

*Summary of  
the Seventh  
Pacific Coast Steelhead  
Management Meeting*



**March 14 - 16, 2000  
Fort Worden State Park Conference Center  
Port Townsend, Washington**

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



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**Pacific Coast Steelhead Management Workshop**  
**March 14 - 16, 2000**  
**Fort Worden State Park Conference Center**  
**Port Townsend, Washington**

**Introduction**

During March 14-16, 2000, the Pacific States Marine Fisheries Commission, with partial support from the U.S. Fish and Wildlife Service, sponsored the seventh in a series of workshops on steelhead (*Oncorhynchus mykiss*) management. The workshop was attended by approximately 72 Pacific 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 steelhead in each management jurisdiction;
- updates on recent activities related to Endangered Species Act (ESA) listings;
- studies on the life histories of steelhead;
- studies and recent developments relating to predation on steelhead; and
- contributed reports on current steelhead research projects.

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 summarize their presentations.

Workshop Steering Committee:

Doug Jones, Alaska Department of Fish and Game  
Bob Leland, Washington Department of Fish and Wildlife  
Art Tautz, Ministry of Environment, British Columbia  
Sharon Kiefer, Idaho Department of Fish and Game  
Bob Hooton, 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

**Steelhead Stock Status Review by Jurisdiction**  
Session Chair: Doug Jones, Alaska Department of Fish and Game

Alaska

Bob Chadwick, Alaska Department of Fish and Game

In 1997 limited available data suggested the overall status of steelhead in Alaska was below historical levels. Recent steelhead data collected by the Alaska Department of Fish and Game consist of weirs, sport fishery catches, and index stream surveys. Data collected at weirs operated by the Alaska Department of Fish and Game on the Karluk River (Southcentral) and the Situk River (Southeast) two of Alaska's largest steelhead producers, show variable but increased adult escapements since depressed returns in the early 1990's. The Situk count in 1999 was the highest in the history of the weir. Since 1990, Statewide Harvest Survey information on the Alaska sport fishery indicated peak steelhead catches in 1993, with declines from 1994 through 1996. In 1997 through 1999 steelhead catches started to increase with the 1999 sport catch exceeding the high of 1993. The sport fishery harvest of steelhead declined sharply following an Emergency Order in 1993 and more restrictive sport fishing regulations 1994 and 1997. Snorkel surveys conducted 1997 through 1999 on 12 index streams in Southeast Alaska indicate a stable population despite a doubling of sport fish effort in the region. Increasing abundance of steelhead statewide is likely due to less exploitation in the high seas gillnet fishery and restrictive regulations statewide that protect spawning steelhead. Continued refinement of research and management actions taken by the department, along with public support, should ensure the viability of wild steelhead throughout its range in Alaska

British Columbia

Bob Hooton, British Columbia Ministry of Environment Lands and Parks

Wild steelhead in British Columbia are divided into three stock groups, coastal summer stocks, coastal winter stocks and interior summer stocks. There are about 400 streams that have been reported by anglers as fished and supporting steelhead catches over a thirty-four year record of questionnaire surveys. Inventory records suggest the number of streams that actually produce wild steelhead is 680 although the number could be even higher depending on how an individual stream is defined. For purposes of assessing wild adult steelhead stock status 12 sites with data sets compiled using consistently applied methodology over a period of 10-20 years were examined. Methodology included weir counts, snorkel surveys, aerial observations, test fishery indices and fishwheel counts. Site specific data were presented. The overall pattern that emerged was severely depressed abundance among southern BC stocks, particularly those on the east coast of Vancouver Island and lower Fraser drainage. West coast Vancouver Island stocks appeared to be relatively better off although preliminary observations on the current sport fishery suggest the relative difference that has prevailed between east and west coast stocks until 1999 may not be as pronounced this year. The province's major stock assessment site at the Keogh River on northern Vancouver Island continues to show poor smolt survival and adult returns at less than replacement levels. Moving north toward the central coast there was a pronounced improvement in stock status. This appeared related to ocean temperature regimes and depressed ocean productivity in the nearshore environment along the southern half of the BC coastline

through most of the 1990s. From approximately Dean Channel on the central BC coast north, including the Queen Charlotte Islands, wild steelhead abundance at all assessment sites has been at or above longer term averages for the past two or more years. In the case of summer steelhead this pattern was influenced markedly by the relative absence of commercial fishery interception of steelhead pursuant to coho conservation measures imposed by federal government fishery managers in 1998 and 1999.

### Washington

Dan Rawding & Bob Leland, Washington Department of Fish and Wildlife

The status of steelhead stocks was reviewed for the seven ESUs located in Washington state. Run size and escapement data were presented for representative streams in each ESU. Selected streams were used to emphasize specific issues, trend changes, current or proposed management programs, and recreational fishing regulation controversies.

Although many wild populations, particularly in the Puget Sound and Olympic Peninsula ESUs, remain healthy and stable, in general, the long-term decline in wild steelhead abundance continues. There is evidence that current management practices and programs are arresting, or possibly beginning to reverse the declines of some runs.

Enhanced data collection, particularly with respect to hatchery-wild interactions and supplementation program undertakings for selected watersheds, has been an increasing focus of WDFW efforts.

In the Upper Columbia ESU, currently designated as endangered under ESA, the *Upper Columbia Steelhead Fisheries Management Conservation Plan*, a plan for the de-listing of hatchery steelhead is nearing completion.

### Oregon

Mark Chilcote, Oregon Department of Fish and Wildlife

Trends in abundance, interactions with hatchery fish, and likelihood of persistence were examined for twenty populations of wild steelhead in Oregon. Overall, winter steelhead populations appear to be showing a modest recovery. The notable exception being populations in the lower Columbia and Willamette basins. In particular, the Clackamas population has undergone a dramatic reduction in numbers to a record low of only 156 fish in 1999. Summer steelhead populations appear to be relatively stable but depressed. Trouble spots in the middle Rogue, Deschutes, and South Fork John Day remain. New information suggests that the straying of hatchery fish, once they return to their basin of release is quite low. It appears these fish home with very high fidelity to the smolt release location. However, the straying of hatchery fish between basins still appears to be a significant problem in spite of recent strategies to reduce this behavior. Quantitative risk assessments support the overall pattern of trends and abundance. The most vulnerable populations in Oregon are those in the Willamette and lower Columbia basins. The assessment also suggest that Snake River populations are surprisingly resilient and relatively secure from the risk of extinction.

## Idaho

Sharon W. Kiefer, Idaho Department of Fish and Game

Idaho historically produced about 55% of the total summer steelhead in the Columbia River basin. An average of 70,000 wild adult summer steelhead entered the Snake River from 1962-70, based on Ice Harbor dam counts (uppermost Snake River dam). During this period, steelhead were the most numerous anadromous fish returning to the Snake Basin. The documented thirty-year decline of Snake River steelhead led to their listing as threatened in October 1997, pursuant to the federal Endangered Species Act. Development of the Federal Columbia River Power System (FCRPS), particularly the four dams and reservoirs on the Lower Snake River from Pasco, Washington upstream to Lewiston, Idaho, is considered to be the primary factor in Snake River steelhead decline.

The majority of steelhead entering the Snake River return to Idaho. About 59% of the historical steelhead habitat in Idaho is still available, primarily in the Salmon and Clearwater river drainages. About 30% of Idaho's existing steelhead habitat is included within designated wilderness or wild and scenic river corridors. Because approximately 69% of the lower Snake River basin is comprised of lands within the jurisdiction of the federal government, most of the steelhead spawning and rearing habitat in Idaho is federally managed.

Little has changed in the status of Idaho steelhead since this meeting's last review in 1998. During the decade of the 1990s, the naturally-produced steelhead run, as counted at Lower Granite Dam (uppermost Snake River dam), averaged only 11,900 steelhead. This is an 83% decline from the 1962-70 period. Even worse, the 1995-99 average was only 8,200 steelhead counted at Lower Granite Dam.

There is likely a complex composition of steelhead stocks in Idaho for which Idaho Department of Fish and Game (IDFG) is just starting a comprehensive genetic survey. For Idaho management purposes, natural and hatchery-produced steelhead in Idaho are classified as A-run and B-run groups. Naturally-produced steelhead are further defined by production lineage as "wild" (endemic) or "natural" (nonendemic or hatchery-influenced). B-run steelhead return exclusively to Idaho, characterized by later freshwater entry and larger adult size at age with a predominantly two-ocean return. For downriver accounting and management purposes, the arrival date at Bonneville Dam has been used to differentiate between the more common A-run and the B-run groups. However, at Lower Granite Dam, IDFG has used length to classify the two groups. Beginning with the 1999-2000 run, steelhead managers agreed to utilize length to classify the runs into "A-run index" and "B-run index" components.

Naturally-produced A and B index groups at Lower Granite Dam averaged 6,400 and 1,800 adult steelhead during the 1995-99 period, demonstrating the especially critical status of B-run steelhead. Parr density trends generally reflect the poor adult returns counted at Lower Granite Dam. The new decade began with an upswing in the A-run index count at the dam to an estimated 10,200 steelhead, but the B-run index remained near 1,000 steelhead.

There is a mix of natural and hatchery steelhead production strategies in Idaho, ranging from wilderness genetic refugia to large-scale hatchery smolt programs. Idaho Department of Fish and Game (IDFG) estimates the statewide accessible habitat could produce at least 4 million steelhead smolts. Areas managed as wild steelhead refugia (natural production, endemic fish) include expansive contiguous habitat: the Lochsa and the Selway drainages of the Clearwater River, and the Middle and South fork drainages of the Salmon River. A few smaller tributaries are also included. Much of the wild steelhead refuge habitat is in areas designated as wilderness

or wild and scenic river.

Since the 1960s, the composition of the steelhead run entering Idaho has changed. The proportion of hatchery origin steelhead has steadily increased due to declining natural spawner return and development of hatcheries. During 1965-69, the Snake River steelhead run was essentially 100% wild. From 1975-79, the steelhead run at Lower Granite Dam averaged 41% hatchery fish, from 1985-89, the run averaged 76% hatchery fish, and from 1995-99, the run averaged 89% hatchery fish. All steelhead hatcheries in Idaho, such as the federal Lower Snake River Compensation Program, were developed during this period as mitigation for federal and private hydropower. IDFG has utilized steelhead smolt production almost exclusively to support sport harvest opportunity for hatchery steelhead in selective fisheries. Steelhead harvest declined from near 20,000 wild steelhead annually in the 1950s and 1960s to near 10,000 as wild fish numbers plummeted in the 1970s. Selective fisheries were implemented in the late 1970s. Wild fish harvest was terminated with the advent of mass marking (adipose fin-clip) in the mid-1980s. Harvest increased to an average of 27,800 hatchery steelhead during the 1990s. Use of hatchery smolts for steelhead supplementation has been limited to small-scale research but is increasing with 10% of this spring's smolt release allocated to return hatchery adults to production habitat.

The future of naturally producing steelhead in Idaho and the Snake Basin will be defined by improvement in smolt-to-adult return rates (SAR). Egg-to-smolt survival, particularly in wild fish areas, has probably not declined significantly from the 1960s. Currently, SARs are not sufficient for consistent replacement. National Marine Fisheries Service (NMFS) has indicated that naturally-produced Snake River steelhead are at significant risk of extinction. For migratory year 1988-96, SARs ranged from 0.10% to 0.71% for naturally-produced juvenile steelhead tagged with Passive Integrated Transponder tags (PIT tags) and detected as adults at Lower Granite Dam, based on IDFG unpublished data. Hatchery steelhead SARs ranged from 0.17% to 0.88%. The estimated number of naturally-produced steelhead smolts for the Snake Basin has been less than a million since 1989. In 2000, an estimated 681,000 naturally-produced steelhead smolts will arrive at Lower Granite Dam from Snake Basin habitat. As illustration, an SAR of at least 1.75% for this year's outmigration would be needed for a runsize equal to the 1990s average of 11,900. Although a crude illustration, it is clear that substantially higher SARs are needed for increased runsize and ultimately, delisting and recovery.

## California

Dennis McEwan, California Department of Fish and Game

Overall, California's steelhead populations appear to be stable or possibly increasing, primarily as a result of six concurrent years of ample precipitation. However, monitoring efforts are inadequate to properly measure population abundance and trends, so the above conclusion is tenuous and is based on a few key streams where adult returns are enumerated, and opportunistic observations. The most encouraging aspect is that steelhead appear to be extending their range into historical habitat where they had not been observed for many years.

### *Klamath Mountains Province and Northern California ESUs*

In 1998, California signed a Memorandum of Agreement (MOA) with the Federal Government to put certain conservation measures in place so that the National Marine Fisheries Service (NMFS) would not need to list the Klamath Mountains Province and Northern California

steelhead ESUs under the ESA, as proposed. The MOA revolved around four major issues: change angling regulations to restrict harvest and incidental mortality; establish a comprehensive monitoring program; continue the state's extensive habitat restoration program; and review and change the State's Timber Harvest Rules that regulate timber harvest on private land so that this activity is more protective of steelhead. After two years of the MOA, NMFS agreed that progress had been made on the first three issues, but the state had not made progress on changing the Timber Harvest Practice Rules, consequently, they are proposing to list the Northern California ESU. Upper Eel River natural steelhead run size continues to be severely depressed and has been fairly constant at about 100 adults through the 1990s; summer steelhead adult returns in the Middle Fork Eel River have also have not improved but remain fairly constant at about 700 adults. High water temperatures and non-native squawfish predation continue to be a problem in the upper Eel River and tributaries. The problems in the Middle Fork Eel River are less obvious as the holding habitat is protected and relatively pristine.

#### *Central Valley ESU*

NMFS originally proposed to list the Central Valley Steelhead ESU as endangered, but upgraded it to threatened in their final determination, citing the conservation efforts of CALFED (a state-federal multi-agency effort to ameliorate habitat problems and increase water supply reliability in the Sacramento and San Joaquin River watersheds) and the Central Valley Project Improvement Act (a federal effort to rectify the habitat problems caused by the U.S. Bureau of Reclamation's Central Valley Project). Habitat restoration achievements over the past five years include removing several diversion dams on Butte Creek, restoring access for wild steelhead to some their former habitat on Battle Creek, and initiation of an effort to remove a diversion dam on Clear Creek. Despite these efforts, it is unknown if wild populations have increased. Our ability to enumerate adult steelhead returns to the upper Sacramento River watershed was eliminated in the early 1990s due to re-operation of the Red Bluff Diversion Dam to facilitate endangered winter-run chinook salmon passage, which eliminated the usage of the counting station at the dam. Steelhead have been observed in recent years in several streams where they had not been observed for several decades, such as the Stanislaus, Calaveras, and Tuolumne rivers in the San Joaquin River system.

#### *Central California Coast ESU*

Adult steelhead have been observed in several San Francisco Bay tributaries in the past few years, such as Alameda and San Fransiquito creeks. These streams have been the focus of habitat restoration efforts by stakeholder organizations that have focused primarily on correcting artificial passage impediments.

#### *South-Central California Coast ESU*

In 1998 the California Department of Fish and Game determined that the Carmel River steelhead population had reached its escapement goal to trigger reopening of the stream to catch-and-release angling. Carmel River steelhead were severely impacted by water development, which was exacerbated by the six-year drought of the late 1980s-early 1990s. Annual adult returns have rebounded from near zero in the late 1980s to nearly 1000 in the past two years. Improvements to New Los Padres Dam (the upstream-most dam on the system) to facilitate both downstream and upstream migration were implemented in the past few years.

*Southern California ESU*

Although we have no adult escapement numbers for southern California streams, opportunistic observations confirmed the presence of steelhead in many streams that were not known to have contained steelhead populations for many years: Carpenteria, Maria Ygnacio, Gaviota, Mission, and Arroyo Hondo creeks in Santa Barbara County; Ventura and Santa Clara rivers in Ventura County; Arroyo Sequit and Topanga creeks in Los Angeles County; and San Mateo Creek in San Diego County. Since the listing, habitat restoration projects have increased in the past five years and include: modifying grade stabilization structures to facilitate passage on Gaviota Creek; development and design of a fishway and screens on the Robles Diversion on the Ventura River; initial discussions on removal of Matilija Dam on a Ventura River tributary to allow steelhead passage to high-quality historical habitat; construction of a new fishway on Harvey Dam on Santa Paula Creek; and various restoration projects in Topanga and San Mateo creek watersheds.

## ESA Update

Session Chair: Bob Hooton, Oregon Department of Fish and Wildlife

### Fishery Management and Evaluation Plans under NMFS' Proposed 4(d) Rules

Lance Kruzic, National Marine Fisheries Service, Hatcheries and Inland Fisheries Branch

The National Marine Fisheries Service has proposed regulations governing the “take” of anadromous fish species recently listed under the Endangered Species Act. These regulations include a process which excepts “take” of listed species in fisheries if a Fisheries Management and Evaluation Plan (FMEP) is developed and implemented. Generally, the criteria proposed for FMEPs include: defining the scope and exploitation rates of the fisheries, identifying the status and structure of the listed populations within the ESU, demonstrating the fishery regime does not appreciably reduce the survival and recovery of the ESU, and monitoring and evaluation. Some of the advantages of the FMEP approach include long-term “take” coverage under the ESA without section 10 permits, more management flexibility, and increased certainty of fishery opportunities in the future. The primary disadvantage of this approach is the time required to develop the FMEP compared to a section 10 permit application. The application of FMEPs in several of the listed ESUs will be discussed.

### Hatchery and Genetic Management Plans (HGMPs)

Herb Pollard, National Marine Fisheries Service, Hatcheries and Inland Fisheries Branch

The ESA section 4(d) rule which applies ESA section 9 take prohibitions to the seven Evolutionarily Significant Units (ESUs) of westcoast steelhead that are listed as threatened under the ESA provides for some limitations on the application section 9. In order for a hatchery program to take advantage of the limited application of take prohibitions, an HGMP is required. The HGMP will also be used to generate a source for comprehensive hatchery program information that will be used in subbasin plans, the Northwest Power Planning Council funding prioritization process, for independent scientific reviews and recovery planning. NMFS, in cooperation with other northwest fishery managers has developed a template to aid in development of standardized, complete plans. The advantages to co-managers in the transition from the previous system of Biological Assessment-Biological Opinion-Section 10 permit is greater flexibility, longer-term planning, local and regional review and approval and integration with other salmon restoration efforts.

## Results of NMFS Coastwide Steelhead Genetics Surveys

David Teel<sup>1,2</sup>, Robin Waples<sup>1</sup>, Paul Aebersold<sup>1</sup>, and Steve Phelps<sup>3</sup>

We have recently conducted genetic analyses of the population structure of steelhead in the Pacific Northwest and California in support of ESA status reviews. In 1996, as part of a coastwide status review, we assembled data from recent allozyme studies conducted by NMFS and WDFW to assist in the identification of evolutionarily significant units (ESUs). Data for up to 51 polymorphic gene loci from 113 samples of steelhead and rainbow trout were used to calculate genetic distances. Using multidimensional scaling and UPGMA tree analysis, we found 6 large geographic clusters within the coastal steelhead lineage: 1) Puget Sound, Washington coast, and lower Columbia River; 2) Oregon coast; 3) Klamath Mountains Province; 4) northern California; 5) central and southern California; and 6) central valley of California. We also identified 2 large clusters within the inland steelhead lineage: 1) middle Columbia River and 2) Snake River. Characterization of the inland lineage was incomplete because of a lack of genetic data for wild populations in the upper Columbia River. Samples of California steelhead showed levels of population differentiation unprecedented for the species. Sacramento River samples were the most genetically distinct of the California samples and clustered loosely with samples of rainbow trout hatchery populations having origins that include collections of *O. mykiss* from the McCloud River. South of California's Eel River samples of coastal populations had large interpopulation genetic differences, but did not form geographically coherent clusters.

Subsequent to the coastwide status review, NMFS has collected allozyme data from new samples in California and Oregon to study several issues relevant to steelhead population structure and the configuration of steelhead ESUs. In an examination of Central Valley steelhead population structure, a new sample from the San Joaquin Basin (Stanislas River) clustered closely with samples from the Sacramento River. However, samples of steelhead in the American River, tributary of the Sacramento River, clustered with a sample from the coast's Eel River possibly reflecting stock transfers known to have occurred between these two basins. A genetic analysis of samples of steelhead populations in the Siletz and Umpqua rivers of the Oregon coast showed that genetic differentiation between summer and winter steelhead occurs at a smaller scale than differentiation between ESUs. Allozyme analysis of several samples of steelhead and resident trout from Oregon's Willamette River basin revealed that fish from westside tributaries do not show a clear relationship with native eastside steelhead, perhaps reflecting the transfer of stock from other Columbia Basin sources. Resident trout from the Upper Willamette River were quite divergent from any of the basin's steelhead samples.

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## Upper Columbia Steelhead Conservation Plan

Art Viola, Washington Department of Fish and Wildlife

Naturally produced steelhead were listed as endangered on August 11, 1997. Even though wild steelhead abundance was declining, total abundance of all steelhead has been relatively stable or increasing in recent years, only because of hatchery supplementation programs. Wells Hatchery stock of steelhead were also listed as endangered. These hatchery reared, fish were considered necessary for the rebuilding of natural steelhead populations because of their genetic similarity to wild Upper Columbia steelhead. The Goal of the conservation plan is to assist with the recovery of ESA listed upper Columbia River wild/naturally produced steelhead (*Onchorynchus mykiss*). The plan contains three objectives to assist with steelhead recovery. Objective 1) Increase spawning escapement with hatchery supplementation. Sub-objective 1.1) Improve the over all fitness of spawners by breeding wild fish with the hatchery stock, and allowing sport anglers to remove hatchery x hatchery cross adults. Objective 2) Reduce hooking mortality of naturally produced juvenile steelhead by closing 90% of all waters in the Upper Columbia that contain anadromous fish to "trout" fishing, the remainder will be open only to catch and release angling. This will occur May 1, 2000. Objective 3) Further reduced interactions between naturally produced fish and hatchery x hatchery cross fish by changing the release location of hatchery x hatchery cross juveniles to waters that do not contain large populations of wild/natural steelhead, e.g., the Okanogan River. Supplementation will have to be reduced as natural steelhead increase in number. Trends in naturally produced juvenile steelhead will be monitored of with smolt traps in the Entiat, Wenatchee and Methow rivers. Trends in adult returns will be monitored at Priest rapids Dam. Sport fishing regulation may need to be adjusted. A study designed to monitor hooking mortality of naturally produced steelhead will be conducted. Decisions, at 5 year intervals, could be made in consideration of monitoring results

## Steelhead Monitoring and Population Health Goals in the KMP

Russ Stauff, Oregon Department of Fish and Wildlife

Historically there has been limited monitoring of wild steelhead populations in the Oregon part of the Klamath Mountains Province (Cape Blanco south to the California border). Specific monitoring projects designed to estimate abundance of either adults or juveniles have been limited to the Rogue and Elk rivers. The only long-term data available for all rivers is an annual estimate of the sport harvest. When the KMP steelhead were proposed for listing under Federal ESA in 1994 the Oregon Department of Fish and Wildlife (ODFW) recognized the need for additional empirical information on steelhead populations. Inventory efforts began at that time included spawning surveys and smolt production estimates. In 1998 the NMFS decided not to list KMP steelhead, contingent, in part, upon Oregon and California implementing monitoring programs to better evaluate these populations. In Oregon the ODFW was committed by the state legislature to developing population health goals. Goals were proposed for adult abundance, juvenile production and density, distribution, life history characteristics, and habitat condition.

Steelhead population monitoring In the Oregon Coast ESU as part of the Oregon Plan for Salmon and Watersheds

Gary Susac, Oregon Department of Fish and Wildlife

The Oregon Plan for Salmon and Watersheds Monitoring Program has implemented a broad range of resource assessment activities ranging from sampling for adult and juvenile salmonid abundance to water quality and biotic condition assessments.

The Oregon Department of Fish and Wildlife Western Oregon Research and Monitoring Program in cooperation with coastal watershed districts has been charged with developing monitoring plans to assess trends in steelhead abundance in Oregon Coastal Basins. We currently have only 2 permanent adult counting facilities in our Coastal basins. One located on the North Umpqua River at Winchester Dam and the other at Gold Ray Dam on the Rogue River. Both rivers drain the western slopes of the Cascades Mountains and may not be characteristic of shorter coastal basins. We have developed 7 long-term monitoring sites where both smolts and returning adults are estimated and 13 sites where only smolts are inventoried. Starting in 1998, we began evaluating the use of spawning ground survey redd counts as a measure of adult abundance. We comprehensively surveyed the area above three adult counting stations for steelhead redds. The relationship between the number of female steelhead passed and redd counts is highly significant,  $N=6$ ,  $R^2=0.98$ ,  $p=0.0001$ . The Relationship of total number of steelhead passed and redd counts is still good,  $R^2=0.95$ ,  $p=0.001$ . . We are currently testing the methodology developed in our calibration work in the Smith River basin.

Steelhead and resident rainbow trout investigations in the Deschutes River, Oregon.

Christian E. Zimmerman, Oregon State University, Department of Fisheries and Wildlife

Since 1994, I have been conducting a series of studies concerning the relationship of steelhead and resident rainbow trout on the Deschutes River and other locations. These studies have included surveys of spawning and rearing habitat-use to determine the degree of segregation or overlap between the two life history forms. I am using analysis of otolith microchemistry to identify the progeny of steelhead and resident rainbow trout and have analyzed samples from British Columbia to San Diego County, California. In this presentation I will give an overview of this work.

The population structure of sympatric anadromous steelhead and resident rainbow trout in the Deschutes River, Oregon and Babine River, British Columbia was determined based on the maternal origin of anadromous and resident adults. Maternal origin was identified by comparing Sr/Ca ratios in the primordia and freshwater growth regions of the otolith with a wavelength-dispersive electron microprobe. Transects of Sr/Ca ratios were similar to those described for other anadromous and resident salmonids. In the Deschutes River, Oregon only steelhead of steelhead maternal origin and resident rainbow trout of resident rainbow trout origin were observed. In the Babine River, British Columbia steelhead of resident rainbow trout origin and resident rainbow trout of steelhead maternal origin were also observed. Based on these findings, I conclude that steelhead and resident rainbow trout in the Deschutes River may constitute reproductively isolated populations. In contrast, steelhead and resident rainbow trout in the Babine River weir area represent phenotypic polymorphisms within the same population.

A single explanation concerning the population structure of sympatric steelhead and rainbow trout cannot be constructed; rather it varies among locations.

As a direct measure of reproductive isolation, I examined spawning habitat use by steelhead and resident rainbow trout. Timing of spawning and redd site selection by sympatric resident rainbow trout and steelhead trout were examined in the Deschutes River, Oregon from 1995 through 1997. Steelhead spawning occurred from mid March through May and resident rainbow trout spawning occurred from mid March through August in the three years studied. Although there was an overlap in the timing of spawning, only 9 - 15 % of the total rainbow trout spawning occurred during the period when steelhead spawned. The timing of fifty-percent spawning by steelhead was 9 to 10 weeks earlier than that by resident rainbow trout. Spawning sites selected by steelhead were in deeper water and had larger substrate than those selected by resident rainbow trout. I concluded that steelhead and resident rainbow trout in the Deschutes River are reproductively isolated based on a combination of spatial and temporal segregating mechanisms.

The timing of emergence and size of fry at emergence was determined for steelhead and resident rainbow trout in the Deschutes River. Traps placed over redds of known origin were used to capture fry emerging from the gravel. There was an overlap in the timing of steelhead and resident rainbow trout emergence. There was no apparent size difference between newly emerged steelhead and resident rainbow trout.

To examine behavioral and population dynamics of newly emerged fry, I conducted experiments with progeny of steelhead and resident rainbow trout. Recruitment from alevin to fry stage of steelhead and resident rainbow trout was compared in laboratory stream channels. Steelhead and resident rainbow trout fry from the Deschutes River, Oregon were introduced as emerging fry from redds within artificial stream channels and monitored for 18 days. Three treatments were examined: steelhead alone, steelhead and resident rainbow trout, and resident rainbow trout alone. Fry were allowed to emigrate freely from the channels into traps at the downstream end of each channel segment. Higher levels of aggression and lower densities of fish at the conclusion of the 18-day experimental trials characterized treatments containing steelhead.

The proportion of juvenile steelhead and resident rainbow trout progeny in mainstem and tributary rearing habitats was examined using otolith microchemistry. Resident rainbow trout progeny numerically dominated in mainstem rearing habitats and steelhead progeny numerically dominated in tributary habitats. Intermittent tributaries or tributaries with intermittent sections may play an important role as steelhead habitat in the Deschutes River basin.

I have examined several samples of *O. mykiss* juveniles from California coastal streams to determine whether they are the progeny of steelhead or resident rainbow trout. One sample of smolts from a small stream just south of San Francisco contained both steelhead and resident rainbow trout progeny. A single juvenile from San Mateo Creek in San Diego County was determined to be the progeny of a steelhead female.

Conservation of Steelhead in Oregon, New Perspectives on Some Old Ideas  
Mark Chilcote, Oregon Department of Fish and Wildlife

The development of conservation strategies to help recover depressed populations of steelhead and other anadromous salmonids is becoming increasingly controversial with respect to hatchery programs. The concept of using hatchery fish to help rebuild populations (supplementation) has yet to be successfully demonstrated in practice. Using three population of steelhead in Oregon as theoretical examples, a range of supplementation strategies were evaluated. It appears that in most situations there is very little long-term benefit of hatchery supplementation programs for steelhead. In addition, new information from steelhead populations throughout Oregon suggests that the higher the percentage of hatchery fish in the natural spawning population the less productive the populations will be. Whether the hatchery stock is of local wild origin or domesticated does not seem to matter. The data can be interpreted as theoretical evidence that when the percent of hatchery fish in the natural spawning populations exceeds 35%, reproductive failure will occur and the population will not replace its self. When this finding is incorporated into the theoretical supplementation examples, the conclusion is that such strategies pose a very large risk to the persistence of wild populations and should be avoided in almost all circumstances.

## Life History

Session Chair: Sharon Kiefer, Idaho Department of Fish and Game

### Prevalence of Age 1+ Steelhead Smolts in the Tucannon River, WA.

Mark Schuck, Washington Department of Fish and Wildlife

Washington Department of Fish and Wildlife (WDFW) personnel documented the presence of age 1+ steelhead smolts emigrating from streams in SE Washington in the early 1980s. Yearling smolts were identified in Asotin Creek, Tucannon River and Cottonwood Creek (a tributary to the Grande Ronde River in Washington for individual years. Little quantitative data were available about their presence in consecutive years, or in other streams within the region.

Beginning in 1998, WDFW operated a rotary smolt trap on the lower Tucannon River below most steelhead rearing habitat. During the 1997 outmigration, the smolt trap had been operated sporadically to sample outmigrant salmon and steelhead. A diverse population of outmigrant steelhead was noted (extended migration period and large size variability was noted). Because of the diversity of habitat and habitat conditions within the Tucannon River, scale samples were collected from all large (> 200 mm) wild steelhead smolts and from a subsample of all other steelhead. An estimate of total steelhead outmigrants was calculated. Similar sampling and an estimate of the 1999 outmigration was conducted the next year.

WDFW examined scales and found that age 1+ steelhead were 57% of outmigrant smolts in 1998 and 37% of outmigrants in 1999. Age 3+ smolts represented 3% and 5% of outmigrant steelhead in 1998 and 1999 respectively. Remaining smolts were age 2+. Lengths of all ages of smolts were fully overlapping in 1998 but age 1+ smolts were noticeably smaller than age 2+ and age 3+ smolts in 1999.

After examining the 1998 smolt trapping data, WDFW conducted extensive snorkel and electrofishing surveys in the Tucannon River during 1999. WDFW personnel attempted to identify if a specific habitat or river reach might be producing yearling smolts. They discovered that juvenile steelhead growth below river kilometer (rk) 40 could produce age 1+ fish of smolt size. However, because of severe high summer water temperatures, little or no smolt production was occurring below rk 20. Age 3+ smolts are likely to be produced from upper river reaches where summer high temperatures are only in the low 60s.

WDFW hypothesizes that several factors may be contributing to the production of yearling steelhead smolts, including:

- Warm stream temperatures in the Tucannon R. below rk 40, coupled with the generally high productivity of the Tucannon River.
- Early spawning of steelhead in the lower Tucannon River, allowing for an extended first year of growth.
- Presence of earlier maturing hatchery steelhead in the lower river.

The ability of age 1+ smolts to produce returning adult steelhead is presently unconfirmed, and must be assessed before conclusions can be made about the adaptive success of this early life history variant in the Tucannon River.

Population Dynamics and Life History Characteristics of Steelhead (*Oncorhynchus mykiss*) in Portage Creek, Lake Superior 1991-2002

J.D. George, Ontario Ministry of Natural Resources<sup>4</sup> and M.A. Bozek, University of Wisconsin-Stevens Point<sup>5</sup>

Portage Creek, a small groundwater-fed tributary to Black Bay, Lake Superior has a self sustaining steelhead (*Oncorhynchus mykiss*) population that was heavily exploited until closure in 1994. The population had been monitored since 1991 in order to access changes and the rate of changes in the population size, size structure, repeat spawning rates and smolting strategies that have resulted from closure. Typical of heavily exploited north shore, Lake Superior streams, Portage Creek had a low repeat spawning rate and there was concern over the size and age structure of the population. Data obtained from Portage Creek would provide a baseline for comparing how other north shore streams might respond to regulation changes. Length, sex and maturity were determined from each individual adult steelhead in the field while life history data (eg. Age, stream years, lake years, maturity and number of spawnings) was extrapolated from scale samples. Eighty percent of Portage Creek steelhead smolt following one year in the stream. Males mature following one and two lake years while females were predominantly two and three lake years. Spawning migrations begin in late April and continue into late June. Actual redd construction occurs from the last week of April to late June peaking from mid May to late May. Migrations and spawning time were influenced by discharge and water temperature. Peak spawning was observed at water temperatures between 8 and 12 C.. Portage Creek steelhead seldom had a maximum age of nine years. Following closure the percent of repeat spawners, age and longevity of the population increased from an estimate of 700 in 1995 to 1200 in the spring of 1999. This study will continue to monitor steelhead population until 2002 or three generations following closure to assess the response to reduced exploitation.

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<sup>4</sup> Presenter. See appendix for address.

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Life Histories and Spawning Strategies of Steelhead (*Oncorhynchus mykiss*) in Ontario waters of Lake Superior 1991-1994

J.D. George, Ontario Ministry of Natural Resources<sup>4</sup> and M.A. Bozek, University of Wisconsin-Stevens Point<sup>5</sup>

Since their introduction in the late 1800's into Ontario waters of Lake Superior steelhead (*Oncorhynchus mykiss*) populations have colonized in relatively pristine north shore streams and have adopted stream-specific life history strategies.

In partnership with the Ontario Ministry of Natural resources anglers collected biological data (eg. Length, sex and scale samples) from seventeen spawning populations from 1991 to 1994. Life history strategies extrapolated from scale samples show that there is considerable variation in the length of stream and lake residency and high rates of repeat spawning for both sexes among streams. One or two years of stream life was dominant with three stream years less common. Maturity occurred following one to four lake years and was also stream specific. Males often matured following one lake year. Females generally required at least two lake years at before first spawning. The incidence of repeat spawning was variable for both sexes ranging from 25 to 77%. In larger streams fall migrations and over wintering was common. In most streams actual redd construction took place in spring from early April to late June, peaking in mid May and was dependent on stream flow and temperatures.

Steelhead in these streams appear to have developed stream-specific life history strategies that may be related to environmental conditions in each stream and augmented by some degree of reproductive isolated. Preserving the life history diversity and behavioral characteristics in each watershed should be a prime management objective. Management recommendations were adopted.

Life-history characteristics of steelhead in Fish Creek, a tributary of the Lochsa River, Idaho.  
Alan Byrne, Idaho Department of Fish and Game

There is little life-history information on specific wild steelhead stocks in Idaho. Idaho Department of Fish and Game (IDFG) chose Fish Creek as a index stream for wild "B-run" steelhead in 1993. Since 1993, we have been monitoring the steelhead population and collecting life-history information from this stream. Fish Creek is a major tributary of the Lochsa River and is managed for wild fish production. We install a weir each spring to count adult spawners, estimate summer parr densities with snorkel surveys, and operate a screw trap from March to November to enumerate and PIT-tag out-migrants.

The adult escapement in 1998 and 1999 was 75 and 72 fish, respectively. This is a steep decline from the peak escapement of 267 fish observed in 1993. The majority of adults return after two years in the ocean and 71% of the run has been females. Adults begin entering Fish Creek in late March and have been trapped as late as June 6 however, the peak period of entry into the stream is April 15 to May 15.

Summer age 1 parr densities have tracked adult escapement and could be used as an indicator of adult escapement the previous year. The parr densities (all steelhead except fry) have been about 10 fish / 100 m<sup>2</sup> from 1996 to 1999. This is a decline from the 1993 to 1995 period when parr densities ranged from 15 to 22 fish / 100 m<sup>2</sup>.

There is a large migration of parr out of Fish Creek in the fall. Over 80% of all migrants were trapped after September 1 in 1998 and 1999. Most of the migrants were parr that had reared in Fish Creek for two or three summers. These fish over-winter in the Lochsa River or further downstream in the Clearwater River. A small proportion of the fall migrants remain in the river an additional year before smolting. Most of the fall migrants become smolts the following spring and resume their migration to the ocean. The smolts begin arriving at Lower Granite Dam (LGR) in late April. There is a narrow migration window past LGR for these fish. About 80% of all smolts were detected at LGR between April 20 and May 10. We are just beginning to get adult returns from our PIT-tagging and should be able to estimate smolt-to-adult survival in the future.

Methods for Determination of Kamchatkan Mikizha *Parasalmo (Oncorhynchus) mykiss*  
(Walbaum) Life Strategy by the Analysis of Recording Structures

Kirill V. Kuzishchin<sup>6</sup>, Ksenia A. Savvaitova, and Dmitry S. Pavlov, Moscow State University,  
Moscow, Russia

*Introduction*

Recording structures (e.g. scales, otoliths, fin rays, some particular bones etc.) are generally using for determination of specimen's life span and life history strategies in salmon and trouts. That is why clarifying the methodical approach to the examination of recording structures is a very important task for the researcher.

The main goal was to examine the morphology of Kamchatkan *P. (O.) mykiss* recording structures to reveal their life history strategy and intrapopulational structure. Particular tasks of the current study were: 1) to examine three different recording structures (scales, otoliths, vertebrae) and their correspondence to the phenotypes of fishes with different life history strategy; 2) to evaluate the significance of different recording structures and select the best of them for the determination of life history strategy of *P. (O.) mykiss* in Kamchatkan rivers; and 3) to examine the possibilities for differentiation of local stocks using the features of recording structures.

*Material and Methods*

The materials of this investigation were represented by scale, otolith and vertebrae samples gathered from *P. (O.) mykiss* populations from Western Kamchatka rivers (Figure 1). Most scale samples were gathered by the "catch-and-release" method; fish were released back into the river after measuring procedures. To evaluate the best definition of life strategy we conducted the examination of three recording structures (scales, otoliths, vertebrae) taken from each fish of the Saichek River population.

The determination of the life strategy was based on analysis of the morphology of recording structures: on scales the number of circuli and the width of annual zones, on otoliths – the width of annual zones and the character of their structure of surface, on the vertebrae – the width of annual zones (Figure 2).

*Morphology of scales, otoliths and vertebrae of P.(O.) mykiss in Saichek River*

Scales

Five different types of scales in Saichek River mikizha were discovered.

Type S-1. There are two parts of the scale: central, with narrow annual zones; and external, with broad annual zones. The external annual zones are 4.5-5 times broader than zones in the central part. The borders between groups of "wide" and "narrow" circuli in the external annual zones are not clear. In the whole only the border of the annual zone is expressed clearly (Figure 3a).

On scales of the S-1 type "spawning marks" exist. Two types of spawning marks were discovered: 1) as a zone without circuli, that looks like narrow light band; and 2) as a number of reduced "circuli" in the front part of the scale (Figure 4). The spawning marks begin forming on

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<sup>6</sup> Presenter. See appendix for address.

the scales of kelts immediately after spawning in fresh water.

Type S-2. It also has narrow annual zones in the central part and wide zones in the external part. However, these external zones are narrower than in the S-1 type. They are only 1.8-2.2 times broader than the central annual zones (Figure 3b).

Type S-3. There are narrow annual zones in the central part. A wide annual zone with 15-18 circuli (from which 3-4 belong to a "narrow" group) is situated behind them. The width of this zone is the same as the width of the external annual zones of type S-2. This broad zone is followed by narrow zones, in which the number of circuli varies as in the central part (from 5 to 12) (Figure 5).

Type S-4. Scales of this type have a central part with narrow annual zones and one broad zone, lacking the annual ring – the so called "open edge" (Figure 6a).

Type S-5. Only narrow riverine annual zones are present - Figure 6b.

### Otoliths

Four different types of otoliths were discovered.

Type O-1 otoliths have a rather big size. There are two parts of the otolith: central, with narrow annual zones; and external, with more broad annual zones. Annual zones in the central and external parts differ in the structure of their surface. Annual zones in the central part have a smooth surface, while the surface of external annual zones is crossed by numerous and deep radial "ditches". Also, external annual zones are less transparent than the central; they have intensive white ("milk") color (Figure 7a).

Type O-2 otoliths have a relatively smaller size compared with the above type. These otoliths have narrow annual zones in the central part and broader ones in the external part. Annual zones in the central part have a smooth surface; the surface of external annual zones has a granular structure, sometimes with shallow radial "ditches". The transparency of the central and external annual zones is the same (Figure 7b).

Type O-3. There are narrow annual zones in the central part; their surface is smooth. A wide annual zone with a granular surface is situated behind them. This broad zone is followed by narrow zones similar in width to the zones in the central part; the surface is more smooth than uneven (Figure 8a).

Type O-4. There are only narrow riverine annual zones with smooth surface (Figure 8b).

No element of otolith morphology that can be considered a "spawning mark" was detected

### Vertebrae

Four different types of vertebrae were discovered.

Type V-1. There are two parts on the terminal part of the vertebra: central, with narrow annual zones; and external, with very broad annual zones. The external annual zones are 4-5 times broader than zones in the central part (Figure 9).

Type V-2. It also has narrow annual zones in the central part and wide zones in the external part. However, these external zones are narrower than in the V-1 type. They are only 2-3 times broader than the central annual zones (Figure 9).

Type V-3. There are narrow annual zones in the central part; and they have a yellowish color. A wide annual zone (about 2 times more in width) is situated behind them. This broad zone is followed by narrow zones (Figure 9).

Type V-4. There are only narrow annual zones on the terminal part of the vertebrae (Figure 9).

No structures that can be considered “spawning marks” were discovered.

*Comparing of morphology of different recording structures*

Different recording structures describe the life cycle of specimens in the similar way. In general, there is a correspondence of types of different recording structures – Table 1. At the same time, the otoliths and vertebrae can not identify some phenotypes.

Table 1. The correspondence of types of three recording structures		
Types of different recording structures		
Scales	Otoliths	Vertebrae
S-1	O-1	V-1
S-2	O-2	V-2
S-3	O-3	V-3
S-4	No	No
S-5	O-4	V-4

The greatest diversity of different life strategy phenotypes can be found using scales; otoliths and vertebrae provide less success. Use of scales is optimal, since scale gathering can be conducted by non-lethal (catch-and-release) methods. This is very important for research of Kamchatkan steelhead, which are listed in the Red Data Book of Russia. Also, “spawning marks” were only discovered on scales, and these can provide the researcher with the age of maturation, repetition of spawning etc. Use of scales also allows comparison of results with published data.

*Structure of scales of P.(O.) mykiss from the Western Kamchatka Rivers.*

*P.(O.) mykiss* in the Saichek River are widely separated from other local populations of *P.(O.) mykiss* in the rivers of Western Kamchatka. In some rivers (Kvachina, Utkholok, Sopochnaya, Krutogorova), besides the 5 scale patterns discovered in Saichek River, one more phenotype was discovered – Figure 10.

In general, the scale structure of this phenotype is similar to type S-1. Scales have narrow annual zones in the central part and broad zones in the external part. The broad annual zones are narrower than in the S-1 type, but they are still at least 3.5 times broader than narrow zones in the central part. There are only 11-16 (sometimes 17-18) circuli in the first external annual zone, from which only 3-4 (sometimes 5) belong to the “narrow” group. The whole “narrow” group of circuli in the first external annual zone does not exceed 0.05 mm in width. The border between groups of “wide” and “narrow” circuli in the first external zone is quite conspicuous. The following zones have the same structure as in the S-1 scales (Figure 10).

Thus in the populations of *P. (O.) mykiss* from the rivers of Western Kamchatka the 6 variants or phenotypes of scale structure were discovered. Analysis of scales allowed us to distinguish several types of life history strategy, which are referred to by the Greek letters:  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\Delta$ ,  $\varepsilon$ ,  $\iota$  (Figure 11). The diversity of scale structure which describes the peculiarities of life cycle can be considered as evidence of two main life strategies in the Kamchatkan *P. mykiss*

(Walbaum): resident (riverine) and migratory (anadromous). The key in Table 2 identifies the scale types and respective variants of the life history strategies.

1 (2)	The annual zones in the scale are approximately equal. There are only narrow annual zones with 5-12 (typically 7-10) circuli in each. The border between groups of "wide" and "narrow" groups of circuli is well defined	Type $\iota$ – riverine form
2 (1)	The annual zones are irregular. Besides narrow annual zones with 5-12 (typically 7-10) circuli there are wide zones with more number of circuli.	
3 (10)	There are two distinct parts in the scales: central with narrow annual zones and external with wide zones.	
4 (9)	There is at least one complete annual zone in the external part.	
5 (8)	The border between the central and external parts of the scale is clearly defined. The annual zones in the external part are more than 3.5 times larger than river zones in the central part.	
6 (7)	The border between groups of "wide" and "narrow" groups of circuli in the first annual zone of the external part of the scale is well defined. There are no more than 5 "narrow" circuli.	Type $\beta$ – anadromous, the life cycle includes "half-pounder stage
7 (6)	The border between groups of "wide" and "narrow" circuli in the first annual zone of the external part is fuzzy. However, the border of the annual zone is, on the whole, clear, There are more than 6 "narrow" circuli.	Type $\alpha$ – Typically- anadromous
8 (5)	The border between central and external parts is fuzzy. The annual zones in the external part are 1.8-2.2 times broader than river zones	Type $\gamma$ – Estuarine
9 (4)	There is one incomplete wide zone in the external part of the scale (9-17 circuli) without the annual ring, so-called "open edge"	Type $\varepsilon$ – "half- pounders"
10 (3)	There is no clear division of the scale into central and external parts. Wide annual zones alternate with narrow river annual zones	Type $\Delta$ – riverine-estuarine

### *Differentiation of P. (O.) mykiss local stocks using the scale structure*

The traits of scale structure may somewhat differ between populations but the main structural characteristics of the scales did not differ greatly. In all types of scales the structure of the central part of the scale, which corresponds to the riverine period of life was similar in the various phenotypes – the number of circuli and width of annual zones was almost identical. By the above features (number of circuli and width of riverine zones in the central part of the scales) local populations of Kamchatka and North America steelhead were differentiated with multivariate statistical methods. Different phenotypes from one river form the single cluster, while clusters from different drainages placed separately (Figure 12a). Populations of North American steelhead differ hardly at all from Kamchatkan in the number of circuli and width of central annual zones and sharply distanced in the space of principal components. The same result shows the cluster analysis (Figure 12b)

### *Conclusions*

1. In populations of *P.(O.) mykiss* from Saichek River 5 different type of scales, 4 types of otoliths and vertebrae were discovered. Types of different recording structures, taken from one fish correspond one to another and describe the life cycle of fish in the same way.
2. The greatest diversity of life strategy phenotypes discovered by scales; all together 6 types of scale structure of *P.(O.) mykiss* were found in Western Kamchatkan populations. Scales were chosen as the best recording structure to describe life history strategy.
3. Phenotypes of scale structure allow researchers to distinguish several types of life history strategy patterns in Kamchatkan *P.(O.) mykiss*.
4. The key to identify the scale types and respective variants of the life history strategy was elaborated.
5. Using the structure of riverine annual zones on the scale (number of circuli and width of annual zones) by the multivariate statistical methods it is possible to differentiate local populations of Kamchatkan and North American *P.(O.) mykiss*.

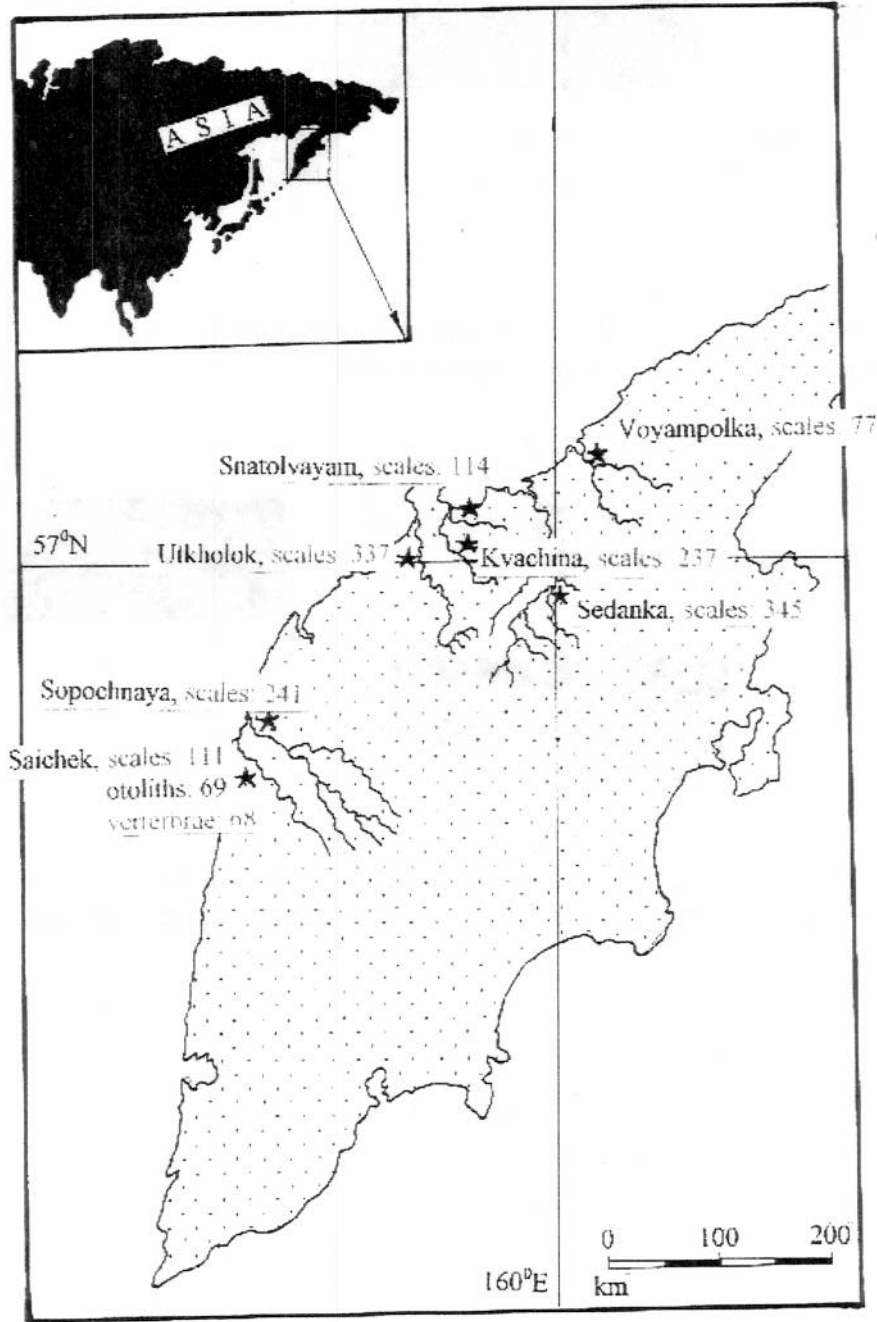
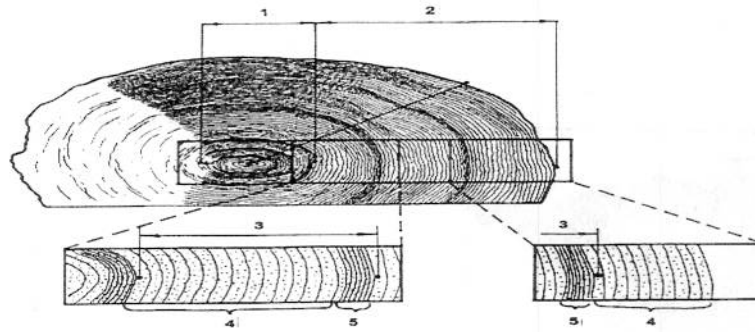
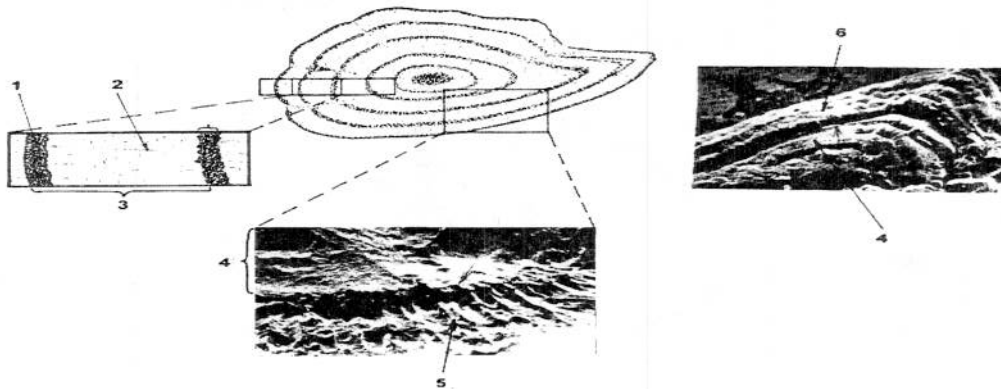


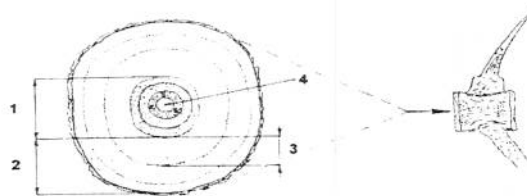
Figure 1. Map of Kamchatkan peninsula with sampled locations, name of the rivers and sample size of *P. (O.) mykiss*.



The structure of Scale: 1 – central part; 2 – external part; 3 – the borders of annual zone; 4 –the group of “broad” circuli; 5 – the group of narrow circuli



The structure of Otolith: 1 – hyaline zone; 2 - opaque zone; 3 – the borders of annual zone; 4 –smooth surface of annual zones; 5 – surface with radial “ditches”; 6 – granular surface



The structure of Vertebra: 1 – central part; 2 – external part; 3 –the borders of annual zone; 4 – the hole in the center

Figure 2. The elements of scales, otolith and vertebrae, used in the present study

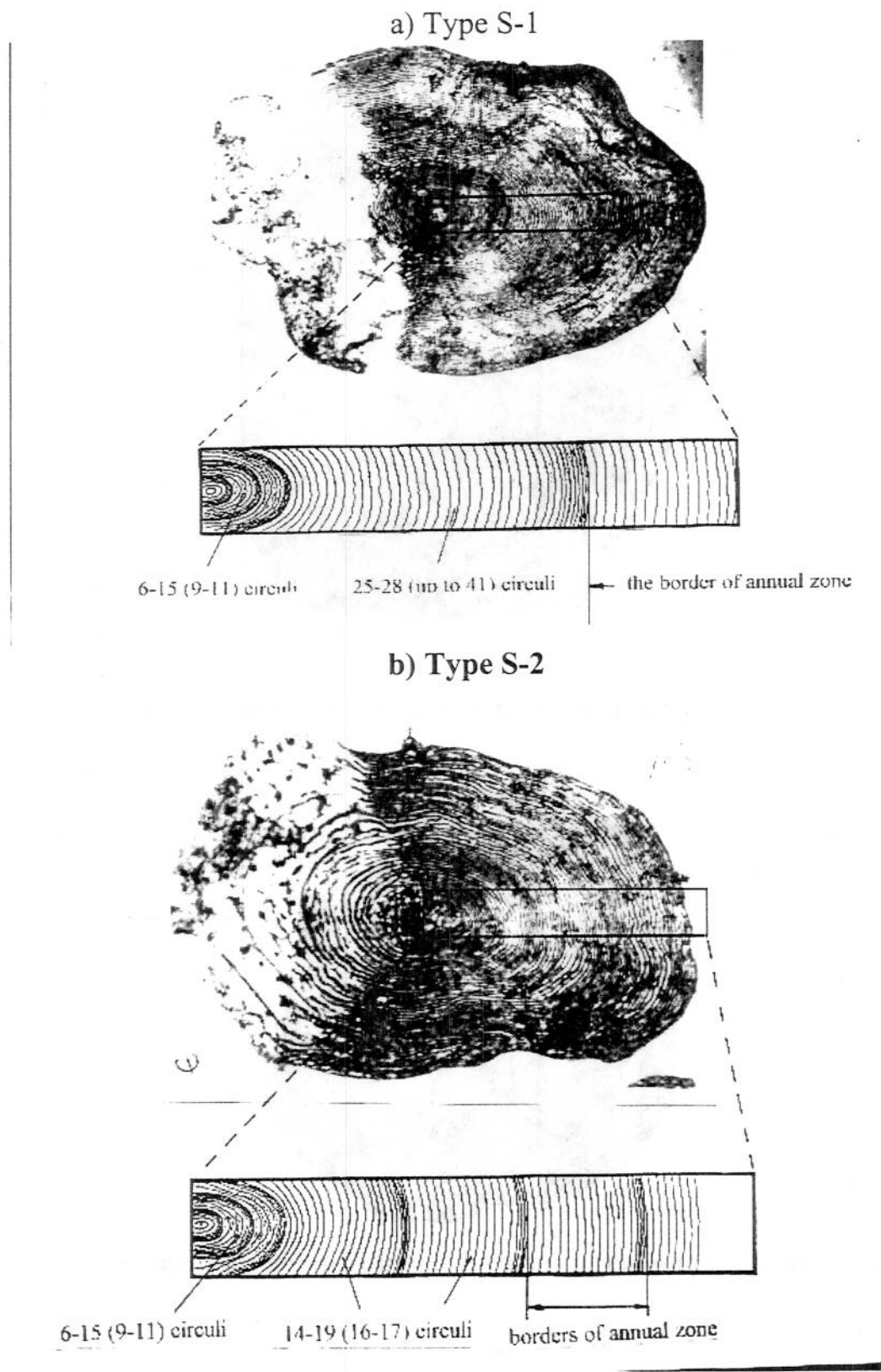


Figure 3. The scales of S-1 and S-2 type from Saichek River



Spawning mark as a transparent zone without circuli



Spawning mark as a number of reduced "circuli" in the front part of the scale

Figure 4. Spawning marks on the scales of S-1 type

a) Type S-3 (age 3.1.1+)

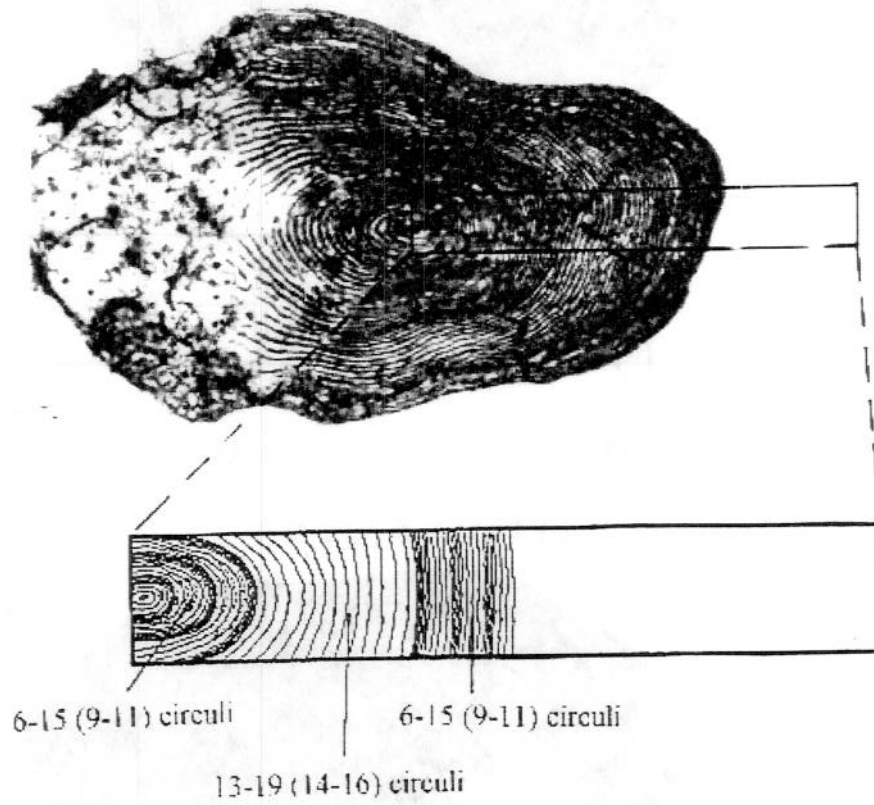
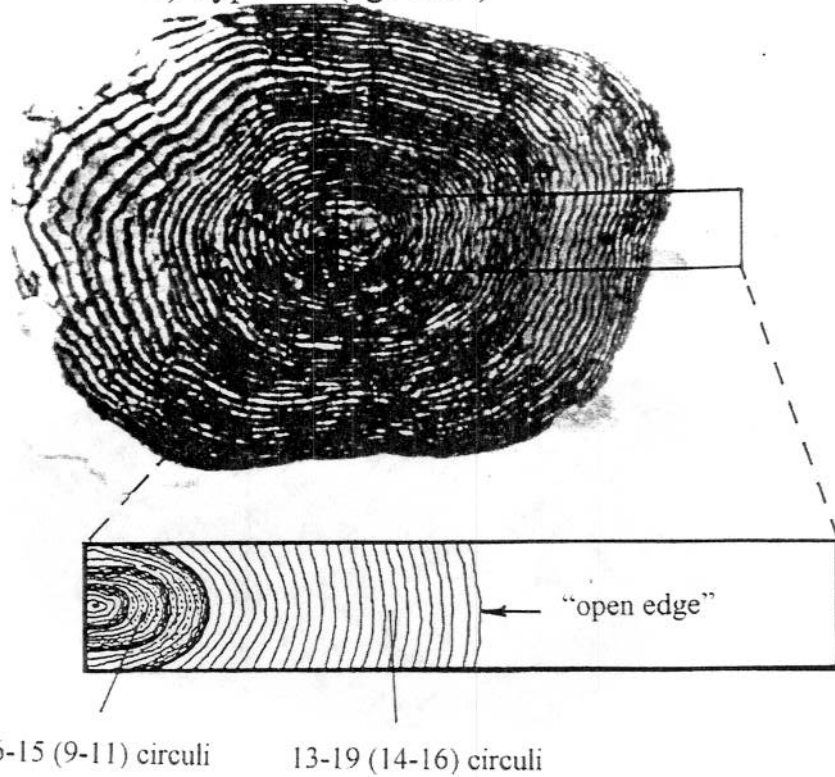
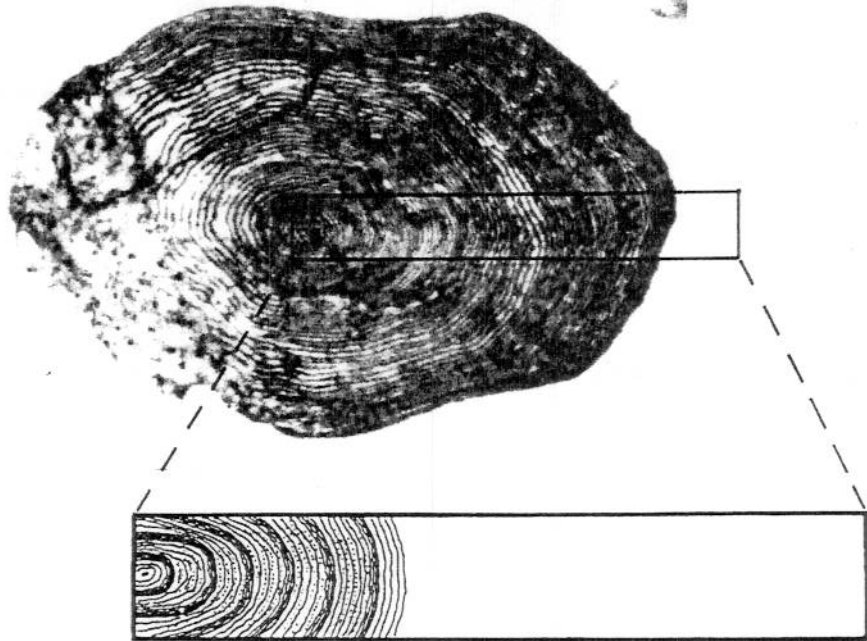


Figure 5. The scale of S-3 type

a) Type S-4 (age 3.0+)



b) Type S-5 (age 5+)



6-15 (most often 9-11) circuli in all annual zones

Figure 6. The scales of S-4 and S-5 types.

### *Introduction*

The life strategy is defined as genetically programmed history of behaviour, maintained by natural selection under frequency-dependent intraspecific competition, so, the main “goal” of any adaptive life strategy is reproduction of fruitful offspring. There exists a large literature discussing about life history strategy in various salmonid species and possible ways of its development. The data on the life strategy in Kamchatkan steelhead and trout of genus *Parasalmo (Oncorynchus)* however are scarce, detailed studies of its local population have begun recently. The goal was to reveal and study different life history strategy variants in the local populations of Kamchatkan *P.(O.) mykiss*. Particular tasks were 1) To reveal types of life history strategy of mikizha in the rivers of Western Kamchatka; 2) To determine the occurrence of fish with different types of life strategy in the rivers of Western Kamchatka and 3) To discuss the nature of existing diversity of life history strategies in *P.(O.) mykiss*.

### *Types of life strategies in Western Kamchatkan mikizha.*

Analysis of scales allowed us to distinguish several scale types, which are referred to by Greek letters:  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\Delta$ ,  $\varepsilon$ ,  $\iota$  (Figure 1). Thus, on the basis of the scale structure in the Western Kamchatka *P. (O.) mykiss*, which would reflect the diverse life modes, it is possible to distinguish the following adaptive norms or life-strategies:

1. typically-anadromous (type  $\alpha$  of scale structure): the smolts after downstream migration from the rivers go off the coastal waters to the ocean at once (Figure 2);
2. anadromous- $\beta$ : smolts spend the first several months in the coastal salt waters, then return to the rivers for wintering, and then go to the ocean up to the maturation (Figure 3);
3. estuariane ( $\gamma$ ) when the fishes after a freshwater period spend several years up to the maturation only in the estuary of the river (Figure 4);
4. riverine-estuariane ( $\Delta$ ), which is characterized by an alternation of river and estuary periods of the life, without respect of the maturity (Figure 5);
5. riverine or resident ( $\iota$ ): the whole life cycle realized in the fresh water (Figure 6).
6. The fish with type- $\varepsilon$  scales, that first migrate to the sea for a few month and then return to the river for overwintering (so called “half-pounders”, see Snyder, 1925), most probably represent the anadromous types  $\beta$ ,  $\gamma$  or  $\Delta$ .

### *The ratio of fish with different scale structure.*

The frequency of occurrence and correlation of fish with different scale structure differs between local populations of Kamchatkan *P.(O.) mykiss* (Figure 7). In Voyampolka River the fish with type- $\gamma$  scales predominate, some individuals have scales of  $\iota$ -type. In Sedanka River, the most fish have  $\iota$ -type scales, and only few individuals –  $\gamma$ -type. Only type- $\alpha$  scales were observed in Snatolvayam River after a period of 5 years of study. Fish with type- $\alpha$  scales predominate in

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<sup>7</sup> Presenter. See appendix for address

Kvachina River, although a few individuals with type- $\varepsilon$  scales were also noted. As in Snatol'vayam and Kvachina rivers, in Utkholok River fishes with type- $\alpha$  scales also predominate. However individuals with  $\beta$ ,  $\varepsilon$  and  $\iota$  types were also observed. All scale types except  $\gamma$  were found in Sopochnaya River, although  $\alpha$ -type significantly predominated. Individuals with  $\alpha$ ,  $\Delta$  and  $\iota$  were noted in Saichek River, even though the  $\alpha$ -type scales were much more often observed.

### Discussion

It is known that the same genotype in different environmental conditions may have various types, differing by morphological and physiological features e.g. the species exists in a number of phenotypic expressions. These types or expressions have various names "phenotypic windows" of the genotype, "the adaptive norms", "the discrete adaptive norms". According to this view, in various ecological conditions, the same species may be represented by one, two or more "adaptive norms". Accordingly, the species represents a system of adaptive norms. Each individual receives from the parents a packet of programs of development, but only one of them will realize under local environmental conditions. Furthermore, the environment acts as a switch, turning on particular genetically determined mechanisms (Mednikov, 1987).

Thus, it is possible to define two main life strategies in the *P. (O.) mykiss*: resident (riverine) and migratory (anadromous). The latter strategy may substantially vary depending on local environmental conditions, such as length of migration pathways and duration of the sea period until maturation (phenotypes  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\Delta$ ,  $\varepsilon$ ).

Because of the finding of multiple scale structure phenotypes, reflecting differences in their life strategy, an important question arises: when several types inhabit the same river do all represent a single self-sustaining grouping or is this diversity only a manifestation of individual variations?

The differences in the scale structure found in the Kamchatkan *P. (O.) mykiss* were interpreted as group differences. Later, this division of *P. (O.) mykiss* at the intrapopulational groupings within local populations was accepted by other investigators apriori (Savvaitova, 1975; Savvaitova *et al.*, 1997). But our material as well as the data available in the literature suggests an alternative interpretation. Most probably the diversity of life history strategies in the *P. (O.) mykiss* of Western Kamchatka is a manifestation of individual variations.

In cases when different phenotypes of *P. (O.) mykiss* occur within the same river, they do not differ in the time of upstream migration for overwintering and spawning, and do not form distinct groups during their migration. Phenotypes, more closely associated with the fresh water, inhabiting in the same water body as anadromous, often exhibit change of their life style (e.g. transition from riverine to anadromous type and vice versa).

This agrees with the view that the transition from one adaptive norm to another may occur within the life cycle of a single generation, at the level of individual organism. Most probably, the main role during the transitions between life styles is played by quantitative changes in the expression of specific key structure genes. The releasing signal from the environment would act on the gene rather indirectly through the "hormonal axis" of the organism (Mednikov, 1987). The importance of hormonal factors in the determining the developmental and behavioural program is well known in salmonid fishes (Hoar, 1965; Barannikova, 1975 and others). While comparing the Kamchatkan populations of *P. (O.) mykiss* throughout in the range and individual phenotypes within the same population the continuum of life history strategies was revealed (Figure 7). The

Some components of the environment in certain reservoirs (e.g. the presence or absence of estuaries, the composition of biota etc.) may be relatively stable from year to year. Thus, individual phenotypes with particular life history strategies adapted to these conditions may remain in rivers with low anthropogenic effects. In other words, the same adaptive norm reproduces, maintaining the dominating type of life history strategy characteristics of the local populations.

For example, in Voyampolka River, which has a large estuary (Figure 8), the estuarine form reproduces, whereas the riverine form inhabits in Sedanka River, where the successful feeding of fish is provided. In small rivers Snotolvayam and Kvachina, where the estuary is small, the anadromous type is predominant. In Sopochnaya and Saichek rivers, which have the lagoons (Figure 9), there are conditions for the occurrence of typically-anadromous, anadromous- $\beta$ , “half-pounders” (type- $\varepsilon$ ), estuarine and riverine-estuarine ecotypes. In cases, when the river is sufficiently large but the estuary is relatively small (Utkholok River) anadromous and riverine types co-occur. All this may create a superficial illusion of stable groupings, existing in Kamchatka mikizha (Maximov, 1972, 1974).

Changing environmental conditions, such as stock reduction through poaching as in Utkholok River or substantial alternation of climate or hydrology, may raise changes in the composition and ratio of phenotypes with different life history strategies (Savvaitova *et al.*, 1997). Thus the Kamchatkan *P. (O.) mykiss* exhibits pronounced variations in the life history strategy. These variations, as in other salmonid species (Thorpe, 1990, 1993, 1994), may depend on both inherited program and ecological conditions, that is, they are likely to be basically epigenetic.

The conservation efforts therefore should be directed to preserve all ecological and genetic diversity of the species, including the whole continuum of life strategies in undisturbed habitats. Our materials demonstrate uniqueness of local populations of the Kamchatkan *P. (O.) mykiss*. They differ in the characters and composition of various life history strategies. Anthropogenic pressure may reduce the individual diversity of phenotypes and shift their composition in particular habitats, thereby destroying the species structure and ecosystem of water bodies.

In conclusion it is necessary to discuss the so-called “coastal” form (Maximov, 1972) and remove a terminological confusion. According to our data, these migratory fish include the stage of “half-pounder”, which is reflected in the structure of their scales ( $\beta$  or  $\gamma$  types). These individuals should not be called “coastal”, as it does not agree with their actual life history strategy. In addition, the term “coastal” is already in use to designate one of the phylogenetic groups of *Parasalmo (Oncorhynchus) mykiss* (Walbaum) in North America (Behnke, 1992).

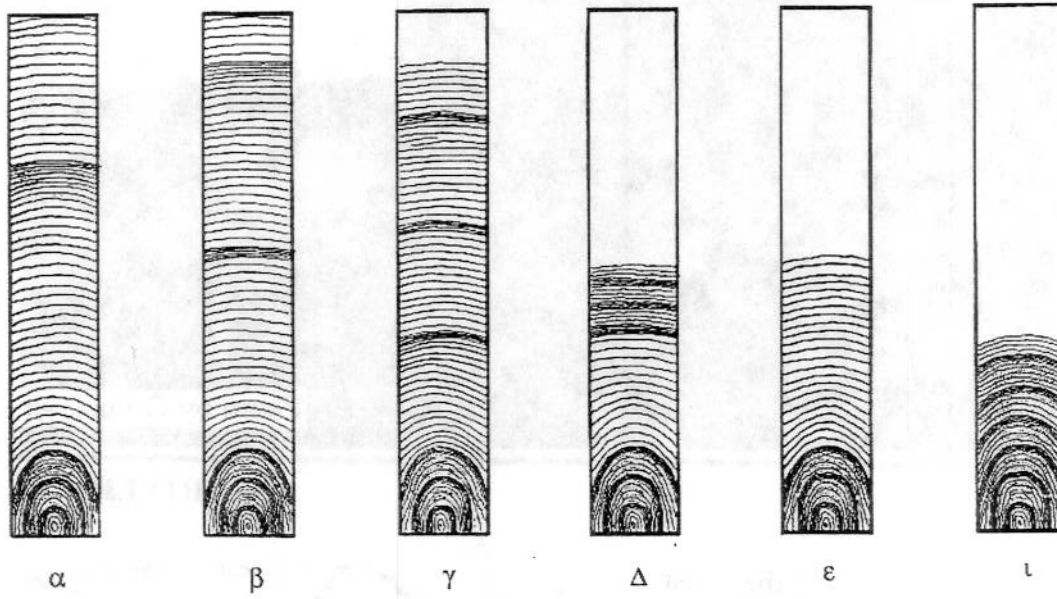
#### Conclusions:

1. In *P.(O.) mykiss* from Western Kamchatkan rivers we described the existence of two main types of life strategy – resident and anadromous. The latter strategy may substantially vary depending on local environmental conditions, such as length of migration pathways and duration of the sea period until maturation.
2. In different rivers the ratio of phenotypes with different life strategy is unequal; it is determined by the interaction of fish genotype and environment, particularly by the river geomorphology.
3. The diversity of life strategies in Kamchatkan *P.(O.) mykiss* is a manifestation of individual variations, thus the variations in life history strategy are epigenetical.
4. Our materials demonstrate uniqueness of local populations of Kamchatkan *P.(O.) mykiss*.

The conservation efforts therefore should be directed to preserve all ecological and genetic diversity of the species, including the whole continuum of life strategies in undisturbed habitats.

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$\alpha$  - typically anadromous;  
 $\beta$  - anadromous-b  
 $\gamma$  - estuarine  
 $\Delta$  - riverine-estuarine  
 $\epsilon$  - half-pounders  
 $\iota$  - riverine

Figure 1. Life history strategy patterns of Western Kamchatkan *P. (O.) mykiss*

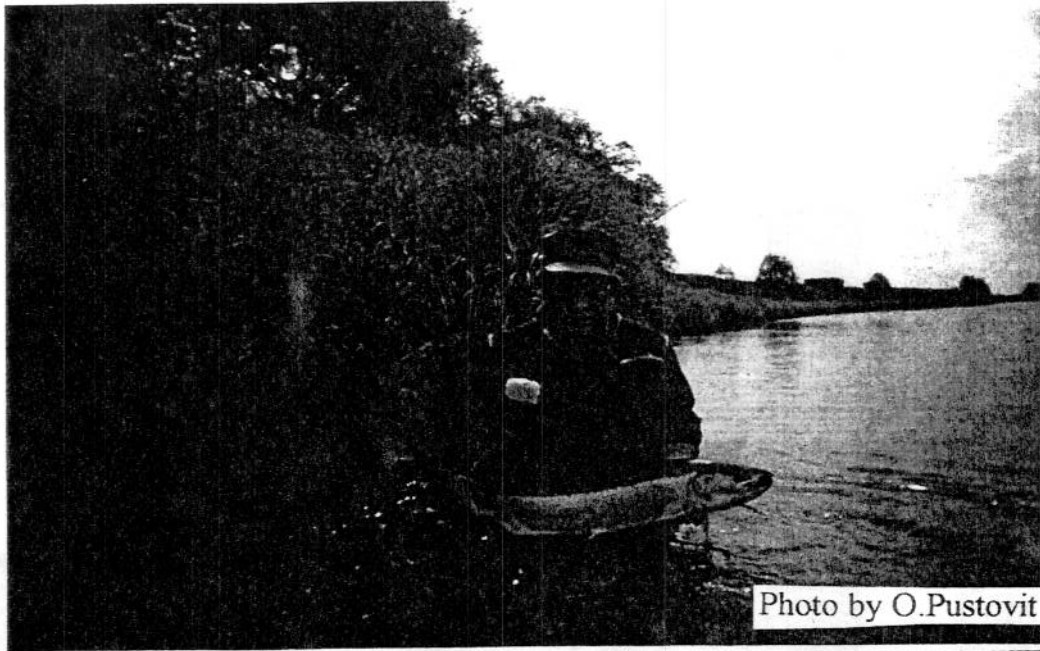


Photo by O.Pustovit

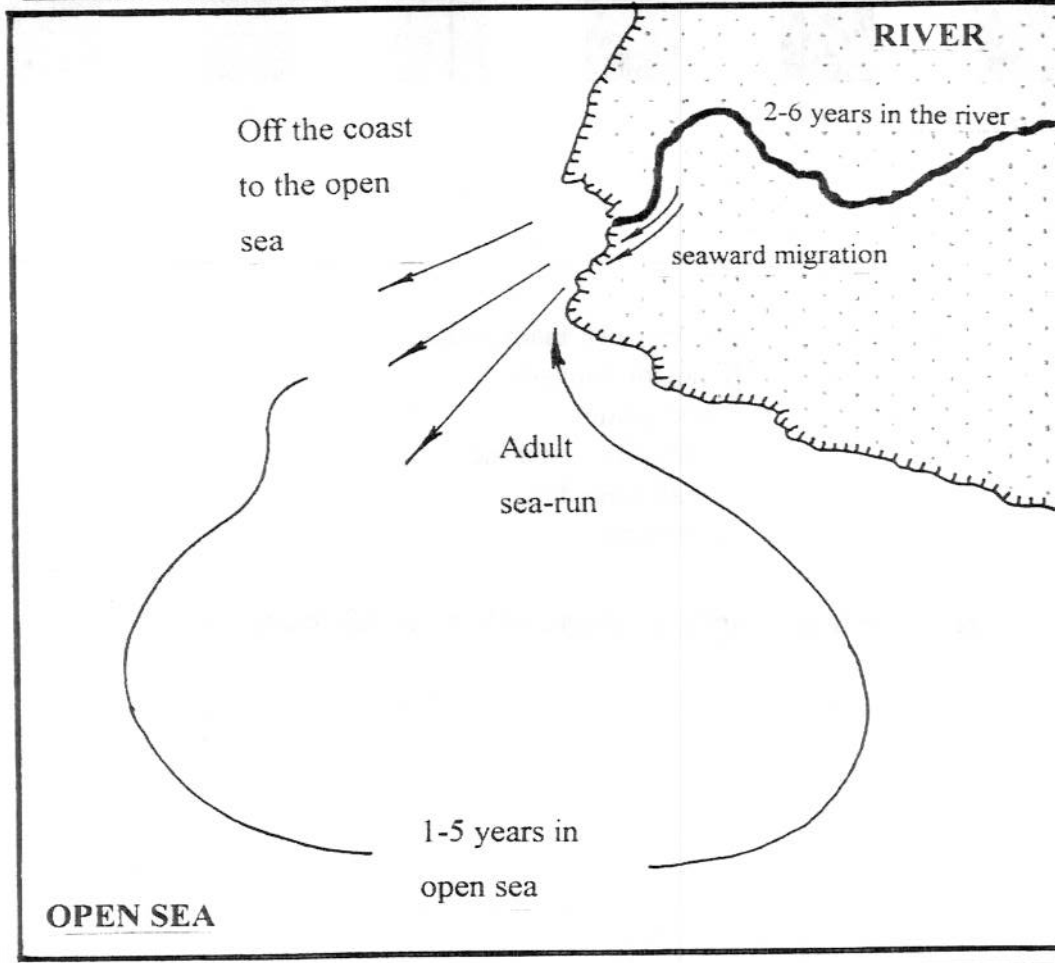


Figure 2. Description of typically anadromous fish

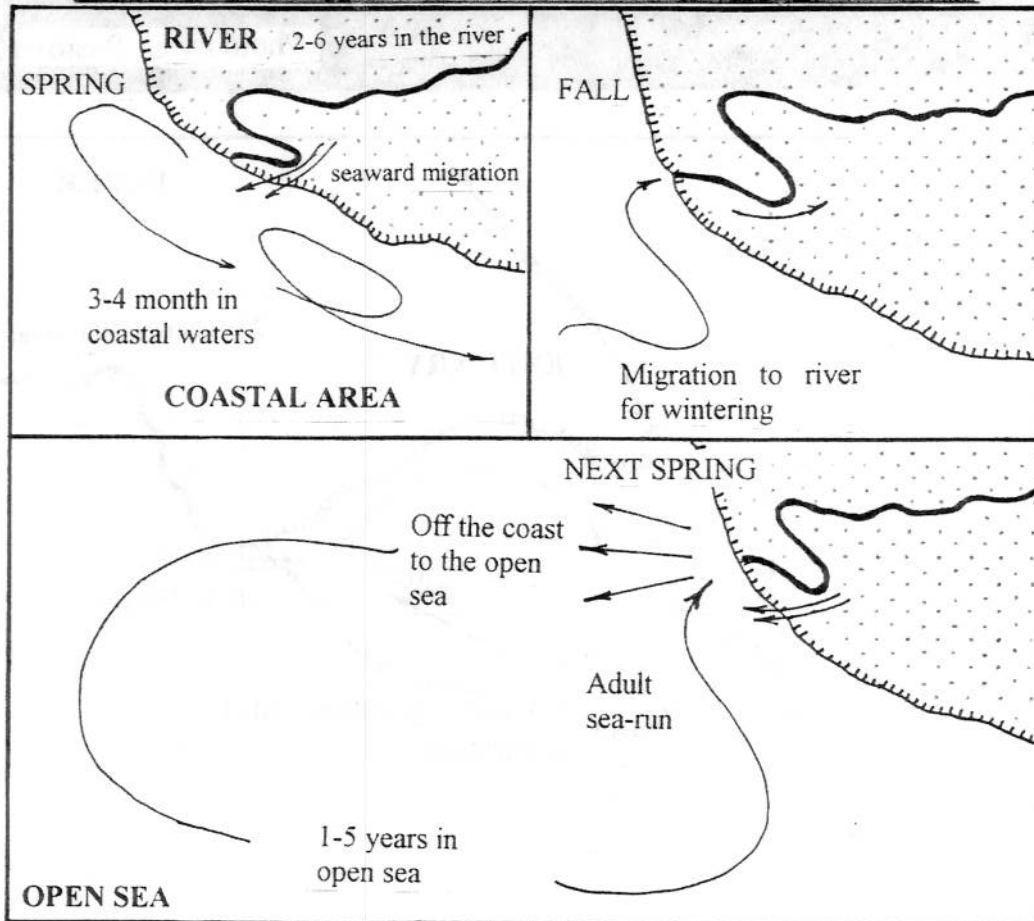
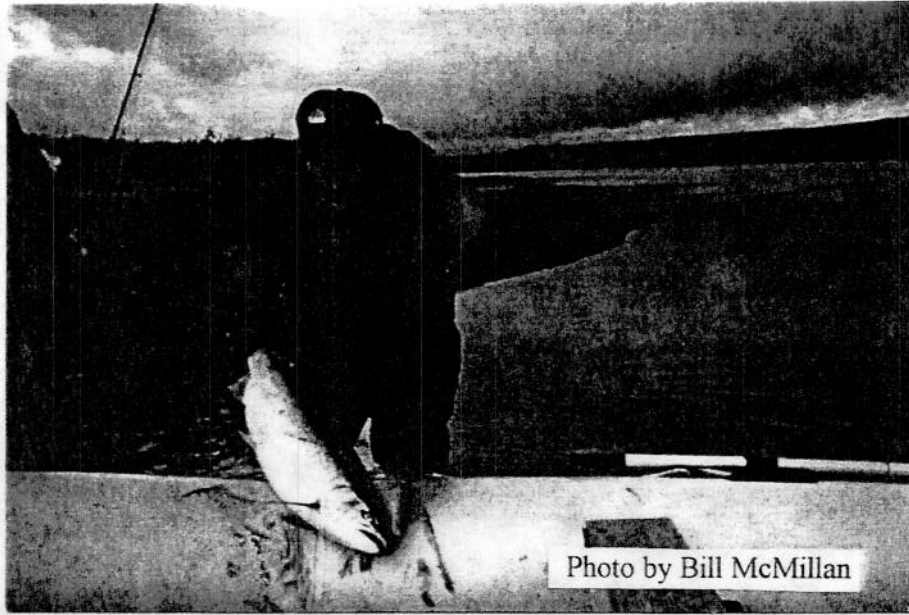


Figure 3. Description of anadromous- $\beta$  fish

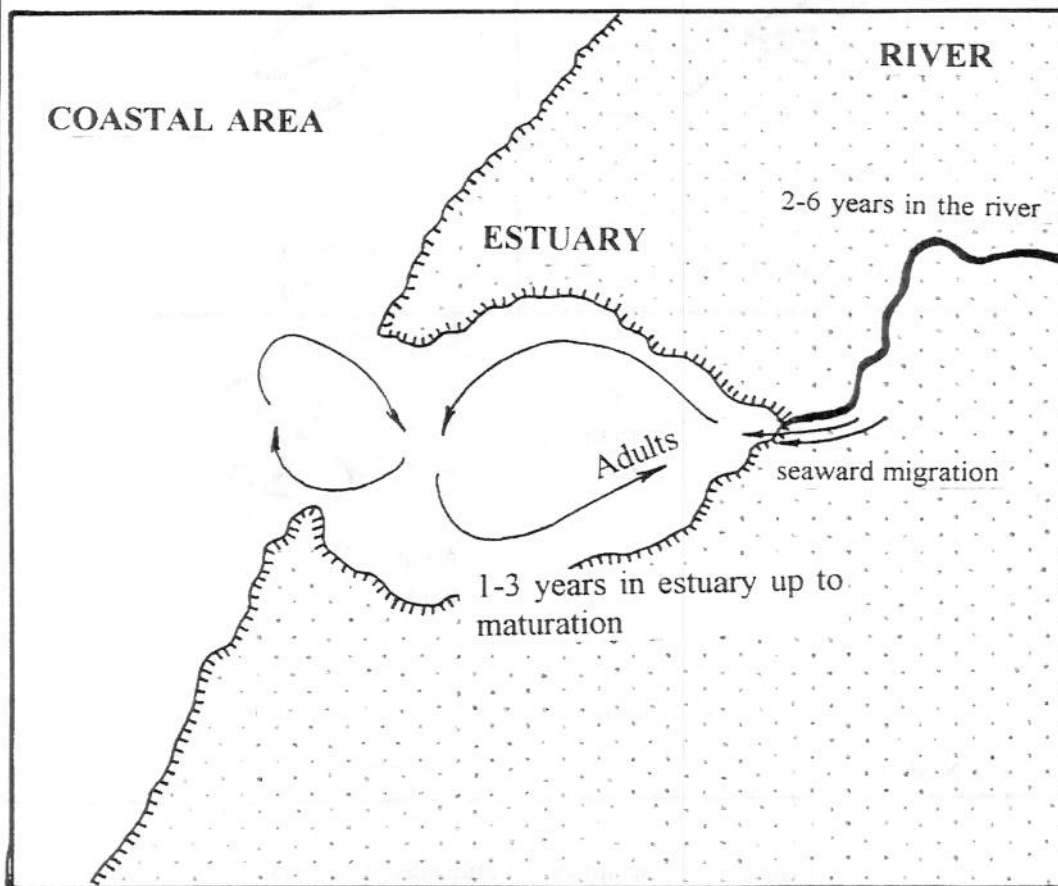
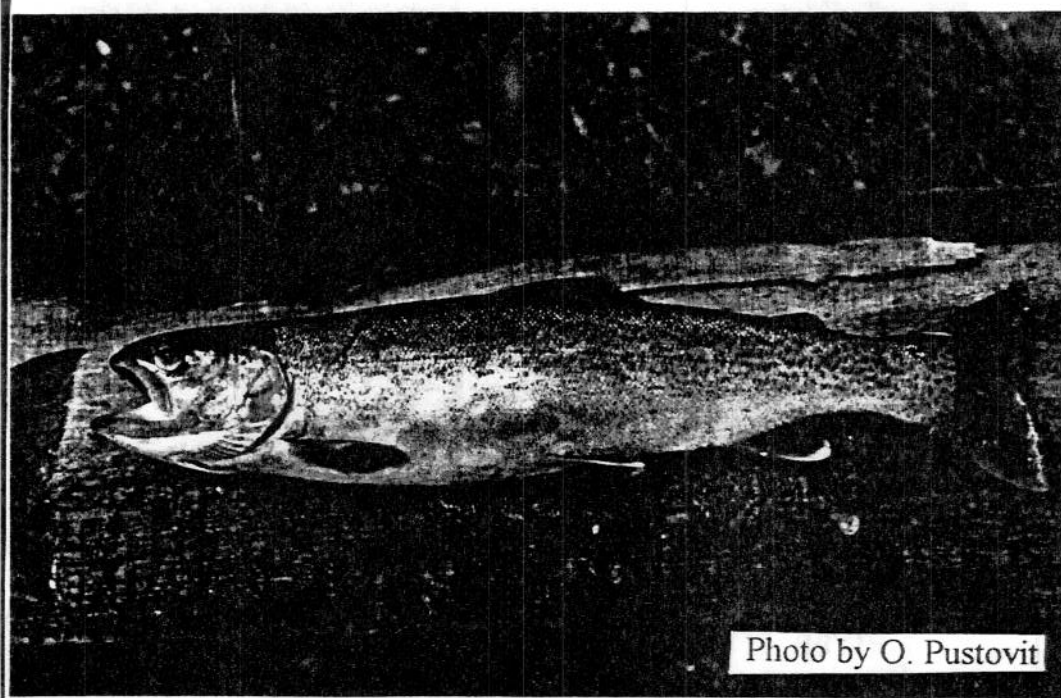


Figure 4. Description of estuarine fish

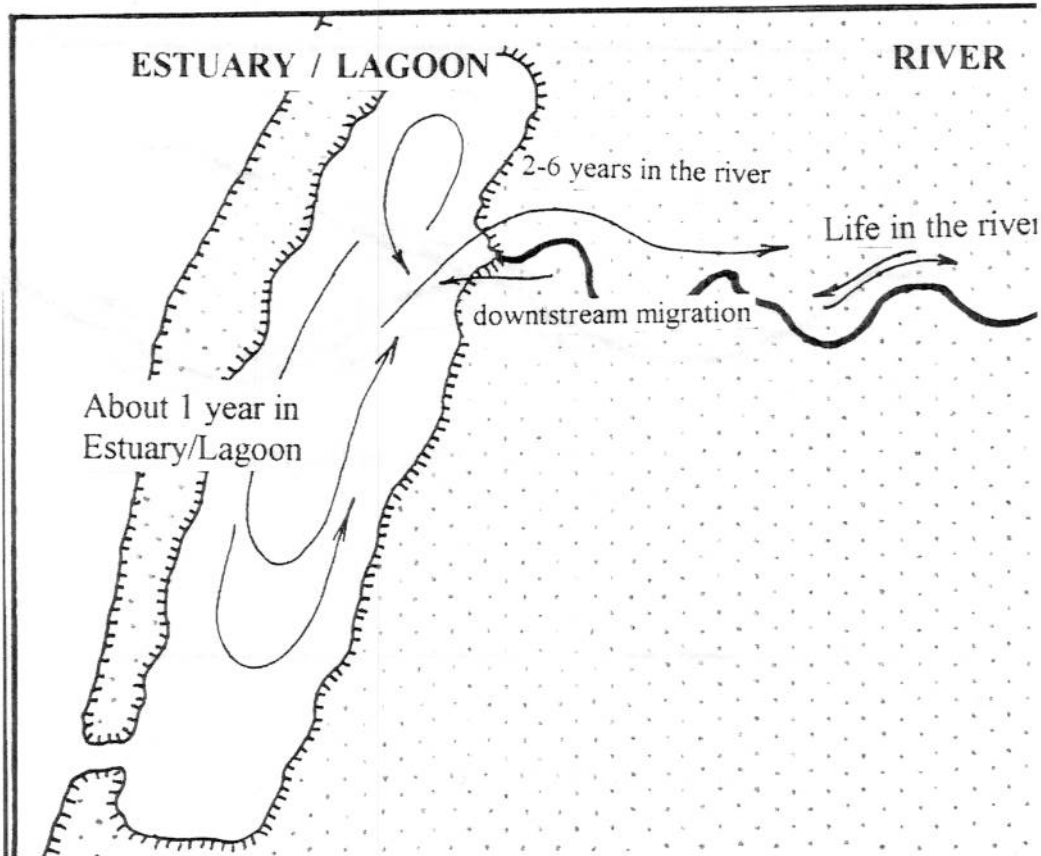


Figure 5. Description of riverine estuarine fish

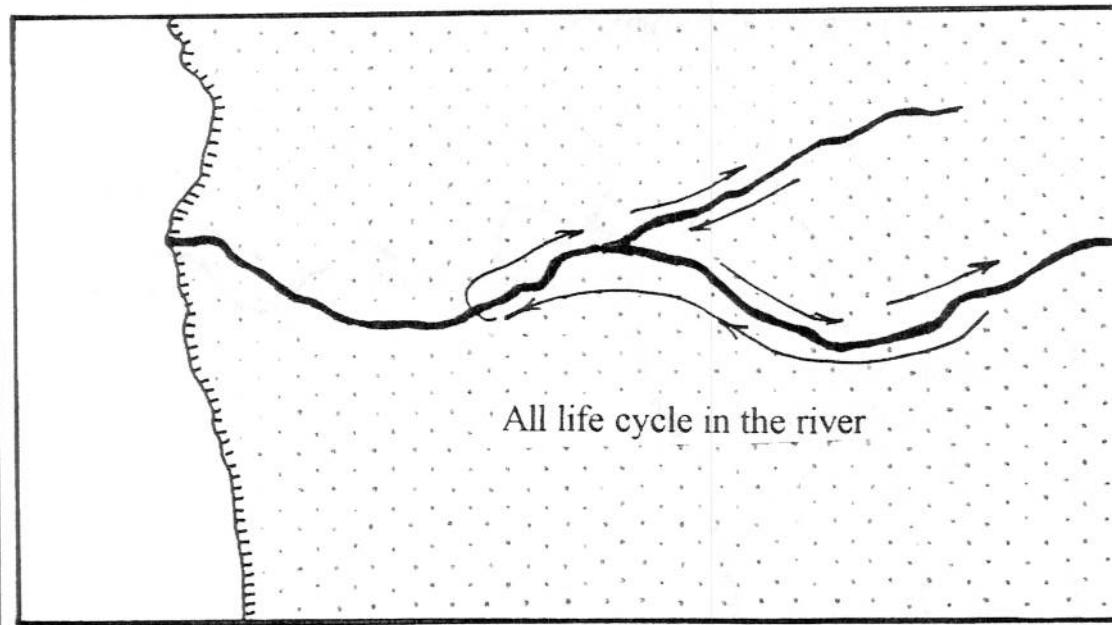
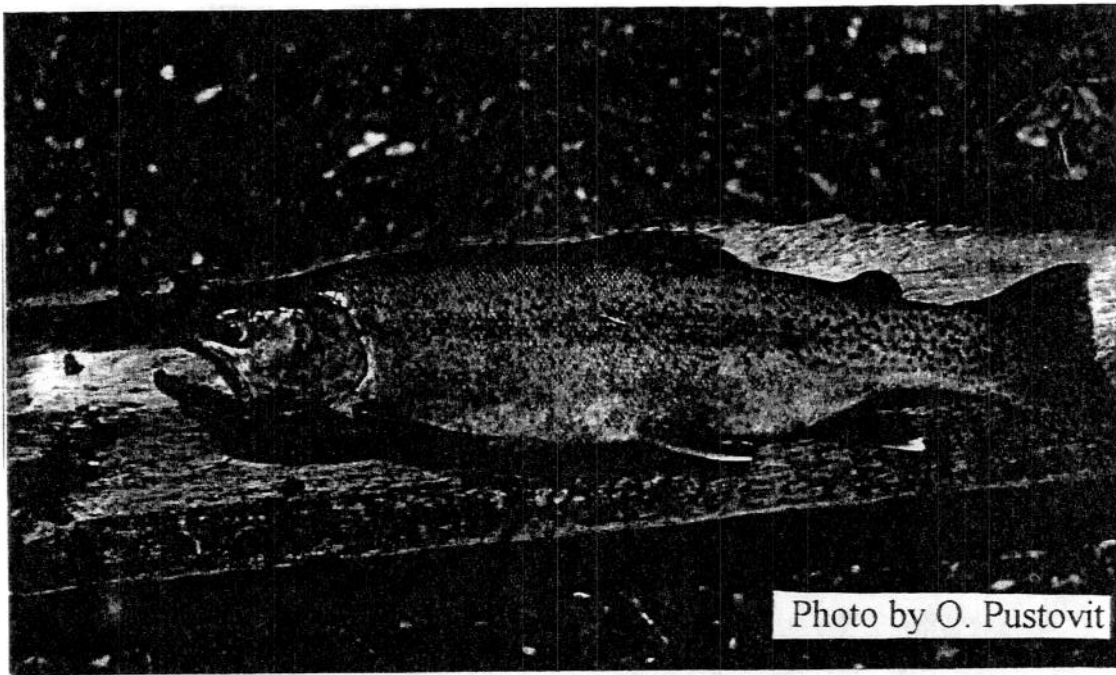


Figure 6. Description of riverine fish

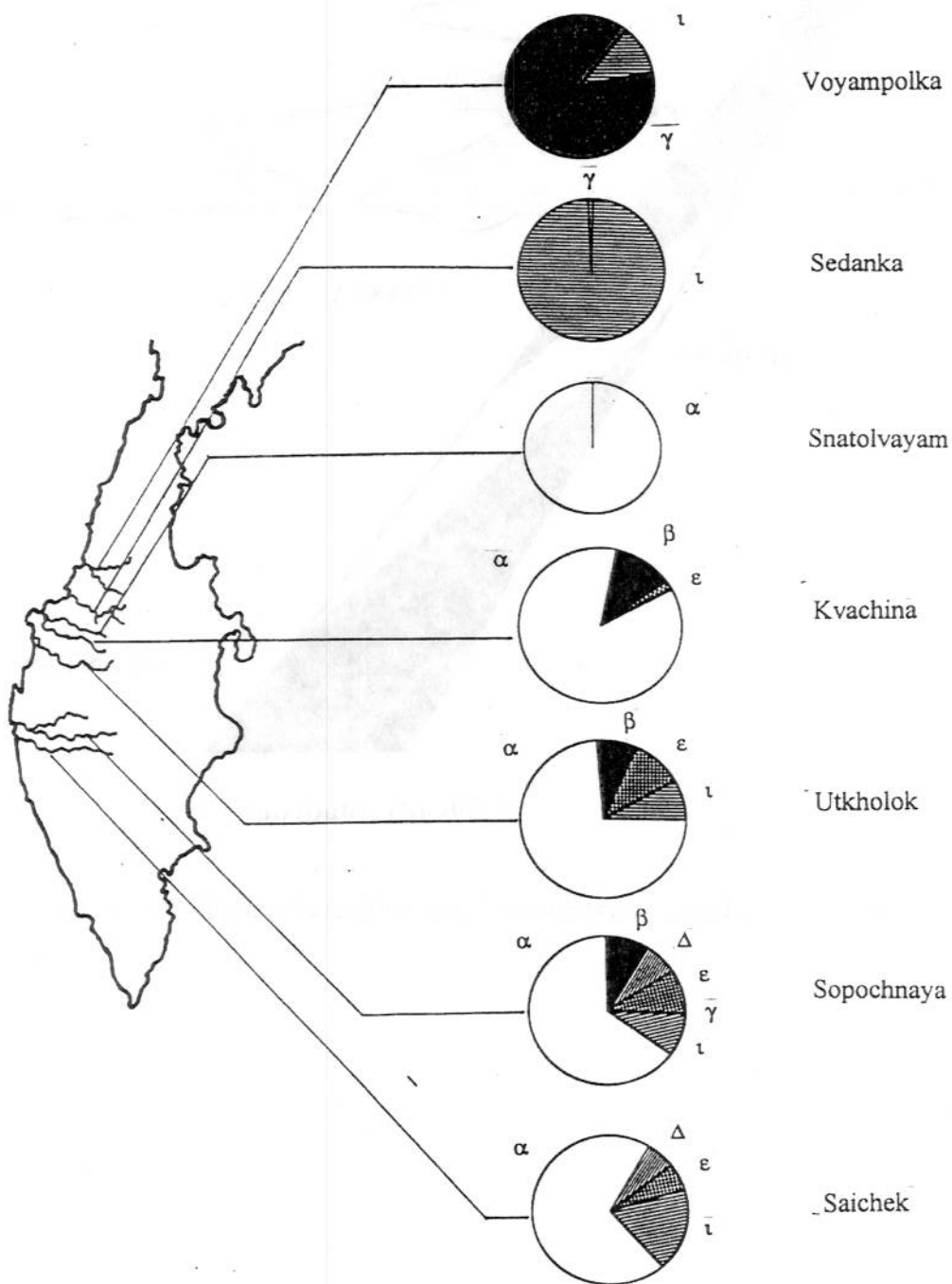


Figure 7. The ratio of phenotypes of *P. (O.) mykiss* in Western Kamchatkan rivers

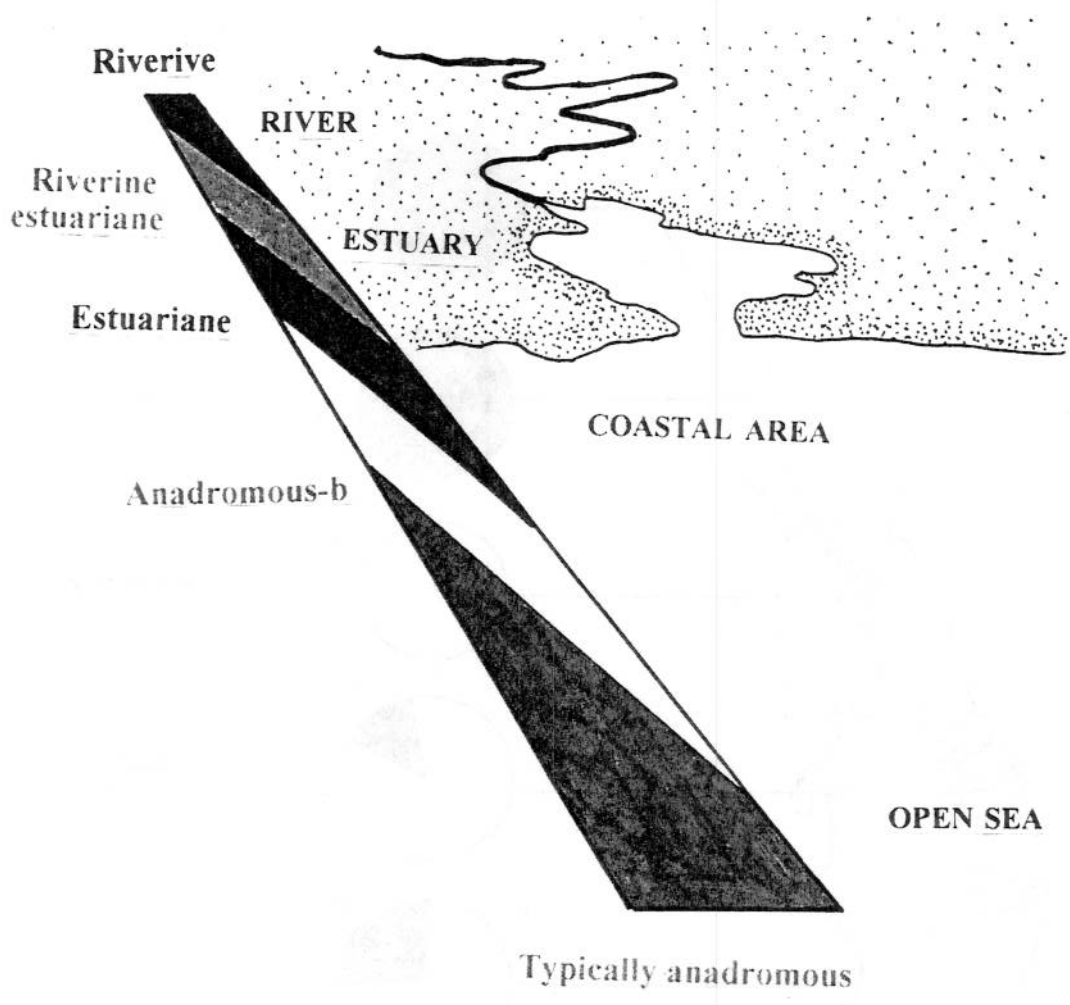


Figure 8. Continuum of life history strategies in Western Kamchatkan *P. (O.) mykiss*

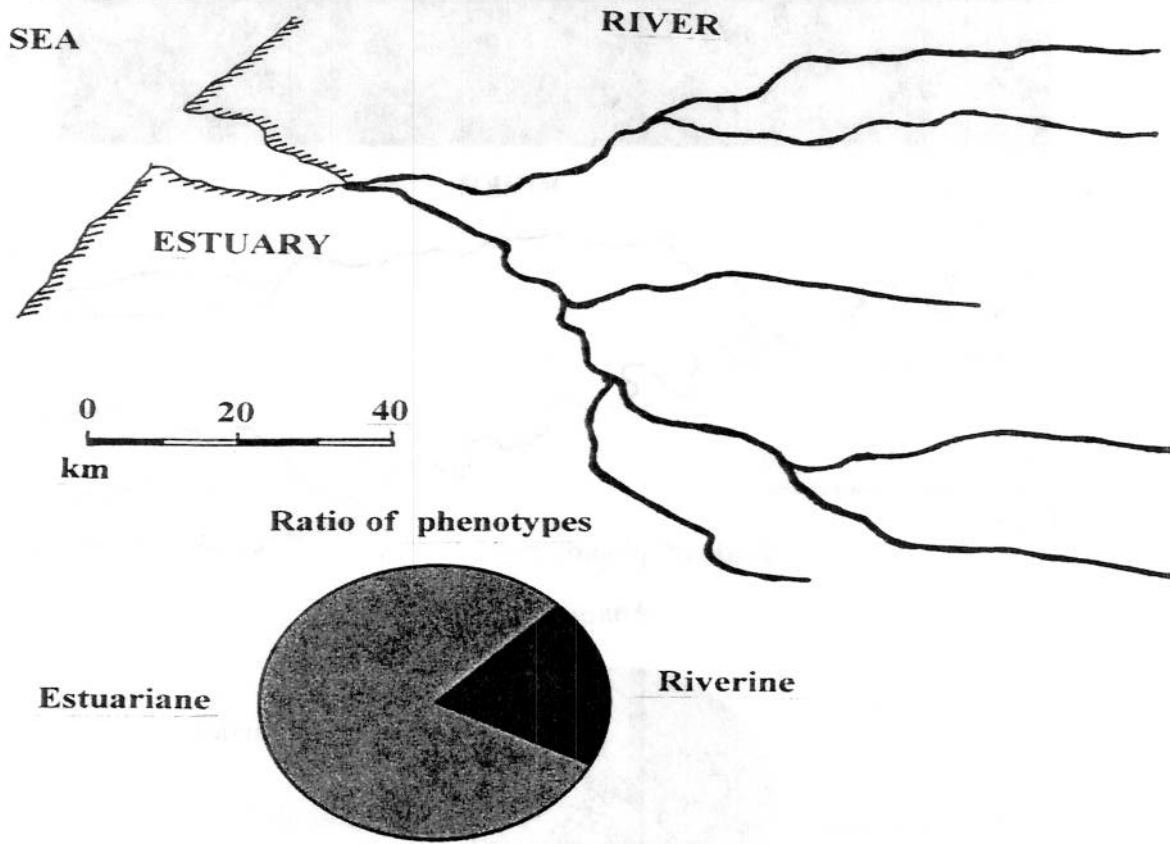


Figure 9. The geomorphology of Voyampolka River and the structure of the local *P. (O.) mykiss* population

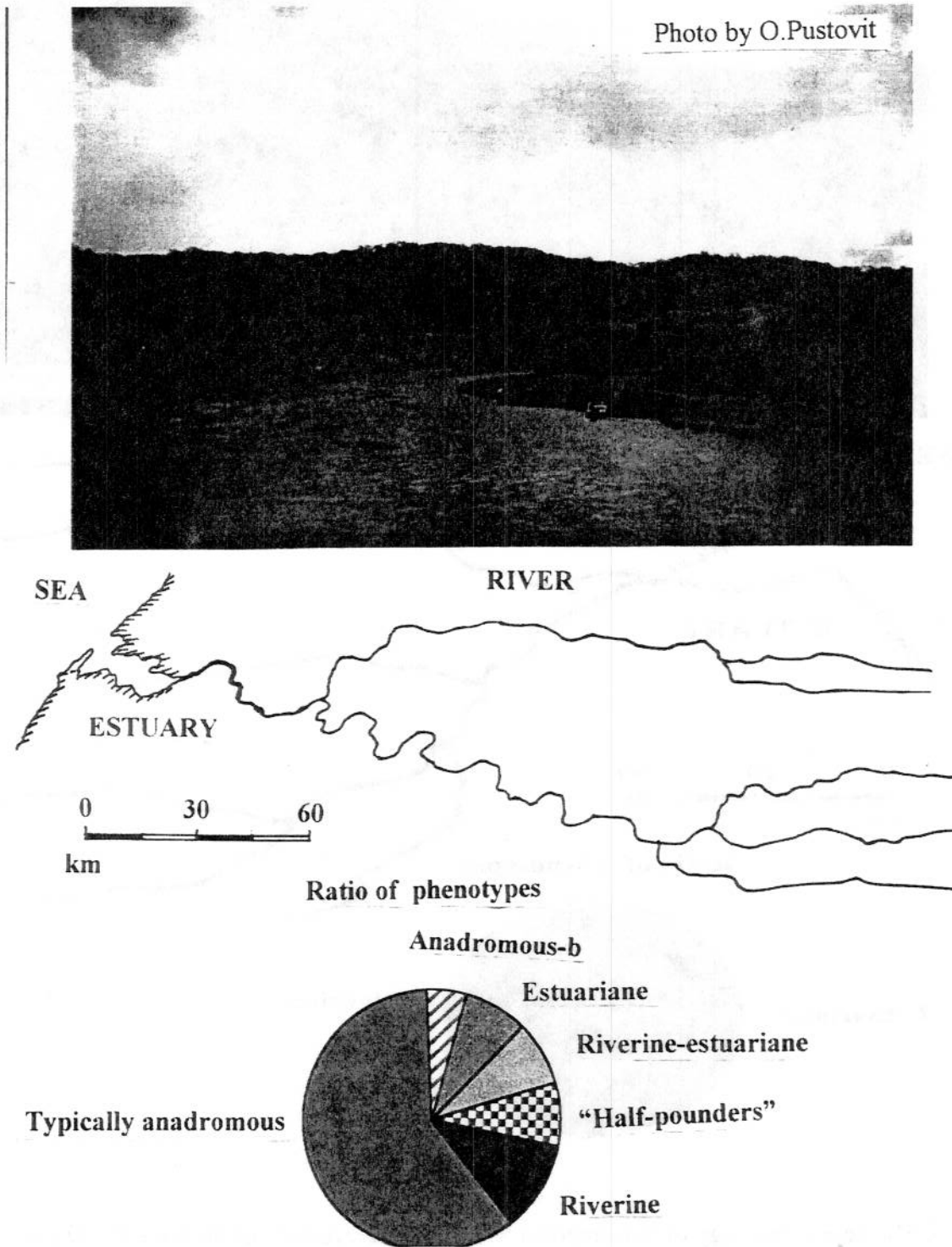


Figure 10. The geomorphology of Sopochnaya River and the structure of the local *P. (O.) mykiss* population

## **Predation on Steelhead**

Session Chair: Bob Leland, Washington Department of Fish and Wildlife

### Proposed Amendments to the Marine Mammal Protection Act to Address Pinniped Conflicts with West Coast Salmonid Populations

Joe Scordino, National Marine Fisheries Service

Populations of California sea lions and Pacific harbor seals (collectively called "pinnipeds") have been increasing on the west coast since the mid-1970s with concurrent increased conflicts with fisheries, human activities, and other marine resources. With the recent listings of salmon and steelhead populations under the Endangered Species Act (ESA), there are increased concerns about the impacts of pinniped predation on small salmonid populations and the recovery of ESA listed salmonids. The decline of the Lake Washington winter steelhead population due to California sea lion predation on returning adult steelhead as they migrate through the Ballard Locks is an example of the severity of the pinniped salmonid conflict. Because of these concerns, Congress requested in 1994 that NMFS conduct an investigation on the impacts of seals and sea lion on salmonids, as well as on west coast ecosystems, and develop recommendations to address the problems in conjunction with the Pacific States Marine Fisheries Commission and west coast States. In February 1999, NMFS submitted a Report to Congress: Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and West Coast Ecosystems that included four recommendations: 1) Implement site-specific management authority that would allow state and federal officials to lethally remove pinnipeds where necessary to protect ESA listed salmon and other marine resources; 2) Develop safe and effective non-lethal deterrent technologies; 3) Reconsider the prior MMPA authorization that allowed commercial fishers to lethally take pinnipeds as a last resort to protect their catch and gear in specific fishery areas where economic impacts are occurring; and 4) Implement the studies necessary to obtain additional information on the expanding pinniped populations and their impacts on other resources, especially ESA listed salmonids. These recommendations, several of which require amendments to the MMPA, will be considered by Congress when it considers reauthorization of the MMPA.

Juvenile Salmonid Predation and Caspian Tern Management in the Columbia River Estuary  
Ken Collis<sup>8</sup>, Daniel D. Roby\*<sup>9</sup>, David P. Craig<sup>10</sup>, Donald E. Lyons, and Brad Ryan<sup>11</sup>

The large Caspian tern colony on Rice Island consumed about 10.8 million juvenile salmonids, or approximately 11% of the out-migrating smolts that reached the Columbia River estuary in 1998. Steelhead smolts and hatchery-reared juvenile salmonids are more vulnerable to tern predation than other salmonid stocks and wild fish, respectively.

In 1999 we attempted to relocate part of the Rice Island tern colony (rivermile 21) to East Sand Island (rivermile 5). After restoration of 8 acres of nesting habitat on East Sand Island, tern decoys, audio playback systems, and selective gull removal were used to encourage terns to nest on the new site. Concurrently, silt fencing was erected on 65% of the former tern colony site on Rice Island to further encourage terns to shift to East Sand Island. Despite greatly reduced colony area, close to the same number of terns nested on Rice Island in 1999 as in 1998 (about 8,000 pairs). Rice Island terns continued to consume mostly young salmon (75% of prey). About 1,400 pairs of Caspian terns nested at the new colony site on East Sand Island, where approximately 1,600 -1,700 chicks were raised (more than twice the nesting success of terns nesting on Rice Island). Terns nesting on East Sand Island consumed 41% fewer salmonids than terns nesting on Rice Island.

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<sup>9</sup> Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331-3803, USA

<sup>10</sup> Presenter. Address also listed in appendix.

<sup>11</sup> National Marine Fisheries Service, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR 97121-0155

Interactions Between Warmwater Fish and Salmonids in Western Washington Lakes

Scott Bonar<sup>12</sup>, Bruce Bolding, Marc Divens and William Meyer, Inland Fisheries Investigations, Resource Assessment Division, Washington Department of Fish and Wildlife

The Washington State Legislature placed a surcharge on fishing licenses in 1996 to enhance warmwater fishing opportunities. The legislation stipulated that warmwater fisheries enhancement should be designed to have minimal adverse effects on native fish species, such as salmon, trout and native non-game fish. Two years ago, the Inland Fisheries Investigations Unit of the Washington Department of Fish and Wildlife started a multi-year project to investigate where interactions between warmwater fish and native species, especially salmonids, occur in Washington; evaluate the extent of this interaction where it does occur; and identify management strategies. As one part of the overall project, we are investigating the significance of warmwater fish interactions with salmonids in western Washington lakes. Hundreds of lowland western Washington lakes contain warmwater species and also serve as migration corridors and rearing areas for salmonids. In three of these lakes, we are electrofishing and netting a variety of warmwater and coldwater fish such as largemouth bass, yellow perch, black crappie, bullhead, pumpkinseed sunfish, bluegill sunfish, cutthroat trout, rainbow trout, coho salmon and prickly sculpin to evaluate the extent of predation and competition among them. To evaluate predation, we are pumping the stomachs of a sample of all of these species biweekly during the spring coho smolt migration and are continuing monthly throughout the remainder of the year. Population estimates of predators determined through mark-recapture and bioenergetics calculations of predator consumption rates will be used to estimate the number of salmonids removed annually by each species and size groups within species. This information is being compared to trap data from each lake's outlet quantifying the size of the juvenile salmonid out-migration to evaluate the significance of predation impact. Competition among warmwater fish and salmon is being evaluated by examining spatial and feeding overlap within lakes, and growth of salmonids in areas containing warmwater fish. Information from the overall project will be used by warmwater fisheries biologists and managers to help decide which types of lakes are most suited for enhancement activities, and how to manage interactions between warmwater and native fish species where they do occur.

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<sup>12</sup> Presenter. See appendix for address.

## Pinniped Predation of Listed Stocks of Salmonids on the San Lorenzo River and Scott Creek

From 1998 - Present

M.J. Weise<sup>13</sup> and J.T. Harvey, Moss Landing Marine Laboratories

Increasing numbers of Pacific harbor seal (*Phoca vitulina richardsi*) and California sea lion (*Zalophus californianus*) have caused concern that predation on salmonids (*Oncorhynchus* sp.) by pinnipeds could increase and possibly affect the recovery of listed salmonid populations. In an effort to quantify the impact of pinniped predation on listed stocks of salmonids harbor seal foraging behavior was monitored during daylight hours at the mouth of the San Lorenzo River for 792.5 hours in 1998 and 1999 and on Scott Creek for 78 hours in 1999. At the San Lorenzo River no seals were observed taking fish in 1998, but six predation events were observed in 1999, one of which was a salmonid. No predation events or pinniped foraging behaviors were observed on Scott Creek in 1999. Active seal foraging during exploratory nighttime observations on the San Lorenzo River in 1999 coupled with evidence of nocturnal dive patterns of seals in Monterey Bay indicated that further nighttime observations were warranted. On the San Lorenzo River in 2000, observations were almost exclusively at night using night vision equipment. During the first half of the 2000 season from 17 January through 6 March, 48 predation events were observed, 11 of which were salmonids. The Monterey Salmon and Trout Project operated a fish trap upstream on the San Lorenzo River and collected information on numbers of steelhead passing upstream, and percentages of fish with pinniped tooth and claw marks. Fish trap data indicated that pinniped tooth and claw marks were observed on 28.3% of the returning steelhead (*Oncorhynchus mykiss*) in 1998 and 33.3% of the steelhead in 1999. Harbor seal fecal samples were collected to describe the food habits and assess the importance and quantity of salmonids in the diet. Preliminary analysis of fish otoliths identified in fecal samples in 1998 indicated that bottom fishes and schooling fishes, such as speckled sanddab (*Citharichthys stigmaeus*; 28.8%), white croaker (*Genyonemus lineatus*; 23.1%), plainfin midshipman (*Porichthys notatus*; 20.5%), and northern anchovy (*Engraulis mordax*; 12.4%) occurred in the harbor seal diet. Salmonid species (*Oncorhynchus* sp.) occurred in 2.5% of fecal samples, but a complete analysis of all prey hard parts in fecal samples may change the relative importance of salmonids in the diet. An estimate of pinniped impacts on the salmonid run on the San Lorenzo River will be calculated following the analysis of observation data from the 2000 season and after all prey hard parts are identified in fecal samples from 1998 through 2000.

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<sup>13</sup> Presenter. See appendix for address.

The Herschel Chronicles Beyond 2000: An Update on Efforts to Control California Sea Lion  
Predation on the Lake Washington Winter Steelhead Run

Steve Jeffries and Steve Foley, Washington Department of Fish and Wildlife

One of the most widely known and intensely studied pinniped/salmonid conflicts involved predation by California sea lions on the Lake Washington winter steelhead run at the Ballard Locks (Locks) near Seattle. The number of wild steelhead consumed by sea lions between 1986 and 1992 averaged 42 to 65 percent of the total run. Uncontrolled predation was identified as a significant factor in declines in this steelhead run and although a variety of non-lethal methods were attempted, escapement was reduced from over 2,500 fish in 1983 to less than 100 fish by 1994. Based on continued declines in escapement for the Lake Washington winter steelhead run, Washington Department of Fish and Wildlife (WDFW) requested authority under Section 120 of the Marine Mammal Protection Act to lethally remove predatory sea lions from the Locks area to prevent further predation losses to this run. On January 6, 1995, the National Marine Fisheries Service (NMFS) issued WDFW authority to lethally remove individual sea lions involved in steelhead predation at the Locks. Following removal of the primary predators this run showed an initial rebound but remains severely reduced. Efforts to ensure escapement and rebuild this run including Locks operation, improved fishway passage, habitat protection and run supplementation are ongoing.

## Contributed Papers

Session Chair: Mick Jennings, Confederated Tribes of the Warm Springs  
Reservation of Oregon

### Legacy of 30+ Years of Potential Hatchery Stock Introgression on Kalama River Steelhead: Still Wild After all These Years?

Patrick L. Hulett, Washington Department of Fish and Wildlife

Allozyme genetic marking approaches were used in two long-term studies to estimate the reproductive success of non-locally derived stocks of hatchery summer and hatchery winter steelhead spawning naturally in the Kalama River. Results of the recently completed winter-run study yielded results that are qualitatively similar to those from the previously published summer-run study. On a per-spawner basis, natural production by the hatchery steelhead was substantially lower than that of the wild adults, particularly as measured to the returning adult stage of their offspring. The disparity in reproductive success was increasingly pronounced at successive (subyearling, smolt, and adult) life history stages of the offspring. These results are believed to reflect genetic differences between the wild and hatchery stocks, though some influence from environmental effects cannot be ruled out. In turn, the genetic components of the reproductive performance differentials likely include both non-local stock source and domestication selection effects.

Continued natural spawning by those non-local stocks poses both ecological and genetic risks to wild steelhead. Significant smolt production by hatchery spawners (with relatively poor adult returns) may hinder wild stock productivity through competition for limited resources in the stream. Moreover, the wild stocks are at risk of genetic introgression because of temporal and spatial overlap in spawning of hatchery and wild stocks. However, genetic analyses from recent brood years demonstrate discrete stock structure among the four spawner groups. This suggests that wild stocks have substantially resisted genetic swamping effects despite 30+ years of potential interbreeding with hatchery stocks. Specific mechanisms responsible for maintenance of stock structure are not well understood, but likely include cumulative effects of both the variable degrees of reproductive isolation between hatchery and wild fish and low rates of adult production from hatchery fish. Importantly, these results DO NOT demonstrate that genetic introgression has not occurred, only that the degree of introgression has not (as of yet) lead to homogenization of hatchery and wild stocks.

Because of continued concerns for ecological and genetic risks to the wild stocks, adults from the genetically dissimilar hatchery stocks are no longer permitted access to the principal spawning areas in the Kalama (upstream of a barrier falls and trap at Rkm 17). In addition, new research has been initiated to evaluate stock performance and the wild stock conservation merits of using locally derived wild broodstock as a source for hatchery steelhead production.

Steelhead Wild Broodstock Programs on the Kalama River: Performance and Risk Evaluations

Chris W. Wagemann, Cameron S. Sharpe, Washington Department of Fish and Wildlife/Kalama Research Team

WDFW is evaluating the use of wild steelhead as broodstock at the Kalama Hatchery Complex (SW Washington) as part of a multi-year study. Two projects have begun: (1) a winter-run project to compare performance of wild broodstocks in the hatchery to traditional domesticated broodstocks, and (2) a summer-run project to compare the natural reproductive performance of wild broodstock reared in the hatchery to the performance of their wild-reared counterparts. Key near-term objectives include: (1) release high quality one-year smolts, (2) monitor rearing and migration performance, and (3) develop genetic monitoring protocols. Fecundity of broodstock and survival, growth, and outmigration characteristics of their offspring were compared among 1998 BY winter-run groups. Similar data are being collected from 1999 BY winter- and summer-run fish. Ultimately, smolt to adult return for SR and WR fish and, especially, spawning success of adults from SR smolt plants will be compared to that of wild reared counterparts for three brood years.

Allozymic variability and genetic divergence in Kamchatka *mykiss* (*Parasalmo* (*Oncorhynchus*) *mykiss*) in Western Kamchatka region.

Sergey D. Pavlov, Moscow State University

*Brief biochemical results*

Genetic variation was analyzed in 10 populations of Kamchatka *mykiss* by protein electrophoresis. Three of 44 loci (sSOD-1 \*, LDH-C \*, EST-1\*) were polymorphic. Rare alleles occurred rarely in sAAT-1,2 \*, LDH-A2 \*, EST-5 \*, IDDH-1,2 \*, sMDH-1,2\* loci. Previous analysis of mitochondrial DNA at D-loop and cytochrome-B sites found no differences between the populations.

*Main points*

- *P. (O) mykiss* species is represented by genetically separated wild populations composed by unique alleles and form a distinct group within the Kamchatka part of its range.
- The eastern Kamchatka population and western Kamchatka populations of *mykiss* can be separated according to heterozygosity levels and polymorphic loci.
- The gene flow between North American and Kamchatka populations is mainly caused by straying in sea-running stocks of the American “coastal” form of steelhead coming to the Ochotskoe Sea.
- The level of a genetic divergence of the Kamchatka populations is low ( $D|0.0002-0.0275|$ ). The estimations of an average heterozygosity are insignificant ( $Hs |0.011-0.037|$ ).
- Differences between the tested American “coastal” form and Kamchatkian populations are insignificant ( $D|0.0109-0.0241|$ ). At the same time, the isolation of the Kamchatkian group from the American “inland” form has another level ( $D|0.1973-0.2367|$ ).

Pacific trouts have been studied for more than 170 years. Nevertheless, the taxonomic status of different forms and of the group as a whole still remains debatable. The reasons are the complex genetic structure of this group and high diversity of phenotypes. While North American populations have been studied extensively, the Kamchatkan forms have received little attention. It was considered that two forms and phenotypes represented the Kamchatka group. One is freshwater mykizha similar to the typical rainbow trout inhabiting mostly on the East coast. The other one - “siemga” occurs in West coast of Kamchatka and is analogous to American steelhead. The last investigations and the work within a KSP program show that phenotypic and ecological diversity of Kamchatkan *mykiss* is much higher than was believed before.

At the same time, genetic peculiarities and divergence of the Kamchatkan population have not been studied enough. Most studies conducted on a karyology, and diversity in mitochondrial and nuclear DNA of the Kamchatkan group show only genetic similarities between Kamchatkan and North American forms. Presently, investigations of diversity in enzyme loci are more successful for interpopulation comparisons in Kamchatkan trout. But, as a whole, there is not enough research of genetic features and divergence of populations inhabiting the Kamchatka peninsula.

The purpose of this work was to study allozymic variability and genetic divergence in a number of the West Kamchatka populations of the *Parasalmo* genus. Samples were taken in 1995-1998 from wild populations of Kamchatka *mykiss* inhabiting the western coast of the

peninsula. Data obtained earlier by us were also included. Samples of liver, muscles and eyes of every individual were frozen in liquid nitrogen and transported to the freezer. The samples were tested by disk-electrophoresis in polyacrylamide gel. We used standard techniques of protein separation and stains.

#### *What data we received*

Eighteen (18) enzyme systems coded by 44 gene loci were tested (Table 1). Using a mixture of alcohols we detected a faster locus ADH-2\* which was not described earlier. Much lower staining expression at this locus was found by us in other salmonid species when a standard staining protocol was used. We believe this locus exists in North American *mykiss* populations also, but we have not seen it in any literature. The ESTD system does not stain well in liver, but stains in muscle and is recognized as the ESTD-2\* locus in other salmonids. Variations were observed at the mMEP-1\* and sMEP-2\* loci, but their genetic interpretation was not possible so these two loci were excluded from the analyses. Those cases where a few individuals had variation that was difficult to score we marked with a "question mark".

Thirty-seven (37) genetic loci were monomorphic. Genetic variants were identified in 8 loci. There were alternative alleles of high frequency in LDH-C \*, SOD-1 \*, EST-1\* loci, and rare alleles in LDH-A2 \*, EST-5 \*, IDDH-1,2\* loci (Tables 1, 2).

Most samples were close to Hardy-Weinberg genotypic distributions in polymorphic loci and had insignificant differences in allele frequencies within one pool. As a result all balanced samples of one pool were combined according to the years. The sample taken from Snatolvayam River was not balanced on distribution in the sSOD-1 \*locus. The sample from the Kvachina River had a lack of heterozygotes at the EST-1\* locus. Nevertheless, we used both populations in our analysis.

#### *Brief description of rivers and the populations.*

The Vayampolka River basin (Figure 1) is formed by two tributaries of approximately the same length (about 200 km) with a common mouth. The river has an extended estuarine zone. The *mykiss* population is represented by the estuarine-river form and differs from other Kamchatka populations of *mykiss* by its structure and some morphological parameters. It is also the most northern of all populations studied at the Kamchatka western coast. This fact and earlier described features of *mykiss* from the Vayampolka River as well correlated with the lowest frequency of the main allele in LDH-C\* locus and high estimations of the  $X^2$ -test regarding the locus when compared to other populations (Table 3).

Sedanka River is one of the tributaries of the Tigil River that is a large river system with a rather complex basin structure. Previous work found high phenotypic diversity in this river. Some individuals had basibranchiostegia teeth, a redband and a cutthroat mark, which are observed in American redband and cutthroat trout. It provides an opportunity to suppose the presence of other forms of trout in the Kamchatka region. Pooled samples included all these phenotypes and had a balanced distribution at polymorphic loci. The rare LDH-A2\*<sub>76</sub> allele was found in this pool and also widely occurs on the American coast. Nevertheless, interpopulation comparisons of western Kamchatka rivers showed that *mykiss* from Sedanka River did not "fall" from the range of samples and it significantly differed only from populations of Vayampolka, Snatolvayam, Ukhtolok, Sopochnaya rivers (Table 3).

Snatolvayam and Kvatchina are small tundra rivers (55 km and 90 km, respectively) with a common estuarine zone. The anadromous populations in these rivers have small phenotypic differences. A lack of heterozygotes was found at different loci from each river: at the sSOD-1\* locus for the Snatolvayam River, and at the EST-1\* locus for the Kvatchina River (Table 2). Taking into account geographic parameters of rivers, a connection between the lack of heterozygotes and heterogeneity of samples taken from each river is hardly probable. The samples are characterized by high difference estimations (Table 3) regarding the third LDH-C\* polymorphic locus. It suggests a separation of populations from each other. The Snatolvayam population is also genetically separated from *mykiss* inhabiting Sopochnaya and Saichek rivers. The population from Kvatchina River is separated from *mykiss* from Ukhtolok, Sopochnaya and Saichek rivers.

Ukhtolok River is the closest to Kvachina and Snatovayam rivers. It is 140 km long, with a high flow fluctuation. *Mykiss* are characterized by a complicated population structure consisting of four different ecological forms. Combined samples from the Ukhtolok River include different ecological forms and has Hardy-Weinberg balanced genotypic distribution at polymorphic loci. The population differs from all studied rivers by allele frequencies at polymorphic loci. One rare heterozygote in an anadromous form showed presence of the LDH-A2\*<sub>76</sub> "American" allele in the population.

Sopochnaya River is a large western Kamchatka river that is about 250 km long, up to 200 m wide in downstream reaches and greatly branched upstream. The population is composed of numerous complex ecotypes. As for the above-mentioned cases, the period of time which adults spend in salt water is the basic criteria for population subdivision. A mixed sample including different forms is balanced at most polymorphic loci (Table 2). Nevertheless, the genetic analysis of each form in this river basin is necessary. A low quantity of heterozygotes at the EST-1\* locus shows that heterogeneity of our samples is possible. When compared with other western Kamchatka populations, *mykiss* from Sopochnaya River demonstrates the most significant differences at all polymorphic loci. A unique allele in IDDH-1,2\* isoloci were found in this population, although the small size of samples and low frequency of the allele does not exclude its presence in other Kamchatka rivers.

Saichek River is a tundra river 130 km long with one main stream and a number of smaller upstream tributaries. Its mouth is situated 30-35 km to the south of the Sopochnaya mouth. The *mykiss* population is represented by anadromous, coastal, river-estuarine and resident ecological types. The sample size from 1997 did not enable significant differences to be detected between types. Combined samples are balanced at all polymorphic loci. The population from Saichek river is also highly separated from other Kamchatkan populations. Sopochnaya and Saichek populations strongly differ in allele frequency at the EST-1\* locus when comparing in pairs. ( $\chi^2 = 13.36$ )

Utka River is a small tundra river of about 100 km long. *Mykiss* inhabiting the river are represented by resident and anadromous forms with a common genetic pool. This is one of the more southern *mykiss* populations in western Kamchatka. It is characterized by polymorphism in sMDH-B1,2\* loci, no variation in LDH-C\*, EST-1\* loci, the lowest frequency of main allele in the sSOD-1\* locus (0.520).

Kishimshina River is a middle stream tributary to Kamchatka River. The *mykiss* population spawns in the Kishimshina River and spends most time in the middle stream of Kamchatka River. It is isolated from western Kamchatka populations and has unique alleles in sAAT-1,2\* isoloci in

the Kamchatka area. Identified genetic variability in ESTD-2\* locus has not been confirmed genetically.

### Discussion

Most of the populations studied were genetically unique; they have reliable differences in allelic frequencies at identified polymorphic loci. It should be especially noted that anadromous populations in adjacent small rivers, such as Snatolvayam and Kvachina, Sopochnaya and Saichek are genetically separated. These facts suggest a high level of homing in Kamchatka populations. It is known that American forms of *mykiss* are characterized by medium indices of straying (3-23%) among salmons. On the basis of our data it is possible to suggest that western Kamchatka *mykizha* is characterized by lower estimations for straying.

A rare *LDH-A2*<sub>76</sub> allele found in Tigil and Ukhtolok basins is an "American" one and it confirms a hypothesis of its presence in the Kamchatka region. In the seventies American populations of *P. (O.) mykiss* were divided into inland and coastal forms (groups) according to differences in *LDH-A2*\* (*LDH-4*) and *sSOD-1*\* (*SOD*) polymorphic loci. According to Okazaki *LDH-A2*<sub>76</sub> occurs at low frequencies in the feeding stock of the coastal group which come to the Okhotskoe sea. *sMDH-B1,2*\*<sub>70</sub> allele, described in an Utka river population, also occurs in the American coastal form and confirms a limited gene flow between American and western Kamchatka populations.

A *LDH-C*\*<sub>50</sub> alternative allele found by the authors is typical for most populations studied in western Kamchatka rivers. The allele did not occur in other natural populations of Kamchatka. It also was not found in an "American" steelhead caught in Okhotskoe Sea. Taking into account the presence of *LDH-A2*<sub>76</sub> и *sMDH-B1,2*\*<sub>70</sub> alleles in the western Kamchatka coast, it is possible to conclude that gene exchange between western Kamchatka and American populations takes place mainly by straying of a feeding group of the coastal form entering in to the Okhotskoe Sea. In cases where the sample size is large enough the polymorphism at the *LDH-C*\* locus can be used as a geographical marker of Kamchatka populations of *Parasalmo* genus.

*IDDH-1,2*\*<sub>140</sub> and *EST-5*\*<sub>115</sub> alleles were not described earlier in the Kamchatka region. They are also not described for a great amount of populations studied on the North America coast. Most likely, these alleles are unique for Kamchatka.

Eastern Kamchatka *mykiss* from the Kamchatka river basin are characterized by a polymorphism at the *sAAT-1,2*\* loci. These loci are monomorphic in all western Kamchatka populations studied. At the same time many populations of steelhead have the same alternative alleles at this loci with a high frequency. So this points to the necessity of collecting samples in unstudied populations of *mykizha* at the eastern coast of Kamchatka.

### Comparison of Kamchatka and North America populations of *P. mykiss*

To assess a genetic divergence, we compared data on *mykizha* populations from the Kamchatka peninsula with data on natural steelhead and rainbow trout from Skykomish and Dry Creek rivers (Table 4). The steelhead population from the Skykomish river is related to the coastal group, and the rainbow trout population from Dry Creek (Columbia river basin) is related to the inland group. When comparing the populations special attention was paid to similarity of techniques and sample size. Monomorphic and not analyzed loci in populations were excluded. So, 10 enzymatic loci coded by 22 alleles were used for a final analysis. Calculated genetic distances (Table 5) formed the basis of the matrix for cluster analysis (Figure 2).

The level of genetic divergence of Kamchatka populations is extremely low ( $D|0.0002-0.0275|$ ). This partly explains a low correlation between dendrograms and geographical localization of samples. The position of eastern Kamchatka populations (Figure 2) can be explained by an absence of data on analyzed loci and also by the inability to detect low variation of sAAT-1,2\* alleles present in Kamchatka river basin using a NTSYS program.

According to the data obtained, the inland form of rainbow trout is the most isolated from Kamchatka populations ( $D|0.1973-0.2386|$ ) which confirms results of previous investigations.

It is interesting to note that the level of difference of the North America coastal form from western Kamchatka populations is such a low one ( $D|0.0109-0.0241|$ ) and that it is related to the same clusters (Figure 2, Table 5). At the same time isolation of the American inland form is another level (Table 4). This confirms the phylogenetic similarity of Kamchatka *mykiss* and American steelhead, revealed with the help of caryology, protein electrophoresis, and analysis of mitochondrial and nuclear DNA.

According to our data the average heterozygosity level in Kamchatka populations is low and fluctuations within populations are not so significant (Table 6). The lowest level is found in eastern Kamchatka *mykizha* (Kishimshina river). It is higher for western Kamchatka populations. The general value for Kamchatka is also low. These values are substantially higher for North American *mykiss* at the allozymic loci. Allele diversity for Kamchatkan and North American populations has a same character of comparison. Such a substantial difference is partly explained by large sample sizes and a wider range of methods used by American researchers. However comparison of polymorphic loci by the same techniques show that a level of genetic diversity in Kamchatka populations is still lower than those in American ones. Using a tris-glycin buffer system for separation, polymorphisms in 12 loci were found in different American steelhead populations while there were 7 known polymorphic loci in Kamchatka *mykizha*.

In conclusion the following can be noted:

1. *P.(O.) mykiss* species in Kamchatka is represented by natural populations; a genetic separation can be proven for most of them. The general mode of allele frequency distribution shows a high level of homing in natural populations. Gene flow between North American and Western Kamchatka *mykiss* is mainly caused by straying in seafeeding stocks of the American coastal form.
2. Presence of *LDH-C\*<sub>50</sub>*, *IDDH-1,2\*<sub>140</sub>* and *EST-5\*<sub>115</sub>* alleles which are specific for the Kamchatka region enable us to consider Kamchatka populations as a genetically distinct group of *Parasalmo mykiss*. Some polymorphic loci can be used as geographic population markers.
3. The eastern Kamchatka population (basin of a largest Kamchatka river) and western Kamchatka populations of *mikizha* can be distinguished according to a heterozygosity level and polymorphic loci. On the whole there is a low level of genetic diversity and divergence of the Kamchatka group.
4. Unique features at the population-genetic level, the presence of specific alleles at protein loci and also the different level of genetic diversity between Kamchatkan and American groups of *P (O). mykiss* show the necessity of saving the natural gene pool of Kamchatka *mykiss*.

Table 1. Tested enzyme systems and loci in Kamchatkan populations of <i>Parasalmo (Oncorhynchus) mykiss</i> (1995-1998 гг.)				
Enzyme or protein name	Enzyme number	loci	Tested Tissues	Alleles
Aspartate aminotransferase	2.6.1.1.	mAAT-1*	m, l	100?
		sAAT-1,2*	m	100, 115**
		sAAT-3*	e	100
Alcohol dehydrogenase	1.1.1.1.	ADH-1*	L	100
		ADH-2*	L	100
Oktanol dehydrogenase	1.1.1.73	ODH*	L	100
		Ck-1*	M	100
Creatine kinase	2.7.3.2	Ck-2*	M	100 ?
		Ck-3*	M	100
		Diaforase	-.-.-.	DIA-1*
Esterase	.1.1.-.	DIA-2*	M	100
		EST-1*	l, m, e	100, 90
		EST-2*	l, m, e	100
		EST-3*	l, m, e	100
		EST-4*	l, m, e	100
Esterase-D	3.1.-.-.	EST-5*	l, m, e	100, 115?
		ESTD-1*	l	100?
		ESTD-2*	l, m	100
Formaldegide dehydrogenase	1.2.1.1.	FDH*	m	100
Fymarase hydratase	4.2.1.2.	FH*	m	100
Superoxide dismutase	1.15.1.1	mSOD-1*	m, e	100 ?
		sSOD-1*	l, m, e	100, 73**
		sSOD-2*	m, l	100
L-iditol dehydrogenase	1.1.1.14.	IDDH-1,2*	l	100, 140
Phosphogluconate dehydrogenase	1.1.1.44.	PGDH	m	100
		GPI-A*	m, e	100
Glucoso-6-phosphate isomerase	5.3.1.9.	GPI-B1*	m	100
		GPI-B2*	m	100 ?
Glicerol-3-phosphate dehydrogenase	1.2.1.12.	G3PDH*	m	100
		LDH-A1*	m	100
		LDH-A2*	m	100,76
		LDH-B1*	e	100 ?
L-Lactate dehydrogenase	1.1.1.27.	LDH-B2*	l	100
		LDH-C*	e	100, 50
		mMDH-x*	m, l, e	100
Malate dehydrogenase	1.1.1.37.	sMDH-A1,2*	l, m, e	100
		sMDH-B1,2*	m, l	100, 70**
Malicenzyme (NADP*)	1.1.1.40.	sMEP-1*	l	100
Phosphoglucomutase	5.4.2.2	PGM-1*	m	100
		PGM-2*	m	100

m - muscle; l - liver; e - eye. The nomination of tissues is given by the degree of activity of loci stain.

\*\* - alternative allele is detected in other Kamchatka populations, or it was described earlier for as (Osinov, Pavlov, 1993).

Table 2. Genotype distributions and frequencies of the basic alleles at polymorphic loci of Kamchatkan populations of *Parasalmo (Oncorhynchus) mykiss*.

Location, year, Sample	Locus	Frequency basic allele(100)	Genotypes SS SF FF (ss) (sf) (ff)	N	$\chi^2$	p
R. Vayampolka, 1997; Vayam.	LDH-C*	0.760	2 7 14 (1.2) (8.6) (13.2)	23	0.49	>0.05
R. Sedanka, 1998; Sed.		0.983	0 1 29 (0) (1) (29)	30	-	-
R. Snatolvayam, 1995-98; Snat.		0.844	1 7 21 (0.7) (7.6) (20.7)	29	0.01	>0.05
R. Kvachina 1995-98; Kvach.		0.983	0 1 30 (0) (1) (31)	31	-	-
R. Utcholak 1995-98; Utchol.		0.900	0 8 32 (0.4) (7.2) (32.4)	40	0.10	>0.05
R. Sopochnaya, 1996-97; Sop.		0.991	0 1 53 (0) (1) (53)	54	-	-
R. Saichek, 1997; Saich.		0.954	0 4 40 (0.1) (3.8) (40.1)	44	0.20	>0.05
R. Sedanka, 1998; Sed	LDH-A2*	0.983	0 1 29 (0) (1) (29)	30	-	-
R. Utcholak, 1995-98; Utchol.		0.975	0 1 39 (0) (1) (40)	40	-	-
R. Vayampolka, 1997; Vayam.	sSOD-1*	0.717	0 13 10 (1.7) (9.6) (11.7)	23	2.45	>0.05
R. Sedanka, 1998; Sed.		0.850	1 7 22 (0.6) (7.8) (21.6)	30	0.07	>0.05
R. Snatolvayam, 1995-98; Snat.		0.758	4 6 19 (1.6) (10.8) (16.6)	29	5.08	<0.05
R. Kvachina, 1995-98; Kvach.		0.806	2 8 21 (1.1) (9.8) (20.1)	31	0.65	>0.05
R. Utcholak, 1995-98; Utchol.		0.825	1 12 27 (1.2) (11.7) (27.1)	40	0.25	>0.05
R. Sopochnaya, 1996-97; Sop.		0.565	8 31 15 (10.1) (26.8) (17.1)	54	1.12	>0.05
R. Saichek, 1997; Saich.		0.590	7 22 15 (7.3) (21.5) (15.2)	44	0.01	>0.05
R. Vayampolka, 1997; Vayam.	EST-1*	0.565	4 12 7 (4.2) (11.6) (7.2)	23	0.03	>0.05
R. Sedanka, 1998; Sed.		0.466	8 16 6 (8.4) (15.2) (6.4)	30	0.08	>0.05
R. Snatolvayam, 1995-98; Snat.		0.517	8 12 9 (6.7) (14.7) (7.6)	29	0.74	>0.05
R. Kvachina, 1995-98; Kvach.		0.500	11 9 11 (7.6) (15.8) (7.6)	31	5.34	<0.05
R. Utcholak, 1995-98; Utchol.		0.600	7 18 15 (6.5) (19.5) (15.0)	40	0.09	>0.05
R. Sopochnaya, 1996-97; Sop.		0.722	7 16 31 (4.1) (21.9) (28.0)	54	3.44	>0.05
R. Saichek, 1997; Saich.		0.465	15 17 12 (12.4) (22.2) (9.4)	44	2.13	>0.05
R. Vayampolka, 1997; Vayam.	EST-5*	0.978	22 1 0 (22.0) (1.0) (0.0)	23	-	-
R. Snatolvayam, 1995-98; Snat.		0.983	28 1 0 (28.0) (1.0) (0.0)	29	-	-
R. Sopochnaya, 1996-97; Sop.		0.981	52 2 0 (52.0) (2.0) (0.0)	54	0.00	>0.05
R. Sopochnaya, 1996-97; Sop.	IDDH-1,2*	0.981	52 2 0 (52.0) (2.0) (0.0)	54	0.00	>0.05

Table 3. Estimation of homogeneity of sample at each of three highly polymorphic loci.									
Loci	Sample*	Vayam	Sed	Snat	Kvach	Utchol	Sop	Saich	Utk
LDH-C*	Vayam		0.002	0.334	0.001	0.031	0.001	0.003	0.003
	Sed	<b>12.83</b>		0.006	<b>1.000</b>	0.081	<b>1.000</b>	0.398	<b>1.000</b>
	Snat	1.17	<b>7.29</b>		0.008	0.444	0.003	0.041	0.003
	Kvach	<b>13.30</b>	0.00	<b>7.58</b>		0.068	<b>1.000</b>	0.416	<b>1.000</b>
	Utchol	<b>4.41</b>	<b>3.96</b>	0.95	<b>4.14</b>		0.006	0.201	0.050
	Sop	<b>23.73</b>	0.17	<b>14.19</b>	0.15	<b>8.30</b>		0.160	<b>1.000</b>
	Saich	<b>11.34</b>	0.97	<b>5.19</b>	0.97	1.88	2.56		0.311
	Utk	<b>10.96</b>	0.67	<b>10.86</b>	0.65	<b>4.29</b>	0.37	1.88	
SSOD-1*	Vayam		0.131	<b>0.697</b>	0.394	0.175	0.106	0.171	0.078
	Sed	2.78		0.250	<b>0.647</b>	<b>0.794</b>	0.001	0.001	0.001
	Snat	0.22	1.56		<b>0.676</b>	0.380	0.021	0.052	0.025
	Kvach	1.18	0.41	0.40		<b>0.820</b>	0.001	0.006	0.001
	Utchol	2.01	0.16	0.91	0.08		0.001	0.001	<b>0.712</b>
	Sop	3.16	<b>14.12</b>	<b>6.09</b>	<b>10.15</b>	<b>14.19</b>		<b>0.754</b>	<b>0.611</b>
	Saich	2.08	<b>11.32</b>	<b>4.37</b>	<b>7.77</b>	<b>10.99</b>	0.14		
	Utk	3.40	<b>12.57</b>	<b>5.79</b>	<b>9.10</b>	<b>12.04</b>	0.18	0.48	
EST-1*	Vayam		0.352	<b>0.695</b>	<b>0.564</b>	<b>0.710</b>	0.064	0.370	0.000
	Sed	1.01		<b>0.731</b>	<b>0.751</b>	0.124	0.005	<b>1.000</b>	0.000
	Snat	0.24	0.30		<b>0.834</b>	0.375	0.012	<b>0.635</b>	0.000
	Kvach	0.45	0.13	0.03		0.297	0.009	<b>0.750</b>	0.000
	Utchol	0.15	2.46	0.94	1.42		0.010	0.094	0.000
	Sop	3.67	<b>10.82</b>	<b>6.97</b>	<b>8.45</b>	3.11		0.001	0.000
	Saich	1.19	0.00	0.37	0.17	3.02	<b>13.36</b>		0.000
	Utk	<b>24.46</b>	<b>31.37</b>	<b>27.04</b>	<b>28.73</b>	<b>21.82</b>	<b>13.94</b>	<b>33.76</b>	

Utk- sample from Utkra river [Osinov, Pavlov, 1993]. Other samples are as in table 1.

Upper corner - the average probability of homogeneity of population (test of Monte-Carlo) on 95 confidence level ( bold numerals are more than 0.5); lower corner - the chi square test (bold numerals are more than 3.72).

Table 4. Frequencies of alleles of polymorphic loci in compared samples of Kamchatka and North America.

Allele	Kamchatka									America	
	Vayam	Sed	Snat	Kvach	Utch	Sop	Saich	Utka	Kamch	Coastal	Inland
LDH-C*a	0.760	0.983	0.844	0.983	0.900	0.991	0.954	1.0	1.0	1.0	1.0
LDH-C*b	0.240	0.017	0.156	0.007	0.100	0.009	0.046	0.0	0.0	0.0	0.0
SSOD-1*a	0.717	0.850	0.758	0.806	0.825	0.565	0.590	0.480	0.784	0.660	0.981
sSOD-1*b	0.283	0.150	0.242	0.194	0.175	0.435	0.410	0.520	0.216	0.340	0.019
SMDH-b1*a	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.989	1.0	0.957	0.962
sMDH-b1*b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.026	0.038
sMDH-b1*b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.0	0.016	0.000
sMDH-A1*a	1.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.989	1.0
sMDH-A1*b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0
sMDH-A1*c	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.005	0.0
LDH-A2*a	1.0	0.983	1.0	1.0	0.975	1.0	1.0	1.0	1.0	1.0	1.0
LDH-A2*b	0.0	0.007	0.0	0.0	0.025	0.0	0.0	0.0	0.0	0.0	0.0
PGM-2*a	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.981
PGM-2*b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.019
LDH-B2*a	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.915	0.365
LDH-B2*b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.085	0.635
GPI-B2*a	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.989	1.0
GPI-B2*b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.011	0.0
sMEP-1*a	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.798	1.0
sMEP-1*b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.202	0.0
IDDH-1*a	1.0	1.0	1.0	1.0	1.0	0.981	1.0	1.0	1.0	1.0	1.0
IDDH-1*b	0.0	0.0	0.0	0.0	0.0	0.019	0.0	0.0	0.0	0.0	0.0
Source of data	Ours	Ours	Ours	Ours	Ours	Ours	Ours	Osinov, Pavlov 1993	Osinov, Pavlov 1993	Phelps et al., 1994	Currens 1997

\* Kamch- sample from Kishimshina river [Osinov, Pavlov, 1993]; Other samples – as in table 1-3.

Table 5. Indices of genetic distances (Nei, 1972) between samples *P.mykiss*, estimated by 10 loci.

	1	2	3	4	5	6	7	8	9	10	11
1. Voyam	0										
2. Sed	0.0128	0									
3. Snat	0.0017	0.0051	0								
4. Kvach	0.0109	0.0004	0.0040	0							
5. Utchol	0.0063	0.0013	0.0016	0.0014	0						
6. Sop	0.0159	0.0161	0.0122	0.0116	0.0157	0					
7. Saich	0.0111	0.0134	0.0083	0.0093	0.0120	0.0005	0				
8. Utka	0.0236	0.0275	0.0210	0.0213	0.0266	0.0016	0.0029	0			
9. Kamch	0.0118	0.0009	0.0046	0.0002	0.0023	0.0095	0.0077	0.0184	0		
10. Coastal	0.0241	0.0152	0.0172	0.0123	0.0173	0.0113	0.0109	0.0160	0.0109	0	
11. Inland	0.2367	0.1973	0.2193	0.2015	0.2066	0.2378	0.2386	0.2622	0.2033	0.2205	0

Table 6. Average heterozygosity level and allelic diversity in Kamchatkan and North American populations of *mykiss*.

Kamchatka populations	$H_s   0.011-0.037  $
The lowest level (it is found in eastern Kamchatka <i>mykiss</i> )	$H_s = 0.011$
Western Kamchatka populations	$H_s   0.021-0.037  $
General value for Kamchatka	$H_t = 0.025$
Allele diversity in Kamchatka populations	$n_e   1.06-1.13  $
North American <i>mykiss</i>	$H_s   0.06-0.5  $
Allele diversity in North American populations. (according to Hodges, Barnhart, 1989; Phelps et al., 1994; Currens, 1997).	$n_e   1.2-1.8  $

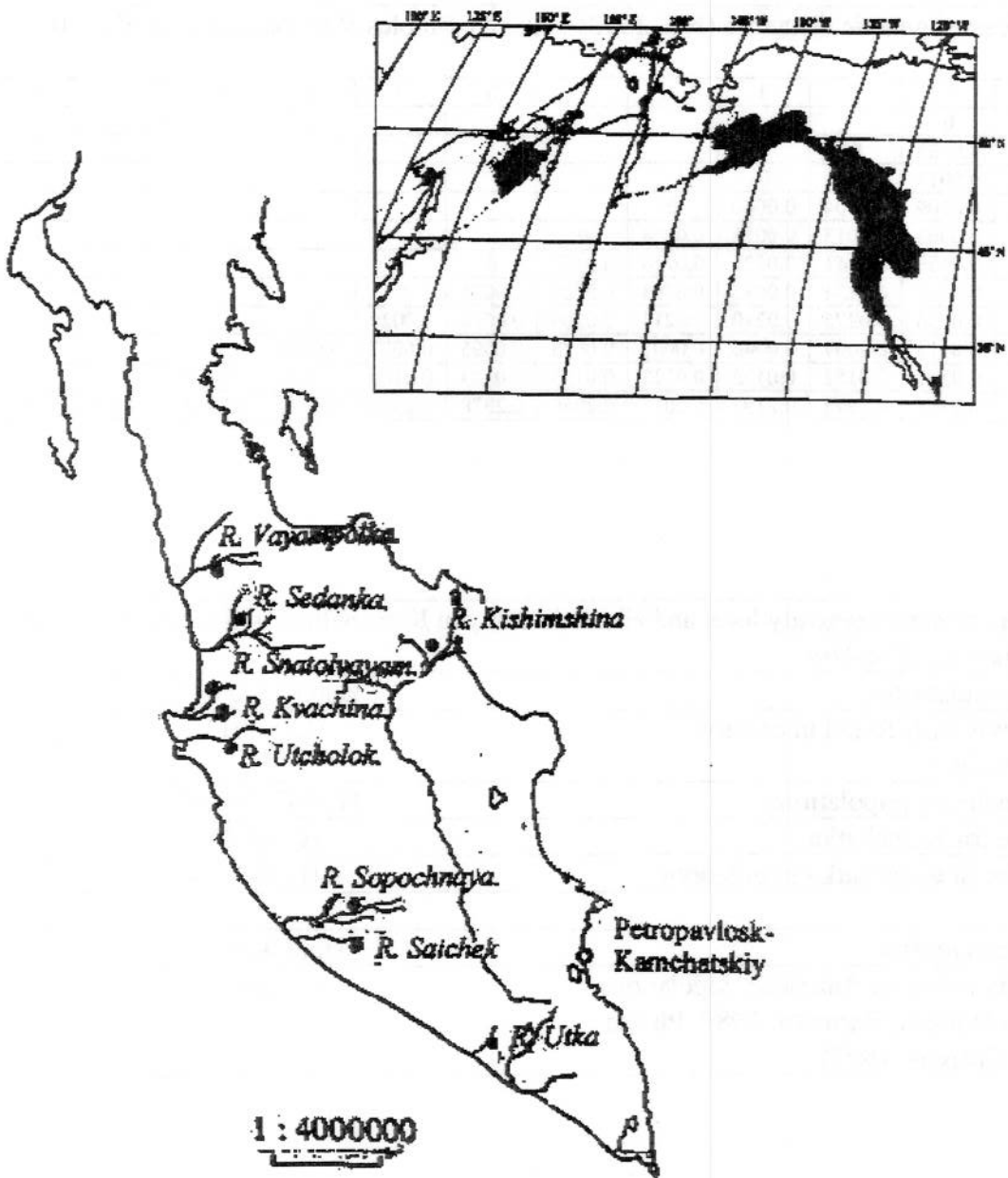


Figure 1. Area of *Parasalmo (Oncorhynchus) mykiss* and locations of Kamchatkan samples.

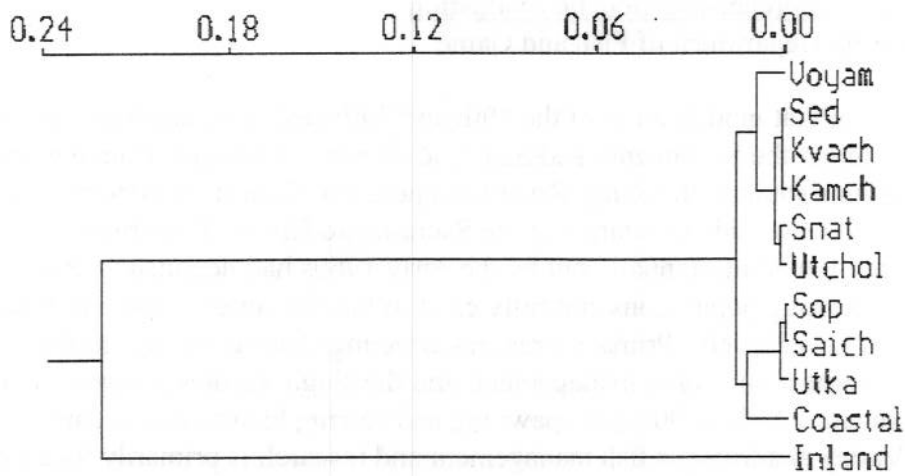


Figure 2. Genetic distances (Nei, 1972) between different Kamchatkan and North American populations *Parasalmo (O.) mykiss* estimated by the UPGMA method of clustering.

Central Valley Steelhead Comprehensive Genetic Evaluation  
Dennis McEwan, California Department of Fish and Game

Prior to extensive habitat modification of the 19th and 20th centuries, steelhead were broadly distributed throughout the Sacramento and San Joaquin river drainages: from the upper Sacramento/Pit river systems south to the Kings River (and possibly Kern river systems in wet years) and in both east- and west- side tributaries of the Sacramento River. Total run size was probably at least 1 to 2 million adults annually but by the early 1960s had declined to about 40,000 adults. Natural spawning populations currently exist in the Sacramento and San Joaquin river systems but at much lower levels. Primary stressors affecting Central Valley steelhead are all related to water development and water management, and the single greatest stressor is the substantial loss (approximately 80% to 90%) of spawning and rearing habitat due to dam construction. Central Valley anadromous fish management and research is primarily focused on chinook salmon (*Oncorhynchus tshawytscha*) and this has led to inadequate efforts to monitor and restore steelhead. Much of the information on historical abundance and stock characteristics that exists for Central Valley steelhead is derived from an intensive California Department of Fish and Game (CDFG) research program in the 1950s. Since this time there has been relatively little research directed at steelhead in the Central Valley, and efforts to restore Central Valley steelhead have been greatly hampered by lack of information.

*Life History and Stock Composition*

Presently, the Central Valley drainages contain only winter steelhead. However, there are indications from fish counts made prior to the era of large dam construction that summer steelhead were present in the Sacramento River system as well. Summer steelhead were probably eliminated with commencement of the large-scale dam construction period in the 1930s that blocked access to holding habitat. The peak period of adult immigration before the occurrence of large-scale changes to the hydrology of the system appears to have been in fall, with a smaller component immigrating in winter. The peak migration into the upper Sacramento River above the mouth of the Feather River was in late September. Examination of adult steelhead counts from the late 1960s to the late 1980s indicates that run timing on the upper Sacramento River does not appear to have changed appreciably. The emigration period for naturally-spawned steelhead juveniles migrating past Knights Landing on the lower Sacramento River ranges from late December through early May, and peaks in mid-March. Most naturally-produced Central Valley steelhead rear in freshwater for two years before emigrating to the ocean. The composition of naturally-produced steelhead in the population estimates in the 1950s ranged from 82% to 97% and averaged 88%. This is probably not reflective of present stock composition in the Central Valley, due to the loss of spawning and rearing habitat and increase in hatchery production. Today, four Central Valley anadromous fish hatcheries (Mokelumne River, Feather River, Coleman, and Nimbus hatcheries) collectively produce approximately 1.5 million steelhead yearlings annually, and there has been a substantial introduction of exotic stocks. The degree of introgression or replacement of native stocks has not been determined, however a NMFS genetic analysis provides some evidence that native Central Valley steelhead may have maintained some degree of genetic integrity: Stanislaus River wild rainbow trout, Coleman and Feather River hatchery populations, and Deer and Mill creek populations form a genetic group distinct from all coastal samples of steelhead. In contrast, the

American River samples (wild fish and those from Nimbus Hatchery ) were genetically most similar to Eel River steelhead which accurately reflects the founding history of Nimbus Hatchery.

#### *Comprehensive Genetic Evaluation*

The CDFG will soon initiate a comprehensive genetic evaluation of Central Valley rainbow trout populations that will provide needed information on the phylogenetic relationships among putative native resident rainbow trout populations, naturally spawning steelhead, and hatchery steelhead that were founded from non-native broodstock.

Specific objectives of the evaluation are:

- Compare genetic profiles and describe phylogenetic relationship of Central Valley naturally-spawning and hatchery steelhead populations.
- Analyze genotypes of self-sustaining, putative native Central Valley rainbow trout populations that are presently isolated above artificial barriers to determine their phylogenetic relationship to anadromous and stream-dwelling rainbow trout populations and strains.
- Provide genetic information on steelhead populations of specific stream systems.
- Evaluate and describe genetic and population structures and genetic variation of Central Valley steelhead.

Projected benefits of this evaluation include:

- Identification of the most appropriate steelhead stocks to use as donors for reintroduction of steelhead to stream systems where they are thought to be extirpated.
- Determination of the phylogenetic relationship of natural stocks to hatchery stocks. This would allow us to assess whether hatchery practices are having unintended genetic effects on the natural populations and whether hatchery populations are significantly different from the natural populations from which they were founded.
- Enhancement of our knowledge of the relationship of individual Central Valley steelhead populations to each other, and the relationship to the non-migratory rainbow trout forms that are sympatric with the steelhead forms or exist in headwater reaches above impassable dams.
- Obtaining measures of the genetic variation within Central Valley steelhead populations, as well as divergence among populations. This will allow resource managers to determine if there has been a reduction of genetic diversity in Central Valley steelhead populations.

Steelhead Research and Monitoring Program, (S-RAMP) Overview  
Philip K. Bairrington, California Department of Fish and Game

In March of 1998, the Department entered into a Memorandum of Agreement (MOA) with NMFS related to the conservation of north coast steelhead. Under this MOA the Department agreed to implement its strategic plans for steelhead which includes significant and extensive research and monitoring activities. Further, under Section 7 of the MOA, the Department agreed to develop a comprehensive monitoring program for North Coast Steelhead. A joint scientific and technical team made up of representatives from state and federal agencies, and tribes would guide this program.

California has not determined appropriate steelhead population health goals in the Northern California (NC) and Klamath Mountains Province (KMP) ESUs. The research we are proposing will help to define those health goals. For the purposes of S-RAMP study plan, our study proposals are organized by overall research objectives designed to answer questions specific to California's steelhead resources.

The 129-page S-RAMP study plan and linked attachments describe S-RAMP's study proposals for the next two years. We consider most of these proposals to be pilot studies. Based on their success, the methods we develop for studying steelhead will be used to evaluate steelhead resources in other waters within the two ESUs. Many of the proposed field studies designed to assess adult abundance use methods dependent on low or medium river flows. If extended high flows conditions are encountered, sampling may be impossible or methods may vary from those proposed in this document.

**S-RAMP MISSION STATEMENT:**

*To determine the population status and trends of wild and hatchery steelhead in California waters north of the Russian River to the Oregon border and to provide guidance and assessment for steelhead-focused restoration work.*

The following three research GOALS were identified to fulfill our mission:

- To locate, collate and centralize information that is currently available related to steelhead in our study area.
- To determine run-size, hatchery/wild population components, distribution, life history, hatchery straying and the genetic diversity of adult steelhead within the KMP and NC ESU's.
- To determine for juvenile steelhead within the two ESUs: relative abundance and out-migration patterns; hatchery/wild interactions; and to develop abundance indices for inter-year and inter-basin comparisons within the KMP and NC ESUs.

Seasonal Movement of Juvenile Steelhead in the Staney Creek Watershed, Prince of Wales Island, southeast Alaska

R. Bramblett, M.D. Bryant<sup>14</sup>, and B.E. Wright, U.S.D.A. Forest Service, Pacific Northwest Research Station

Seasonal movements and distribution of juvenile steelhead and other sympatric salmonids were studied in the Staney Creek watershed with weirs on two 2<sup>nd</sup> order tributaries and surveys with minnow trapping on ten tributaries including those with the weirs. Results from the weirs show that juvenile steelhead move into tributaries during the fall freshet season and emigrate in spring. Catch per unit effort (CPUE) of steelhead from the minnow trap samples were lower during the summer and higher during the fall in the tributaries. Main stream habitat had higher CPUE of steelhead than the tributaries during the summer. Catch per unit effort in the tributaries appeared to be related to the location of spawning redds in the main stream; more steelhead juveniles were observed in tributaries that were located near spawning areas of adult steelhead. Results from this study illustrate the importance of links between main stream habitats and small, 2<sup>nd</sup> order tributaries.

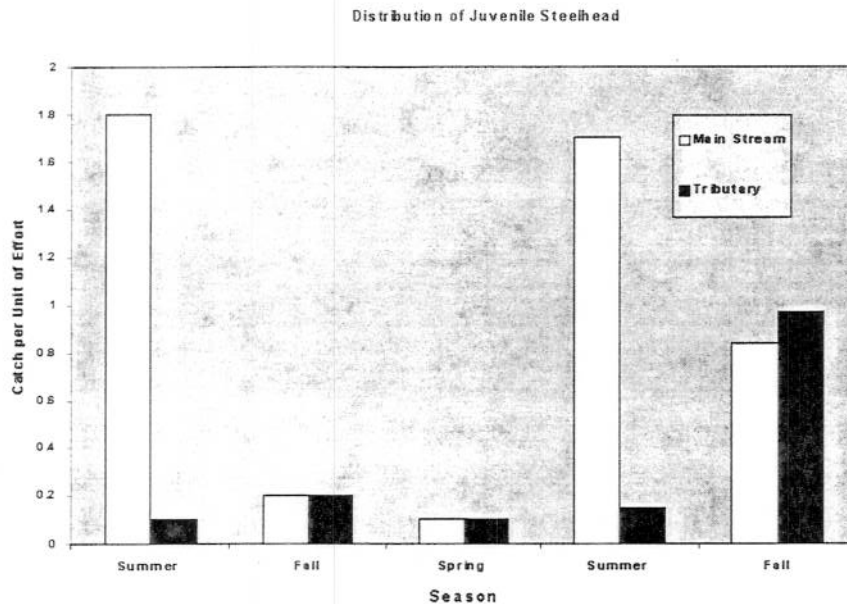


Figure 1-- Seasonal distribution of juvenile steelhead in Staney Creek and tributaries measured by catch per unit of effort (CPUE) during 1996-1997.

<sup>14</sup> Presenter. See appendix for address.

## Trends in Steelhead Smolt to Adult Survival

Dan Rawding, Washington Department of Fish and Wildlife

Indices of smolt to adult survival were examined for a number of wild and hatchery steelhead stocks in the Northwest from the 1970's to the present. In general smolt-to-adult survival remained high or increased through the mid to late 1980's, and declined to record low by the early to mid 1990's. Wild steelhead populations followed a similar pattern and there was a strong correlation between smolt-to-adult survival indices and wild steelhead run sizes. A Ricker stock recruitment function with a marine survival parameter was fitted to a number of steelhead stocks. The marine survival parameter improved the R-squared value and allowed Ricker curves to be fitted over a range of marine survivals for each stock. These data suggest in periods of low ocean productivity, wild steelhead run sizes, harvest rates, and escapement goals developed for average conditions cannot be met. Since we observed 10-fold changes in wild steelhead recruits and smolt-to-adult survival, scientists cannot accurately assess the risks to and the health of wild steelhead populations without an understanding of smolt-to-adult survival for these populations.

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