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**MARINE FISH CULTURE & ENHANCEMENT**

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I extend a special thank you to the conference speakers, who took considerable time away from their research to share their experiences and knowledge with us. Conference coordinator Terry Nosho of WSGP spent many weeks contacting potential speakers and finalizing the workshop agenda. WSGP science writer Kris Freeman handled publicity and press relations in addition to drafting portions of the proceedings and editing the entire document. In addition, the meeting could not have been possible without the interest, encouragement and financial support of Linda L. Jones, Ph.D., acting director, Northwest Fisheries Science Center, National Marine Fisheries Service; and of Dan Swecker, Washington Fish Growers Association.

The members of the planning committee shared invaluable time and expertise. We wish to offer special recognition to Ronald Hardy, Ph.D., and Conrad Mahnken, Ph.D., of the National Marine Fisheries Service and to professors William Hershberger and Robert Stickney of the University of Washington School of Fisheries. These men participated in a subcommittee to accelerate decision making in the planning and production phases, took active roles during the workshop and reviewed this manuscript.

The organization of this conference affected everyone on the Washington Sea Grant Program staff, and we are indebted to them for their patience and perseverance. I wish to extend special thanks to WSGP Communications for designing and producing conference materials and to WSGP staffers Susan Hester and Susan Cook for efficiently handling the registration process.

In addition I would like to thank Pete Granger, Washington Farmed Fish Commission; Arnie Einmo, Dory Seafoods; and Tim Smith, Pacific Coast Oyster Growers Association, for their generous donations of farmed salmon and shellfish. Those who attended the conference were treated to these delectable seafoods at a luncheon and the workshop reception. Finally, the elements were kind, and we were able to treat our visitors to some spectacular weather, which helped make their stay memorable as well as productive.

*Louie Echols, Director  
Washington Sea Grant Program*

## Preface

Marine aquaculture and enhancement have generated growing interest among state and federal governments. In 1993, the Washington State Legislature passed laws requiring the Washington Department of Fisheries (WDF) to engage in artificial propagation of marine fish to enhance severely depressed recreational fishery stocks, specifically halibut, lingcod, Pacific cod and rockfishes. WDF also was instructed to use expertise at the University of Washington School of Fisheries. At the federal level, several activities are under way, fueled by the decline in commercial marine fish stocks. A National Marine Fisheries Service (NMFS) task force is drafting a marine fish enhancement initiative to incorporate into its strategic fisheries recovery plan. Individual Sea Grant programs are evaluating marine culture proposals for possible funding. The private sector, too, has expressed strong interest in marine fish farming and enhancement projects. Ultimately, the technologies developed by university and government scientists will be transferred to commercial hatcheries and farms.

Serious efforts to enhance marine fish stocks with hatchery technologies are under way in several regions of the United States. Work is being done with striped bass on the East Coast, snook in Florida, white sea bass and halibut in California, redfish in Texas and South Carolina, and mullet and Pacific threadfin in Hawaii. In the Pacific Northwest, however, marine fish enhancement efforts and research activities have been limited. The University of Washington initiated halibut research, and Canada's Department of Fisheries and Oceans Pacific Biological Station began extensive work on lingcod, halibut and sablefish. These projects were shelved, however, because of changing priorities. Regional marine aquariums have conducted limited culture work. For example, the Point Defiance Zoo and Aquarium in Tacoma, Wash., and the Vancouver Public Aquarium in Vancouver, B.C., have reared many species of marine fish over the years. Also notable are culture programs at several NMFS marine field stations, where fish are raised for experimental purposes other than farming or enhancement.

In general, the greatest experience and expertise are found overseas. Japan, Norway, the United Kingdom and Mediterranean countries are leaders in sea farming and enhancing marine fish stocks. Therefore, WSGP, NMFS and Washington Fish Growers Association agreed in 1993 that efforts to culture Pacific Northwest species would benefit if international and North American expertise could be assembled in a workshop format. Clearly, policy makers, researchers and citizens need to see the big picture in order to make intelligent decisions about appropriate technologies and management for the Pacific Northwest. This conviction led to the workshop "Marine Fish Culture and Enhancement," Oct. 4-6, 1993, in Seattle. Workshop speakers were chosen for their expertise with species similar to those identified for priority by the Washington State Legislature.

## Note

Several months following the MFC&E Conference but before these proceedings were published, the Washington Department of Fisheries (WDF) merged with the Washington Department of Wildlife to form a new agency, the Washington Department of Fish and Wildlife. Because these proceedings are a historical record, we have retained the designation Washington Department of Fisheries except in the appendices, where the new name is used.

## Marine Culture and Enhancement: An Overview

Puget Sound's marine fisheries are declining. Once abundant, fishes such as lingcod, herring and halibut are now difficult to find and catch. Is there anything we can do to bring these species back? Possibly.

For decades, salmon biologists have collected eggs in the wild and then nurtured and fed the resulting juveniles until they were ready for release to their native streams. By helping more young to survive, salmon hatcheries ultimately increase the number of adults available for sport and commercial fisheries. In a similar way, marine hatcheries could "stock" the sea, boosting populations of marine fish.

The Washington State Legislature has recognized the potential for enhancing marine or saltwater species of fish and in 1993 passed legislation that will fund enhancement research through an increased fee for marine sport fishing licenses.

Local aquaculturists also have a tremendous interest in marine fish cultivation. Because of restrictive permitting requirements and a lack of suitable sites, the opportunities for growth in near-shore salmon culture is extremely limited. To expand, the industry may have to go offshore, rearing marine fish in floating cages, or onshore, pumping seawater to tanks.

To meet the needs of fishers, aquaculturists and fisheries managers, Washington Sea Grant Program coordinated the Marine Fish Culture and Enhancement workshop. It was convened in October 1993 to consider the following questions:

- Can marine fish populations be enhanced?
- Can certain species be cultured for the market?
- Do any examples of marine hatcheries exist that may help us in our thinking?

The workshop, sponsored by Washington Sea Grant Program, University of Washington; Northwest Fisheries Science Center, National Marine Fisheries Service; and Washington Fish Growers Association, featured reports on successful marine enhancement projects in Japan, Europe and North America.

After two days of discussion, the more than 100 biologists, managers and aquaculturists attending came to a cautiously optimistic conclusion: By building on existing research, it is possible to establish a system of marine hatcheries in Puget Sound, given adequate funding and facilities.

The task will not be easy because marine fish are more difficult to rear than salmon. For example, newly hatched marine larvae are minuscule compared to salmon of the same age and are simply too tiny to ingest the commercial feeds used for salmon and trout. Therefore a marine



hatchery manager also must be a plankton farmer. However, once biologists can rear one type of marine fish, they can raise many, since the necessary techniques are similar for a wide range of species.

Additional observations:

- Technology transfer from successful marine enhancement programs in Japan and Europe could jump-start Puget Sound efforts. For example, there are many similarities between the Atlantic halibut being raised in Norway and the Pacific halibut that lives in Puget Sound.
- Possible candidates for Puget Sound enhancement include lingcod, rockfish (copper, quillback and black), Pacific cod, Pacific halibut, pollock, greenling and cabezon.
- Fisheries managers can benefit from enhancement studies by increasing their knowledge of the early life histories of many saltwater fish. The larvae of many marine species are extremely difficult to identify and collect in the wild. Often, biologists have been able to study marine larvae only by hatching eggs in a lab. Aquaculturists will require and generate detailed information about the life histories of the fish they rear, knowledge that surely will benefit fisheries management.
- Careful evaluation is necessary to determine if hatchery releases will actually enhance marine stocks. For instance, if long-term climatic and oceanic cycles are the true drivers of population size, then adding more juveniles to the mix may have little or no effect. However, if a shortage of young fish limits a particular fishery, then releasing juveniles may increase the numbers of catchable fish.
- Support from citizens and user groups is critical to any enhancement program. The people who ultimately will benefit from and pay for hatchery programs must be part of enhancement planning from the very beginning.
- The recreational fishing sector may be the most important source of enhancement support in Washington. Sport fishers have been the primary drivers behind three of the most extensive and productive marine enhancement programs in the United States, donating time, money and expertise to efforts to replenish stocks of white sea bass in California, red drum in Texas and striped mullet in Hawaii.
- Washington state's tribal nations should be included in any marine enhancement effort.
- Marine enhancement requires long-term funding support. Estimates for the time necessary to establish a viable and productive marine culture program ranged from five to 50 years. Most of the conference participants placed the time frame at about five to 10 years. Researchers also need a good place to work. Washington currently lacks an adequate marine lab for research. An ongoing project on Pacific halibut has been housed in makeshift and borrowed space, including, at one point, a converted one-car garage.
- The potential effect of hatchery releases on native stock and habitat should be carefully considered and studied.
- Releasing small quantities of hatchery-reared fish is the most efficient way to learn about marine culture and the possible effects, if any, of hatchery fish on native wild stocks. Experimental releases also can be a powerful management tool. They are an excellent way to gather information about the feeding habits and habitat needs of young fish. This information, now sorely lacking for most species, could greatly improve the management of existing commercial and recreational fisheries.

The following proceedings offer more detail in all these areas. The first portion of this report consists of abstracts of the technical papers presented during the meeting. The second portion is a summary of work group discussions and considers a variety of management and technical issues.

## Panel: Perspectives Into the Next Decade

*Dan Swecker*

*Washington Fish Growers Association, Rochester, Wash.*

Members of the Washington Fish Growers Association are involved primarily in the production of salmon and trout. Trout have been farmed in the western United States since the turn of the century. With Washington's plentiful water resources, it was an early participant in this industry. The state later established enhancement programs for wild salmon runs and now supports the largest state-run hatchery system in the world. Today our state produces about 2 percent of the world's farmed salmon, primarily Atlantic salmon grown in marine net pens.

However, commercial salmon culture in Washington has not reached its potential. It has been limited by citizen concerns over the siting of net pens. This has led to difficulties in obtaining leases. When several companies began farming salmon in net pens during the 1970s, local residents opposed new permits, citing concerns over potential environmental problems. Our industry responded aggressively and proved that the environmental concerns were unwarranted. Nonetheless, opposition over use conflicts and aesthetics remains strong. Essentially, the owners of waterfront residences don't want their scenic views affected by aquaculture facilities, and they don't want to drive around net pens in their boats. This opposition has helped generate a regulatory process for obtaining leases that is too expensive and unpredictable for most potential fish farmers. (In Washington all marine sites must be leased from the state.)

As a result, in the early 1980s aquaculture investment moved north to British Columbia, where new farms were built with government assistance and little opposition. In 1983 there were three salmon farms in British Columbia and about 20 in Washington. Today, there are more than 1,000 sites in British Columbia and only nine producing salmon farms in this state.

The Washington Fish Growers Association is working to ease some of the regulatory constraints on marine fish culture in Washington. During the last session of the Washington State Legislature, we successfully lobbied for passage of a law that requires the Washington State Department of Ecology to establish standards for siting marine net pens. We believe these standards will help streamline the permit process. The law also was revised to obtain longer-term leases of state-owned subtidal bedlands for aquaculture. Finally, the state legislature approved a budget item establishing a new Aquaculture Certification and Diagnostic Center to serve the needs of our industry. We hope these changes signal a new era in finfish aquaculture in Washington.

Now let us turn our attention to the culture of marine fish. I believe that the private sector should be involved in every step of the process, from initial research to actual commercial production

of any marine fish species found suitable. I also believe that the private sector can produce fish for enhancement on a more cost-effective basis than the public sector.

In my opinion, the best way for the private sector to participate in the research and development of marine fish culture and enhancement is through agreements with public institutions to accomplish common goals. One major objective should be the development of reliable sources of seedstock.

I believe there are many reasons that justify further research on marine fish culture. One overriding consideration is species preservation. We hear much these days in the United States about depleted, threatened and endangered stocks of salmon, trout and steelhead. Are other marine species far behind? Members of the commercial aquaculture community in Washington see an opportunity to preserve the genetic diversity of wild stocks through captive brood stock programs. For a brood stock program to succeed, we need to research any harmful effects of captive rearing on genetic diversity and develop methods to minimize those effects.

If we are successful at preserving our natural resources, it never may be cost effective for aquaculture to rear most marine species for the consumer's plate. This does not mean we should abandon efforts to commercialize marine fish. Other forms of agriculture are diversifying into genetic engineering, creating more efficient ways to produce pharmaceuticals and medications that are prohibitively expensive under current production techniques. Opportunities for biotechnology may be uncovered by increasing our knowledge of marine fish species.

*Louie Echols, Director*

*Washington Sea Grant Program, University of Washington, Seattle*

It is a pleasure to host this gathering, which has brought in distinguished experts from around the world to help us address some pressing issues in the Pacific Northwest. We face a complex situation as we consider the culture and enhancement of marine fish in the Pacific Northwest and the world. First, fish stocks are declining, fisheries habitat is in trouble, and many stocks are essentially tapped out. Second, human population is expanding. As the population increases, so does the demand for fish protein and for access to recreational fisheries. Natural variability is going to dictate substantial swings in productivity, even without environmental pressure. When you put variability on a downswing together with increased demand, you have a serious problem. To make matters worse, our knowledge of marine fish is very limited.

Given these basic conditions, what are some of the actions we must consider? We must look at both fisheries management and seafood production in some very different ways than we have in the past. We have no choice. We're going to have to build cooperative partnerships of a very different sort than we have had, involving government, industry and universities. I believe the Northwest is a particularly good place to build these partnerships. But, as we see here today, the expertise in many cases is located elsewhere. Once again, we are importing technology.

We must learn a great deal more about marine fish and about the environment in which they live. We also have to look at the potential for enhancement. It is far too early for a sure judgment on the real possibilities, but we must look at it hard. I suggest that whether we take a careful, concerted look or not, there are going to be enhancement activities. I would rather we go about it rationally.

We also must consider gene banking and species preservation techniques. I realize this concept

raises a host of other issues and concerns. But we have lost far too many salmonid species and subspecies already, and I believe that we face similar problems with certain species of marine fish. We must keep emphasizing technology transfer in this area.

There are some caveats to consider as we study possible marine enhancement. As I mentioned, we have a lot to learn. And, as we have begun to learn from very hard experience in this part of the world, not all enhancement enhances. Sometimes it does not work. Sometimes it may do harm. And, like restoration and mitigation of habitat, enhancement can be an easy way out, an excuse simply to keep doing the wrong things, the activities that damaged our fish stocks in the first place and brought us to the place we are now.

If we do get into enhancement, we must view it as an exercise in adaptive management. We're not only going to have to experiment, but we're also going to have to quantify our results. This kind of research will cost more in the short run but much less in the long run by helping us avoid missteps and miscalculations.

Finally, many of the necessary "partners" are severely wounded. Agencies are underfunded; industry is in disarray; science funding for resource issues has been on the decline. Therefore, there's a real question whether the necessary level of commitment genuinely exists for a long-term, concerted, very careful enhancement effort.

I believe the best hope for the future of marine fisheries is in groups like this, committed people from around the world who are sharing their knowledge, hard won in every case, and trying to work together cooperatively as we search for a better way to manage, enhance and protect our marine fish stocks.

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# MFC&E Abstracts

## NEEDS, APPROACHES AND CONCERNS

# Status and Characteristics of Marine Fish Stocks Along the Pacific Coast of North America With Regard to Enhancement

*Richard A. Neal*

*Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, Calif.*

Following is an overview of the status of major marine fish stocks from Alaska to Mexico with an emphasis on characteristics that may be of interest from an aquaculture or stock-enhancement viewpoint. Characteristics considered include current catch, potential yield, population trends, vulnerability to loss of genetic diversity, reproductive characteristics, mortality rates, vulnerability to environmental changes and unit value. For each characteristic, species are classified in broad categories (usually high, medium, or low) for general comparisons. No effort is made to evaluate individual species with regard to their potential for enhancement or for species use in aquaculture; however, on the basis of data presented, some groups emerge as obviously better candidates than others. The characteristics are considered from the standpoints of both recreational and commercial uses of species.

For convenience, groups of similar species are considered, including salmonids, rockfishes, small pelagics, large pelagics, flatfishes, other demersal species and miscellaneous minor species. Summaries of the most important observations by species group follow:

### **A. Salmonids**

Notable characteristics of the salmonids, which represent our most successful marine enhancement effort, are their low fecundity, the high impact of environmental variation, low reproductive success (man-caused), high unit value and anadromous behavior. Risk of loss of genetic diversity is high because individual runs are vulnerable to extinction.

### **B. Rockfishes (*Sebastes* spp.)**

The most interesting characteristics of this group include infrequent reproductive success in terms of recruitment, long life span and survival rates of early life history stages influenced by the ocean environment. High value in the recreational fishery and a lack of regular natural recruitment make some species candidates for further exploration of the benefits of enhancement.

### **C. Small Pelagics**

Although some species have low or declining populations, reproductive success is linked to natural environmental fluctuations, and unit value is extremely low. This group probably does not

merit consideration for enhancement.

#### **D. Large Pelagics**

Marlin and tuna have relatively high unit value and rapid growth rates. Some populations are declining, little is known about mortality rates, and migratory patterns are only partly understood. Further examination of this group is encouraged.

#### **E. Flatfishes**

This very large and diverse group has stable populations with variable but successful recruitment. Stocking of limited areas in Europe has met with mixed success. Only the California halibut is being stocked today along the Pacific Coast. Opportunities for beneficial enhancement are not obvious with this group.

#### **F. Other Demersal Species**

Pollock, sablefish, Pacific cod, lingcod and Pacific whiting as a group are heavily used and very valuable commercially. They are abundant and grow rapidly. Recruitment is subject to environmental fluctuations. Generally, populations are maintained in spite of heavy fishing pressure. While many are not viable candidates for enhancement, a few species of interest to recreational fishers (e.g., lingcod) warrant further consideration.

#### **G. Miscellaneous Minor Species**

A few additional heavily depleted species are considered, including white sea bass, giant sea bass, totoaba and striped bass. To the extent these species are not reproducing successfully, enhancement seems to offer potential; however, if slow growth and late reproduction are factors (as they are for white sea bass) overfishing may be an ongoing threat. The introduced anadromous striped bass is a special case of successful enhancement.

In conclusion, additional information on biology and behavior of most species is needed to evaluate their potential for enhancement. Attention is focused on possibilities for genetic manipulation and the potential impact of enhancement with "improved" marine species.

## Marine Fish Stocks in Washington: Status and Enhancement Considerations

*Mary Lou Mills*

*Marine Fish and Shellfish Program,*

*Washington Department of Fisheries, Olympia, Wash.*

Fishing and other pressures on marine fishes have increased over the past decade and will continue to rise as the population and the popularity of fishing grow. Resources in Puget Sound have seriously declined, and we are evaluating the role of enhancement in rebuilding populations and meeting future needs.

The marine fish stocks off the Washington coast support productive commercial and recreational fisheries, and many species are intensively managed by the Pacific Fishery Management Council. With the exception of Pacific Ocean perch, coastal stocks are in stable condition. Because of the healthy condition of marine resources on the coast, the discussion of the status and enhancement considerations for marine fish in Washington will focus on Puget Sound stocks only.

In Puget Sound, the Washington Department of Fisheries (WDF) is responsible for the protection and management of more than 100 species, although fewer than 30 are actively managed. Groundfish harvests are at their lowest level in more than 50 years (Figure 1). Declining abundances of many species, resultant restrictive regulations and changing fisheries all contribute to the decreased harvest levels.

Although herring, English sole and dogfish stocks are relatively healthy in Puget Sound, many of the stocks important to recreational and commercial fisheries have declined substantially in recent years (Table 1). Over the past decade, WDF implemented more restrictive regulations to reduce harvests and promote stock rebuilding (Table 2).

Our knowledge of historical trends in abundance of most species is limited, and historical catch patterns (Figures 2-10) are considered generally indicative of abundance trends. The lingcod resource in northern Puget Sound has deteriorated significantly. Restrictive regulations were introduced in 1992 to reduce fishery harvests by more than 75 percent. Although the condition of the rockfish resource is not well known, catch rates and average sizes of key rockfish species in the recreational fishery indicate that the abundance of rockfish is declining.

The Pacific cod resource remains at a low level, despite very restrictive regulations imposed upon commercial and recreational fisheries in central and southern Puget Sound. The pollock resource is at a low level as well, especially in southern Puget Sound, where recreational harvests have decreased substantially since the late 1980s. Like cod and pollock, the whiting resource remains at a very low level, even though there has been little or no harvest for several years. Similarly, the surfperch resource remains in poor condition despite fishery restrictions since the late 1980s.

Causes of the declines in many Puget Sound marine fish stocks are not well understood, and a variety of factors probably have contributed to the declines. Water temperatures during the winter have been warmer than average for more than a decade, which may adversely affect survival of young cod and other gadids. Also, fishery overharvests probably contributed substantially to the decline in cod and whiting stocks. Increased predation by marine mammals may be a significant factor in the decline of whiting, lingcod and other marine fishes. Shoreline development may limit access to



fishing grounds for surfperch and may reduce survival of other juvenile marine fishes through degradation of critical nearshore habitat.

Other factors, which have not been evaluated in Puget Sound, also may contribute to the declines in marine fish abundance. For example, chemical contaminants appear to reduce reproductive success, and micro-layer contaminants reduce larval survival. Several studies have shown that larvae of many marine fish species die from consuming phytoplankton that produce paralytic shellfish poisoning (PSP). Therefore, the spread of PSP in time and space in Puget Sound may be a factor in marine fish declines, although this has not been studied in Puget Sound. In addition, competition for space or food, such as with the large releases of cultured salmon, is an unknown but possibly significant factor.

WDF is approaching marine fish enhancement cautiously, to avoid mistakes made in other enhancement programs and to take the wisest actions for maintaining healthy marine fish resources and fisheries. One of the important lessons learned from 100 years of salmon enhancement is not to oversell technology. And it is clear that the public interest is better served through ecosystem management, so we must manage the whole system rather than targeting one resource at the ecological expense of others. Fiscal restraint is another reason for caution. We must carefully evaluate the probability of enhancement success, costs, benefits, and incremental, adaptive management steps. A primary concern is that we not jeopardize natural production by enhancement efforts, either through shifting recovery efforts from natural stocks to enhancement or through any unintended negative effects of enhancement projects.

We are at the beginning stages in evaluating enhancement for marine fishes, and this conference will help us in this process. To date, we have concentrated on alternatives to enhancement, such as reducing harvest and maintaining habitat quality, for rebuilding natural populations. Rebuilding natural populations to former levels may take many years because many marine fishes do not reach maturity and reproduce until age 5 or older. To be successful over the long term, we still have much to learn about the life history, habitat requirements, and other factors affecting abundance of marine fish in Puget Sound.

Our course ahead must be based on the accumulation of information about the causes of declines coupled with the wisest possible use of technology.

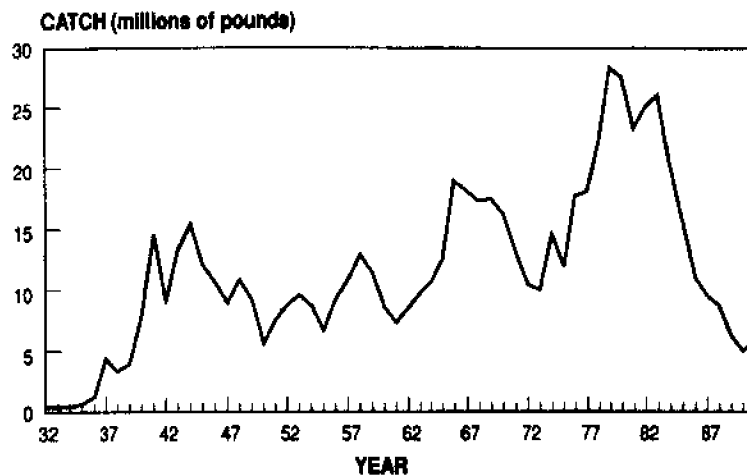
**Table 1.** Current stock condition and recent trends for major marine fishes in Puget Sound

SPECIES	CONDITION	TREND
Herring	Healthy	Stable
English Sole	Healthy	Stable
Dogfish	Healthy	Unknown
Lingcod	Poor	Declining
Rockfish	Poor	Declining
Pacific Cod	Poor	Declining
Pollock	Poor	Declining
Whiting	Poor	Stable
Surfperch	Poor	Stable

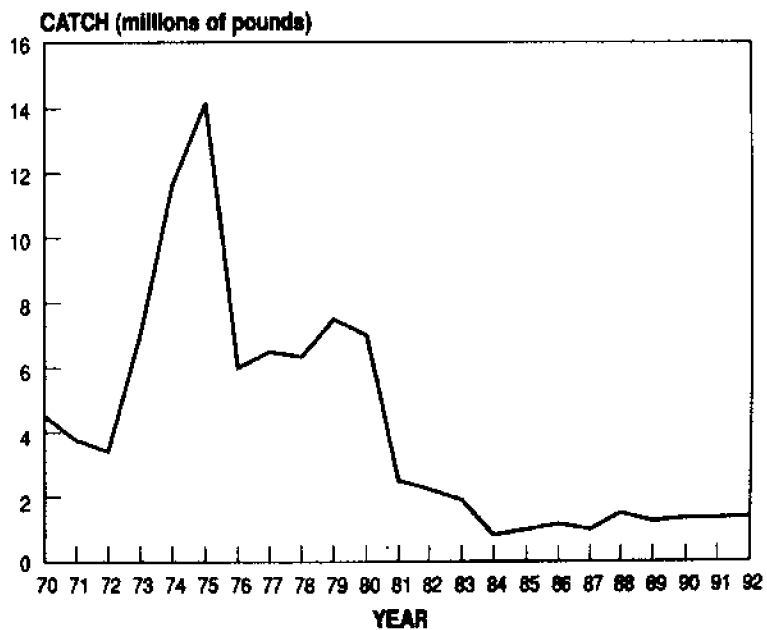
**Table 2.** Fishery regulation changes to conserve Puget Sound groundfish

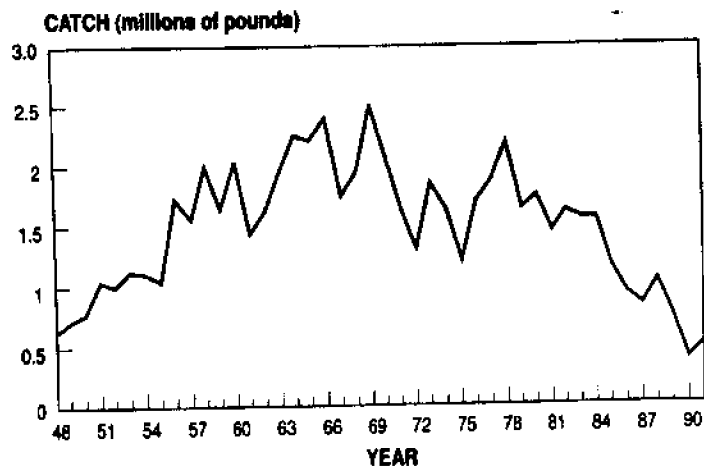
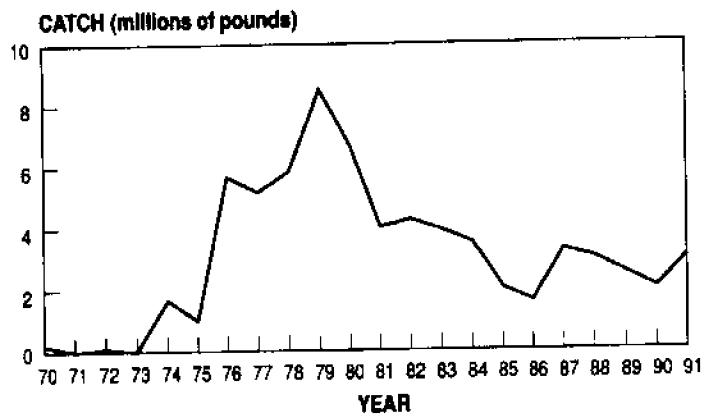
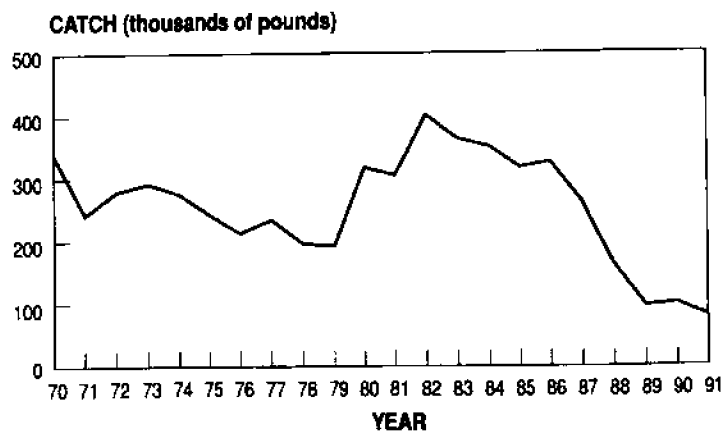
1978-83	Lingcod moratorium
1984	Rockfish bag limit reduced from 15 to five in central and south Puget Sound San Juan Islands closed to bottomfish troll and handline jig gears (lingcod, rockfish conservation)
1985	22-inch minimum size limit on lingcod imposed Depth and area restrictions added to the bottom trawl fishery
Late 1980s	Successive shortenings of the commercial drag seine seasons (surfperch conservation)
1987	Puget Sound closed to commercial set net fishery for Pacific cod
1988	Surfperch bag limit reduced from 15 to 10
1989	Legislature closed Hood Canal and central and south Puget Sound to bottom trawl fishery
1990	Pollock bag limit reduced from 15 to five in central and south Puget Sound
1991	Pacific cod bag limit reduced from 15 to two in central and south Puget Sound Agate Pass closed to winter fishing (Pacific cod conservation) Winter closure of bottom trawl fishery in Port Townsend and Protection Island areas (Pacific cod conservation) Ban on roller gear for bottom trawl fishery (lingcod and rockfish conservation)
1992	Lingcod conservation changes: Minimum size limit raised from 22 to 26 inches for all fisheries except spear Maximum size limit of 40 inches added for all fisheries except spear Season reduced to six weeks for all fisheries Handline jig and bottomfish troll fisheries banned east of Sekiu Sablefish trip limit of 250 pounds established for all commercial fisheries

**Figure 1. Puget Sound Groundfish Catch**

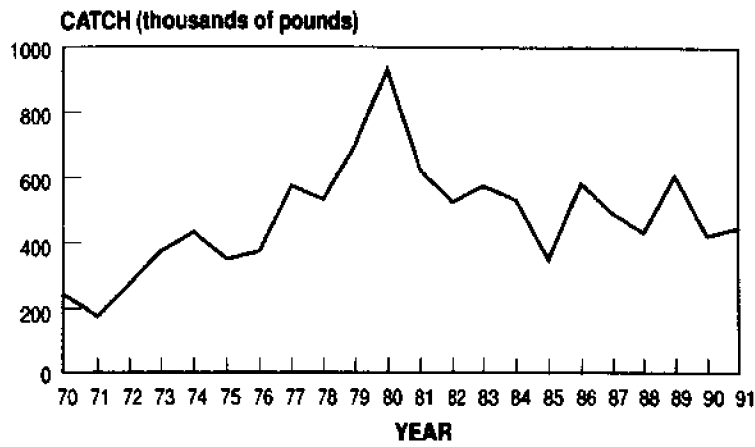


**Figure 2. Puget Sound Herring Catch**

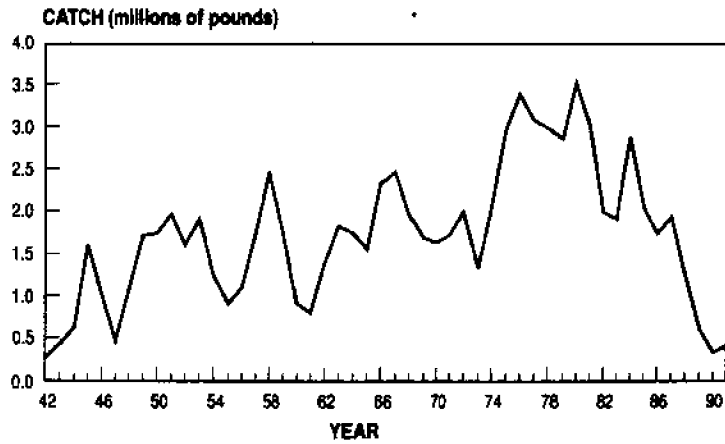


**Figure 3. Puget Sound English Sole Catch****Figure 4. Puget Sound Dogfish Catch****Figure 5. Puget Sound Lingcod Catch**

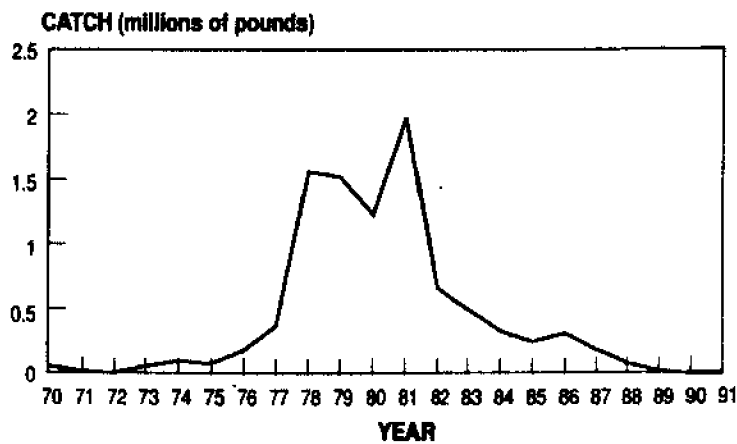
**Figure 6. Puget Sound Rockfish Catch**



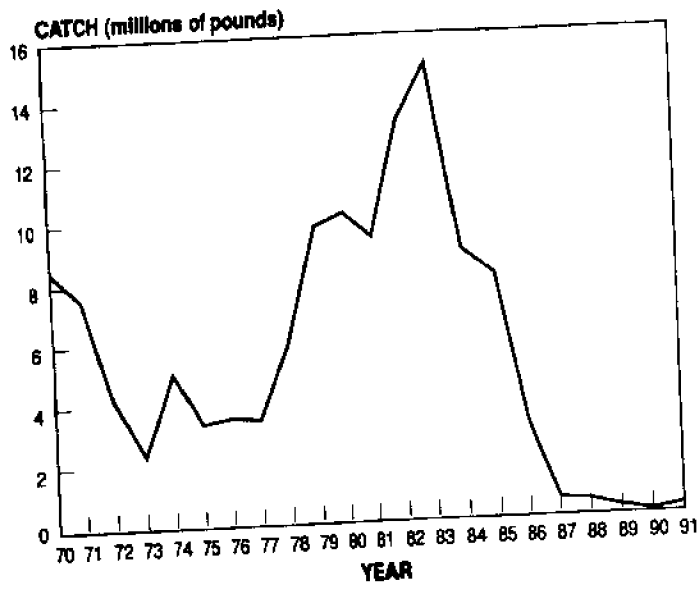
**Figure 7. Puget Sound Pacific Cod Catch**



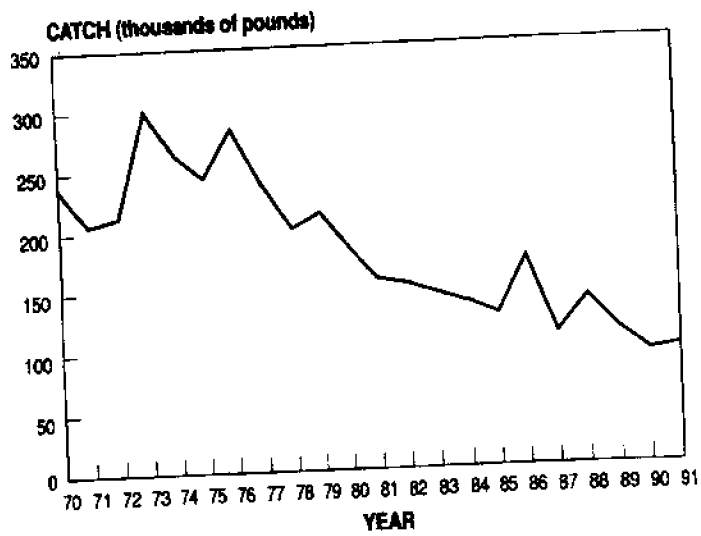
**Figure 8. Puget Sound Pollock Catch**



**Figure 9. Puget Sound Whiting Catch**



**Figure 10. Puget Sound Surfperch Catch**



## The Need for a Responsible Approach To Marine Stock Enhancement

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Three principal tools are available to fishery managers for replenishing depleted species and managing fishery yields: 1) regulating fishing effort, 2) restoring degraded nursery and spawning habitats, and 3) increasing recruitment through propagation and release (stock enhancement). The potential of the latter method has not been convincingly documented with marine fishes. Two general problems have restricted development of marine stock enhancement technology this century. One major obstacle has been our inability to evaluate the success of hatchery releases. Before the development of modern marking methods, fish tagging systems could not be used with the small life stages released by hatcheries. The other impediment to the development of marine enhancement has been our inability to culture marine fishes beyond early larval stages to the juvenile stage (fingerlings and larger sizes).

Faced with declining stocks and an expanding world population, custodians of our natural resources around the globe are looking at marine enhancement with renewed interest. To develop and evaluate its full potential, a process is needed for designing and refining stock enhancement tactics based on the combined effects of managing the resource (i.e., the interactive effects of hatchery practices, release strategies, harvest regulations and habitat restoration). Fortunately, recent advances in tag technology and marine fish culture provide basic tools for a new approach to marine enhancement. Together, these tools allow an empirical evaluation of cultured fish survival; feedback on hatchery-release impacts can be used to refine enhancement strategies. Release impacts on wild stocks, and the fisheries based on them, can be quantified and evaluated.

These new tools provide the basis for significantly increasing wild stock abundances. To ensure the successful use of these tools and to avoid repeating past mistakes, we must take a responsible approach to developing, testing and managing marine stock enhancement programs. Each component below is viewed as an essential aspect of a responsible approach to controlling and optimizing enhancement.

1. Have a process for prioritizing and selecting target species
2. Develop a species management plan that identifies harvest opportunity, stock rebuilding goals and genetic objectives
3. Use genetic resource management to prevent inbreeding and outbreeding depression
4. Use disease and health management
5. Consider ecological and life-history patterns when forming enhancement objectives and tactics
6. Identify released hatchery fish and assess stocking impact
7. Use an empirical process for defining optimum release strategies
8. Define quantitative measures of success

9. Identify economic and policy guidelines
10. Have a process for changing production and management objectives and strategies based on stocking impact

Combining new marine fish culture and tagging technologies with these 10 principles is gaining support as a responsible approach to marine stock enhancement.

Empirical data are lacking to assess accurately the impact of hatchery releases on wild populations. Partly because of this uncertainty, there is increasing division of conservationists into two camps—one adamantly favoring fishing regulations and the protection and restoration of habitat over hatchery releases, the other supporting propagation and release as an additional tool to manage fisheries and restore declining stocks. This split must be reconciled. Is stock enhancement of marine fishes a powerful, yet undeveloped, technology for rebuilding depleted wild stocks and increasing fishery yields? Or are emerging marine enhancement programs merely futile attempts at recovering precious resources, thus diverting money and attention away from habitat restoration and the regulations needed to control overfishing? If enhancement does indeed have potential to help conserve and replenish rapidly declining marine stocks, then can we afford not to develop its full potential as rapidly as possible?

There is only one way to answer these questions. We must act now to assess empirically the actual potential of marine stock enhancement through carefully planned research programs. Using strong inference (Platt, 1964) and addressing each of the components listed above, research programs will either document the value of marine stock enhancement or disprove the idea that enhancement is a useful concept. Without determined and careful attention to the 10 points listed above, marine hatchery releases in the 1990s may serve only to fuel divisiveness between the two conservationist camps, with little or no positive effect on natural resources.

The hypothesis that marine hatchery releases can increase fish abundance has at least two corollaries that need to be tested: 1) cultured marine fish survive and grow in the wild, and 2) cultured fish do not displace wild individuals. Both are being tested in Hawaii. Research to date has shown that abundances of striped mullet (*Mugil cephalus*) can be substantially increased using information from small-scale pilot releases to establish release conditions for full-scale stock enhancement. Pilot releases were conducted from 1989 to 1991 to examine the impact of release protocols on survival through the nursery phase of the life cycle. The release variables—fish size-at-release (SAR), release microhabitat and release season—all had substantial impacts on survival of cultured striped mullet tagged and released on the islands of Oahu and Hawaii. The effect of SAR on survival was significantly altered by release habitat and by release season. These results were used to plan experiments to test both of the above corollaries.

In 1992 during the spring and summer, 80,507 cultured striped mullet were coded-wire tagged and released into Kahaluu Stream, the principal mullet nursery in Kaneohe Bay, Hawaii. Monthly sampling to track release impact revealed that yield per stocked juvenile was at least fourfold greater than yields from initial releases in Kaneohe Bay. This 400 percent increase in survival was achieved by basing fish size-at-release, release site and release season upon the results of the pilot releases conducted before this release. In summer 1993, around 5,760 wild mullet were captured, tagged and released back into two nursery habitats in Kaneohe Bay. After three weeks, 29,354 cultured mullet were tagged and also released, but at only one of those nursery sites. Monthly monitoring will determine



whether there is greater dispersal of wild fish at the site where cultured fish were released. As of six months after the hatchery release, there is no significant difference in the dispersal rates of wild fish at the treatment and control sites.

### References

Platt, John R. 1964. Strong Inference: Certain systematic methods of scientific thinking may produce much more rapid progress than others. *Science* 146 (3642): 347-353.

### Selection of Species for Stock Enhancement

**Table 3.** Results of ranking process for species selection criteria (first workshop)

Criterion	No. of Responses	Overall Weight	Weight as % of Total	Priority Rank
Commercial/recreational demand (necessary criterion)	11	108	12.63	1
Availability of viable spawn	12	104	12.16	2
Juvenile release will increase adult population	11	90	10.53	3
Ease of larval rearing	12	83	9.7	14
Cost effectiveness	11	64	7.49	5
Ease of juvenile rearing	12	61	7.13	6
Ease of monitoring impact/experimental design	11	58	6.7	87
Extent of recruitment limitation	9	51	5.96	8.5
Likelihood of rapid success	8	51	5.96	8.5
Impact on resident biota	5	29	3.39	10
Low ratio of mortality to growth	4	24	2.81	11
Documented historical decline	4	23	2.69	12
Availability of habitat	5	19	2.22	13.5
Movement patterns (residential vs. migratory)	5	19	2.22	13.5
Socioeconomic attractiveness (profile)	5	14	1.64	15
Inshore seasonal availability (stick around)	2	13	1.52	16
Fishing mortality (fishing pressure)	2	12	1.40	17
Facilities	3	11	1.29	18
Ease of protection until market size	3	8	0.94	19
Local reproduction: degraded or limited habitat	2	4	0.47	20
Availability of food	1	2	0.23	21.5
Ease of transport and distribution	2	2	0.23	21.5
Size at capture	0	1	0.12	25
Non-consumptive uses	0	1	0.12	25
Seasonality/environmental factors	0	1	0.12	25
Mitigation issues (pollution)	0	1	0.12	25
Cost of monitoring effort	0	1	0.12	25

From Prioritization of Marine Fishes for Stock Enhancement, published by the Oceanic Institute

**Summary of results by broad categories**

Socioeconomic considerations (necessary)	23.391
Biological culture considerations	29.012
Enhancement considerations	25.843
Fishery knowledge	9.364
Ecological considerations	8.545
Release considerations	2.576
Infrastructure considerations	1.297

**Table 4.** Summary of the 27 final species selection criteria.

1. **Commercial/recreational demand.** There must be a recognized demand by commercial and/or sports fishing groups for the specific fish. Only those fish that satisfy this criterion will be further considered.
2. **Ease of maturing and spawning.** The fish should have the potential to mature and spawn successfully in captivity.
3. **Releasing juveniles should increase fish population.** Releasing juveniles should provide an otherwise unavailable supply of new recruits to the local fish population. (This is often the case when the number of reproducing adults has been sharply reduced by overfishing.)
4. **Ease of larval rearing.** Larvae of the fish can be hatched from eggs produced by brood stock and then raised to juvenile size using existing culture techniques.
5. **Cost effectiveness of stock enhancement process.** The value to society derived from increasing populations of this fish is likely to be great enough to justify the costs involved in raising juveniles for release and distributing them at release sites.
6. **Ease of juvenile rearing.** Large numbers of fry can be reared and maintained in captivity until release.
7. **Ease of experimental design and monitoring of impact.** The fish should lend itself to release-recapture experiments and to monitoring programs set up to determine effectiveness of attempts to enhance the fish population.
- 8.5a. **Extent of recruitment limitation.** Recruitment of juveniles should be a primary limitation on growth of the existing fish population.
- 8.5b. **Likelihood of rapid success.** The fish species should have the potential for a marked increase in fish population size and landings in the near future.
10. **Impact on resident biota.** Releasing juveniles should not interfere significantly with other sea life currently living in or near release sites.
11. **Low mortality-to-growth ratio.** Mortality rate should compare favorably with growth rate in wild populations (death rate before reaching maturity should be relatively small).
12. **Documented decline in fish stock or fish landings.** There should be fewer of these fish in the ocean now than in past years.
- 13.5a. **Availability of habitat.** Sufficient areas of the fish's preferred habitat should be available in Hawaiian coastal waters to support increased fish populations.
- 13.5b. **Movement patterns (residential vs. migratory).** The released fish should remain in Hawaiian waters as adults rather than migrating elsewhere.

15. **Socioeconomic attractiveness.** The fish should have a strong appeal to the general public.
16. **Inshore seasonal availability.** The fish should be present in Hawaiian waters year-round rather than only at certain times of the year.
17. **Fishing mortality (current fishing pressure).** If there is currently a great deal of fishing pressure, minimal protective and enforcement measures should be required to insure successful stock enhancement.
18. **Facilities.** Hatchery and nursery facilities should be currently available for this fish.
19. **Ease of recruitment until market size.** It should be possible to protect the released fish from capture until they are large enough for commercial or recreational fishing.
20. **Hearty enough to reproduce in degraded or limited habitat.** The fish should be able to survive in areas of damaged or destroyed habitat.
- 21.5a. **Availability of food.** Adequate food resources should exist in the wild to support the released fish.
- 21.5b. **Ease of transport and distribution.** Juveniles should be relatively easy to transport from the hatchery to release sites.
- 25a. **Cost of monitoring effect.** Costs of tagging and recovery should not be excessive.
- 25b. **Seasonality and environmental factors.** The fish population should not be strongly affected by changes in the weather or environmental disturbances.
- 25c. **Mitigation issues.** Enhancement should not require a reduction in current levels of pollution in order to be successful.
- 25d. **Non-consumptive uses.** Does this species attract divers and other observers?
- 25e. **Size at capture.** How large do these fish have to be in order to be considered large enough to keep?

## MARINE FISH CULTURE

### Recent Advances In Marine Aquaculture in Japan

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Japan is the world's most varied producer of aquaculture products and is currently growing more than 60 species of marine finfish, shellfish and sea vegetables. Marine farming, or commercial production of a species through private aquaculture, often leads to the establishment of coastal hatcheries that release fish for marine fisheries enhancement. Both forms of aquaculture are important in producing the consistent supply of high-quality seafoods demanded by the Japanese consumer.

Japan produced about 10 million tons of seafood in 1989, of which approximately 11 percent was produced directly through marine farming. In addition, 2 million metric tons of low-value fish from the capture fishery are used annually in the manufacture of aquaculture feeds. Aquacultured species tend to be high in market value. Although marine-farmed products constitute only about 10 percent of annual Japanese fishery production by weight, they account for 25 percent of the total annual revenue from fishing and aquaculture combined.

In 1989, Japanese private aquaculture produced 480,000 tons of sea vegetables such as wakame, konbu and nori. In the same year, the industry produced 410,000 tons of mollusks, pearl oysters, oysters and scallops. Other high-production categories included finfish (coho salmon, sea bream, horse mackerel, yellowtail) and crustaceans and ascidians (Karuma prawn, crabs and sea squirts). Production from Japanese marine farms increased by approximately 3 percent per year from 1960 to 1987, and the industry now employs approximately 60,000 fresh- and saltwater farmers throughout Japan. Factors limiting the growth of commercial aquaculture in Japan include lack of an export market, competition from foreign producers (primarily Korea and Taiwan), shortage of low-cost marine proteins used in feeds, degraded water quality in farming areas as a result of urban development, self-pollution from farms and lack of a technological base for commercialization of new species.

Marine fisheries enhancement promises to play an increasingly important role in Japan by enhancing the natural resources that provide much-needed revenue to economically depressed coastal fishing communities. In 1990, Japanese hatcheries released 12.9 billion seedlings of some 80 marine and anadromous species. Production of significant marine ranched species in 1990 included 10 billion scallops, 2.2 billion chum salmon, 0.5 billion Karuma prawn, 0.6 billion flatfishes and rockfish and 0.8 billion blue crabs.

Although this production data is impressive, and Japan's marine fisheries enhancement in general is considered successful, many technical problems related to the refinement of culture systems

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remain unsolved. Of the 37 species of marine finfish used in experimental releases, for example, only four were successful enough to have been adopted for commercial use. Successful species of finfish were red sea bream (*Pagrus major*), Japanese flounder (*Paralichthys olivaceus*), black sea bream (*Acanthopagrus schlegelii*) and black rockfish (*Sebastes schlegelii*). Releases of most other species are still considered experimental, and many marked seedlings are being released to evaluate their contribution to coastal fisheries.

## Production of Juveniles With Emphasis on Atlantic Halibut

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The development, or propagation, of Atlantic halibut (*Hippoglossus hippoglossus* L.), is undergoing change in Norway today. Substantial effort is now being invested by the Norwegian Research Council to promote a sound commercial business. Other candidate species judged to be fairly promising are the scallop (*Pecten maximus*) and Atlantic cod (*Gadus morhua*). The common wolffish (*Anarhichas lupus*), the spotted wolffish (*A. minor*) and the turbot (*Scophthalmus [Psetta] maximus*) also are subjects for Norwegian scientific projects.

### Production of Atlantic Halibut Juveniles

The production cycle can be divided into at least six periods:

1. brood fish management and production of fertilized eggs
2. egg incubation
3. hatching and yolk sac period in silos
4. first feeding on live feed
5. weaning to a formulated feed
6. on-growth

The latter should be divided in several phases according to the fish's environmental demands as well as economic considerations. Survival rates, especially for periods (4) and (5), are variable and too low. The overall survival from stripped egg to a well-weaned juvenile will therefore vary between 0 percent and more than 40 percent.

Brood fish caught in the wild need several years in captivity before they produce a reliable amount of high-quality eggs. The timing of stripping appears to be crucial for the viability of the eggs. Repeated careful handling of the female halibut seems not to affect the ovulatory rhythms. Eggs should be incubated at temperatures around 6 C and should be disinfected and transferred to larvae incubators before hatching (at 12-13 days).

The halibut eggs and yolk sac larvae are particularly sensitive to light and will respond with negative buoyancy as well as delayed hatching. The buoyancy varies also throughout development. Both eggs and larvae are susceptible to stress, and thus special consideration must be taken regarding the design and tending procedures of egg and larvae incubators. The yolk sac period is long in halibut, more than 30 days in a favorable temperature regime. Before first feeding, larvae should be transferred to suitable tanks. This period currently is carried out in outdoor tanks, based on a regime consisting of brine shrimp nauplii (*Artemia* sp.) and natural zooplankton from a manipulated saltwater basin.

**Recommended literature for further reading**

- Bergh, Ø., G. Høvik-Hansen, I. Huse and A. Jelmert, 1991. Studies on diseases of cultured juvenile Atlantic halibut. NOAA Tech. Rep. NMFS 111.
- Haug, T. 1990. Biology of the Atlantic halibut, *Hippoglossus hippoglossus* (L. 1758). *Advances in Marine Biology* 26: 2-33.
- Helvik, J.V., D.O.O. Berntsen and B.T. Walther, 1991. The hatching mechanism in Atlantic halibut (*Hippoglossus hippoglossus*). *Int. J. Dev. Biol* 35: 9-16.
- Kjørsvik, E., A. Mangor-Jensen and I. Holmefjord, 1990. Egg quality in marine fishes. *Advances in Marine Biology* 26: 71-113.
- Mangor-Jensen, A., T. Harboe, S. Tuene, K. Boxaspen and L. Skjolddal, 1990. Intensive production of halibut fry. In R.L. Saunders (ed.) Proceedings of Canada-Norway finfish aquaculture workshop, September 11-14, 1989. *Can. Tech. Rep. Fish. Aquat. Sci.* 1761:153-159.
- Naas, K.E., T. Næss and T. Harboe. Enhanced first feeding of halibut larvae (*Hippoglossus hippoglossus* L.) in green water. *Aquaculture* 105: 143-156.
- Norberg, B., V. Valkner, J. Huse, I. Karlsen and G. Lerøy Grung, 1991. Ovulatory rhythms and egg viability in the Atlantic halibut (*Hippoglossus hippoglossus*). *Aquaculture* 97:365-371.
- Opstad, I. and Ø. Bergh, 1993. Culture parameters, growth and mortality of halibut (*Hippoglossus hippoglossus* L.) yolk sac larvae in upwelling incubators. *Aquaculture* 109:1-11.
- Pittman, K., Ø. Bergh, I. Opstad, A.B. Skiftesvik, L. Skjolddal and H. Strand, 1990. Development of eggs and yolk sac larvae of halibut (*Hippoglossus hippoglossus* L.). *J. Appl. Ichthyol.* 6:142-160.
- Pittman, K., A.B. Skiftesvik and L. Berg, 1990. Morphological and behavioral development of halibut, *Hippoglossus hippoglossus* (L.) larvae. *J. Fish. Biol.* 37:455-472.
- Tilseth, S. 1990. New marine species for cold-water rearing. *Aquaculture* 85:235-245.
- Tilseth, S., G. Blom and K. Naas, 1992. Recent progress in research and development of marine cold water species for aquaculture production in Norway. *J. World Aquaculture Soc.* 23(4):277-285.

The Institute of Marine Research, Austevoll Aquaculture Research Station, employs about 50 people, including 17 scientists. We work on marine cold-water aquaculture and are a large research facility recognized nationally and throughout Europe. The station provides good facilities for different kinds of experiments on a small, medium and large scale. The station aims to produce scientific knowledge in order to promote biologically as well as economically sound farming of marine species in Norway. The station is one hour from Bergen, where the main body of the Institute of Marine Research is located. The Institute advises the Norwegian Ministry of Fisheries in its management of living marine resources.

## USES OF JUVENILES

### Marine Fish Enhancement: Concepts and Concerns for Artificial Propagation

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Pacific salmon hatcheries are the most prominent example of fish culture for marine fish enhancement. For the most part, salmon hatcheries have been successful in producing fish for recreational and commercial fisheries and for restocking areas where runs have been wiped out. Unfortunately, reliance on hatcheries historically has been viewed as appropriate compensation for habitat loss. This philosophy often has worked to the detriment of wild stocks by tacitly condoning environmental degradation and worsening decline through overexploitation in mixed-stock fisheries.

The impact of salmon hatcheries on petitioned and listed species is a concern under the Endangered Species Act (ESA). The traditional production-oriented hatchery is not compatible with the goals of the Endangered Species Act to restore threatened and endangered species to their habitat. A new generation of conservation hatcheries must be developed to supplement and recover depleted populations. Conservation hatcheries should apply combinations of captive brood stocks, behavioral conditioning and optimal release strategies for restoration efforts. In addition, rearing-container structures and feeding strategies should mimic natural conditions. Artificially propagated juveniles should be similar in growth, development and behavior to their wild cohorts. These same considerations should be applied to the operation of other marine species enhancement programs.



## Evaluating the Use of Hatchery-reared Juveniles To Enhance Depleted Marine Fisheries In Southern California

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Since 1984 the California Department of Fish and Game has administered the Ocean Resources Enhancement and Hatchery Program, which has been dedicated to evaluating the economic feasibility of culturing and releasing juvenile marine fish into wild habitats along the Southern California coastline. The initial OREHP research goals were to:

1. Capture and maintain brood stock
2. Develop techniques for the artificial control of spawning requirements of juvenile fish
3. Develop protocols for hatching and rearing larvae and small juveniles
4. Evaluate the economic feasibility of enhancing marine fish populations
5. Assess the pattern of mortality during the first year of life to determine the optimum age and size for release
6. Define release sites to realize maximum survival
7. Develop techniques to differentiate genetically differing stocks and assess the impact of released fish on wild stocks
8. Determine and evaluate pertinent population characteristics and habitat

These goals applied to both of the program's target species, white sea bass (*Atractoscion nobilis*) and California halibut (*Paralichthys californicus*).

Substantial work on evaluating the life histories of both species has concentrated on identifying juvenile habitats where releases would occur. Estimates of population size for early life stages have been made using density estimates obtained from field sampling and applying these to digitized computer maps of known habitat areas in Southern California.

Post-release mortality is evaluated through mark-and-recapture experiments using both coded wire tags and fluorescent marking with oxytetracycline. Feasibility is tested via a bioeconomic computer model that compares costs of culturing fish to a given release size, weighted by post-release survival to recruitment, to the value of the fish recruited into the commercial fishery. The resulting benefit-to-cost ratio also is used in sensitivity analyses to evaluate the priorities for future research work.

A frequent criticism of enhancement programs is that insufficient effort is dedicated to understanding post-release survival and subsequent recruitment. OREHP developed a double marking technique that employs coded wire tags and oxytetracycline. Since 1985, efforts to recapture hatchery-reared sea bass have employed beach seines, beam and otter trawls, gillnets, and hook and line. The catch of each gear type was generally size-specific and partially determined by where the gear could be used effectively. Gillnets were efficient in capturing sea bass 150-850 mm TL (age I-IV). A hook-and-line sampling program was initiated in 1992 using the sampling effort of fishers aboard commercial passenger vessels to target white sea bass greater than age V.

An expanded mark-and-recapture program is proposed that will increase the number of fish

released over a larger geographic range. This program will use gillnet sampling to evaluate the effect of various controllable release parameters. The program also will use specimens from both the commercial and recreational catch to evaluate the contribution to the fishery.

The use of hatcheries to enhance depleted fisheries has, for some anadromous fish species, been an accepted management tool since the 1800s. Intense interest has developed worldwide to expand the use of hatchery enhancement to include other fish species, mollusks and crustaceans. Concern has been raised that such efforts might significantly affect wild stocks by flooding the reproductive population with individuals whose genetic variability, and therefore their overall fitness, has been diminished by hatchery selection protocols.

Some fear that the use of hatchery fish to supplement marine stocks might adversely affect the wild populations by saturating the available habitat with fish having more uniform genetic character, thereby out-competing wild genotypes and supplanting them with a more uniform (i.e., less variable) and less adaptive genotype. However, it is difficult to study this problem definitively since wild strains continue to be influenced by selective pressures, such as diminishing habitat and changes in water quality, outside the control of the experimenter.

The issue of reduced genetic variability is less of a concern for the panmictic species that are currently being investigated for enhancement potential. In these populations, discrete subpopulations may occur both spatially and temporally but do not remain discrete over time. Hatchery fish produced to enhance such populations should attempt to encompass as much of the genetic variability as is observed in the wild population. This demands a conscientious effort to review the genetic character of the wild population, as well as a stringent protocol for brood stock management. Techniques that can be used toward this end include maintaining a large number of brood fish, rotating brood fish between spawning pools to ensure random mating and introducing new brood fish to the hatchery population at regular intervals. If hatcheries are to become more widely used to supplement wild populations, then special care will need to be taken to ensure that already depleted wild stocks are not adversely influenced by the loss of genetic variability.

The OREHP research evaluates the potential use of cultured fish for the enhancement of wild populations as a real and quantifiable resource management tool. This research may allay the concerns of management biologists responsible for establishing the methods by which environmental problems can be mitigated.

## Texas Red Drum Enhancement Works

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Red drum (*Sciaenops ocellatus* L.) is an estuarine-dependent sciaenid that inhabits estuaries, bays and coastal regions from New York to Mexico. It has historically supported vital recreational and commercial fisheries throughout its range. In Texas, the red drum population began a dramatic decline in the 1970s, prompting the Texas Parks and Wildlife Department (TPWD) to implement a three-pronged recovery plan. The management approaches used were:

1. Initiation of an independent monitoring program to assess relative abundance
2. Implementation of restrictive regulations to reduce fishing pressure including license restrictions; size, bag and possession limits; a commercial quota; restrictions on netting; and a ban on commercial sale of red drum
3. Development and implementation of a marine enhancement program based on the release of hatchery-reared fingerlings and assessment of subsequent survival

Recently, the red drum bay population in Texas rebounded to near-record highs thanks to a number of factors. TPWD's long-term management plan using hatcheries to supplement natural spawning played a crucial role in mitigating the decline of the red drum population. It has taken TPWD 21 years to reach the current stage of its stocking and recovery program; to date, more than 115 million fingerlings have been stocked in marine waters. The use of hatcheries, coupled with traditional fisheries management practices, has proven to be a powerful combination in managing Texas' natural resources wisely. All scientific evidence to date strongly suggests that hatchery fish did indeed enhance the Texas red drum bay population. The overall strategy used by the TPWD can serve as a blueprint for other marine enhancement programs.

## U.K. Mariculture: Experiences and Prospects

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Historically, finfish consumption in Northern Europe and the Mediterranean has been dominated by a preference for marine fish. This preference continues today, and with the problems of overfishing and the subsequent imposition of catch quotas and other controls on traditional fishing methods, attention has increasingly been directed toward the possibilities of farming the seas. Despite this interest, current exploitation of coastal waters has been dominated by the culture of Atlantic salmon rather than more typical marine species such as the turbot, cod, halibut, bass and bream that the market probably would prefer. Undoubtedly, one of the main reasons for the growth in salmon production is the similarity in culture methods for salmon to those of the rainbow trout, which has been cultivated in Europe for some 120 years.

Developments in the culture of non-salmonid marine species also have been constrained by a lack of information about management of the brood stock, difficulties in the artificial spawning and stripping of fish and the much poorer survival (quality) of the resultant eggs and larvae. There also are many questions relating to the optimum conditions and facilities required for egg incubation, larval rearing and on-growing of fish to table size. Water temperature is an important determinant, too, with bass, bream, mullet, turbot and Dover sole requiring much higher ambient temperatures for optimum growth than do halibut, cod and wolffish.

It is the supply of eggs and larvae, however, that remains the single most important constraint on the development of marine aquaculture. The eggs of most marine species are several hundredfold smaller in volume than salmonid eggs. Consequently, these eggs have much shorter periods of incubation before hatching and produce larvae up to 10 times smaller than the corresponding salmonid stages. As a result, quite different approaches have had to be adopted by most marine hatcheries compared to those used for salmonids. Whereas salmonid fry can take artificial food immediately on first feeding, the mouth gape of most other marine larvae requires their feeding with much smaller food particles. As yet it has not proved possible to fabricate an artificial diet that is small enough to be eaten, resistant to leaching, and digestible and that contains a properly balanced formulation. Consequently, most hatcheries have had to rely on live foods (e.g., *Artemia* nauplii, rotifers, algae and copepods). These vary in their nutrient composition and in their abilities to produce healthy, good-quality larvae. In general, plankton harvested from the wild give better results, but there are problems relating to the continuity and seasonality of their supply. Considerable efforts have gone into the culture of *Artemia* and rotifers and in the enrichment media and types of algae on which these invertebrates are grown. This has dramatically improved the survival rates of many marine larvae in culture. We now have double-figure survivals to weaning for bass, bream, turbot and

cod larvae and much improved survivals for halibut. Further work on the specific nutrient requirements of each individual species of marine larvae no doubt will continue to improve this position. However, the culture of live foods is a complex and technically demanding procedure requiring much staff time and capital expenditure.

In the United Kingdom, the first attempts at rearing marine fish began in the 1960s with work on the plaice and on **lemon and Dover soles**. The larvae of these species were successfully reared on live foods (i.e., *Artemia* nauplii and rotifers in the government laboratories of Ministry of Agriculture, Food and Fisheries), but further attempts at culture were not made because of the low market value of the plaice and lemon sole and the difficulties of on-growing all three species on artificial diets. Attention then turned to the Atlantic turbot and halibut, which along with the Dover sole are among the highest-value species found in European waters. By feeding with live feeds and using enrichment procedures involving high (HUFA) lipid-high protein emulsions, large numbers of turbot larvae are now being produced. Subsequent experiments on the on-growing of this species, however, indicated a temperature optimum of 18 C. Hence commercial exploitation of turbot moved from the United Kingdom to the warmer waters of northern Spain and, to a lesser extent, the Atlantic coast of southern France, where altogether some 1,500 tons now are being produced. Although growth has been good at these sites, high mortality rates have been reported during the summer months, especially when temperatures exceed 17 C. Recently, further commercial trials in Scotland have shown that reasonable growth can be achieved at lower temperatures without increased rates of mortality, providing the day-length is artificially extended.

**Sea bass and bream** have been considered, but their temperature optima for on-growing are 20-24 C. Hence their production always will be limited to the Mediterranean or to places where ready supplies of waste heat are available. At present only the culture of bream is of any significance because, although the production of the significantly larger bass larvae is easier than bream, bass takes one year longer to reach table size.

**Cod** remains a possibility for the United Kingdom because of the high consumer regard for this species. Its relatively low market price, however, makes economic intensive culture extremely unlikely. Rearing trials also have been complicated by the extreme cannibalistic behavior of the young fish.

The **Dover sole** is an attractive proposition because of its very high price at first sale, but the dependence of the young fish on smell and taste for feeding and the consequent difficulties of providing an acceptable fabricated alternative to live feeds have prevented further developments in its culture. Possibly, the potential for culture of the Dover sole lies more in sea ranching or an enhancement of wild populations by stocking with juvenile fish. There also are questions relating to the temperature optima for growth of sole, which are similar to those of the turbot.

Other species of potential interest include the **sturgeon** and the **wolffish**. However, little work has been done on either of these fish in the United Kingdom.

The development of methods for the culture of **Atlantic halibut** has been especially problematic because of the high salinities, low temperatures and much longer periods of time required for egg incubation and larval rearing. It still is not possible to predict reliably the optimum time to strip the brood stock, and partly as a consequence of this, egg quality is invariably poor. There also are considerable problems with the feeding of the larvae, particularly as they approach metamorphosis, with the best results being achieved by feeding with copepods in addition to other live foods. Despite these difficulties, however, adequate numbers of larvae now are being produced in both Norway and

Scotland. Providing no significant problems arise with on-growing (and none have appeared in our trials so far), it is likely that this species will be the first non-salmonid marine fish to be farmed in any great numbers in U.K. waters.

## PACIFIC NORTHWEST SPECIES OF PARTICULAR INTEREST

### Marine Fish Cultivation Research At the Pacific Biological Station

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Because of the high value of sablefish (*Anoplopoma fimbria*), it has been considered a candidate for commercial farming. The sablefish was first studied by Kennedy in the late 1960s (Kennedy, 1972). He showed that second-year juvenile sablefish captured from the wild could be reared to a commercial size in tanks or cages. It has been concluded since then, however, that production of juveniles in hatcheries was necessary for successful commercial farming of sablefish. One reason for this is that wild stocks of sablefish are fully used now. Another is that there are practical difficulties involved in live transport of juveniles captured at sea.

Research was started in the mid-1980s to develop new techniques to spawn captive adults, incubate eggs and rear the larvae. The first experiments on egg production and larval rearing began with gametes collected from spawning fish at sea. Eggs were incubated first in static containers and later in flow-through upwelling incubators (Alderdice et al., 1988a, b; McFarlane et al., 1991).

Temperature control is very important during the egg and larval stages. The optimal temperature during early rearing is 6 C (42.8 F). After about 12 to 15 days, the eggs hatch. Another 15 to 20 days elapse before the larvae begin to feed.

We did not succeed in rearing larvae beyond the 12mm size in several years of feeding trials with rotifers (*Brachionus plicatilis*) and *Artemia*. We believe that the reason for this is that the feed organisms are deficient in essential fatty acids. Experiments conducted with rotifers fed on separate microalgal diets have shown significant differences in growth and survival of the larvae (Whyte et al., 1994). Nevertheless, levels of eicosapentaenoic (20:5n3) and docosahexaenoic (22:6n3) fatty acids in the rotifers are much lower than in sablefish eggs or in zooplankton that the larvae consume in the wild.

In parallel with the egg and larval studies, work started on spawning of captive adult sablefish. Although male sablefish frequently mature and spermiate without hormonal treatment, only one out of more than 150 female sablefish held at the Pacific Biological Station ripened spontaneously without hormonal induction in three years of experiments (Solar et al., 1992). It was possible to induce mature female sablefish captured during the previous autumn to spawn by injection of the hormone LHRH, but they failed to remature during the subsequent spawning season.

We thought this could be because of the effect of elevated temperature. Spawning normally

takes place at depths of 300-700 meters, whereas the water supply for our laboratory tanks is drawn from a depth of 20 meters. This was tested in 1991 by installing insulated 12-foot tanks supplied with ambient and chilled seawater, which were mixed to regulate temperature. During the 1992 spawning season, five out of eight females matured on chilled water compared with one out of eight females at ambient temperature.

During the past year, research effort was redirected from sablefish to the lingcod (*Ophiodon elongatus*). This research was initiated with funding from the Salmonid Enhancement Program (SEP). In its long-term planning process, SEP wished to learn the feasibility of producing juvenile lingcod for restocking in the Strait of Georgia.

The results of exploratory studies this year have shown it is possible to produce post-metamorphic juvenile lingcod by feeding brine shrimp (*Artemia* sp.) to the larvae. Lingcod eggs collected in the wild were incubated in 200-liter tanks. After hatch, groups of larvae were placed in 5-liter pails for closer monitoring and feeding trials. The larvae were fed *Artemia* enriched with Super Selco (Artemia Systems N.V. Baasrode Belgium). Active feeding began about a week after hatch. Larvae tolerated a wide range of salinities, from 30 percent down to 20 percent. When held in covered, darkened pails, larvae had higher survival than at higher light intensity. However, mortality was very high after the yolk was depleted. We attribute this to an inability of young larvae to fully digest the *Artemia*. Partially digested *Artemia* were seen emerging in the feces of young larvae.

#### References

- Alderdice, D.F., J.O.T. Jensen and F.P.J. Velsen. 1988a. Preliminary trials on incubation of sablefish eggs (*Anoplopoma fimbria*). *Aquaculture* 69:271-290.
- Alderdice, D.F., J.O.T. Jensen and F.P.J. Velsen. 1988b. Incubation of sablefish (*Anoplopoma fimbria*) in a system designed for culture of fragile marine teleost eggs. *Aquaculture* 71:271-283.
- Kennedy, W.A. 1972. Preliminary study of sablefish culture, a potential new industry. *J. Fish. Res. Board Can.* 29:207-210.
- McFarlane, G.A., J.O.T. Jensen, W.T. Andrews and E.P. Groot. 1991. Egg and yolk sac larval development of Pacific halibut (*Hippoglossus stenolepis*). International Pacific Halibut Commission Technical Report 24:1-22.
- Solar, I.I., E.M. Donaldson, I.J. Baker, H.M. Dye, A. von der Meden and J. Smith. 1992. Reproductive physiology of sablefish (*Anoplopoma fimbria*) with particular reference to induced spawning. Pages 49-53 In Nat. Mar. Fish. Serv. NOAA Tech. Rep. 106: Marine Ranching. Proceedings of the Eighteenth U.S. Japan Meeting on Aquaculture, Port Ludlow, Washington, 18-19 September 1989, R.S. Svrjcek, Editor.
- Whyte, J.N.C., W.C. Clarke, N.G. Ginther, J.O.T. Jensen and L.D. Townsend. 1994. Influence of composition of *Brachionus plicatilis* and *Artemia* sp. on-growth of larval sablefish (*Anoplopoma fimbria* Pallas). *Aquaculture* 119:47-61.



## Sea Ranching the Black Rockfish, *Sebastes schlegeli*, in Japan

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Black rockfish was selected as a suitable species for mariculture because its growth rate is the highest of the rockfishes of Japan, because it has a narrow migration range and because it has a good flavor.

### Obtaining and Rearing Larvae

Pregnant female fish migrate inshore from offshore to give birth to many larvae in the spring. They were caught with set nets in Sendai Bay before spawning. We were able to make pregnant females spawn 30 days early by raising water temperatures to 12-14 C from the natural 7-9 C. Every pregnant female gave birth to 50,000-200,000 larvae in a laboratory tank. The progeny (F1 or F2) were reared as brood stock at Miyagi Prefectural Marine Hatchery.

Larvae were kept in indoor tanks and fed rotifers, brine shrimp, cod eggs, fish larvae and commercial crumbled feed in sequence. They were fed commercially crumbled feed only at 50 days after hatching at 13-17 C.

### Black Rockfish Releases

When the fry grew larger than 30mm total length (TL), they were moved into seawater net pens and reared to 80mm TL. This took 30 days. They were then marked by a ventral fin removal. This mark could be clearly recognized in about 85 percent of the fish after one or two years. In other tagging methods, the rate of recognition was only a few percent after one year.

Fry with marks were released into a sea grass area. They remained in the grass area at a depth of less than 10 meters for two to four weeks after release. After they grew to 10cm TL or larger, they started to move around widely in the bay. They stayed in the bay for at least one year after release. Most of the released fish (> 20cm TL, 1 year old) recruited to offshore stock from the bay in autumn.

### Recapture/Recruitment to Fishery

Test catches showed that the black rockfish preferred to live in artificial reefs rather than natural reefs. Furthermore, observations by ROV (remote-controlled TV camera) showed that they stayed inside the reef in the daytime and disappeared from it at night. In spring (March to May), bigger fish (> 30cm TL, more than 3 years old) left the reef and appeared at the coast ready to spawn.

Rockfish are caught with set nets, with gillnets and by game fishing. Fishers were taught through meetings, posters and newspapers not to catch small rockfish less than 20cm in length. For three mornings every week, our research staff counted and measured the rockfish for sale at the fish market where all rockfish were landed from Shizugawa Bay. Recapture rates were calculated to be 1.4 percent to 3.0 percent (catch/release) in the 1983 to 1985 year classes but increased to 11 percent to 15 percent in the 1986 to 1990 year classes. Because release numbers were less than 60,000 in 1983-85 and more than 100,000 in 1986-90, the higher recapture rates were thought to be related to the higher release numbers. On the other hand, the catch of natural fish is actually increasing in

**Shizugawa Bay.**

For a commercial fishery, the recapture rate should be higher than 20 percent (containing catch of natural fish). Some new release methods now are being tried to prevent mortality just after release.

## Overview of Sea Ranching of Atlantic Cod And Review of the Norwegian Sea Ranching Program

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In 1864 the famous Norwegian scientist G.O. Sars raised the question of whether the production of cod could be increased by artificial fertilization of cod eggs and large-scale releases of yolk sac larvae. It was supposed that the production of fish was directly proportional to the number of eggs produced by the spawning stock. The releases started in 1884 and continued more or less unaltered until 1971, when data from 1920 to 1969 were analyzed. The analysis showed that the effect of the releases could not be separated from random variations. It was concluded that the releases of yolk sac larvae had no beneficial effect on the production of cod.

In 1914 Johan Hjort suggested the critical stage hypothesis: that the size of year class strength of fishes was established at the early life stages, when the larvae changed from yolk-sac to exogenous food. Empirical studies supported the view that the year class strength was established during the early life stages, and systematic investigation on the age structure of fish population showed that the variation in abundance was related to fluctuation in year class strength. This variation was shown not to be related to the size of the spawning stock. Hjort put forward the idea of rearing fish larvae through the critical stage for release at a later stage.

The technique for mass production of Atlantic cod fry was developed in 1983, nearly 70 years after Hjort published his critical stage hypothesis. The fry are produced in large seawater ponds. The production is based on natural plankton. The consistency of fry production is achieved by removing predators from the pond and by adding fertilizer to promote phytoplankton and zooplankton production. After metamorphosis (15mm TL), the fry are fed dry pellets until harvest at 30mm length.

An enhancement experiment with coastal cod was started in 1983 by the Institute of Marine Research at Austevoll Archipelago on the west coast of Norway. The cod were tagged and released as 0-group. The results suggested that reared cod did not differ from wild cod in growth and survival. The released cod remained in the release location both as juveniles and after maturation. Natural recruitment in the release area was investigated, and it was shown that the released cod contributed significantly in the corresponding year classes. The reared cod recruited to the local fishery as 2-group cod at a size of about 30cm. Fewer than 35 percent of the released cod survived to the 2-group stage. The mortality was attributed to predation and cannibalism, and it decreased with increasing size at release. After recruitment to the local fishery as 2-group, the natural mortality of cod decreased to about 20 percent per year, while the fishing mortality increased to nearly 50 percent per year. The local fishing pattern had, however, a negative effect on the yield in the commercial fishery because most of the recaptures were undersized fish caught by sport fishing.

Based on these results the Norwegian Fisheries Research Council established a national cod enhancement research program in 1985. The scope of this program was first to determine whether the production of cod could be increased in fjords in southern, western and northern Norway by release of reared juveniles and second to examine which ecological factors determine this production. More than 175,000 juvenile cod were released from 1988 to 1990 in Masfjorden in western Norway.

As 1-group the three manipulated year classes in the fjord consisted of more than 50 percent reared individuals. The results from this enhancement experiment suggest the factors that determine year class strength reduced year classes from strong to poor at 1-group stage. Density-dependent mortality is suggested as the main reason for the observed decrease in abundance. The release did not result in any measurable increase in the cod stock in Masfjorden. Considerable insight has been obtained on fjord ecology and results from modeling suggesting that the advected food source is a limiting factor on cod production. These results suggest that releases should be carried out on a more open coastline. This recommendation has been adopted by the Norwegian Sea Ranching Program established by the Royal Norwegian Ministry of Fisheries in 1990. This program also includes species such as European lobster, Atlantic salmon and Arctic char and will continue until 1997.

## A Review of the Research Efforts on Pacific Halibut, *Hippoglossus stenolepis*, With Emphasis On Research and Development Needs

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Research conducted on Pacific halibut in Washington to date has been a collaborative effort of the University of Washington School of Fisheries (SOF), the International Pacific Halibut Commission (IPHC), the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS) and Stolt Sea Farms. We also have collaborated with scientists and conducted research at the Nanaimo Laboratory of the Department of Fisheries and Oceans (DFO) in Canada. Interest in the research community was inspired by a desire on the part of IPHC to study captively reared Pacific halibut larvae as a means of learning more about early life history and, in particular, growth rates and morphological changes at various ages. There also was interest in evaluating the potential of producing Pacific halibut postlarvae or juveniles for enhancement and for commercial culture. SOF investigators became involved with Pacific halibut culture in 1986.

Brood fish have been captured on several occasions by IPHC staff and transported to facilities operated by USFWS, NMFS and Stolt Sea Farms. Adults adapt well to both circular fiberglass tanks and unmodified salmon net pens. Eggs and milt can be obtained from adults during the normal spawning season (winter months) without hormone injections by exposing the fish to ambient water temperatures. We have maintained low light levels by covering the spawning tank, but there does not seem to be a strong influence of photoperiod on development. Spontaneous spawning has not occurred, so it has been necessary to strip the adults at appropriate times. Males develop early in the spawning season and remain running ripe for several weeks. Females develop later and are multiple spawners. Several thousand eggs per batch can be obtained every few days from ovulating females. Though there is not complete overlap in the timing of egg and milt availability, procedures for cryopreserving sperm have been developed. Studies that have been conducted to date have addressed the following:

- Use of circulating hormone levels to sex adults and predict the time of spawning
- Developing egg incubation chambers
- Developing larval rearing containers
- Rearing larvae to first feeding
- Evaluating the effects of salinity on egg and larval development
- Examining the effect of light quality and quantity on larval development

Results from the studies mentioned, along with the experience gained and the results of various other observations, indicate that successful larval rearing is within reach. Research is needed to evaluate the nutritional requirements of brood stock; to find the best types of food for first-feeding larvae; to develop prepared feeds for postlarvae; and to determine the environmental requirements of larvae, postlarvae and juveniles. Among the environmental requirements that should be studied are temperature, salinity and dissolved oxygen. In addition, the tolerance of halibut to nitrite and ammonia should be determined.

Once the technology and protocols for producing postlarval Pacific halibut have been developed, emphasis should be placed on expanding the approaches to the point that sufficient numbers of postlarvae can be produced for enhancement stocking or captive growout. Facilities for scaling up to meet the potential demands for fish used either for enhancement or captive culture do not exist in Washington at this time. Additional research on wild halibut stocks will be required to determine the best locations for stocking cultured halibut and the best sizes to stock.

It seems likely that Pacific halibut can be reared throughout much of their life cycle in salmon net pens. The amount of time required to produce marketable fish remains to be determined. As the technology for halibut rearing develops, it is likely that growout periods can be reduced through proper nutrition, stress reduction, selective breeding and other management approaches. Realistically, the research required before Pacific halibut can be used in either enhancement or commercial culture will require at least a decade, and perhaps two or more decades. The time required will depend, in part, on funding.

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Luncheon Address

## Marine Fish Culture and Enhancement

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With the world's population of fish from the oceans topping out at 100 million metric tons annually and beginning to decline, our only options for increasing or even maintaining supplies are to improve management radically stock by stock, and to accelerate production from aquaculture. It seems essential to do both, but the political management of the ocean fish stocks is so disastrous, and so out of control of national governments, that marine fish culture is probably the most effective approach.

Let us look first at examples of ineffective national management. A few years ago, I visited the Lowestoft Laboratory in East Anglia, where some of our early and most respected fishery scientists worked. A large chart on the wall showed the condition of the stocks in the North Sea and around the British Isles—almost all overfished and producing less than they would have under effective management.

Next, consider our U.S. federal fisheries management. The level of U.S. landings during the 1980s was about 3 million metric tons annually, but the average income of commercial fishers (after adjustment by the Consumer Price Index) tended to decline. The annual number of U.S. vessels found in violation of fishery regulations has tripled from about 400 to 1,200. Off New England the traditional stocks of cod, haddock and flounders have been overfished so severely that they are now producing only about 25 percent of the maximum yield sustainable under effective management.

Consider an outstanding example of replacing such mismanagement with an effective system. A few decades ago, when Alaska was still a territory under federal management, its salmon stocks were severely depleted. Production, which had started early in the 20th century, had risen to a peak sustained for about two decades and then dropped to about half that level. After Alaska became a state, the new state management was much concerned about the decline in salmon fisheries. I suggested to the Alaska Chamber of Commerce in a speech in October 1963 that they were simply forcing the state's large number of fishermen to be inefficient in order to achieve conservation. Subsequently the state introduced a limited entry system, under which every legal fisher owned a right to fish a specified kind and amount of gear in a specified area. Since then the state has maintained good research on the condition of the stocks and obtained good catch statistics. The catches have shown a sustained increase to approximately double the level the state had inherited from the federal system, as well as a substantial increase in earning per fisher and the value of their investments in permits. The increases, however, have been slightly augmented by hatchery production, principally of



pink salmon.

Successful management also occurred during the 48-year regime of the International Pacific Salmon Fisheries Commission that dealt with the Fraser River salmon (mostly sockeyes and pinks) that spawn in Canada but migrate through the ocean fishing areas of both Canada and the United States (Roos, 1992). This fishery is complex politically, environmentally and financially. Major issues arose after rock slides and rock dumping during railroad construction prevented millions of salmon from reaching their spawning grounds after 1914. The problems were studied for years, and an international fisheries convention was finally ratified in 1937. The total runs, which had averaged about 11 million fish in the early part of the 20th century declined to about 3 million from 1920 to 1940 and then were restored to averages of 10 million during the 1980s. Almost all this restoration was accomplished by protecting natural runs. Substantial efforts were made to develop hatcheries for both sockeye and pink salmon but were only marginally successful.

Hatcheries become essential, however, in the absence of natural or assisted access to enough spawning and rearing areas where adults and young are protected. The practice of salmonid culture has been thoroughly proved during this century. One of the leaders was Professor George Embury at Cornell University, under whom I worked in the 1930s. He not only improved the salmonid culture systems, but he also shaped the entire freshwater management system in the state of New York. He did so by instigating a statewide biological and environmental inventory that provided a thoroughly informed basis for stocking, regulatory and aquatic environmental management activities.

Salmonid stocking is now commonplace in southern Canada and the northern United States. Most of it involves trout, including the domestic brook and lake trout and the European brown trout. But Pacific salmon have been introduced successfully into the Great Lakes and support a significant fishery.

As the marine production from wild stocks tops out, there is no alternative to increasing supplies through aquaculture. We are doing it around the world with about 100 species suitable for commercial and sport fishing, plus about 1,000 ornamental species for aquariums. Why not further increase the supply by taking advantage of natural environments where it is possible to stock and grow the species desired? We do this with many farm and forest crops.

The state of Washington is stocking about 1.4 million pounds annually of young anadromous fish in addition to more than 2 million pounds of non-anadromous species. Coastal aquaculture is increasing rapidly in many parts of the world, especially for the more valuable species such as lobsters and shrimps. One prefecture in Japan—Miyagi—is producing about 120,000 metric tons of cultured products annually, about 35 percent of which are marine plants. Some people may object to almost any such efforts, but there is probably no alternative other than decreasing the economic and political demands of the human population.

I would like to stress that society has an urgent need to identify environmental professionals who can be trusted as we trust physicians, engineers, attorneys and others who advise us on complex issues. We must shape our fisheries profession in terms of understanding people and working with them.

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## Work Group Discussion Summary

**F**ollowing a series of technical presentations, MFC&E participants broke into six groups to discuss the possible application of enhancement technology for Puget Sound fisheries. Each group considered the same five questions (see appendix). All groups reconvened for a wrap-up session at the end of the conference, when each group leader presented a summary of the discussion. Each group included a rapporteur, who summarized the group's conclusions on a flip-chart, and a recorder, who took more extensive notes.

This approach was used to determine areas of agreement and to elicit more input that otherwise might be lost. The resulting discussions were lively and varied. The following summary highlights common themes discussed by the work groups and incorporates other information where appropriate.

#### **Why consider enhancement?**

Washington Department of Fisheries catch statistics indicate that most recreational and commercial populations of marine fish in Puget Sound are severely depressed. Schools of cod can no longer support commercial fishing. Recreational fishers have to search long and hard to find halibut and lingcod, which once were abundant. The causes for decline are not understood but may include overfishing, repeated warm surface water occurrences, marine mammal predation, lack of food, toxic or noxious phytoplankton or some combination of these.

#### **Is there adequate information to initiate a marine hatchery program in Washington?**

The cautious consensus of the work groups was *Yes* in the case of some species, such as cod and halibut, where substantial work has been done in other countries. Other species also were considered, but not enough is known about their juvenile life histories or the causes of stock declines to make a determination.

Although technology from Japan, Norway and the United Kingdom can be imported to provide a head start for Puget Sound enhancement, researchers here need to develop their own site- and species-specific technology. Researchers need to establish a base of information on larval fish rearing, culture conditions, fish nutrition, fish pathology, physiology of growth and development, reproduction and behavior.

#### **What progress has been made so far?**

The Pacific Northwest lags far behind other fishing countries in enhancement research. Established culture technology for Pacific Northwest species is generally lacking or in the very early stages.

Some work has been done by marine aquariums and research facilities of the National Marine Fisheries Service at Manchester and Mukilteo, Wash.; the School of Fisheries, University of Washington; Peninsula College, Port Angeles, Wash.; and Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, B.C., Canada. These efforts have been aimed at laboratory rearing for

purposes other than commercial application or enhancement. The exception is the research projects on halibut being conducted by University of Washington School of Fisheries at the U.S. Fish and Wildlife facility at Marrowstone Island and by the Pacific Biological Station at Nanaimo, B.C. The latter agency also has conducted research projects with lingcod and sablefish (a.k.a. black cod).

**What is the estimated time to establish viable and productive culture in Puget Sound?**

Estimates ranged from five to 50 years. However, most groups placed the time frame at five to 10 years.

Establishing and refining a viable enhancement program is a long process. Washington Department of Fisheries salmon biologists have been at it for decades; the successful red drum program in Texas started more than 20 years ago.

**What is the potential for technology transfer from other countries and regions?**

The Pacific Northwest could reap considerable benefits from the experience of enhancement and aquaculture programs in Europe and Japan and in other regions of North America. Many species of marine fish are being cultured in captivity in Japan, Europe and Asia, and several are being used to enhance stocks around the world. Marine rearing technology appears to be well developed for some species, such as Atlantic cod, Atlantic halibut, plaice, turbot, sea bream, black rockfish, white sea bass, mullet and red drum as described in the technical papers presented at the MFC&E workshop.

There also are success stories in the United States. For example, a Texas hatchery program has helped restore stocks of red drum in Gulf of Mexico bays to near-record levels and has begun releases of spotted sea trout. Programs in California and Hawaii have shown good pilot results and are gearing up for full-scale enhancement programs.

Importing this technology could result in dollar and time savings on the enhancement learning curve if the technology is applied in a biologically and environmentally responsible manner.

**Technology transfer from one species to another**

Since the basic steps required to produce juveniles are similar for most marine fish, the technological developments reported at the workshop will apply to species of interest in the Pacific Northwest.

According to the technical papers presented, the first stages of marine culture are the toughest. The main bottlenecks appear to be weaning and first feeding, the period when the larvae have exhausted their yolk sacs and must begin hunting and digesting food for themselves. Providing appropriate food is difficult because marine larvae are too small to digest the commercial fishmeal pellets and grain feeds developed for salmon, trout and catfish. Some species of marine larvae can survive only on a diet of live plankton.

However, Puget Sound biologists won't be able to adopt this technology wholesale. They will have to adapt the techniques developed in the Atlantic and eastern Pacific to their own stocks. For instance, research will be needed on a variety of species differing in their basic reproductive strategies. Lingcod lay egg-masses with the male guarding the nest, while the rockfishes are live-bearers. Some species have small pelagic eggs, while others have relatively large eggs.

Researchers also will have to engineer juvenile releases so they have the most benign and beneficial impact possible on local habitats. To gather the necessary information, biologists will need to make small-scale, experimental releases of fish, then track their growth and survival.

**Criteria for selecting species for enhancement to augment natural production**

Although political considerations may affect funding, species selection must proceed on a solid scientific basis, or enhancement will fail. For instance, the work groups agreed that enhancement efforts shouldn't automatically target the most depleted or most popular fish in their area.

When discussing this mixture of socioeconomic and biological factors in species selection, many work groups referred to selection criteria developed by Ken Leber, Ph.D., and members of the fishery and aquaculture community in Hawaii. The list, crafted during two workshops, was used during the first phase of the Oceanic Institute's stock enhancement research to select test species for pilot releases. A copy of this list is included in the technical portion of this proceedings. Following are the major criteria selected by the work groups.

1. Commercial and recreational demand
2. Availability of viable spawn
3. Juvenile release will increase adult population
4. Ease of larval rearing
5. Cost effectiveness (difficult to determine until culture is established)
6. Ease of juvenile rearing
7. Ease of monitoring impact (returns, yields)
8. Likelihood of success
9. Impact on resident biota
10. Availability of habitat
11. Stays where it is stocked (i.e., doesn't swim to Canada)
12. Life history known
13. Availability of technology

**Marine fish with the greatest enhancement potential  
For the Pacific Northwest**

1. Lingcod
2. Rockfish (copper, quillback and black)
3. Pacific cod
4. Halibut
5. Pollock
6. Greenling
7. Cabezon

**Why these species?**

1. The first four species were originally identified as priority species for enhancement in Puget Sound by the Washington State Legislature. All work groups also identified them as priority species for enhancement.

2. Several of these species are popular with recreational fishers, a group that may be a source of political and funding support for enhancement activities. The new \$10 surcharge on Washington state recreational fishing license holders, which has been earmarked for enhancement of salmon and possibly of other species, is an example of a way that research might be funded. The value per pound of fish caught probably would not be an issue, so long as anglers had a reasonable expectation of

catching a few fish. It was generally recognized, however, that the public will be incensed by such fees if there aren't fish to catch.

#### **Criteria for selecting species for captive rearing and direct marketing**

Once the culture technology for enhancement is developed, it was generally thought that spin-offs would accrue for commercial culture. In turn, aquaculture technology could be used as the basis for feasibility studies to determine if enhancement releases would be successful.

Although there would be tremendous technical synergy between commercial rearing and enhancement, the following species selection considerations for captive rearing are somewhat different from those for enhancement of commercial and recreational fisheries:

1. Supply and demand
2. Dollar value of species
3. Cost of production
4. Availability of juveniles through hatchery culture and/or wild capture
5. Growth rate
6. Understanding of early life history
7. Technical feasibility
8. Overall profit potential

#### **Candidate species for captive rearing**

1. Halibut
2. Sablefish
3. Petrale sole
4. Perch—surf, white, and blue
5. Rockfish
6. Cabezon

#### **Why these species?**

While anglers often seek an exciting fishing experience, aquaculturists select for good yield and price per pound. Lingcod is a popular sport fish because it fights the hook and often escapes. The sports enthusiast who reels in one of these big fish has generally had a satisfactory adventure for the day.

But lingcod has too low a yield (the ratio of usable meat to overall body weight) to be attractive for commercial culture. Aquaculturists are more likely to pick a fish such as halibut, which has a high yield (up to 57 percent for Atlantic halibut farmed in Norway).

#### **Other captive culture considerations**

Once aquaculturists have determined the species with the best biological potential for captive rearing, they have to consider the pragmatic considerations of siting for-profit hatcheries and grow-out facilities. Following are important questions for commercial culture:

1. Are there hatchery construction constraints?
2. Is siting a problem for net pens or shore-based facilities?
3. Is there a conflict between private and public fish culture?
4. Are commercial/government cooperative relationships workable?

### Generating support for enhancement

Support from user groups and individual citizens is critical to any enhancement plan. According to MFC&E speakers, that means that the people who ultimately will benefit from and pay for hatchery programs must be part of enhancement planning from the very beginning—including species selection.

Programs in Japan and northern Europe have concentrated on species harvested by commercial fisheries and suitable for farming. Therefore, they have worked primarily with commercial fishing fleets and aquaculturists. A Japanese enhancement program for black rockfish, for example, involves extensive participation by commercial fishers, who assisted researchers in projects such as marking hatchery fish.

In the United States, by contrast, the most successful marine enhancement programs are aimed at replenishing sport fisheries. Don Kent, vice president of the HUBBS-Sea World Research Institute, San Diego, and head of a program aimed at enhancing populations of California sea bass, credits sport fishers with obtaining 10 additional years of research funding. "They flooded the legislature with mail," says Kent. "It's much more effective to have 500 letters hitting the legislature than to have one guy, a lobbyist, knocking on doors." The California program is funded by sport fishing fees: \$1 of each \$20 annual license is dedicated for white sea bass enhancement.

In Texas, anglers helped fund a hatchery used to rear juvenile red drum. "Our main hatchery is a joint venture between the Gulf Coast Conservation Association, a sport group; Central Power and Light, a private power company; and the Texas Parks and Wildlife Department," says Larry McEachron, TPWD science director. The TPWD hatchery program has increased the population of red drum in Texas bays. "We still get donations for specific projects or equipment needs, such as computers," adds McEachron. Most of the hatchery's operating monies come from funds appropriated through the Dingell-Johnson/Wallop-Breaux Federal Aid in Sport Fish Restoration Act.

Dingell-Johnson/Wallop-Breaux funds also pay many of the bills for a striped mullet restoration program in Hawaii, which enjoys substantial political support from anglers dismayed by the decline of wild stocks, according to Ken Leber, Ph.D., of the Oceanic Institute, which conducted the preliminary R&D work on mullet enhancement with funds from the National Marine Fisheries Service. Now that much of the preliminary work on striped mullet has been completed and production is being transferred to state facilities, the Oceanic Institute is transferring its attention to species that will generate even more sports interest. "We need a high value fish," says Leber. "We've begun work on Pacific threadfin (*Polydactylus sexfilis*), or moi, as it's known locally."

In Washington state, DJWB funds are used almost exclusively for salmonid programs.

### The relationship between constituent support and species selection

While discussing the issue of constituent support, MFC&E work groups tackled several major questions. First, should biologists choose species for enhancement based on political or biological considerations? Second, which user groups would be most likely to support enhancement projects?

Picking a popular species can help generate the political momentum needed to get funding for enhancement research, which tends to be lengthy and expensive. But what happens if the most popular fish is the hardest to rear? What if habitat for this species is so diminished that enhancement can't succeed?

Kent reported that, in his experience, an informed advisory committee does take biological and technical factors into consideration.

Work group members noted the need to distinguish among the three possible bases of support for enhancement projects: aquaculture, recreational fishing and commercial fishing. Members of one group may not wish to advocate research that they feel will support a competing group. Washington's commercial fishers have watched salmon prices drop in the last few years, due in part to a vastly increased supply of foreign and domestic farmed salmon on the U.S. market. In addition, competition for quota is a perpetual source of tension between the sport and commercial fishing sector.

Ideally, a species selected for enhancement would have the support of several sectors. MFC&E work groups considered Puget Sound species that could be supported by recreational fishers, commercial fishers and/or aquaculture. In Washington state, support from tribal nations is also extremely important. State agencies and tribal nations already cooperate in salmon enhancement projects.

Building political consensus for the species selected can be especially important if enhancement benefits don't shake out exactly as planned. Norway's cod enhancement program was initiated to boost commercial fisheries. The hatchery cod survived well but attracted anglers, who caught the fish when they reached pan-size, before they were large enough to recruit to the commercial fishery. If these fish are to go to commercial harvesters—and this was the original goal of the program—they must be protected from sport fishers, perhaps through area closures.

#### **Issues and concerns related to fisheries management**

Good habitat and effective fisheries management are essential to the success of any enhancement program. As one conference participant said, if there isn't adequate feed or clean water to support fish stocks, breeding fish for release is just "throwing good fish after bad." Likewise, if a stock has been depleted by overfishing, enhancement won't increase its numbers unless over-exploitation also is curbed.

Work groups stated that management and enhancement should be integrated, and that all management options possible to increase stocks should be used in conjunction with enhancement releases. Some participants argued that enhancement should be the last resort, used only after all available management techniques have failed to restore a fishery.

In general, work groups stated that they hoped to avoid the management problems generated by salmon enhancement programs.

Following are some of the questions biologists, citizens and policy makers should ponder while considering an enhancement plan.

1. Why is the species in decline?

The work groups agreed that research must be able to answer this question if we are to manage the stock back to health. We must know the impediments to natural production before we can increase a stock's size through artificial production.

If lack of recruitment (a lack of juveniles) is the cause of declining populations, then enhancement can be tremendously helpful in restoring fishery stocks.

2. Is fishing pressure the main factor reducing population size?

If non-fished stocks also are declining, other factors may be at work.

3. a. Has loss of habitat caused the population decline?

b. How will enhancement affect habitat?



The amount and quality of available nursery habitat must be considered when policy makers set goals for an enhancement program. If the program goal is to build up a breeding biomass that will increase stocks on its own with no additional releases, the program will fail if the young don't have enough food or protection from predators. Different marine species may require different types of breeding habitat. Herring, for example, spawn in eelgrass beds.

If the necessary habitat is in short supply, policy makers have the option of establishing a permanent hatchery system, as in the case of salmon enhancement programs located in areas where breeding habitat has been destroyed by dams and development.

In some cases, habitat restoration or creation projects, such as artificial reefs, could substitute for or supplement enhancement programs. On the other hand, marine enhancement programs could be used to mitigate habitat loss, as in some salmon enhancement programs.

4. What other environmental processes may be affecting stocks?

- Paralytic shellfish poisoning?
- Noxious phytoplankton blooms?
- Predation by marine mammals?
- Contaminants?
- Diseases?
- Natural cycles?

5. How does this population interact with other stocks?

If one marine stock is enhanced, will others suffer because of increased competition for food or increased fishing activity?

6. Are we dealing with common stocks in Puget Sound, or are there separate stocks?

**How can enhancement research benefit overall fisheries management?**

Carefully planned releases can generate enormous amounts of hard data in a relatively short period of time. Through lab observations of marine eggs and larvae and capture studies of released juveniles, biologists can gain information on the life history, growth, survival and behavior of saltwater species. This knowledge can be used to strengthen fishery management approaches and models. The potential efficiency of hatchery work in generating life history data has been proved in a wide range of studies in both temperate and tropical climates, including releases of juvenile cod in Norwegian fjords and of striped mullet in Hawaii.

**What kind of program is needed?**

There was debate among the work groups as to whether researchers should concentrate their efforts on one species or on multiple species simultaneously. Proponents of a one-species start proposed focusing on a fish with good political support and a good chance of technical success—"an achievable goal" that, if reached, could garner support for more extensive future work on additional species. These participants noted that much of the European work on Atlantic cod and Atlantic halibut could transfer to Puget Sound fisheries.

Other conference participants suggested that early work should concentrate on larval research, finding those species that survive best from hatching to first feeding. According to proponents of a multi-species approach, working on several species increases the chances for success and may provide some synergism.

Both approaches would require a multi-pronged and adaptive program aimed at gaining information on each species' life history, ecology, juvenile behavior, etc., combined with a research culture effort that would produce juveniles for release. Other necessary characteristics include multi-disciplinary expertise, long-term commitment in funding and political support and economic payback.

#### **Who should be involved?**

Research programs should draw on the expertise of university, government, tribal nations and private industry. Tribal involvement would be essential in planning and implementing any saltwater hatchery program. The expertise of tribal and state biologists in managing large-scale hatcheries, albeit for anadromous fish, would be invaluable.

Government agencies may need to shift policy in order to allow private industry involvement in fisheries research. Cooperative public/private programs may be the most desirable from a cost and management perspective. Contract rearing is an example. The private sector could raise juveniles for release under an agreement with regulators. The regulatory agencies would get fish without investing in capital construction and would be able to shift many of the risks of culture to commercial growers.

Memoranda of agreement could provide a good foundation for joint research and could speed the transfer of new technology. The timely exchange of research findings and technology through workshops, seminars and publications would benefit industry, the research community and public interest groups.

#### **What kinds of resources are needed?**

All work groups stressed the need for a consistent source of funding to support the sustained effort necessary to establish a successful enhancement program.

A major obstacle to enhancement research in the Pacific Northwest is the lack of suitable marine lab facilities. Prof. Robert Stickney of the University of Washington, who has conducted halibut culture studies since 1986, has had to conduct his research on "a fin and a prayer" at makeshift, borrowed labs including, at one time, a converted garage. Dr. Stickney's hard-scrabble research is in sharp contrast to the Norwegian halibut culture effort, which has received more than \$30 million in government funds, not including capital expenditures for buildings. MFC&E work groups noted the need for production-scale research facilities.

Currently, the region's only large marine laboratory is the Hatfield Marine Station in Newport, Ore. In Puget Sound and adjacent waters, only small facilities are available for limited work—National Marine Fisheries Service at Manchester and Mukilteo, Wash.; the University of Washington at Friday Harbor, Wash.; the U.S. Fish & Wildlife Service at Marrowstone Island; and possibly Battelle Marine Lab at Sequim, Wash.

#### **Changes needed in regulations, policy and permitting for successful marine fish culture in the Pacific Northwest**

Aquaculturists face many regulatory obstacles. For example:

- Water quality regulations require that the water discharged by farms be cleaner than it was before they piped it in for use.
- The current state permitting process for fish culture is cumbersome and subject to veto at the local level. The various legal and paperwork requirements can be extremely expensive for the applicant to satisfy; costs can exceed \$500,000 for a single site.

Work group participants discussed ways that government could ease the regulatory burden on finfish growers. Two of their suggestions are:

- To streamline or facilitate the process of clearing drugs and chemicals for use in fish culture.
- To recognize two types of industries—enhancement and captive culture—and develop regulations accordingly. Federal and state authorities should recognize farmed fish as a domestic animal and not subject them to regulations that pertain to wild-capture fisheries. Industry supports a current move by the U.S. Department of Agriculture to classify farmed fish as livestock.

**What assistance does private industry need to develop marine fish culture in the Pacific Northwest?**

Private industry will need help in identifying suitable sites, in developing environmental impact statements and in working with local governments. They also will need help getting marine fish brood stock and access to research. Technology transfer on topics including culture techniques, larval rearing, diets and health certification will be essential to the success of private ventures.

**To hatch or not to hatch: What are the alternatives?**

Regulators and policy-makers considering marine enhancement and culture have several options:

1. Do nothing and hope for a reversal in declining marine fish stocks and/or focus restoration efforts on management initiatives and habitat preservation and restoration.
2. Focus research efforts strictly on captive rearing of fish for commercial sale.
3. Plan and initiate enhancement research involving all interest groups, including commercial and sport fisheries.

The consensus of workshop participants was for the third alternative. A recent inventory of U.S. marine fish stocks shows that many are fully or over-exploited. Global production of marine fish also is in decline. To continue feeding our planet's population, we may need to farm our seas further, either by culturing fish for sale or releasing juveniles to enhance wild stocks. There are political, technical and perceptual impediments to marine culture and enhancement, but these are not insurmountable.

If the Pacific Northwest's marine fish stocks continue to decline, citizens may demand that these stocks be restored. When that time comes, researchers and managers will need more information than is currently available to make sound decisions. Workshop participants therefore recommend initiating multi-disciplinary technical, ecological and economic studies now. At the very least, enhancement studies will generate precise information on the biology and behavior of native stocks that will be of great value to fishery managers.

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# Appendices

## A. Work Group Discussion Questions

1. Is the technology for marine fish culture developed adequately to allow reasonable expectations of success for enhancement or for captive rearing in the Pacific Northwest?
2. What species of marine fish would you identify as having the best potential in the Pacific Northwest for: (a) rearing for enhancement (i.e., release into the natural environment to augment production), and (b) captive rearing for direct marketing?
  - A. Why did you choose these species?
  - B. Is there adequate information to initiate a hatchery program for these species? If not, what missing information is the most critical?
  - C. What would you estimate the time frame will be for the culture of each species to be viable and productive?
3. What permitting/regulatory/policy changes need to be addressed for marine fish culture to be successful in the Pacific Northwest?
4. What type of assistance is needed to enable the private fish culture industry to directly and effectively contribute to the development of marine fish culture in the Pacific Northwest?

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