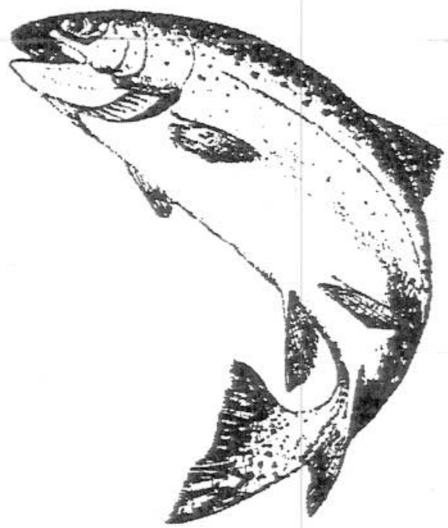
Summary of
the Fifth

Pacific Coast Steelhead Management Meeting



March 5 - 7, 1996
Menucha Conference Center
Portland, Oregon

Sponsored by:
Pacific States Marine Fisheries Commission
and
U.S. Fish and Wildlife Service

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Pacific Coast Steelhead Management Workshop
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INTRODUCTION

During March 5-7, 1996, the Pacific States Marine Fisheries Commission in conjunction with the U.S. Fish and Wildlife Service sponsored the fifth in a series of workshops on steelhead (*Oncorhynchus mykiss*) management. The workshop was attended by approximately 67 West Coast fisheries managers and researchers representing the states of Alaska, Washington, Idaho, Oregon, and California, the province of British Columbia, and the Russian Republic. Topics for this workshop included:

- an update on the status of Endangered Species Act (ESA) petitions and the status of steelhead in each management jurisdiction;
- an introduction to coastwide databases and their uses;
- a discussion of when and how hatchery supplementation should be used;
- a discussion of the interactions between hatchery and wild steelhead; and
- a discussion of ocean and estuarine influences on steelhead survival.

The workshop was structured as a series of panel presentations, followed by discussion and/or questions from the audience. It was intended as a forum to allow steelhead managers and researchers on a coastwide basis to discuss common problems and to share insights into possible solutions. The following abstracts prepared by the speakers, or based on notes of the session chairs, summarize the presentations.

Workshop Steering Committee:

Doug Jones, Alaska Department of Fish and Game
Bob Leland, Washington Department of Fish and Wildlife
Bruce Sanford, Washington Department of Fish and Wildlife
Art Tautz, Ministry of Environment, British Columbia
Ed Bowles, Idaho Department of Fish and Game
Mark Chilcote, Oregon Department of Fish and Wildlife
Dennis McEwan, California Department of Fish and Game
Mick Jennings, Confederated Tribes of the Warm Springs
Al Didier, Pacific States Marine Fisheries Commission

SESSION I: STOCK STATUS

Session Chair: Roger Harding, Alaska Department of Fish and Game

ESA Update

Tom Wainwright, National Marine Fisheries Service

In response to petitions to list populations of steelhead (*Oncorhynchus mykiss*) as threatened or endangered under the U.S. Endangered Species Act (ESA), a comprehensive status review of steelhead populations from the states of Washington, Idaho, Oregon, and California was conducted by a team of scientists from the National Marine Fisheries Service. After considering available information on steelhead genetics, phylogeny and life history, freshwater ichthyogeography, and environmental features that may promote reproductive isolation and local adaptation, we identified 15 Evolutionary Significant Units (ESUs) that can be considered "species" under the ESA--12 for coastal steelhead and 3 for the inland form.

Coastal steelhead (*O. m. irideus*) occur from Alaska to southern California. Within the range covered by this status review there are two ecotypes of coastal steelhead, the ocean-maturing winter steelhead and the less common stream-maturing summer steelhead. Genetic data indicate that the two ecotypes are not monophyletic, and some ESUs include both forms. Of the 12 coastal steelhead ESUs, 4 are in Washington, including 2 that straddle the Columbia River into Oregon. Two ESUs are in Oregon, with a third spanning southwest Oregon and northwest California. The remaining five coastal steelhead ESUs are in California, where extreme environmental conditions promote unusual life history strategies, and genetic variability among populations is high.

Inland steelhead (*O. m. gairdneri*) occur in the Fraser and Columbia River Basins, generally east of the Cascade Crest, although some uncertainty exists about the exact boundary between coastal and inland forms. Inland steelhead are almost exclusively of the stream-maturing summer steelhead ecotype. The inland steelhead ESUs include two in the Columbia River Basin and one in the Snake River Basin.

Various risk factors were identified for each ESU. All ESUs face freshwater habitat degradation, although the degree and causes vary among ESUs. Major causes of habitat degradation include urbanization, siltation resulting from land management activities, water diversions, dams, and other stream blockages. Other risk factors include genetic introgression from hatchery stocks of steelhead and rainbow trout, recent unfavorable climatic and ocean conditions, and harvest activities. In general, populations at the southern and eastern extremes of the species range are at greatest risk.

Conclusions of the biological status review have been reviewed by co-management agencies and have been transmitted to the NMFS Northwest and Southwest Regional Offices. Regional office staff have prepared draft documents evaluating conservation measures and factors for decline. Final determinations regarding possible listing proposals are pending.

Status of California Steelhead

Dennis McEwan, California Department of Fish and Game

Steelhead rainbow trout (Oncorhynchus mykiss) were once abundant in California's coastal and Central Valley rivers and streams. Like many of California's resources, steelhead numbers are declining. In the early 1960's, total statewide abundance was estimated to be about 600,000 adults. Today, rough estimates place the total statewide population at about 250,000 adults. Most populations for which there are good estimates show a persistent declining trend, especially among the natural spawning stocks.

In the Central Valley, steelhead ranged throughout the tributaries and headwaters of the Sacramento and San Joaquin rivers prior to dam construction, water development, and watershed perturbations of the 19th and 20th centuries. Present steelhead distribution in the Central Valley drainages has been greatly reduced due to water development and dam construction. The *California Fish and Wildlife Plan* of 1965 estimated a total average run size of 40,000 adults for the entire Central Valley system. The estimated average annual run size in the Sacramento River above the mouth of the Feather River for a six-year period beginning in 1953 was 20,540 fish, 88% of which were of natural origin. The present annual run size for the total system is probably less than 10,000 fish, of which 70% to 90% are of hatchery origin. Adult steelhead counts at the Red Bluff Diversion Dam (RBDD) on the mainstem Sacramento River have declined from an average annual count of 11,187 adults for the ten-year period beginning in 1967, to 2,202 adults annually in the 1990's. The decline of the natural stocks has been greater than that of the hatchery stocks.

The historical range of steelhead on the north coast (north of San Francisco Bay) has not been reduced as drastically as it has in other areas of the State. North coast rivers and streams have the greatest amount of steelhead habitat in the State and the most abundant populations. However, these populations have also experienced recent declines. On the Trinity River (a major tributary to the Klamath River) total run size has ranged from about 3,000 to 11,000 adults over the past five years. Natural stocks comprise about 50% of the total run. Wild spawning winter steelhead stocks of the upper Eel River have collapsed. The M.F. Eel River summer steelhead population, the most abundant summer steelhead population in California, experienced an increase last year for the first time in several years. Escapement was estimated to be 1,148 adults, which is greater than the previous six-year average (618), but similar to the average annual escapement of the 1980's (1,195). In river systems that have both hatchery and natural stocks, the natural stocks appear to be declining at a faster rate. Most populations appear to have rebounded slightly due to the cessation of the recent six-year statewide drought and the return of more normal precipitation throughout the State.

Southern steelhead (those inhabiting coastal streams south of San Francisco Bay) were formerly found in coastal drainages as far south as the Rio Santo Domingo in northern Baja California. At present, Malibu Creek in Los Angeles County is thought to be the southern-most stream containing a known spawning population. Many of the larger rivers have impassable dams and diversion structures in their lower reaches. Consequently, access to headwater tributaries (which may serve as refugia during frequent drought conditions) has been severely reduced.

Southern steelhead stocks are the most jeopardized of all of California's steelhead populations: numbers have declined drastically in nearly all streams. The estimated annual spawning escapement for coastal areas south of San Francisco Bay in the early 1960's was 59,750 steelhead. A current estimate of steelhead abundance for this area is not available, but is probably only a few thousand fish. The estimated abundance in streams south of Point Conception is probably on the order of 100 adults. A recent status review of these populations found that of 122 streams south of San Francisco Bay which were known to have contained a steelhead population: approximately 20% of the streams still contained populations that had not declined significantly from historical levels; 47% had populations with production that was less than historical levels; and 33% no longer supported steelhead populations.

In response to these persistent declines, the California Department of Fish and Game has developed a statewide restoration and management plan for steelhead. The plan identifies freshwater habitat loss and degradation as the primary cause of the declines, mostly due to excessive diversion of stream flows, blocked access to historical spawning and rearing habitats, and chronic watershed perturbations. Implementation of recovery measures identified in the plan has been postponed indefinitely, however, and more drastic measures may be necessary to protect and restore the more critically depressed stocks.

Status of Steelhead in Oregon

Bob Hooton, Oregon Department of Fish and Wildlife

Oregon has two subspecies of steelhead trout. Coastal steelhead trout (*Oncorhynchus mykiss irideus*) are distributed among Oregon coastal and lower Columbia River streams upstream to and including Hood River. These populations are dominated by winter (ocean maturing) races with the exception of summer (river maturing) races in the Rogue, Umpqua, Siletz, and Hood rivers.

Inland Columbia Basin steelhead trout (*O. m. gairdneri*) are distributed in Columbia River streams upstream of Hood River to Hells Canyon Dam on the Snake River. These populations are dominated by summer races with the exception of winter races in Fifteenmile Creek, near The Dalles, Oregon.

Oregon coastal steelhead with strong populations of wild fish have shown recent improvement in returns in 1994 and 1995, compared to declines in the late 1980's and early 1990's. Returns of winter and summer race adults on Rogue and Umpqua rivers in 1995 approached long term averages, as measured at Gold Ray and Winchester dams, respectively. In 1995, wild steelhead on the Salmonberry River (Nehalem Basin on the north coast) showed the best returns since 1987.

Mid-coast basins, however, (Siuslaw, Alsea, Siletz) dominated by long-term releases of Alsea Hatchery winter steelhead showed little or no improvement in returns. Efforts are underway in these basins to systematically convert hatchery releases to programs which utilize local broodstocks, in order to improve hatchery survival rates and reduce interactions of hatchery and wild fish.

Oregon inland steelhead in the Columbia Basin continue to suffer long-term impacts from widespread hydroelectric development, in combination with recent droughts in 1992 and 1994. Returns of wild winter steelhead over Willamette Falls in 1995 (2,702 adults) were the lowest in 25 years of counting. Counts there during spring 1996 are also expected to be poor, due to low, warm stream flow during smolt emigration in spring 1994.

Wild A-run summer steelhead counts over Bonneville Dam in 1994 were the lowest of record. There was, however, a modest rebound in 1995, with a strong showing of 1-salt adults. This pattern was consistently reflected in returns to Oregon streams such as the Hood, Deschutes, John Day, and Umatilla rivers. Of concern is the high number of stray steelhead into the Deschutes River from upper Columbia and Snake rivers. In recent years, up to 70% of steelhead entering the Deschutes River are out-of-basin strays. It is believed that this is the result of steelhead smolts poorly imprinting on their native streams when they are barged and trucked around mainstem Snake and Columbia river dams. The Oregon Department of Fish and Wildlife is currently reviewing methods to improve sustainability of wild steelhead to the Deschutes Basin, including physical removal of stray steelhead at Sherar's Falls, in order to reduce impacts of hatchery fish on wild stocks.

Washington State Steelhead Stock Status and Statewide Trends

Bob Leland, Washington Department of Fish and Wildlife

An inventory of the status of wild salmon and steelhead stocks in the state of Washington was completed in 1993. In the Salmon and Steelhead Stock Inventory (SASSI), the Washington Department of Fish and Wildlife (WDFW) and tribal biologists rated the current status of each stock (i.e., spawning population) as either "Healthy", "Depressed", "Critical", or "Unknown". (Note: these terms are different than the terms "threatened" or "endangered" under the federal Endangered Species Act). The SASSI document is the first step in a process to restore all of Washington's salmon and steelhead stocks to healthy and productive levels. As new information is available, SASSI will be regularly updated and revised.

Of a statewide total of 141 wild steelhead stocks in SASSI, 36 (26%) were rated Healthy, 44(31%) were rated Depressed, 1 (<1%) was rated Critical, and 60 (43%) were rated Unknown. Of the 96 wild winter-run stocks identified, 34% were rated Healthy, 27% were rated Depressed, none were rated Critical, and 39% were rated Unknown. Of the 45 wild summer-run stocks identified, 7% were rated Healthy, 40% were rated Depressed, 2% were rated Critical, and 51% were rated Unknown. The status and number of wild steelhead stocks in Washington state are summarized in the following table.

Summary of Wild Steelhead Stock Status in Washington, 1992

	Healthy		Depressed		Critical		Unknown		Total
	No.	%	No.	%	No.	%	No.	%	
Puget Sound									
Winter-runs	12	50%	2	8%	0	0%	10	42%	24
Summer-runs	2	18%	1	9%	1	9%	7	64%	11
Combined	14	40%	3	9%	1	3%	17	49%	35
Hood Canal/Strait									
Winter-runs	2	10%	9	45%	0	0%	9	45%	20
Summer-runs	0	0%	2	40%	0	0%	3	60%	5
Combined	2	8%	11	44%	0	0%	12	48%	25
Coastal/Grays Harbor									
Winter-runs	15	60%	2	8%	0	0%	8	32%	25
Summer-runs	1	11%	0	0%	0	0%	8	89%	9
Combined	16	47%	2	6%	0	0%	16	47%	34
Willapa Bay									
Winter-runs	2	33%	0	0%	0	0%	4	67%	6
Summer-runs	0	--	0	--	0	--	0	--	0
Combined	2	33%	0	0%	0	0%	4	67%	6
Lower Columbia									
Winter-runs	2	11%	12	67%	0	0%	4	22%	18
Summer-runs	0	0%	2	40%	0	0%	3	60%	5
Combined	2	9%	14	61%	0	0%	7	30%	23
Upper Columbia									
Winter-runs	0	0%	1	33%	0	0%	2	67%	3
Summer-runs	0	0%	13	87%	0	0%	2	13%	15
Combined	0	0%	14	78%	0	0%	4	22%	18
Statewide									
Winter-runs	33	34%	26	27%	0	0%	37	39%	96
Summer-runs	3	7%	18	40%	1	2%	23	51%	45
Combined	36	26%	44	31%	1	1%	60	43%	141

The Washington state harvest trend (both sport and tribal) for winter and summer steelhead over the last five years (1990/91 through 1994/95) is 191,000 fish. The high during this period was 261,100 for the 1992/93 season and the low was 150,300 in 1989/90 (the third lowest in the past 20 years). The 20-year average for both tribal and sport harvest of summer and winter steelhead is 220,800 fish.

The Boldt Case area, harvest of winter and summer steelhead by tribal and sport fishers averaged 67,000 fish for the 1990/91 through 1994/95 period. This five year time period included the two lowest harvests in the past 20 years: 44,700 in 1990/91 and 51,000 in 1993/94. The 20-year summer and winter harvest average in the Boldt Case Area for both tribal and sport fisheries is 96,800.

The summer steelhead harvest by sport anglers over the past five years (1990-1994) has averaged 63,150 (2,300 wild fish and 60,850 hatchery fish). Most streams in the state are under a wild steelhead release regulation from June 1 through November 30. The regulation has decreased the wild summer steelhead harvest by sport anglers from a high of 13,200 in 1986 to 1,500 in 1994.

The winter steelhead harvest by sport anglers over the past five years (1990/91 - 1994/95) has averaged 14,000 wild fish and 39,800 hatchery fish. Even with the imposition of "emergency wild release" regulations, the wild winter steelhead harvest has ranged from 10,000 to 23,000 over the last five years.

Wild winter steelhead escapement goals have generally been met on the coastal streams of Washington and in the Puget Sound area. The Puget Sound exceptions are in Hood Canal and in extreme South Sound (Nisqually River). Wild escapements to the Columbia and Snake rivers are still below goal.

Status Of Summer Steelhead In Idaho

Ed Bowles, Idaho Department of Fish and Game

Snake River wild summer steelhead populations are imperiled. Adult returns totaled up to 60,000 annually as recent as the late 1960s. Returns have declined to only 8,000 wild fish in the 1994-95 run year. Declines of wild summer steelhead have generally mirrored declines of Snake River spring/summer chinook; the major cause of decline for both species is considered to be mortality associated with juvenile migration through the hydroelectric system on the lower Snake and Columbia rivers. Recent declines have likely been exacerbated by extended drought and reduced ocean productivity. Snake River chinook stocks were listed for protection under the federal Endangered Species Act (ESA) in 1991 and 1992. Snake River steelhead were petitioned for ESA protection in 1994.

Spawning and rearing habitat is not limiting recovery of Snake River summer steelhead. Habitat problems exist and contribute to population status, but population declines are consistent in both high quality and degraded habitats. Many of these populations in high quality habitat are managed for wild fish and have never had hatchery releases.

Decline of wild summer steelhead and spring/summer chinook in the Snake River has alarming ecological significance. The Snake River historically produced approximately 50% of the entire Columbia River production potential for these important fish. This production potential has increased to approximately 70% as a result of habitat loss in Washington and Oregon. As the ecological "cornerstone" for summer steelhead and spring/summer chinook in the entire Columbia River Basin, loss of Snake River stocks would have significant ecological ramifications to the Columbia River ecosystem.

Harvest opportunities for steelhead in Idaho are limited to hatchery fish, which are identified by an adipose fin clip. Anglers are required to release all wild fish. Hatchery programs represent mitigation from private (Idaho Power Company) and federal (Bonneville Power Administration, Army Corps of Engineers) hydroelectric development. Although egg-take and smolt production targets are usually met, fisheries are inconsistent and sometimes do not meet mitigation goals. Recently, adult returns have barely been adequate to meet egg-take needs; further constraining harvest opportunities.

British Columbia Stock Status and Update

Art Tautz, B.C. Ministry of Environment

British Columbia sport catch (catch plus release) has declined by about one third from the levels experienced in the mid- to late-1980s. These declines resulted from decreases in both the number of fish returning and in the number of anglers fishing. Number of licensed anglers declined from a high of 44,000 in 1989 to about 32,000 in 1995. This is about equal to the levels experienced in the early 1980s.

Freshwater and ocean survivals have been monitored in British Columbia since the late 1970s. The Keogh River on northern Vancouver Island has annually provided counts of out-migrating smolts and adult returns. Numbers of smolts produced has declined in 1994 and 1995 to about 2,000 fish, or about one third of the river's carrying capacity. These are the lowest recorded levels since 1977 and 1978. Causes of the low smolt production are under investigation, but results are likely due to lower numbers of returning adults combined with low flow/environmental conditions in rearing years.

Ocean survival has also shown significant declines, both in absolute terms and when adjusted for smolt size effects. Smolts produced in 1982-1985 experienced good - perhaps exceptional - conditions in the ocean. Survival then decreased in 1986-1989, and reached historic lows in 1990 and 1991. Mackerel predation in 1991 is considered to have been responsible for an almost 10-fold reduction in marine survival. The 1992 smolt year has shown significant improvement, but has not reached historic levels.

Other projects in B.C. include adult radio-tagging studies on the Skeena, stock ID work using laser ablation (rare earth) and genetic methods (microsatellite), electronic counting and image analysis, development of selective harvest methods, habitat capability analysis, and work on consensus management processes.

Population Status of Steelhead Trout in Southeast Alaska

M.D. Bryant and S.C. Lohr, PNW Research Station, U.S. Forest Service

We report on the status of steelhead trout in southeast and parts of southcentral Alaska. Our objectives are to describe and compare age structures, sex ratios, spawning frequencies, and body lengths among stocks; determine freshwater residence, immigration and emigration timing of adults; and identify temporal trends of populations. Steelhead are reported to occur in more than 500 rivers and tributaries throughout coastal Alaska. Of these, 12 runs have sufficient data to compare biological characteristics and to assess population trends. Fewer than four of these 12 runs have long term (>7 years) weir records. Escapement counts, angler harvest, or weir counts (>1 year) indicate escapements of fewer than 100 fish in 60% of the 500 streams and rivers. A wide range of age classes, both freshwater and ocean, were observed, but most winter-run steelhead juveniles spend 3 to 4 years in fresh water. Summer-run fish generally spend 2 to 3 years in fresh water. Winter-run fish spawned from 2 to 4 times after their initial spawning, whereas summer-run fish spawned 1 to 2 times after their initial spawning. Of the five stocks with escapement index data for more than seven years, four showed no significant trends. The Situk River showed a significant increase with time, but peak counts were significantly and positively related to the number of survey trips. The number of survey trips also increased with time. Several significant management issues emerge from the analysis: 1) the length of time steelhead juveniles spend in fresh water makes them more susceptible to habitat effects in watersheds of southeast Alaska; 2) small run sizes in the majority of the streams places them at greater risk from over-exploitation or adverse habitat effects; 3) escapement estimates from single surveys tend to under-estimate escapements; and 4) insufficient data exist to accurately assess effects of habitat changes resulting from management activities in watersheds. We were not able to identify unique stocks based on available biological data.

The Red Book of Russia as an Important Element in the Strategy of Conservation of Rare and Endangered Fishes

D.S. Pavlov, Chairman, Department of Ichthyology, Moscow State University

In accordance with the federal law governing wildlife, rare and endangered species are entered in the Red Book of the Russian Federation. This law and the Red Book are the legal basis for the protection and conservation of rare and endangered species. The Ministry of Protection of the Environment and Natural Resources has overall responsibility for coordinating all activity impinging on species in the Red Book; specific project dealing with the species are dealt with by the Interagency Commission for the Red Book. The anadromous form of *Salmo mykiss* (steelhead) has been included in the Red Book since 1983. As with other species protected by the Red Book, the taking of steelhead is permitted only for purposes of scientific research. The Department of Ichthyology of Moscow State University is the officially designated Curator responsible for coordination of all scientific research projects on steelhead in Russia.

The report discusses the general strategy of conservation and protection of rare and endangered fishes in Russia, with specific reference to steelhead.

Problems of Study and Conservation of Kamchatka Trouts

K.A. Savviatova, Department of Ichthyology, Moscow State University

The report discusses some historical aspects of the study of Kamchatka trouts, the significance of Kamchatkan steelhead for the study and conservation of the species throughout its range, the goals and expected results of the joint Russian-American steelhead program, and the results of the joint Russian-American expeditions to Kamchatka in 1994 and 1995. It shows that as a result of a decrease in the abundance of the typically anadromous steelhead groups in the Utkholok River since the early 1970s, the structure of this population has changed in a rather short time (less than 25 years). Thus, a decrease in the abundance of the steelhead stock can result in a relatively quick change of the life strategy of intrapopulation groups, and a transition of these groups from one to the other can occur. Under stable environmental conditions and high abundance of steelhead, the population structure has not changed: in the Kvachina and Snatolvayam rivers, where the numbers of steelhead have not changed noticeably, the populations are still represented only by typically anadromous groups. It is possible that all intrapopulation groups belong to a single stock. Apparently, under specific conditions the environment acts as a switch that determines the path of development along one of several possible alternative routes. Discovery of a salmonid in Kamchatka resembling the American cutthroat trout shows that the diversity of forms of Pacific trouts in Kamchatka is higher than previously believed. The study shows the need for an inventory of the forms of Pacific trouts throughout the entire range. The main attention should be paid to differentiation of steelhead groups, to the study of their reproductive relations, and to the possibility of transitions between them. These local populations and intrapopulation groups form the diversity of Pacific trouts, and their protection and recovery is important.

SESSION II: COASTWIDE DATABASES

Session Chairs: Al Didier, Pacific States Marine Fisheries Commission
Art Tautz, B.C. Ministry of Environment

NMFS Pacific Salmonid Databases

Tom Wainwright, National Marine Fisheries Service

As part of ESA status review work on seven species (steelhead, sea-run cutthroat, coho, chinook, chum, pink, sockeye) of Pacific salmonids,
NMFS Northwest Fisheries Science Center coordinated the compilation of two databases of information on salmonid abundance and artificial propagation throughout the west coast, from California through southern British Columbia.

The population abundance database was compiled by a team led by Big Eagle and Associates (Red Bluff, CA). The "database" is actually comprised of several databases and miscellaneous tables providing information on marine and freshwater catch, escapement, historical abundance, and juvenile abundance for individual populations. This effort was completed in December 1995.

The artificial propagation database was compiled by Natural Resources Consultants (Seattle, WA). It is comprised of two databases: hatchery release information and hatchery return and spawning information. The hatchery release database is similar to the RMIS database, but has some additional records added; it includes release date, number released, number tagged, size at release, release location, etc. The return/spawning database contains an extensive compilation of hatchery broodstock records, including stock, run, number returning, number spawned, number passed upstream, number of eggs, egg-to-release survival, and percent return. This effort was also completed in December 1995.

Future plans include integrating this data with PSMFC's StreamNet data, providing public access, establishing mechanisms for updates, and geographic expansion to include the rest of BC and Alaska.

Information Systems in British Columbia

Art Tautz, British Columbia Ministry of Environment

There are several important trends affecting the development of information systems in British Columbia and elsewhere. These include: 1) increased processing power; 2) improved communications; 3) relational data base technology; and, 4) Internet and the World Wide Web. Increased processing power and vastly improved communications systems have dramatically increased our ability to store and access information. This is best demonstrated by the speed and capacity of personal computers and with the explosive development of the World Wide Web.

A significant limitation of the web and the HTML structure lies in the fact that one can only retrieve information in the manner in which it is stored in the system. Relational data base technology, however, provides a vehicle for creating new links and associations of data, provided that the relational rules are followed when the data base is designed. Combining relational data systems with interactive Internet technology will fundamentally change the way we use and access information.

In British Columbia we are at the organizational/data collection stage of map/GIS and data base development. Projects include:

1. Watershed Atlas - with watershed codes, to 1:50,000 scale, and containing map base attributes;
2. Fish Information Summary system - implemented on an Oracle/Arcing platform and containing escapements, regulations, stocks, and stocking history;
3. Data Base Warehouse - with multiple formats, multiple interfaces, distributed copies, and quality assurance in the regions;
4. Web sites and Bulletin Boards; and
5. Fish Base - a biological data base of all fishes of the world, based in CD ROM, whose interactive potential is being evaluated.

The StreamNet Database
Duane Anderson, Pacific States Marine Fisheries Commission

StreamNet is a regional aquatic information system designed to provide timely, accurate, and well documented data to a broad user community. The overall goal of StreamNet is to compile, maintain, and enhance a high quality, regionally consistent set of fish and wildlife data that is directly applicable to regional policy, planning, and management, and to provide that data to users' desk tops. Specific emphasis continues to be placed on tailoring the project to meet specific Fish and Wildlife Program monitoring and evaluation needs.

The primary geographic area covered by the project includes the states of Idaho, Montana, Oregon, and Washington. The primary participants in the project include the Pacific States Marine Fisheries Commission(PSMFC), representatives from each state's primary fish and wildlife agencies, the U.S. Fish and Wildlife Service, the Columbia River Inter-Tribal Fish Commission, and the Shoshone-Bannock tribe. The project is funded by Bonneville Power Administration, and is managed by staff at PSMFC.

Currently, the primary data content of the system is focused on anadromous fish. Data categories include detailed time series trends of various measures of adult spawner escapement, as well as dam counts, freshwater and marine harvest, hatchery releases and returns, and distribution (presence/absence data). The system also includes a comprehensive list of dams and hatchery facilities. All data in the system is tied to a single geographic referencing system (the EPA reach file) allowing for the retrieval of all data types through a single query interface. Other data types available include mainstem and tributary historical flow and temperature data, nearshore ocean upwelling indices, and sea surface temperature and pressure measurements. Future data content will include detailed distribution data for resident fish as well as more comprehensive stream habitat data.

Data access is provided through a number of means. The primary one currently available is through the project's distributed information system (DS). The DS is a PC compatible system operating in the Windows environment that provides full query and reporting capabilities for most of these data types. Project participants also cater to specific ad hoc queries (at the state and regional level) that are not currently supported in the DS. Finally, plans are underway to provide on-line access to much of the data through the world wide web on the Internet.

Geographic information systems in steelhead management: will spatial and tabular realms join in marriage?

Martin Hudson and Peter Hahn, Washington Department of Fish and Wildlife

Recent technical advances in Geographic Information System (GIS) software have made it possible to build a compatible and efficient marriage between spatial river graphics data and tabular fish and in-stream habitat information. This "marriage" has recently been proven to be a reality through an innovative GIS procedure called "dynamic segmentation"[1]. Dynamic segmentation is an enhanced database management system for linear features now packaged with Environmental Systems Research Institute's (ESRI) Arc/Info GIS software. Because of this recent enhancement, digitized points or pairs of points defining linear information can now be easily referenced to a hydrology layer and efficiently stored in related tabular data sets rather than as separate layers, a procedure that has often left GIS data management for rivers and fish information quite cumbersome and impractical for analytical purposes.

Until the last three years, Washington Department of Fish and Wildlife (WDFW) and other resources management agencies have mainly used GIS for managing terrestrial wildlife and habitat information, and only minimally for river resource information because of the fore mentioned reasons. The primary basis for extensive use of GIS in managing terrestrial wildlife information is attributed to the traditional polygonal or area and point design of GIS databases, a design that lends well to terrestrial habitat area and species point location database management and analysis while not for linear features such as rivers and streams. Recent development of dynamic segmentation GIS has now come of age for linear features, having evolved into a very powerful management and analytical tool for river and fish resource databases.

Before dynamic segmentation, laborious tabular data entry procedures were often used to link data to each effected "reach" within a relevant stream river or stream. (A river "reach" is the smallest encoded unit within the US-EPA reach system, the GIS hydrology layer used by StreamNet, WDFW, ODFW, IDFG and other agencies and universities.) Data that were attributable to less than a full reach could be digitized and stored as a separate GIS layer, however, this significantly compromised connectivity and usability with the main GIS hydrology layer. For example: this procedure produced an "all or nothing" attribute for fish presence within a reach, when in reality only a partial use of the reach by a given species was often the case. Other information such as riparian, river bank and in-stream habitat data were virtually impossible to link to a hydro layer because of this "all or nothing" limitation. But with dynamic segmentation, these situations have been alleviated for linear databases, including all types of transport layers (highways, power lines, pipelines) and in this case, rivers and streams.

The first major project completed at WDFW using dynamic segmentation was a study documenting salmon and steelhead habitat degradation in the Chehalis River[2]. The project

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[1] Hudson, M.. 1995. Dynamic Segmentation and River Resource Database Management: A proposal for Developing an Advanced GIS Fish/Hydro Database. Washington Department of Fish & Wildlife, StreamNet Project, funded by Bonneville Power Administration.

[2] Wampler, P.; Knudson, E.; Hudson, M.; and Young, T.. 1993. Chehalis River Basin Fishery Resources: Salmon and Steelhead Stream Habitat Degradations. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA.

was a cooperative effort completed by the US Fish and Wildlife Service (USFWS) and the former Washington Department of Wildlife during 1992 and 1993. This project demonstrated that linear data (bank and riparian degradation) and in-stream point data (beaver dam and point source pollution locations) could be accurately located along a river and stream GIS layer. The project was viewed as a fisheries database landmark in GIS applications and is still being released today to various private and public agencies. A final document containing several maps was completed and presented to the US Congress as a report titled "Chehalis River Basin Fishery Resources: Salmon and Steelhead Stream Habitat Degradations".

A second, more advanced dynamic segmentation project was completed for the WDFW Integrated Landscape Management (ILM) initiative. This project consisted of an intense study of riparian types as compared to known stream classifications developed by the Washington Department Natural Resources (WDNR). This information proved necessary for developing long-term management plans within the ILM study area. Much of the technology developed for the study is now being enhanced and transferred to the statewide 1:100,000 scale EPA river reach system layer for Washington State. A 1:24,000 scale hydrology layer is also available through the WDNR but it still requires considerable work to achieve stream trace continuity or the ability to network, a necessary function for to take advantage of dynamic segmentation and related fisheries analyses. However, it is anticipated that this layer will provide a foundation for a more dense and advanced GIS rivers database in the years to come. Small watershed analysis projects covering a few townships in size are presently being completed by the Olympic National Forest using the WDNR layer, illustrating the future potential of this layer.

The state of fish/hydro GIS databases, detailed aquatic habitat, stream gradient, flow and other data layers is that they are largely non-existent or highly fragmented among various agencies within the Pacific Northwest (such as localized watershed analysis projects). For existing field surveys and consequent tabular data sets, it has often been the case that data were not always collected in the necessary detail or consistency (not all species recorded for example). There has been a subsequent loss of utility for species diversity and habitat "gap" analyses, and for developing a consistent statewide data layer. Usually there is also not a linkage between the tabular data sets and GIS data layers. However, we anticipate that this should change in the future.

Companion statewide GIS data layers now available in several of the resource agencies are: public land survey (township-range-section), transportation layers (highways, pipelines, electric transmission lines), county boundaries, city boundaries and attributes (sewage lines, storm sewers, sidewalks, streets, property ownership), major public lands, place names (mountains, rivers, lakes), elevation grids, soils, geology, vegetation (including LANDSAT and aerial photography data in raster format), climate, precipitation, and groundwater. At WDFW the major terrestrial wildlife database is called the "Priority Habitats and Species". Private sector GIS data also exist, such as telephone lines, local power lines, gas pipelines, and various forest and timber related data. Much of the information from these layers can now be efficiently transferred to a linear database using dynamic segmentation.

As with most tabular database used for analysis, GIS layers should be field verified before detailed analyses are made. Layers that are currently being compiled should be source documented with field verification procedures used. Database managers and system developers should include a comprehensive database dictionary for their data sets with archived and catalogued data forms. Along with this they should include methodology codes for every measurement, linked reference citations, and comments.

The Washington Rivers Information System (WARIS) is the major state-wide aquatic GIS database for Washington State. The database is managed by WDFW under a cooperative agreement with the StreamNet Project, formerly the Coordinated Information System (CIS) and Northwest Environmental Database (NED) projects. WARIS currently has presence-absence information for anadromous salmonids and selected resident game fish, anadromous barriers, qualitative resident fish habitat ratings, hatchery and dam locations. But because of the limitations previously described for linear GIS databases, the database offers only a marginal value as a functional GIS rivers and stream information source for analytical purposes. However, WARIS is currently in the process of being converting to dynamic segmentation at 1:100,000 scale using the EPA river reach system. When this stage of the project is completed later this year, the database will more accurately represent attribute features for rivers and streams, including fish presence-absence, and known spawning and rearing areas, thus, significantly increasing its analytical capabilities. Long-term plans call for the addition of several in-stream habitat and substrate variables and detailed riparian information. The database will be managed and accessed completely via a Graphics User Interface (GUI) or mouse driven windows environment. Traditional tabular and GIS database management methodology for linear databases will have been superseded by the highly automated technology offered by dynamic segmentation.

Another major fish information system managed by WDFW is the "Stream, Lake and Fish Database" or SLFD. This database is another example of what could become a "marriage" between the now familiar tabular fisheries data and a comprehensive GIS. At present the SLFD is a predominantly tabular, state-wide database containing field sampling information, such as from electrofishing, snorkeling, hook and line, gillnets, traps and spawning redd surveys for char. All sample sites have been digitized. The tabular database consists of related, semi-normalized, data tables containing GIS derived location attributes, site and sample specifics, and information on fish, habitat, chemistry, methods used and various qualifiers. In time, an active relational link of the tabular information will be made with the digitized points.

A large amount of the data now used by steelhead managers will not be significantly affected by GIS capability. The most likely uses of GIS could be for expanding spawning distribution and expansion analysis, habitat and carrying capacity analysis (including restoration planning), mark recaptures and straying analysis, and habitat based spawning escapement models. Analyses of such data could include correlations between species use and habitat types, for example. Such automated analytical process are built-in to the dynamic segmentation data management module, thus, making such procedures fairly simple and automated. When coupled with an interactive Graphic User Interface, such a GIS will become accessible to the many rather than the technical few. However, it will require agencies to commit more resources to building and maintaining good, useful and geographically linked data systems. It will also require agencies, tribes and universities to cooperate in order to facilitate effective sharing of such information.

SESSION III: HATCHERY SUPPLEMENTATION

Session Chair: Steve Foley, Washington Department of Fish and Wildlife

Supplementation - What Is It And When Is It Appropriate?

Steven A. Leider, Washington Department of Fish and Wildlife

In contrast to the traditional goals of harvest-oriented hatchery programs, the goal of supplementation is to increase natural production and harvest benefits while maintaining the genetic resources of the target populations, and keeping genetic and ecological impacts to non-target populations within specified limits. Key elements of this definition include emphasis on natural production and on genetic and ecological risk factors for both the target and non-target populations. Uses of supplementation include: preservation of stocks facing extinction, rebuilding of stocks persistently below carrying capacity due to factors other than fishing, and for rigorous evaluation of key questions about the efficacy of supplementation. Implementation of supplementation programs in compliance with this definition is complicated, requiring focused attention on several key aspects: clearly stated goals and objectives, assessment of factors limiting production, benefit/risk analyses, development of genetically and ecologically appropriate protocols regarding hatchery operations, and development of a comprehensive monitoring and evaluation plan and related decision-making framework. Supplementation should be only be considered in the context of a range of complementary strategies to achieve rebuilding objectives; supplementation alone would not be expected to ameliorate the fundamental causes of decline.

There are no universally accepted guidelines regarding the point in time at which intervention with supplementation programs is appropriate; thus, prospective programs should be considered on a case-by-case basis, attempting to balance the opposing risks of acting too early vs. too late. The context afforded by existing policy frameworks and stated management objectives will direct decisions about supplementation. However, intervention would seem appropriate in the following circumstances: prior to the point at which stock abundance is so small that year class failure is a distinct possibility; after performing a benefit/risk analysis indicating a that a reasonable likelihood of a positive response exists; and in the context of comprehensive basin or management plans aimed at alleviating limiting factors.

Insufficient evidence exists at the present time regarding the efficacy of supplementation in the context of recognized biological risks. Thus, a prudent approach would be to view supplementation as an experimental strategy that should incorporate substantial risk containment measures, even in situations for which the efficacy of alternative rebuilding actions is also unclear. Species like *Oncorhynchus mykiss*, which have particularly complex freshwater life histories (e.g., long and complex freshwater and saltwater life cycles, different forms - anadromous, resident), provide major technical challenges for supplementation planning, implementation, and evaluation.

Ecological Risk Assessment of Hatchery Steelhead Supplementation in the Upper Yakima Basin

Geoffry McMichael, Todd Pearsons, and Steven Leider, Washington Department of Fish and Wildlife

In response to proposed supplementation of steelhead in the upper Yakima basin, species interactions research was initiated to better understand potential ecological impacts of releases of hatchery steelhead on wild trout populations. In our primary experiment we released about 33,000 hatchery-reared steelhead smolts into a Yakima basin tributary annually from 1991 through 1994. Behavioral interactions between residual hatchery steelhead and wild trout were observed by snorkeling in control and treatment streams. Distribution and movement of residual and hatchery steelhead were examined through use of traps, and abundance was investigated by electrofishing. Hatchery-reared steelhead dominated rainbow trout in the majority of contests and were typically larger. Types of behavioral interactions observed in treatment streams were generally more violent and subsequently were expected to be energetically more expensive than those seen in control streams. Displacement of wild trout by hatchery steelhead was seen within channel units, may have occurred over a short stream reach (about 500 m) in 1994, and was not detected over large spatial scales. Density of wild rainbow trout appeared to have been influenced by releases of hatchery steelhead. Mean annual abundance and biomass of wild rainbow trout showed general downward trends in both control and treatment streams, however, the decrease was greater in the treatment stream. Residual hatchery steelhead were relatively abundant in 1994 and were observed over 12 km upstream of the area where they were released, in an area containing populations of wild bull and cutthroat trout. Growth experiments in instream enclosures in 1993 and 1994 indicate that the presence of residual hatchery steelhead reduced growth rates of wild rainbow trout. Broodstock used to produce the hatchery steelhead smolts we released varied from all wild BY1990) to all hatchery origin (BY1992), with two years (BY1991 and BY1993) being mixed. Offspring of hatchery-origin adult steelhead had higher in-basin survival than offspring of wild steelhead. Spatial and temporal overlap of spawning steelhead and rainbow trout is complete. This overlap increases the likelihood of hatchery steelhead adults or precocious males interbreeding with resident rainbow trout; the phenotypic consequences of such matings are unknown. To minimize negative impacts of hatchery-wild interactions on wild salmonids, we recommend release strategies (E.g., timing, location, and life stage of fish released) that minimize spatial and temporal overlap between residual hatchery steelhead and wild trout and steelhead, as well as a robust risk containment plan. Our research has led us to form the following hypothesis: Supplementation of steelhead in the upper Yakima basin will negatively affect growth and abundance of rainbow trout. This hypothesis may be tested through monitoring and evaluation.

Ecological Risk Containment Associated with Steelhead Supplementation in the Upper Yakima basin

Steven Martin, Todd Pearsons, and Steven Leider, Washington Department of Fish and Wildlife

Ecological risk containment approaches are being developed to control unanticipated ecological impacts resulting from proposed steelhead supplementation in the upper Yakima River. Ecological risk containment requires knowledge of the demographics and status of the population at risk sot that the range of variability of the species at risk can be determined. Based on this type of knowledge, a monitoring plan can be constructed with specific objectives for the population at risk. In the upper Yakima River, baseline monitoring of rainbow trout abundance, distribution, spawning characteristics, genetic composition, age, growth, and movement has been ongoing since 1990. Results from six years of rainbow trout population abundance estimates in tributary index sites indicate that it would take at least 25 years of post-supplementation sampling to detect a 10% reduction in rainbow trout abundance at these sites. In the mainstem Yakima River, however, population abundance variability is much lower, and detection of a 10% reduction in rainbow trout abundance would be possible with only two to three years of sampling following supplementation. Similarly, rainbow trout growth in the Yakima River has exhibited low variability, and therefore may be an excellent monitoring variable. For example, based on the length-at-age of rainbow trout collected in one section of the Yakima River, we may be able to detect a 5% decrease in the length at age-1 by collecting as few as 16 fish. The distribution of rainbow trout in tributary sites has exhibited low variability as well, averaging 97% of the sites sampled. Based on this average it appears that, after arcsine transformation of the data, it would take only eight years to detect a 10% decrease in rainbow trout distribution in tributaries. Since it is difficult to assess and contain all of the possible ecological risks associated with a project of this scope, the inevitable question arises: Is ecological risk containment possible. Our answer is yes, at least for the variables we have measured and the variability we have observed.

Alternative Hypotheses for the Benefits and the Risks Posed by Hatchery Supplementation of Naturally Spawning Populations of Steelhead

Reg Reisenbichler, NW Biological Science Center

Various persons have insisted that hatchery supplementation programs (releasing hatchery fish to augment the numbers of naturally spawning fish) will have only a trivial effect on the carrying capacity or productivity of naturally spawning populations, particularly if wild (naturally spawned) fish exclusively are used for hatchery brood stock -- i.e., if hatchery fish are always only one generation removed from wild fish. I explore this thesis using existing data and a simple model to evaluate the cumulative effects of supplementation over several generations, and find the thesis false. The existing data better support the hypothesis that supplementation of naturally spawning salmon populations with hatchery fish will substantially decrease the productivity for fish spawning naturally, and will result in total production far less than anticipated if genetic changes are not considered.

Natural selection for fish that do well in the hatchery environment (domestic selection) has been demonstrated for steelhead (*Oncorhynchus mykiss*), and coincides with loss in genetic fitness or survival for rearing in natural streams. This loss should reduce the carrying capacity and productivity (adult progeny per spawner) for naturally spawning steelhead populations when hatchery fish augment these populations. The magnitude of reduction, in part, depends on when the period of limiting (density dependent) mortality occurs for naturally spawning fish.

The available data suggest progressively declining fitness for natural rearing with increasing generations in the hatchery -- the reduction in survival from egg to adult may be about 25% after one generation in the hatchery, and 85% after many (>6) generations. Such reductions for an entire population in stream systems where the amount of spawning habitat limits the natural spawning population would reduce carrying capacity and productivity by these same amounts. Reduction in survival from yearling to adult may be about 15% after one generation in the hatchery, and 67% after many generations. Such reductions for an entire population in stream systems were the limiting period for natural production occurs at or shortly before the juvenile fish become yearlings would reduce carrying capacity and productivity by these same amounts.

To investigate the cumulative effect of supplementation, I consider a supplementation program were all hatchery fish spawn naturally and, after the first generation, all wild fish are taken into the hatchery as brood fish. The fish all mature at the same age (i.e., no overlap in generations), and year-to-year variation in environmental conditions is ignored. The existing data suggest that each generation of hatchery rearing moves the relative survival for a population (survival relative to that for the original wild population) one-third of the way to the asymptotic value (approximately 0.5 for survival to yearling or 0.2 for survival to adult). I assume that natural selection on each generation of fish rearing in streams will likewise move relative survival one-third of the way to the asymptotic value for natural rearing -- i.e., 1.0.

This supplementation program produces a saw-toothed decline in the fitness or success for rearing in natural streams, until by the ninth generation egg-to-adult survival is reduced by 50%. If the naturally spawning population is limited by the amount of spawning gravel, the associated carrying capacity is reduced by 40% within four generations, and 50% after nine. Application of spawner-recruit models to a reasonable set of scenarios shows that the actual production (hatchery plus natural) with supplementation can be only one-third that expected if the genetic consequences of hatchery rearing are ignored. If supplementation is discontinued, the population may be in danger of extinction depending on how quickly it can regain fitness for natural rearing.

The cumulative effects of supplementation will vary with the proportion of wild fish brought into the hatchery each year, the productivities for hatchery and natural rearing, and the period of density-dependent limitation for natural rearing. Although I present results for only a few combinations of these parameters, the results are sufficient to show that managers can seriously overestimate the benefits of hatchery supplementation by ignoring the genetic consequences. Modifying hatchery environments to reduce domestication my ameliorate the genetic problems, but the practicable level of amelioration is unknown and may be slight.

Additional work is needed to better describe and understand the rates of genetic change in survival or fitness (domestication and naturalization); to predict the cumulative effects of supplementation for other sets of parameter values; and to design and evaluate alternative hatchery environments for reducing domestication selection.

Limiting Hatchery Steelhead Straying Using Direct Tributary Releases

Ken Kenaston, Oregon Department of Fish and Wildlife

Oregon adopted a Wild Fish Management Policy in 1992 that established standards for the level of hatchery fish in wild spawning populations. Oregon has a large hatchery steelhead program designed to provide fish for recreational fisheries. Many steelhead programs were out of compliance with this policy because of the large proportion of hatchery steelhead in the spawning population. Changes in the smolt release strategies are being examined to try to retain these popular hatchery steelhead programs while reducing the proportion of hatchery fish I the spawning populations. Imprinting smolts in a tributary acclimation pond and direct tributary releases were equally effective at returning adults to the tributary of release and reducing straying into other spawning areas.

SESSION IV: HATCHERY-WILD INTERACTIONS

Session Chair: Alan Byrne, Idaho Department of Fish and Game

Allozyme Variation in Selected Alaskan Steelhead Populations and their Comparison to Populations in the Pacific Northwest and British Columbia

Cheryl Seifert, Alaska Department of Fish and Game

Indigenous Alaskan steelhead (*Oncorhynchus mykiss*) populations from five streams in four distinct geographic areas of the state were examined for allozyme variation by starch-gel electrophoresis. Analysis of 39 loci indicated that heterogeneity exists among these populations. Samples were broken into age classes and re-examined. Within-stream results showed that there was no heterogeneity among rainbow, but some year class variation was observed among steelhead. No significant differentiation was observed between rainbow and steelhead within a stream. Significant differentiation was observed among streams at 13 of 22 polymorphic loci suggesting that fish from different drainages should be considered separate populations.

Electrophoretic data on wild steelhead trout populations from British Columbia, Washington, and Oregon were compared to Alaskan populations. Data from only four loci (MDH, LDH, IDHP, and SOD) were available for comparison among regions. A more intensive comparison of loci is currently being conducted for these regions to provide a better picture of steelhead genetic variability coastwide.

Life history characteristics of steelhead trout vary along the Pacific coast and within streams. Many streams studied in Alaska have both ocean and river (spring and fall) maturing fish. Sampling for this research included ocean maturing fish form four streams and river maturing fish from one stream. Alaskan steelhead populations show an increased age at smoltification and average size from north to south along the coast, while population sizes tend to decrease.

Mixed Stock Fishery Concerns

Gregg Mauser, Idaho Department of Fish and Game

Many harvest regimes for salmon and steelhead in the Pacific Northwest remain technically primitive, biologically harmful, and economically wasteful because managers are unwilling to make the effort to identify and selectively harvest species and stocks. Realistic options are needed to take advantage of strong runs while protecting weak stocks from undue impacts. Harvest rates for summer steelhead in the Columbia River are presently driven by the Endangered Species Act and by treaty Indian fisheries, both associated with fall chinook salmon.

In recent years, the threatened status of a remnant population of fall chinook in the lower Snake River has afforded some relief from incidental harvest and sale of substantial portions of declining Snake River wild steelhead runs. Unless steelhead are protected, planned fall chinook salmon enhancement programs may negate this temporary situation. Steelhead numbers are declining, despite restrictions in other fisheries. A method of selectively harvesting fall chinook, especially surplus fish produced in supplementation programs, is needed. Selective harvest programs can benefit managers of strong stocks by allowing more harvest of target species in mixed stock fisheries.

Sport fishery programs for steelhead in the Columbia River now limit harvest to adipose-clipped hatchery fish. Selective harvest of hatchery-reared steelhead has allowed consumptive fisheries to continue or increase, while reducing harvest impacts on invaluable wild runs. Selective steelhead harvest needs to be extended to treaty fisheries to provide harvest sharing and to strengthen efforts to save wild runs. Pass-through provisions are also needed to provide fishing opportunity for upriver producers of hatchery fish and to meet escapements required to continue programs.

One solution might be to modify adult passage facilities at Columbia River dams to select portions of hatchery runs for harvest. In the short term, Columbia River tribes are not likely to accept the changes in fishing areas and opportunity that would result. Long-term consequences of continued mixed-stock fisheries may be equally unacceptable, however.

Though harvest levels, especially those of the last decade, are not responsible for the decline of Columbia River salmon and steelhead, fishing can contribute at very low abundance levels by reducing escapements critical to population maintenance and recovery. Reductions in abundance and increases in hatchery components are added forces acting to lower already dismal survival rates. The demise of upriver runs may be imminent, despite our best intentions and most expensive mitigation projects.

In a world ideal for some Columbia River interests, mixed stock fishery concerns would vanish with upriver runs. It may be possible to bolster weak fall chinook stocks and increase surplus production simply by building more hatcheries. It is unlikely that fall chinook programs can sustain lost upriver production on a long-term basis, but they may never have to. Productive sockeye salmon and spring/summer chinook fisheries on the mainstem Columbia and tributaries have already passed into history, gone and largely forgotten.

Remnant upriver runs still provide some impetus for maintaining the lower Snake and Columbia rivers' migration corridor. Without upriver stocks and management concerns, it may be possible to temporarily overcome higher mortalities at the four lower Columbia hydroelectric projects simply by increasing mitigation requirements. However, as hatchery stock productivities decline and in-river hazards increase, lower river fisheries could slip into oblivion -- with the help of ever increasing hatchery programs -- just like their predecessors. Thus, the final scenario could be similar for both up- and downriver stocks.

The outcome for this and many other fisheries may eventually depend on what we learn or fail to learn from efforts to preserve weak stocks. If we are willing to innovate, the result may be salmon and steelhead populations that are diverse and productive enough to still support consumptive uses. Selective harvest may be one tool managers need to succeed in that endeavor.

Findings and Implications of Ongoing Long-term Studies of Hatchery and Wild Steelhead in the Kalama River

Pat Hulett, Washington Department of Fish and Wildlife

Findings from nearly two decades of research on genetic interactions of hatchery and wild steelhead in the Kalama River have important implications regarding genetic risks associated with concurrent management of hatchery and wild stocks in the same river.

Studies conducted from the mid 1970s to the mid 1980s showed that hatchery summer-run steelhead, due to their preponderance in the spawning population, were parents of a majority of the naturally produced juvenile summer steelhead in the Kalama River. Yet, relative to hatchery adults, wild summer-run spawners parented nearly 10 times as many of the naturally produced offspring that returned as adults. The offspring of wild summer-run survived better than those of hatchery summer-run throughout both the freshwater and marine rearing portions of the life cycle.

Results obtained to date from similar studies of winter-run steelhead, ongoing since 1985, indicate that wild winter-run also are more successful at naturally producing offspring that survive to return as adults than are their hatchery counterparts. Early indications from available data suggest the difference in hatchery vs. wild natural reproductive success is at least as great for winter-run as was found for summer-run steelhead in the Kalama River, particularly to the returning adult stage.

There is also evidence of genetic introgression (at low levels) from the hatchery summer-run stock to the wild winter-run stock in the Kalama, despite substantial differences in peak spawn timing of the two stocks (mid January vs. mid April, respectively). In addition, we note the potential for inter-racial gene flow from hatchery winter to wild summer stocks in the Kalama, based on their more similar spawn timing (early March and mid February peaks, respectively).

Risks imposed by genetic introgression from hatchery to wild stocks can be managed by controlling the relative abundance and the temporal and/or spatial segregation of hatchery and wild spawners, as well as considering the appropriateness of the hatchery broodstock used. Examples of management options that may be available on a case-by-case basis will be discussed, along with information needs regarding the practical merits and ultimate benefits of such options.

The Effects of Hatchery and Wild Ancestry and Environmental Factors on the Behavioral Development of Steelhead Trout Fry (*Oncorhynchus mykiss*)

Barry Berejikian, National Marine Fisheries Service

Domestication selection, as well as environmental factors, may cause hatchery and wild steelhead trout to exhibit important behavioral differences. Agonistic behavior of steelhead fry (*Oncorhynchus mykiss*) differed between a wild population and a locally derived hatchery population. Levels of agonistic behavior of hatchery steelhead were much greater than for wild steelhead when both populations were reared in natural environments or under low rations and low densities. Such differences suggest that hatchery and wild steelhead populations have asymmetrical food and/or territory requirements, possibly created by differences in natural selection regimes between hatchery and natural environments. The extent to which such differences determine the outcomes of interactions between offspring of wild and hatchery steelhead spawning in streams will depend on the size differences and emergence dates of the populations as well as genetic bases of aggression.

Hatchery steelhead were less able to avoid a benthic predator (sculpin, *Cottus asper*) than were wild steelhead in one stream and two laboratory experiments. Sculpin can be significant predators on juvenile steelhead in streams, thus selection in natural streams may favor individuals with appropriate anti-predation responses. These results suggest that relaxed benthic predation pressures in the hatchery environment over several generations may have reduced the ability of the hatchery population to avoid benthic predators. Brief visual exposure to predation (i.e., experience) improved the ability of fry to avoid predators. Thus, anti-predator training may improve post-release survival of hatchery-reared fry, but the benefit of such training for fry of hatchery ancestry may be limited.

The behavior of steelhead fry stocked into natural streams was profoundly influenced by approximately 3 months of rearing in a hatchery. Hatchery-reared fry and naturally-produced fry (from the same population) differed in their use of stream habitats. Hatchery- and wild-reared fry competed directly for territories. Although wild fry had some competitive advantage (perhaps prior residence) to counteract the larger size of hatchery-reared fry, wild fry were displaced from the most heavily utilized areas by hatchery-reared fry.

Supplementation programs designed to rebuild depleted or declining populations will likely become more prominent in light of continual declines in anadromous salmonid populations. Managers must consider potential consequences regarding genetically-based changes and environmental influences of hatcheries on important behavioral attributes of juvenile steelhead and other salmonids.

Biological feasibility of Rearing Steelhead to Maturity in Marine Net-Pens in Southeast Alaska

Frank Thrower, National Marine Fisheries Service

Wild steelhead (*Oncorhynchus mykiss*) from southeastern Alaska were spawned in 1986 and 1987 to determine the biological feasibility of rearing this species to maturity in marine net-pens. For each brood year, most smolts were fin-marked and/or coded-wire tagged with binary coded-wire tags, and released at age-2; some were retained for grow-out in marine net-pens. During the spring maturation period in 1990 and 1991, one net-pen was fitted with a waterproof barrier 1 m deep and fresh water was piped into the net to provide a freshwater layer for osmotic relief for maturing fish (artificial freshwater lens system, AFLS). Reciprocal crosses between captive and ocean-ranched adults indicated little difference in egg viability; however, captive males had lower sperm viability than ocean-ranched males. Captive spawners were maintained in an AFLS, and survival to second spawning exceeded 60%. Use of an AFLS allowed good growth, successful maturation, and produced good quality gametes.

SESSION V: OCEAN AND ESTUARINE INFLUENCES

Session Chair: Doug Jones, Alaska Department of Fish and Game

Oceanographic Controls on the Distribution of Pacific Salmon, and Possible Impacts of Future Climate Changes on Salmon Production

David Welch, Department of Fisheries and Oceans, Canada

A series of fisheries surveys were conducted in winter, spring, and summer in order to establish the oceanographic factors determining the southern limit to the distribution of Pacific salmon. We use a combination of Generalized Additive Models and Maximum Likelihood Estimation techniques to demonstrate that: 1) salmon exhibit strong species-specific threshold responses to temperature in the open North Pacific Ocean; 2) the southern edge of the salmon distribution is a step-function, with salmon abundance dropping at the threshold temperature by 1 to 2 orders of magnitude in ±0.4°C; 3) north of the southern boundary, salmon abundance is largely insensitive to temperature in most seasons; and 4) the thermal boundaries we have found appear to have been stable for at least the last 30 years. Our analysis suggests that the seasonal variations in the temperature at the boundary appear to be caused by salmon attempting to maximize their growth rates by regulating body temperature as the amount of food available varies through the year.

The consequences of these observations are that Pacific salmon undergo a previously unsuspected reverse migration in the ocean, moving North in winter to colder regions of the Pacific (<7°C), and then moving South in summer into warmer regions (<15°C). Application of the Canadian Climate Center's General Circulation Model suggests that North Pacific surface temperatures should increase by about 3°C under a two-times CO_2 climate. Increases in temperature of this level are large enough to completely eliminate currently used thermal habitat from the North Pacific in winter, and to greatly restrict the area of the North Pacific thermally available to Pacific salmon in other seasons.

This reverse migration is possibly unique in the animal kingdom. The fact that we find such a sharp response throughout the North Pacific, and for all species of Pacific salmon, suggests that the behavior that sends all species of salmon to sea for much of their life, and results in these strong behavioral responses to ocean temperatures is under strong evolutionary selection. This suggests that the predicted changes in the amount of thermal habitat available in the North Pacific could have a large impact on future salmon production.

Ocean Distribution of Steelhead

Bud Burgner - Fisheries Research Institute

Steelhead are distributed in the north Pacific Ocean from the coast of California across the Pacific to about 162° East Longitude. They have been found from approximately 40° north latitude up to the Aleutian Chain and Gulf of Alaska. Only one or 2 steelhead have ever been captured in the Bering Sea but most ocean cruises simply do not go north of the Aleutian Peninsula. Rainbow trout are found up to the Kuskokwim River and all through Bristol Bay but steelhead populations are very limited north of the Aleutian Chain.

Steelhead generally shift north in the summer to just south of the Aleutian peninsula. In May they are found in waters of about 7-7.9°C, in June in waters from 8-8.9°C. and in 9 to 9.9°C in July. Summer run steelhead from the Columbia River distribute generally farther south than do steelhead from British Columbia. Adults from the Columbia River return by moving down the coast and as a result, there have been recoveries of CWT steelhead all the way from Southeast Alaska through British Columbia and along the coast of Washington. Steelhead from British Columbia also return down the coast but stocks of other areas of Washington return to spawn during the winter months when few fisheries are occurring and as a result, few have been recovered in those other areas of the coast.

Work from the Japanese research vessels the Wakatake Maru and the Oshoro Maru indicate that steelhead feed predominately on fish and squid. Fish tends to be the primary diet in the southern parts of the ocean distribution and as steelhead move north squid tend to dominate in their diet and occasionally amphipods dominate the diet. Squid are less nutritious per unit weight than fish, however. Recent scale pattern analysis indicates that in the period of early ocean residence, wild steelhead grow faster than hatchery smolt. This analysis was done by measuring the growth between circuli.

Steelhead are found on the Kamchatka Peninsula and two recent trips have been conducted there with assistance from FRI, NMFS, and the Wild Salmon Center. Analysis of scales collected from steelhead on the Kamchatka Peninsula show a very high rate of repeat spawners compared (over 60%) to steelhead from areas of the United States and British Columbia.

Implementation of the Washington Department of Fish and Wildlife's Marine Mammal Protection Act Section 120 Authorization to Protect the Lake Washington Winter Steelhead Run from California Sea Lion Predation

Steve Jeffries, Washington Department of Fish and Wildlife

Section 120 of the MMPA established a process which allows NMFS to authorize "... the intentional lethal taking of individually identified pinnipeds which are having a significant negative impact on the decline or recovery of salmon fishery stocks...". In order to protect the severely depressed Lake Washington winter steelhead run, NMFS granted WDFW a conditioned Section 120 authority on January 4, 1995 to lethally remove individual sea lions at the Ballard Locks near Seattle.

This conditioned authority was based on recommendations of a Pinniped/Fishery Interaction Task Force, and required WDFW to identify individual sea lions, monitor fish passage, monitor sea lion predation rates, deploy an acoustic harassment system, use other non-lethal deterrence techniques, and, if practical, capture and hold sea lions prior to allowing lethal removal.

Activities during the 1994/1995 steelhead run included the capture and marking of 210 individual animals, with several animals subsequently identified for potential lethal removal based on their predatory behavior. The main predator was captured and held in captivity for the duration of the steelhead run. Additional problem animals were also captured and translocated out of the area. No sea lions were lethally removed. Pending modification of WDFW's Section 120 authority by NMFS, similar activities are planned for protecting the Lake Washington winter steelhead run during the 1995/1996 season.

LIST OF REGISTERED ATTENDEES

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