Harvest Team Strategic Research Plan 2005-2010



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"A realistic view of the management process is: 1) develop biological, economic, social and legal objectives, 2) forecast run size, 3) formulate fishing plan, 4) consult with user groups (or management councils), 5) finalize fishing plan, 6) execute fishing plan, and 7) evaluate management impact on the resource" (Sprout and Kadowaki 1987). Under ESA, number 7 takes on a whole new level of complexity.

Executive Summary

Research at the Northwest Fisheries Science Center on salmon harvest management and its impact on salmon populations supports the Pacific Fisheries Management Council process, Pacific Salmon Commission technical work, regulatory processes at the Northwest Regional NMFS office including ESA and NEPA work, and salmon recovery work through the Technical Recovery Team process in the Pacific Northwest. Members of the Salmon Harvest Team sit on technical committees for these various processes, contributing to the scientific deliberations and analyses of salmon abundance, productivity, viability, and harvest. Current and planned research by the team focuses on how to better utilize information to manage salmon harvest, and includes:

Coast wide review of Chinook stock escapement goals for harvest management: A recent desire and effort in the PSC community has been to standardize methodology for determining escapement goals. We are responding to this need by developing methods to describe and correct for bias in estimating stock-recruit relationships.

Assessment model to incorporate GSI-based stock composition data: Development and expansion of genetic stock identification for Chinook is currently being funded through the Pacific Salmon Commission to improve stock identification for fishery catches. We have initiated a collaboration with UW researchers to develop and evaluate methods for utilizing these data.

Risk assessment and rebuilding exploitation rate analyses for Puget Sound Chinook and chum: In evaluating the state and tribal harvest management plans under the Section 4(d) of the ESA, the NW Regional Office needs to determine exploitation rates that will allow recovery of the listed stocks. We have initiated collaborations with Regional Office staff to develop improved methods of determining these exploitation rates.

Predicting coho abundance from environmental trends: In order to effectively set harvest regimes on Oregon coastal coho salmon and many other salmon stocks, information is needed about factors contributing to variation in freshwater and ocean survival rates. We are therefore continuing and initiating research to develop improved life-cycle models that incorporate environmental and climate variation.

Juvenile Chinook survival in Puget Sound estuaries: Understanding the productivity of salmon at multiple life stages is important for production models used by harvest managers. We are currently working with the Fish Ecology Division and the Tulalip Tribe to collect data on how juvenile salmon make use of the estuary habitat.

Climate variability and salmon abundance in the northeast Pacific: Understanding long term variations in salmon abundance is important to successful harvest management in order to adjust management to regimes of differing salmon abundance. Harvest Team staff are heading a multi-agency effort to reexamine the climate factors responsible for the basin-scale patterns of salmon production in the Northeast Pacific

In addition to these specific current and planned projects, future research will be focused primarily on determining the effect of harvest on the Viable Salmon Population (VSP) factors, especially spatial distribution and diversity, which have been less studied than the effects on abundance and productivity.

Introduction and Background

Developing sustainable fisheries management has long been a goal for fisheries managers. Many studies of salmon biology, life history, and population dynamics, in relation to harvest management, can be found in the early part of the 1900s. During this time many studies were made on the relation of catch statistics and salmon returns. This information was unified into Ricker's (1954) work on "stock and recruitment" analysis. By the 1960s salmon harvest had become quite competitive and complex. Economists began to seriously examine the salmon fisheries; the need for limited entry was recognized. As declines in the abundance of salmon were noted, mainly through decreased fishery catches and later through decreasing numbers of salmon observed on the spawning grounds, managers realized that it was important to start looking at how harvest goals were determined and to better understand the relationships between salmon productivity and harvest. It also became imperative to study the relationship between salmon and their changing habitat. Harvest models started to become more complex with increasing data and parameter needs. See Quinn (2003) and Prager and Williams (2003) for reviews of the development of fishery harvest models and Sands (2004) for a review pertaining to the salmon harvest management.

Management bodies

Harvest regulations for Pacific Northwest salmon are governed by regional councils (Pacific Fisheries Management Council, PFMC, for Washington to California fisheries and North Pacific Fisheries Management Council for Alaska fisheries), internal treaties (e.g., 1974 Boldt Decision and 1969 US v. Oregon, continuing jurisdiction of the courts), and international treaties (the 1991 agreement between Russia, Canada, Japan, and the U.S. creating the North Pacific Anadromous Fish Commission to limit high seas bycatch of salmon and the 1985 Pacific Salmon Treaty with Canada regulating coastal harvest on commingling stocks (Burke 1994), as well as by the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA 1996) and Endangered Species Act (ESA 1988, Littell 1992). NOAA is responsible to see that salmon fishery plans abide by the limitations imposed by the ESA.

All of the regulatory bodies responsible for salmon management are required to utilize the best science available in making decisions about the amount of harvest allowable; however, social, economic, and political factors also influence the decisions. Science must act as an advisor to policy determination. As any scientific output has a degree of uncertainty in the estimations made, and human nature is to disregard unfavorable output when uncertainty is expressed, the scientific predictions or estimations should be expressed in terms of risk instead of uncertainty. Research that helps to fill our information gaps about the survival of salmon and the effects of particular harvest practices can help inform the process and reduce uncertainty (NRC 2004).

Management under two conditions of stock status

Management must be addressed differently for the two states of salmon status, depressed levels and healthy, productive levels. Although the changing state of any stock or population will be a continuum, managing depressed stock in the same way as for healthy, productive stocks does not work. Not only will the answer to the question of how and what to harvest be different, but the monitoring needs will be different. Under conditions of low wild/high hatchery abundance or of depressed stock levels and ESA listed salmon, the ultimate goal is to rebuild the wild salmon stocks. Under restored, healthy salmon abundance the goal is to ensure sustainable salmon fisheries while also maintaining sustainable wild salmon populations.

Under the current condition of depressed salmon stocks, the short-term issue is to evaluate the risk that harvest imposes on the depressed stocks and to develop low risk harvest regimes under the recovery process. The long-term issue, under future recovered salmon abundance, is to identify an appropriate harvest regime for healthy, viable stocks given the variability in production driven by environmental and ecosystem factors, natural and human-induced.

Under both types of conditions, there is also the need for Center staff to provide scientific input to current management processes on applying the harvest rules under use. This includes improving current harvest models used to translate harvest actions into resulting salmon escapements, comparing results from multiple models, evaluating current escapement goals, and improving forecasting of abundance.

Ecosystem approach

NOAA has recognized the need to look at fish as part of an ecosystem, where many factors affect the survival of the fish and the fish in turn contribute to the function of the ecosystem. In NOAA's recent document "New Priorities for the 21st Century – NOAA's Strategic Plan Updated for FY 2005-FY 2010," (NOAA 2004), the first of five agency goals states: "Protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management." This is particularly pertinent to salmon harvest management under today's depressed natural origin salmon levels and the multiple pressures on the salmon from their changing ecosystem. The effects of harvest on salmon viability must be examined in context of the changing impacts from other sources, anthropologic and natural. The amount of harvest that can be taken while maintaining viable salmon populations is dependent not only on the state of the salmon, but on the state of the salmon's ecosystem.

Definitions

The terms stock and population are used interchangeably to reflect a limited, usually by spawning locality, group of salmon. The term bycatch is used to mean salmon caught or killed incidentally in non-salmon fisheries. The term incidental mortality is used to mean salmon killed in the process of salmon harvest but not legally landed (e.g., drop off mortalities, catch-and-release mortalities). Hatchery fish are those resulting from spawning and incubation in hatcheries and wild fish are those that result from naturally spawning salmon. Hatcheries release fish to serve a variety of purposes. There are hatchery fish that are produced with the aim of providing harvest and hatchery fish that are produced to help maintain wild production until habitat improvements are made to allow the wild fish to be self sustaining.

In this discussion we are considering the effects of harvest on naturally-produced fish, referred to as wild fish, as these are the fish we want to rebuild and be self-sustaining. However, hatchery produced salmon are sometimes also included in ESA listings, so harvest regulations will need to address thses fish as well. While total salmon production in the North Pacific has actually increased during the last 30 years, the proportion that is hatchery production has increased greatly (NOAA 1996) and the proportion from naturally spawned salmon has decreased, especially in the Pacific Northwest.

Program Mission and Expertise

The salmon harvest team in the Conservation Biology Division consists of four members and includes researchers who have actively worked with management processes with State, Council, Pacific Salmon Treaty, and Treaty Tribes. Members of the team sit on technical committees for these various processes, contributing to analyses of salmon abundance, productivity, and viability under alternative harvest scenarios. The mission of the team is to provide analytical and research support to management processes governed by the Council and the Pacific Salmon Treaty, and to the NMFS Northwest Regional Office and conduct research into improving harvest management. Staff members collaborate with other researchers at the Center and at other institutions on salmon research relevant to a better understanding of salmon biology and ecology that aides in management of this valuable renewable resource.

Under the Pacific Salmon Treaty, agreements are made between the U.S. and Canada for harvesting all species of Pacific salmon as they migrate through waters of both countries. Technical committees addressing Pacific Northwest issues include: Chinook Technical Committee (CTC), Coho Technical Committee, Chum Technical Committee, Fraser River Panel Technical Committee (sockeye and pink salmon), Selective Fisheries Evaluation Committee, and Technical Committee on Data Sharing. Work is currently being done to evaluate escapement goals for Chinook, determine ways to improve evaluation of population specific harvest of Chinook and coho. Three of the team members are on various technical committees of the PSC.

The Pacific Fisheries Management Council (PFMC) is one of eight regional fishery management councils established by the Magnuson Fishery Conservation and Management Act of 1976 for the purpose of managing fisheries 3-200 miles offshore of the U.S. coastline. The Council is responsible for fisheries off the coasts of California, Oregon, and Washington, including groundfish, coastal pelagic species, highly migratory fish, halibut, and salmon. Chinook and coho salmon are the main salmon species managed by the Council. In odd numbered years, the Council may manage special fisheries near the Canadian border for pink salmon. Sockeye, chum and steelhead are rarely caught in the Council's ocean fisheries. The Council's Salmon Fishery Management Plan describes the goals and methods for salmon management. Every year the Council follows a preseason process to develop recommendations for management of the ocean fisheries. For the salmon fisheries, the process is aided by the Salmon Technical Team (STT), 8 people drawn from state, federal and tribal fisheries management agencies and by the Salmon Advisory Subpanel (SAS), 17 members who represent commercial, recreational, and tribal interests, as well as a public representative and a conservation representative. The Center currently has a seat on the STT (R. Kope). The STT helps the Council by summarizing data from the previous season, estimating the number of salmon in the coming season, and analyzing the effects of the Council's recommendations and amendments. The Scientific and Statistical Committee (SSC) advises the Council on all fisheries. The SSC reviews Fishery Management Plan (FMP) amendments, coordinates stock assessments for groundfish and coastal pelagic species, and reviews methodologies used for salmon harvest management. Dr. P.W. Lawson on the Harvest Team is a past chair of this committee and currently chairs the salmon subcommittee.

NOAA Fisheries Northwest Regional Office (NWR) conserves, protects, and manages Pacific salmon, among other fish species, and their habitat under the ESA and other laws. The office is responsible for preparing ESA Section 4(d) rules for submitted fishery plans and prepares Environmental Impact Statements (EIS) for fishery management plans. They rely on Harvest Team staff for help in scientific review of plans and development of risk assessment and ceiling exploitation rates that will not jeopardize rebuilding of listed ESUs. Dr. N.J. Sands has been working with NWR staff on these issues, particularly for stocks in the Puget Sound area.

Research Approach

Harvest research by the Salmon Harvest Team can be grouped into three overlapping areas: 1) short term research and analysis to address specific issues raised by governing and regulatory bodies (e.g., PFMC, PSC, and NMFS NW Region); 2) conducting research aimed at reducing risk from harvest under conditions of depressed salmon abundance and during salmon recovery efforts; and 3) research to improve the sustainability of harvest when stocks are healthy and self-sustaining.

Research and analyses to support governing bodies

Both the PFMC and the PSC deal with present day management issues of both depressed and abundant stocks of salmon. Of general interest to these bodies is how we can improve current harvest models and the parameters used in them in order to reduce risk to the sustainability of salmon populations and fisheries. More specifically, one area of concern addresses estimation of stock/population specific harvest mortalities. Index hatchery stocks marked with CWTs have been a standard method, especially for Chinook salmon. Both the PFMC and the PSC are currently looking for ways to either improve CWT estimates or develop new methodologies to use other techniques such as otolith marks or genetic stock identification. This will require changes in how the estimates are made since different types of data and different assumptions will be necessarily employed.

In addition, both the PFMC (2000) and the PSC (2004) list the estimation of total mortalities as an important research focus; this refers to better coverage and precision in incidental mortality estimation. While some information is available, it is quite area, gear, and species specific. Estimations are currently made for all fisheries (PSC 2004), but new fisheries specific information would be incorporated in current PFMC and PSC modeling efforts to improve the estimations. This is important now for the mark selective fisheries that have recently been introduced and result in increased catch and release mortality.

The PSC is interested in evaluation of the impact of mass marking and selective fisheries on their ability to evaluate all harvest impacts on natural stocks. Since selective fisheries allows harvest of hatchery fish (adipose clipped fish) while releasing wild (unclipped fish), harvest rates of hatchery fish no longer represent harvest rates on wild fish without additional marking schemes and analyses. Analyses of these impacts are being conducted by the Selective Fisheries Evaluation Committee of the PSC with some results published (PSC 2002). Many of the assumptions used on incidental/release mortalities and the ratio of unmarked to marked fish in the fishery need further evaluation.

The PSC and the CTC, in their work on assessment of Chinook harvest impacts on the stocks, are interested in developing biologically based escapement goals for coastwide Chinook stocks/populations. Current studies are being made by members of the committee on the development of goals based on spawner-recruit relationships and on habitat based relationships.

The PFMC is taking notice of ecosystem management ideas and encourages the development of probabilistic habitat-based models that incorporate environmental variation to establish harvest polices and enable risk assessment for fishing strategies.

The NOAA Fisheries NWR is interested in being able to develop rebuilding exploitation rates (RERs) for all Chinook stocks for ESA Section 4(d) rulings. RERs are maximum exploitation rates directed at Chinook populations that allow rebuilding of salmon abundance until viable recovery levels of abundance and productivity have been reached. While data from some populations lend themselves to this analysis and analyses have been done for these populations, many of the populations have scanty or extremely variable data that have been difficult to analyze to date.

The NWR office is also interested in being able to compare harvest exploitation rate estimates from the PFMC harvest models with the exploitation rates used to derived RERs (these latter rates are derived from analyses similar to the PSC CTC exploitation rate analyses). Harvest rates derived from the PFMC model are used to determine compliance but are not easily comparable to the RER estimates. Differences in these estimates are due to the different basic assumptions used by the different models and different aggregations of stocks and fisheries used.

Based on an assessment of the needs identified above, current and planned research in these areas by the Harvest Team includes:

Coast wide review of Chinook stock escapement goals for harvest management

Within the PSC community, escapement goals for Chinook salmon have been developed by many methods, some more rigorous than others. In would be useful, therefore, to standardize methodology for determining escapement goals. In particularly, the utility of using stock-recruitment curves to develop goals is being reviewed by the CTC and alternative methods are being discussed. Harvest Team staff are contributing to solving this problem through both active CTC membership and independent research on statistical biases in estimating stock-recruit relationships.

Development of an assessment model to incorporate genetic based stock composition data into harvest management

In the late 1990s Washington began mass-marking hatchery coho salmon with an adipose fin clip, a mark previously sequestered as an external cue that the fish carried a coded-wire tag in its nasal cartilage. Instead, Washington initiated mark selective fisheries which allowed retention of only ad-clipped coho. More recently the mass marking of Chinook salmon has begun, and in 2004 mark selective fisheries for Chinook salmon were implemented on a limited scale. With the application of mass marking and mark-selective fisheries the ability to continue to assess the impacts of fisheries on unmarked natural stocks is compromised. The NWFSC's Genetic Program has long been a leader in the use of molecular genetic information to estimate the stock composition of catch in fisheries, and is currently leading the development and expansion of a standardized coastwide microsatellite baseline for Chinook funded through the Pacific Salmon Commission. However, a fisheries assessment model to explicitly incorporate genetic stock composition data has not been developed. The Salmon Harvest Team has therefore initiated a collaboration with University of Washington researchers to develop and evaluate methods for directly utilizing genetic stock identification data into fishery assessments. The method they are developing will be based on an approach similar to the Stock Synthesis model used for assessing groundfish fisheries. This approach has the flexibility to incorporate any type of observational data, as long as the relationship of the data to the population can be mathematically described and the observational error structure can be specified or approximated. This project will included an analytical comparison of current methods based on CWT data alone, inclusion of catch composition as auxiliary data, and methods based solely on catch composition as an alternative to current CWT-based methods.

Risk assessment and rebuilding exploitation rate analyses for Puget Sound Chinook and chum salmon

In evaluating the state and tribal harvest management plans under the Section 4(d) of the ESA, the NW Regional Office wishes to determine stock specific rebuilding exploitation rates (RERs) that would will be consistent with recovery of ESA listed stocks. The estimates rely on cohort run reconstruction and stock-recruit relationships to describe the population dynamics and comparisons are made over several spawner:recruit functions. In addition, because salmon productivity varies markedly over time as a function of freshwater and ocean habitat conditions, Harvest Team staff are developing and evaluating methods to include environmental factors in the assessments. Future work will include greater collaboration with the NWFSC's Fish Ecology and Environmental Conservation Divisions to further explore ways of incorporating ecosystem variability into Chinook salmon harvest management in Puget Sound.

Research to Improve Salmon Harvest Management Under Conditions of Depressed Salmon Abundance

Reducing risk from harvest under conditions of depressed salmon abundance during salmon recovery efforts is obviously important; determining how to measure the risk is likewise important. Risk is measured against viability of the stock or population; viability is determined based on factors of abundance, productivity, spatial distribution, and diversity (McElhany et al. 2000). In order to understand the risk of various harvest levels on depressed salmon stocks, one must understand the population dynamics at low population levels and understand the risk from other sources of mortality currently impacting the population.

Depressed stocks in fishery management are designated in two ways. Under the Magnuson-Stevens Act (MSFCMA 1996) stocks may be declared overfished, triggering specific management actions if they drop below specified levels in the Pacific Coast Salmon Plan (PFMC 2003). Under the Endangered Species Act (ESA 1988) groups of stocks (Evolutionarily Significant Units) may be listed as threatened or endangered if there is a body of evidence that suggests they are at risk of extinction or may become so in the foreseeable future.

Stocks can become depressed for a variety of reasons and depressed stock levels are usually the result of multiple factors. Poor survival can occur at all stages in the life cycle of salmon. Starting with early life stages, freshwater productivity may be reduced by habitat alterations. Mortality in freshwater may be increased by dams, changes in flow regimes, introduction of (or change in abundance and distribution of) predators including fish, birds, and mammals. Simplification of habitat through the removal of complex structure may render juvenile salmon more vulnerable to predators. Environmental changes in temperature or rainfall and runoff patterns may disrupt life-cycle adaptations or make fish more vulnerable to parasites and disease (Lawson et al. 2004). Hatchery juveniles may interact with naturally-produced fish by competing for resources (food or space), attracting predators, disrupting migration timing, or spreading disease. When they return as adults, hatchery salmon may interbreed with wild populations, potentially leading to genetic deterioration of the wild stocks. Upstream spawning migrations may be disrupted by migration barriers such as dams or the presence of chemical pollutants (Collier 2003). Marine survival is naturally highly variable (Coronado & Hilborn

1998, Logerwell et al. 2003). Cyclical changes in marine (and freshwater) survival driven by climate variability can cause a stock to decline in abundance or distribution to the point it is identified as depressed (Lawson 1993). Finally, overly high harvest rates in the ocean or in freshwater can directly force a stock into depressed status. In determining what levels of harvest can be sustained by a population, an understanding of the effects and variability of these other factors is necessary.

Under the current depressed levels of many salmon populations, a better understanding of factors influencing returns per spawner at low population levels is needed so that we can better understand the risk from harvest, which is a managed, quantifiable (in theory) source of mortality. While estimates of harvest related mortalities could always be improved given additional funds and monitoring programs, the understanding of levels, trends, and variability in other mortalities due to natural conditions and human activities is extremely important at these low population levels. Quantifying density dependence is particularly important, even at low abundance levels, as capacity limitations from habitat conditions are a major contributor to poor stock status. Capacity limitation may affect the salmon at more and different stages in the life cycle than in the past. At low abundance levels the occurrence of depensation factors becomes important to estimating returns from spawning.

The mixed-stock nature of most ocean and in-river fisheries makes it difficult or impossible, to avoid capturing and killing (directly or incidentally) weak stocks in fisheries directed at stronger stocks. Eliminating fishing-related mortality on all ESA-listed salmon stocks, for example, would require closing a wide variety of fisheries including most trawl and hook-and-line fisheries in the nearshore ocean. To the degree that it is possible, NMFS is committed to maintaining fishing access to strong stocks and minimizing economic disruption while rebuilding weak stocks (NOAA 2004). Any fishing-related mortality poses additional risks to depressed stocks. The challenge is to quantify the additional risk to the stocks as a result of fishing in a way that can assist harvest managers and policy-makers in balancing the benefits of fishing against the risk to protected stocks.

Key questions for managing fisheries under these circumstances include the following:

- How well do current risk assessment models quantify the risk of harvest on depressed and recovering salmon populations?
- How does harvest affect each of the viable salmon population (VSP - McElhany et al. 2000) criteria (capacity, productivity, spatial distribution, and diversity)?
- At what abundance or density do depensatory effects become stronger than compensatory production factors for individual populations?
- Are the factors currently limiting salmon population productivity density dependent?
- How quickly do salmon populations respond to small changes in harvest rates?
- How do catastrophic and random events affect extinction probability of small populations and do they need to be factored into harvest decisions?
- Are there ways to effectively use hatcheries to sustain salmon harvest without unacceptable impacts on natural populations?

Current and planned research by the harvest team to address these issues includes:

Incorporating environmental variation into salmon harvest management of Oregon Coast coho salmon

Environmental variation, operating on both short term (annual) and long term (decadal) time frames greatly influences salmon survival rates in both the freshwater and ocean environments. Understanding this variation, and using it to predict trends in salmon survival rates, is clearly important for effective management of these stocks. For example, in order to effectively set harvest regimes on Oregon coastal coho salmon, information is needed about freshwater productivity and annual variability in abundance. The Harvest Team is collaborating with the Fish Ecology Division and the Oregon Department of Fish and Wildlife to develop life cycle models that incorporate the influence of environment, from freshwater, to estuarine, to ocean, on the productivity and survival of coho salmon. These models will then be used to give managers better information about how to determine appropriate harvest levels under highly variable conditions.

Research on how juvenile Chinook salmon use Puget Sound estuaries

Understanding the factors influencing survival rates of salmon at multiple life stages is essential for improving the production models used by harvest managers. Life-cycle and harvest/production modeling efforts have routinely been constructed and run using very general assumptions about juvenile survival rates. One area that has consistently lacked detailed knowledge is the juvenile transitions from freshwater to saltwater in estuaries, and the subsequent first few months in marine waters. The Harvest Team is collaborating with the Fish Ecology Division and the Tulalip Tribe to develop better information on how ESA listed Chinook salmon use Puget Sound estuaries. Current knowledge suggests that use of estuarine and nearshore marine habitats provide juvenile salmon opportunities to improve survival through increased growth in productive rearing grounds, and express multiple life history strategies that result in populations that are resilient and robust. Better defining the contribution of multiple life histories of juvenile salmon to resulting overall production (i.e., related to VSP parameters of spatial structure and diversity) of the returning population will provide valuable input into both life cycle and harvest/production models. The Team's current research is focused on examining the abundance, distribution and timing of juvenile salmonid utilization of the Snohomish River estuary and nearshore areas. The aim is to better understand life history stages and survival of juvenile salmonids during the transition from freshwater to saltwater, including interactions between hatchery and wild fish. This information is expected to be useful for both harvest managers and for recovery planning. The Snohomish is rapidly become a test watershed for ecosystem management and salmon recovery planning, and this project is designed to be integrated into other studies in the watershed.

In the near future, the Harvest Team is planning to initiate work on a similar project on the Elwha River. The bulk of the Elwha River is in the Olympic National Park wilderness area, but it has been blocked by pair of impassible hydropower dams for nearly 100 years. The dams are scheduled to be removed in 2007, allowing for a fantastic opportunity to study how salmon recolonize a near-pristine river system. The Harvest Team, in collaboration with other NWFSC scientists and partner state and tribal agencies, is planning a project to study how juvenile salmon change their use of the Elwha River estuary and nearshore environment after the dam removal. Because many salmon originating in Puget Sound and the Strait of Georgia use the habitat near the mouth of the Elwha River during their migrations through the Strait of Juan de Fuca, the results from the project are likely to also provide important information on other Puget Sound salmon stocks.

Research to improve harvest management of healthy, self-sustaining salmon populations

Healthy stocks, for the purpose of this discussion, are those not listed as threatened or endangered under the ESA or overfished under the Magnuson Act. The level of harvest that a healthy stock can support is important to understand for fishery management, and is expected to vary dramatically due to natural short and long-term environmental changes. In particular, the survival rates of salmon stocks vary dramatically over time in response to changing environmental conditions. These include climate cycles affecting both marine and freshwater conditions and natural (fires, landslides, floods) and anthropogenic (logging, diking, filling, polluting) changes in freshwater habitat. Marine habitat may also experience longer-term changes analogous to freshwater habitat, but natural biotic cycles in the marine system are poorly understood. The effects of large-scale fishing on the productivity of ocean ecosystems are likewise poorly understood at best.

We understand that climate cycles result in 10-fold variations in the survival of salmon entering the ocean, and that additional variability occurs in fresh water. The intensity of harvest a stock can support is tied to these survival rates. A harvest rate appropriate for a stock that is experiencing 10% marine survival will be unsustainably high for the same stock when marine survival drops to 1%. The institutions that manage salmon harvest often cannot respond instantly to these dramatic changes in survival. Research is therefore needed to predict interannual and cyclical variability in survival and to guide harvest managers in setting appropriate harvest rates under different conditions. This may include keying annual harvest rates to indicators of stock status and climate conditions (see PFMC Amendment 13 to the Salmon FMP).

A related issue is how harvest itself changes distributions of diversity within and among salmon populations. Under natural (unharvested) conditions, spawner escapements would probably vary at least 10-fold over a period of decades. One effect of harvest is to reduce this variability. Escapement goal management attempts to maintain spawner abundance at a theoretical optimum to maximum productivity. The result may be a stock whose escapement has varied less than 3-fold over much of the past 50 years. This style of management may have unintended consequences including altered spawn timing and maturation rates, selection for smaller size at maturity, reduced genetic diversity, and reduced freshwater productivity through loss of nutrient inputs and gravel conditioning. These changes may cause unrecognized shifts in MSY that lead to over harvest. Other factors that can lead to over harvest include environmental variability in productivity and large scale straying by hatchery fish, which can lead to errors in estimating MSY or applying harvest policy. In particular, due to high levels of environmental variation on multiple time scales, the concept of MSY may not even be appropriate as a management tool for many salmon stocks (Larkin 1977 and others). Research is therefore needed to understand the long-term affects of harvest on the genetics and population dynamics of healthy stocks and to make recommendations for truly sustainable long-term harvest policies.

Key questions related to these topics include:

- In determining levels of harvest that are sustainable over long time periods, what are the appropriate metrics to determine sustainability (escapement numbers versus spawner numbers, spawner density and distribution, environmental regimes, etc.)?
- What selective pressures does harvest impose on populations and can management apply selectivity to the benefit of the populations?

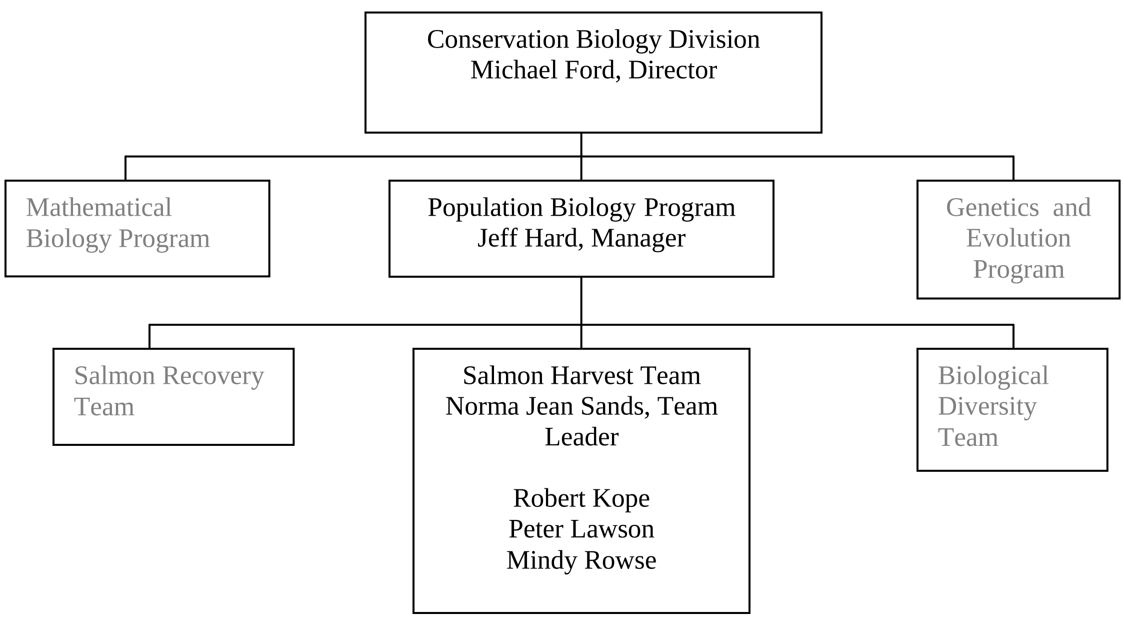
- How does the reduced variability of spawner abundance under standard harvest management strategies affect population productivity or diversity?
- How can we improve on the concept of maximum sustainable yield (MSY) to include variability and ecosystem function? Are there better methods to determine MSY than the ones currently used for salmon management?

Current research conducted by the harvest team on these topics includes:

Climate variability and salmon abundance in the northeast Pacific

Understanding long term variations in salmon abundance is important to successful harvest management in order to adjust management to regimes of differing salmon abundance. Climate-driven variability for many salmon species in Alaska and the Pacific Northwest has shown an inverse relationship (Hare et al. 1999), such that periods of high salmon abundance in Alaska coincide with periods of low abundance in the Pacific Northwest. Starting in about 2000, however, abundances have been high in both regions simultaneously. A member of the Harvest Team is heading a multi-agency effort to reexamine the climate factors that are thought to be responsible for the basin-scale patterns of salmon production in the Northeast Pacific in order to explain the most recent patterns. The investigation may also shed light on the effects global warming may have on salmon populations in the future. This project is likely to lead to additional collaborations on research to understand the effects of long-term climate change on both healthy and recovering salmon stocks.

Program Organization



Prioritizing Research and Allocating Resources

The Salmon Harvest Team's first priorities are the real-time needs of the Pacific Fisheries Management Council, Pacific Salmon Commission and the NMSF Northwest Regional Office. Other priorities include the research projects discussed above, and summarized below. Note that most of the Harvest Team's projects are collaborations with other programs, and only the Harvest Team portion of these projects is reported below. Two of the current Harvest Team members also are also currently working largely on salmon recovery planning projects, and these projects and their funding are not reported below.

Table 1. Draft timeline for initiation and completion of Salmon Harvest Research programs. Base funding represents annual funding from NMFS (% of employee cost). Other funding represents outside funds or short-term grants received from within the agency. Shading indicates estimated duration.

			Funding 05			Fiscal Year					
Research Area	Who	Priority	% time	Base	Other	05	06	07	08	09	10
1 Review of Chinook esc goals											
1a. Bias in stock recruit estimates	RK	1	5%	6.7K							
1b. Review using MSY	RK	2	5%	6.7K							
1c. Using habitat based goals	RK	3	0%								
2. Assessment model using GSI data	RK	1	20%	27K							
3. Risk assessment and RER analysis	NJS	1	10%	12K							
4. Predicting coho abundance	PL	1	2%	2.5K							
5. Juvenile Chinook survival											
5a. Snohomish Estuary	MR	1	90%	81K							
5b. Elwha nearshore	MR	2	2%	2K							
6. Climate variability and salmon abundance	PL	1	25%	32K							
7. Harvest impacts on VSP parameters	new	2									

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