ISSUE: FISHING PRESSURE AND IMPACT ASSESSMENT

Working Group Chairs: Roland Barnaby, Mark Lussier

What are the steps to implementation?

The critical step to implementation will be the identification of markers for the discrimination of hatchery-raised fish. It is currently unclear what type of marker is best, and a research program is required to examine various markers and their costs and benefits for such a program. The desirable attributes of this marker are that it must be easily identifiable, cost effective, non-mutilating, and have little impact on the survivability of the fish

For full implementation of stock enhancement, a program will be needed to retrieve the identification information. It will be critical to identify a person or group that retains primary responsibility for the interpretation of the identification information. Clearly, the fishing industry must be a full and willing participant in this process; fisherman must be committed to the accurate retrieval of the identification information.

What are the obstacles to implementation?

An early obstacle will be to obtain the funding for the research necessary to develop identification tags for hatchery-raised fish. The next obstacle will be to secure the cooperation of fishing industry.

There is another obstacle that is less obvious: a somewhat negative attitude on the part of some portions of the fishing community. Community attitudes can make the funding of research projects to evaluate prospects for enhancement more difficult to obtain.

Another attitude that will present an obstacle to implementation of stock enhancement are concerns - primarily on the part of the environmental conservation constituency - about alteration in the genetic makeup of natural populations of groundfish that may be unavoidable with successful enhancement.

What resources are required for implementation?

Funding for research projects and the associated equipment is essential to evaluate possible methods for impact assessment.

We believe that a central agency or group program will be required that retains primary responsibility for the interpretation of identification data of ranched fish. This group should also be charged with the assessment of the economic, environmental, cultural, and social impacts of enhancement of natural stocks of groundfish.

Who should be involved?

The fishing industry must maintain active involvement and support of the concept of stock enhancement. Fisheries organizations will also be required in any full-scale effort. Scientists, including academic researchers and research staff of several agencies, will be needed to assist with the selection of appropriate methods for implementation and evaluation.

WORKING GROUP REPORT
ISSUE: PROGRAM DEVELOPMENT AND FUNDING CONSIDERATIONS

Working Group Chairs: Ken Beal, Rich Langton, Norm Stavis

What are the steps to implementation?

Any approach to the evaluation and implementation of stock enhancement of groundfish in the Northeast should work within the New England Groundfish Reinvestment Program. Funding for the critical studies needed to evaluate prospects for the success of enhancement with hatchery-raised fish should be provided from these funds. Funding for the hatchery production of juvenile fish for release into natural ecosystems should be provided by private sources, including venture capital.

We also recommend the formation of a public/private corporation, the "Gulf of Maine Stock Environment Corporation", that would perhaps parallel the Maine Groundfish Study Commission.

What are the obstacles to implementation?

One of the gravest concerns is that as we slowly develop the research rationale, seek funding through the competitive grants process, and devise an overall program plan, the industry continues to approach collapse.

Since a coordinated program will require funding from a variety of sources, we will need to work in a coordinated and complementary fashion with multiple funding sources, including: the Saltonstall-Kennedy Program, the Northeast Groundfish Reinvestment Program, the Sports Fish Restoration Act, etc. Coordination of multiple, distinct funding sources can be very complicated, especially when there is a sense of urgency.

The current lack of a means to rapidly and inexpensively determine the origin of fish and to distinguish between wild and raised fish is a significant obstacle to success. The only means of making stock enhancement through aquaculture profitable for individual companies is through retention of ownership or payment for released fish. There is currently no mechanism or policy that would make this possible.

We will also eventually require the assistance of NOAA funding for replacement of industry funding for the initial investment phases.

What resources are needed?

A stock enhancement effort will require a marriage between NOAA and industry, both to provide funding and to put the program into effect. We would hope for increased attention to this particular effort from NOAA/NMFS. We also hope that USDA funding will be available for some of the aquaculture aspects of this program.

We will also need to pursue legislative support for such a program. If early research suggests that stock enhancement of groundfish is economically feasible, we might expect support from the New England Congressional delegation.

Who should be involved?

The players in the programmatic effort should include the private industry lobby, the governmental scientific sector, and NOAA's new Office of Sustainable Development (John Bullard, Director).

Cod Sea Ranching: Identifying the Next Steps

MEETING AGENDA

October 26th, 1993 at The New England Center, UNH, Durham, NH

8:30 Registration / Coffee and Pastries

9:00 Welcome; Dr. Ann Bucklin, Director, UNH Sea Grant Program

9:15 Results of the Masfjorden Experiment in Cod Enhancement, Norway; Geir Dahle, Deputy Head, Aquaculture Department, Institute of Marine Research, Bergen, Norway

10:15 Comparative Results of Stock Enhancement in Various Species; Dr. Hunt Howell, Professor of Zoology, University of New Hampshire, Durham, NH

10:45 COFFEE BREAK

11:00 Industry Perspective: How We Got Here and Where We Need To Go; Norman Stavis, President, North Coast Seafoods, Boston, MA

11:30 Research Perspective of Cod Ranching: Studies of Early Life History; Dr. Larry Buckley, URI/NOAA Cooperative Marine Education and Research Program, Narragansett, RI

12:00 Sea Ranching: The Maine Approach; Dr. Richard Langton, Maine Department of Marine Resources, Boothbay Harbor, ME

12:30 Lunch at the New England Center (catered)

1:30 Plenary Session: What Do We Need to Know to Proceed?

2:30 What Are the Next Steps? (Formation of Working Groups)

3:00 COFFEE BREAK

4:00 Summary of Strategic Plan(s) (Working Group Reports)

5:00 Adjourn

Sponsored by the New Hampshire / Maine Sea Grant Program
Questions? Call UNH Sea Grant (603-749-1565) or Ann Bucklin (603-862-0122)

ABSTRACT OF PRESENTATION

Results of the Masfjorden Experiment in Cod Enhancement, Norway

Geir Dahle, Deputy Head of the Aquaculture Department
Institute of Marine Research
Bergen, NORWAY

Norwegian cod sea ranching programs have provided valuable information for future, similar programs in different habitats or areas. Biological and ecological knowledge about the release sites, as well as knowledge about physical and chemical conditions is vital to be able to measure the impact of release and to optimize release strategies. Surveys of the release and grow-out areas before and during a restocking or enhancement program is a key factor in the development of ecologically- and economically-based sea ranching programs. Several factors (including price and quality of juveniles, and the value of the recaptured fish) will determine whether sea ranching can be economically feasible. There is usually a close correlation between the quality of the juveniles and their prospects for survival. The quality of the juveniles should then be a second key factor in the development of a sea ranching program.

If the aim of the release program is a "put and take" fishery, it is not essential that the reared individuals resemble wild conspecifics. However, strict demands must be made of the individuals that are to be released in an enhancement or restocking program. The consequences of releasing genetically divergent individuals with unnatural behaviors may result in reduced survival rates. If the aim of the release program is to enhance recruitment to overfished populations, the released animals must also have natural spawning behavior. Artificial rearing environments will produce individuals that differ in some traits from wild populations, but the deviations from normal behavior and phenotype appear less in cod produced in natural sea water ponds compared to fish reared in commercial plastic or concrete pens.

ABSTRACT OF PRESENTATION

Comparative Results of Stock Enhancement in Various Species

Hunt Howell, Professor of Zoology
University of New Hampshire
Durham, NH

Declining natural populations, combined with advances in finfish aquaculture techniques, have caused a resurgence of interest in stock enhancement. Research associated with enhancement is both widespread and diverse. At present, there are well over 50 species being evaluated, and studies are being conducted in a dozen or more countries. Two largely government-supported stock enhancement programs in the United States, the red drum efforts in the Gulf of Mexico and the striped bass efforts along the eastern seaboard and Gulf of Mexico, were discussed. Approximately 15 million juvenile fish are released each year in both of these programs. Although natural populations of both species have risen since the implementation of stocking, there are insufficient data to demonstrate that these increases have resulted from the enhancement efforts. Indeed, given the very high mortality of the stocked fish, it is probable that very strict fisheries regulations, imposed along with the enhancement programs, may have resulted in the observed population increases.

A third enhancement program, involving the Japanese flounder, was discussed. This effort is being supported by the Japanese government and the fishing industry and has been quite successful. The program's success has resulted from relatively low production costs, high survival rates of stocked fish, high market value of this species, and very restrictive harvesting regulations.

A broad overview of stock enhancement efforts to date leads to the conclusion that enhancement is technically feasible for many species, but that much more research is needed before it becomes economically feasible for most species. Lastly, it was noted that stock enhancement cannot, at least in the near future, be considered as an alternative to increasingly restrictive fisheries management plans.

ABSTRACT OF PRESENTATION

Industry Perspective: How We Got Here and Where We Need To Go

Norman Stavis, President
Northcoast Seafoods
Boston, MA

Abstract not yet available

ABSTRACT OF PRESENTATION

Research Perspective of Cod Ranching: Studies of the Early Life History

Larry J. Buckley
URI/NOAA CMER Program
University of Rhode Island
Narragansett, RI

The Early Life History Investigation at the Northeast Fisheries Science Center, Narragansett Laboratory, has been spawning and rearing marine fishes in captivity for over two decades. The eggs and larvae produced are used for experimental studies of the effects of natural and anthropogenic variability on growth and survival. The group has spawned and reared to the juvenile stage many of the important demersal and pelagic species found in the Northwest Atlantic, including cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), silver hake (*Merluccius bilinearis*), summer flounder (*Paralichthys dentatus*), winter flounder (*Pleuronectes americanus*), yellowtail flounder (*Limanada ferruginea*), tautog (*Tautoga onitis*), mackerel (*Scomber scombrus*), and sand lance (*Ammodytes americanus*).

Characteristics of cod that make the species a good candidate for aquaculture include: 1) the ability to produce viable eggs through most of the year by manipulation of temperature and photoperiod, and 2) good growth and survival at low prey densities (< 100 plankters/ml). On the negative side, cod have a high rate of cannibalism. As is the case for most marine fish, cod larvae have an absolute requirement for live food during the larval stage. Cod larvae are too small at first feeding to consume brine shrimp.

Net pen culture of larvae was discussed as an alternative to either land-based culture or pond culture as practiced by the Norwegians. Results with winter flounder and tautog in Rhode Island estuaries showed average survival and extremely high growth compared to traditional laboratory culture. Larvae can be stocked in the enclosures at hatching.

A need for more information on the timing and causes of mortality during the early life stages of cod in the environment was stressed. The role of physical forcing and biological interactions on recruitment of cod is under active investigation currently by researchers at several institutions funded by NSF, NOAA, and the US Global Climate Change Program.

ABSTRACT OF PRESENTATION

Sea Ranching: The Maine Approach

Richard W. Langton
Maine Department of Marine Resources
West Boothbay Harbor, ME

The first regular session of the 116th Maine Legislature saw the introduction of a bill entitled,"An Act to Establish Cod Hatcheries". In its original form the bill proposed a $100 surcharge on all commercial fishing licenses in 1993 for the construction of two groundfish hatcheries along the Maine coast. Following public hearing the bill was rewritten to create a 13 person groundfish hatchery study commission, with representatives from the scientific, fishing, business and environmental communities, that has two specific charges. By January 1, 1994, the Commission is to report to the Legislature regarding the economic feasibility of producing hatchery-raised groundfish in the State at a production level that will affect the fishery. If this first charge results in a positive report then the Commission will, by January 1, 1995, determine the need for one or more hatcheries and the appropriate methods for revitalizing localized schools of groundfish, and the tendency of groundfish to return to their breeding areas. In addition, the Commission will study the relationship between hatchery-raised fish and wild stocks to determine the impact of introducing hatchery-raised groundfish into the groundfishery. The operation of the Commission is funded through a $10 surcharge on all commercial fishing licenses issued in 1994.

As of the end of October, members of Maine's Groundfish Study Hatchery Commission were appointed and the group has formally met once to consider a plan of action. This plan, which is consistent with the first Legislative charge, includes the development of an economic model to evaluate potential hatchery success. The input parameters for the model have been identified and the logic flow developed to the point that a very preliminary example was run and a "ballpark" estimate of economic viability generated for illustrative purposes at the present meeting.

The critical determinant of economic viability is accurately determining the survival of hatchery reared fish until capture in the fishery. The necessary survival rate depends upon a series of factors that can be estimated from previous fish hatchery experience or from biological and economic information that is readily available. These input parameters include 1) knowledge of the timing of critical life stages (e.g., the time of first feeding for larval gadoid fishes), 2) the rate of natural mortality for juvenile and older fish, 3) weight at age, 4) catch at age, 5) price per unit weight of harvested fish (e.g., landed value), and 6) hatchery and other operating costs. The model is then run by making an initial guess for the required survival rate from the hatchery through to adulthood. The costs and benefits are accumulated and the original guess refined until a "breakeven" hatchery survival rate is

determined. Whether this survival rate is feasible is a biological judgement. These calculations can be repeated for any species of fish and can consider enhancement programs based on larval release, juvenile release, or up through the aquacultural production of an adult, market size, fish.

Two examples were presented at the meeting that demonstrate the required survival rate, of hatchery released larvae up through age at capture, for the breakeven of a larval release enhancement program. The biological input data were based on Atlantic cod with an estimate of larval production costs from salmonid production. In the first instance, catch rate ranged from 30% to 70% of the entire population of fish being landed in any one year and larval production costs ranged from $0.02 to $0.03 per hatchery produced larvae. The interest rate, price per pound of fish, and natural mortality were held constant at 10%, $1.20 and 20% per year respectively. The resulting breakeven survival rate ranged from 8 to 13 larvae per 1000 larvae released. In a second example the catch rate was held constant at 50% while the interest rate varied. In this case the breakeven survival rate ranged from a low of 7 per 1000 when the interest rate was set at 5% and catch rate was 30% to a high of 18 per 1000 when the interest rate rose to 20% and cost of larval production increased to the maximum of $0.03 per larva.

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