THE OSPREY

A Newsletter Published by the Steelhead Committee
Federation of Fly Fishers

FEDERATION OF FLY FISHERS
CATCH AND RELEASE

Dedicated to the Preservation of Wild Steelhead • Issue No. 39 • May 2001

Maximum Sustainable Yield: A Formula for Overharvest?

by Nick Gayeski
— Washington Trout —

"How much harvest-related mortality can a healthy wild steelhead stock sustain?" This is a question to which every angler concerned with the preservation of wild steelhead populations should devote careful thought. Answering this question requires a basic understanding of how wild salmonid populations are structured, how population structure influences population dynamics, and what measurements can be made of populations in order to describe and understand structure and dynamics.

In the following article, Washington Trout's Nick Gayeski sets forth some basic concepts used to describe and analyze the structure and dynamics of anadromous salmonid populations. He places a particular emphasis on understanding the idea of maximum sustainable yield and its sustainability as it applies to the harvest of wild steelhead and other anadromous salmonids, as well as its shortcomings and pitfalls.

This article is an abridged version of a longer paper. Readers interested in delving deeper into this subject can receive an Adobe Acrobat PDF version by e-mailing their request to The Osprey editor at jyusk@teleport.com.

Age Structure, Overlapping Generations and Density Dependence

Steelhead populations are composed of individuals of several different age and size categories or classes. Age and size as well as individual growth rates are closely related to maturity. Populations can be broadly sub-divided into mature (adult) and immature (juvenile) members. Depending upon specific population conditions, either or both adults and juveniles may be composed of several age classes. Individuals may become mature at age 3, 4, 5 or more, and may remain juveniles for 2, 3, 4, or more years.

Most steelhead populations contain a mixture of juveniles and adults of differing ages in differing proportions. For most populations, this results in the offspring from any one year's spawning (called a cohort) maturing at different ages over a period of several years. For example, if the adult component of a particular population in any one year contains three-, four- and five-year-olds, members of the year 2001 cohort will make up part of the spawning populations in 2004, 2005, and 2006. Conversely, the spawning population in year 2001 will be made up of members of the 1996, 1997, and 1998 cohorts.

In this way, steelhead populations are composed of individuals of varying ages from several different generations. Such populations are characterized by age structure and by an overlapping of generations. Both are important features of the life history of each population.

A third concept often employed in characterizing populations of steelhead and other salmonids is density dependence. This is the notion that the survival of members of a population between key life stages, such as from one-year-old parr to two-year-old smolt,

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FROM THE PERCH — EDITOR'S MESSAGE

Why MSY and Where's the Water?

by Jim Yuskavitch

Just how many steelhead or salmon can be safely harvested from a population before that population is threatened? And what exactly are those threats? Such questions stimulate lively debate among anglers, fishery managers and, with increasing frequency, politicians as well.

In this issue of The Osprey, Washington Trout's Nick Gayeski answers those questions and more in his thorough and readable discussion of maximum sustainable harvest — a mix of science and philosophy that has been a cornerstone of fisheries management for as long as that profession has existed. You'll find it more than informative as he dissects the principles and science behind the concept of MSY, examines what its real impacts are as currently practiced, and offers a formula better attuned to the long-term welfare of wild fish.

Since it's always encouraging to hear about someone getting it right, Jon George of the Ontario (Canada) Ministry of Natural Resources has written a wonderful account of his agency's management of wild steelhead populations on Lake Superior's wild North Shore.

It's also encouraging to see fish management agencies continue working to get it right. That story is found in the results of a recent report prepared by Oregon Department of Fish and Wildlife researchers on strategies to minimize the impact of hatchery steelhead on wild populations.

You'll also read in this issue a sobering report on the coming drought, its likely impact on salmon and steelhead in the Pacific Northwest and the tepid response of the Bonneville Power Administration and National Marine Fisheries Service by Steelhead Committee chairman Bill Redman, along with some thoughts how on it might actually be possible to do something about it in an essay by environmental attorney Dan Rohlf.

Looking back to our February 2001 story on the hydropower relicensing of Oregon's North Umpqua River — things have changed and remain the same.

The Oregon Department of Fish and Wildlife has signed a Memorandum of Agreement with licensee PacifiCorp for mitigation stipulations that includes reconstructing a fishway on Rock Creek, improving instream habitat on East Fork Rock Creek, re-connecting the Clearwater River with the North Umpqua River, reducing non-native brook trout populations on the Clearwater and the purchase of some conservation easements. "But," says author Jeff Dose, "none of the agencies has proposed removing Soda Springs Dam." At this point, Dose sees the Environmental Impact Statement public comment process as the last hope for North Umpqua fish advocates to make any substantial changes in the conditions PacifiCorp will have to meet to receive a new license from the Federal Energy Regulatory Commission.

We'll keep you posted.

Letters To The Editor

A Few Good Attaboys

Dear Editor

Enclosed please find a small donation in support of The Osprey. "Pound for pound" The Osprey is in a league by itself. I wish you every success in your continuing advocacy for wild salmon.

Bob Hooton
Nanaimo, British Columbia, Canada

Dear Editor

Just a quick note to congratulate and thank you for publishing The Osprey. It represents a lot of work and is a great tool for the preservation of wild steelhead. Keep up the good work.

Dick Watts
Richland, Washington

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THE OSPREY

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The Osprey is a publication of The Federation of Fly Fishers and is published three times a year.

CHAIR'S CORNER

Fish Out of Water

by Bill Redman

— Steelhead Committee —

With a substantial majority of the Pacific Northwest's electric power derived from hydroelectric dams, water and power are inseparably, and now disastrously, linked. Take a power shortage driven by a significantly over-subscribed BPA power system, recent year cuts in support for energy conservation and alternative sources, and a strange admixture of regulated and deregulated prices across the West and between generation and delivery. Stir in a 50 year drought in the winter of 2000-2001, and we have power shortage adding to water shortage and simply not enough water to go around for power, irrigation, and fish.

The magnitude of the impact of the water shortage on steelhead and salmon may be temporarily masked in the eyes of the public by the relatively bountiful returns of adults to the Columbia system in 2000 and the early part of 2001, at least by the standards of recent years. However, the 2000 and 2001 returning adults benefited from the high water spring migration seasons of the late 1990's when they were downstream migrating smolts. I am persuaded from observing these runs for about 40 years that strong spring flows from abundant rainfall and snow pack are as important as any habitat related factor in the numbers of returning adults from that year class, especially where dams impede downstream migration. The consequences of this year's frighteningly low flows will hit home in one to four years, when this year's downstream migrants return as adults.

This year's shortage is bringing about amazing transformations, in which golden words and high sounding goals for salmon and steelhead are replaced by the stark revelations of true intent and priorities. The values of government people critically important to the human management of water, power and fish in the Northwest stand naked for the world to see, and the fish rank last. Several recent examples come to mind.

The Bonneville Power Administration 2000 Annual Report arrived in my mail around the middle of March. In his letter to the President leading off the report, Acting Administrator and CEO Stephen J. Wright named BPA's five goals, fish and wildlife being number three on the list. The letter begins this way:

"Dear Mr. President:

The agency is well on its way to accomplishing all the major goals it set for itself three years ago: ... creating a regional fish and wildlife plan that is legally defensible, scientifically credible and implementable; ..."

In the March 8th Portland Oregonian, Wright was quoted as saying that "all plans to cut electricity production to help fish" by ensuring adequate instream flows should be suspended. So much for BPA's fish goal.

I left home in late March with a growing concern that the water shortage was growing rapidly into a major calamity for this year's smolts. When I returned home in mid-April, the news contained a barrage of bail outs by those I thought bore at least some responsibility for the welfare of the fish. According to the National Marine Fisheries Service biological opinion, April 3rd is the date to begin spill to help ESA listed Upper Columbia and Snake River steelhead and chinook salmon in their downstream migration through the hydro system. By then BPA had announced a power emergency — no spill at the dams for at least two weeks. Two weeks later, it extended the emergency and the ban on spill through the end of April. One month down in the migration season and two to go, with negligible likelihood of change in policy by the decision makers.

Wright's bottom line on his priorities was contained in his statement of March 29th: "Our analysis shows that we cannot meet the standard operations called for in the biological opinion, maintain reliability, refill reservoirs and stay in the black financially under the latest runoff forecast, ... We will have just enough energy to meet our own loads only if we dramatically reduce planned spill operations."

Established by the Northwest Power Act of 1980, the Northwest Power Planning Council has the dual mission of protecting fish and wildlife in the Columbia Basin and ensuring an adequate power supply. The first week of April, Council Chair Larry Cassidy said: "We understand there are some uncertainties associated with transporting fish, but in this year when drought has reduced our region's hydropower generating capability ... it is prudent to retain water in the Columbia/Snake River hydropower system by reducing spill at the dams." This statement was made in spite of a March 30th letter from the Independent Scientific Advisory Board, whose mission is to provide scientific advice to the Power Council. In this letter, Advisory Board Chair Jim Lichatowich wrote that the ISAB "encourages the judicious use of surface spill at dams in the Columbia-Snake River system ... Spill, in whatever form, facilitates in-river passage, which spreads the risk (or benefit) of different routes of passage among members of populations of smolts to help maintain biological diversity, and also retains fish in the river for important monitoring." Cassidy's statement sounds like another vote for power over fish.

On April 13th, the acting regional director of the National Marine Fisheries Service, Donna Darm, supported extension of the emergency declaration shutting down spill. She said: "The issue is reliability ... If we spill water now and are wrong about the forecast, we risk rolling blackouts this summer." This from the federal official responsible for the welfare of ESA listed Columbia/Snake steelhead and salmon, and whose biological opinion on the listed fish calls for spill. She puts reliability of the power system ahead of reliability of the downstream migration.

With little or no water allocated to spill for the downstream migration, the fallback position of the agency and

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council managers is to revert entirely to capturing the maximum number of smolts possible at the upstream dams, barging or trucking them to below Bonneville Dam and dumping them back in the river. Controversial at best, this approach has never been proven successful as measured by adults returning to the spawning beds. BPA and the Corps of Engineers defend out-of-river transportation by quoting statistics on the high percentage of barged smolts that are returned to the river alive. This is just the start of the dangers of barging. Often mentioned are delayed mortality from the stress of the trip and disease transmission in the confined quarters. Less often mentioned are the likely disruption of timing of the smoltification process, the preparation for conversion to life in salt water, and the loss of at least part of the imprint of the migration route, which guides the adults back to their natal streams. It appears there will be very little in-stream migration of smolts this spring, even though, after 20 years of transporting smolts, there is still a severe lack of information on its long term effects as measured by returning adults.

It comes as no great surprise in this environment that the Federal Energy Regulatory Commission held hearings in early April in which they invited licensees (utilities) to submit proposals for changes to project operations that will result in increased generation. Constraints to increased generation according to FERC include in-stream flows, ramp rates, reservoir fluctuations, and run of river operations, in short the requirements that help to protect fish. The public response to FERC must be immediate and overwhelming opposition to short cuts that would harm the fish.

However, it came as a severe shock when Tom Fitzsimmons, Director of the Washington Department of Ecology, the state agency responsible for setting and enforcing in-stream flows, signed an order April 5th that reduces in-stream flow requirements in the Columbia system by up to 25 percent for the next six months. With admittedly inadequate in-stream flow requirements as the starting point, the Department's solution to a sadly over-appropriated river is to let the steelhead and salmon take the hit. Droughts are a part of the natural cycle, and minimum flow requirements are most important in these times. If you live in Washington, add your voice to the swell of opposition to this move by contacting the Department, and Governor Locke, who supported the order. And if you are really concerned for the long haul, give your support to the Center for Environmental Law and Policy, an eminently worthwhile organization whose mission is to ensure that adequate in-stream flows are set and enforced in Washington.

The one positive signal coming from this situation is that the Northwest may finally be coming to the realization that it can no longer afford to have about 20 percent of BPA's power generating capacity dedicated to the aluminum industry and its 7,500 jobs. To help correct the supply demand imbalance, BPA's Wright recently asked these companies to voluntarily close down for up to two years; a good idea. For doing so, BPA will pay the companies money to be passed on to their laid off employees, still less expensive to BPA than the cost of going to the current market to buy power equivalent to the amount used by the smelters. As of this writing, Alacoa was the only the aluminum company to accept this offe.

For years the aluminum companies defended their disproportionately high power usage and low rates by pointing to the jobs supported. But in December of 2000, Kaiser Aluminum in Spokane, followed by some of the others, torpedoed this argument by shutting down, laying off 1,200 workers, and reselling their BPA power on the open market at enormous profit. With this move, it became obvious that jobs were not the primary criterion for management decisions.

In any event, the aluminum companies' power rates appear to be heading substantially higher, which may wipe out their ability to remain competitive with producers in other areas. There is no denying the heartache that can result from job loss; there will be pain. The bottom line is that there isn't enough power and water to meet all of the region's needs. This looks like the option with the highest potential for power saved and the least amount of human, economic, and environmental impact.

I don't mean to discount the value of electric power, which brings enormous convenience and efficiency to the lives of all of us; nor do I dismiss lightly the value of agricultural products watered by rivers. But who is looking out for the fish when the government officials responsible for their protection are bailing out in multiples, now that the situation is getting tough.

Options for citizen action in this environment appear to be limited, but at a minimum, I urge the following:

1. Insist to everyone who will listen that we as a society go all out with water and power conservation in the next six months and beyond.

2. Storm the ramparts of every government and quasi-governmental agency involved in this mess with testimony, letters, calls, and e-mails demanding that the fish be given serious weight in the mix, not just lip service.

3. Demand a high priority scientific peer review of transportation vs. in-stream migration alternatives for the Northwest Power Planning Council and BPA by the Independent Scientific Advisory Board.

4. Insist that the issue of the upper Snake River basin water and its use for the next six months be addressed. Urge that the government buy water from farmers, especially potato farmers, whose crops are in over supply, prices depressed, and production costs exceed market prices. Demand that the purchased water be used for spill to move the smolts along on their seaward migration.

I have focused on the Columbia Basin, because it contains the world's largest hydroelectric system, and its water is intricately interwoven with power. But this drought is region wide, and the impacts on fish will go way beyond the Columbia.

For late-breaking news on the Columbia and Snake rivers issue and FFF's role see page 18

MAXIMUM SUSTAINABLE YIELD, CONTINUED

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is in part dependent upon the size of the population relative to the size (and quality) of its habitat. At relatively high densities, a smaller proportion of individuals can survive than when densities are lower. Density dependence is generally thought to be an important feature of juvenile steelhead survival in the freshwater environment. (The ocean survival rate for adults is not thought to be density dependent — the survival rate for four-year-old steelhead is the same whether there are 5,000 or 500,000.)

Stock-Recruit Relationships

When it comes to characterizing steelhead and salmon populations and managing them for harvest, age structure, overlapping generations and density dependence are reflected in what are known as stock-recruit relationships, which are generally depicted by the use of stock-recruit curves. A stock-recruit curve expresses the number of recruits from a cohort that are expected to be produced by a given number of parent spawners. A recruit is generally defined as an adult of a certain age or life stage available for harvest or spawning.

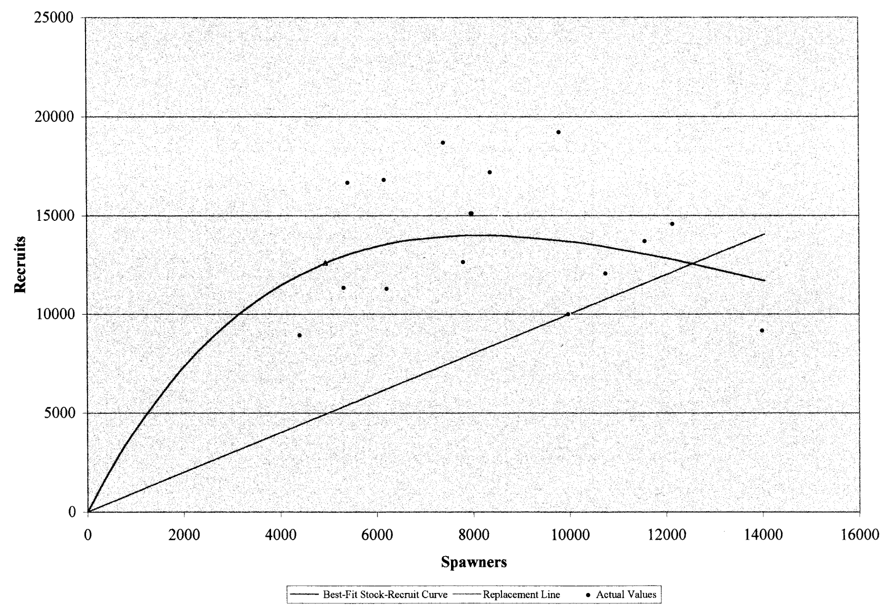
Because each year's return (run) is composed of adults of several ages, annual run sizes are usually inadequate predictors of run size in specific future years. Rather, the dynamics of steelhead populations are better characterized in terms of recruits from annual spawner numbers. This requires decomposing annual run numbers into recruits from the different prior spawning years, based on the age composition of the adult population.

Used properly and cautiously, the application of stock-recruit analysis to steelhead population data can be informative and helpful for proper stock management. Used uncritically and with too much faith, stock-recruit analysis can lead to and support poor management decisions. The concept of maximum sustainable yield (MSY) comes straight out of a generally uncritical use of stock-recruit theory.

Stock-recruit analysis consists of taking spawning and return data for a series of years, estimating the adult recruitment from each spawning year

Figure 1

Quillayute Steelhead, Brood Years 1978-1993
(Return Years 1982/83-1998/99)
Ricker Equation (R = a*S*EXP^(-S/b), where R is
Adult recruits, S is parent generation spawners, and
EXP is the base of the natural logarithm, ~2.71828).
a = 4.656; b = 8138; eq = 12517



(using population age data) and then estimating a spawner-to-recruit function from the series of spawner and recruit data. The estimated function is in the form of a mathematical equation. There are two prominent stock-recruit equations commonly employed in analysis of salmonid populations, the Ricker and the Beverton-Holt. They are similar, so for purposes of illustration we use the Ricker equation and its associated Ricker curve. The appropriate equation is given in Figure 1.

Stock-recruit equations characterize the dynamics of the population by estimating two variables or "parameters." One parameter (a) characterizes the inherent productivity of the stock at low densities. The other parameter (b) determines directly or indirectly the maximum level of recruitment and the spawning stock size at which that level of recruitment is achieved. In combination, the two parameters determine the equilibrium size of the stock (eq.), which is the point at which the total spawning escapement produces just enough total recruits to equal and hence to replace itself. This is depicted on the right-most portion of the stock recruit curve by the curve crossing (intersecting) the straight "replacement" line depicting X# spawners = X# recruits (see Figure 1).

The curve depicted in Figure 1 indicates the presence of density dependence in the dynamics of this population in two ways: 1) The gradual flattening of the slope of the curve as points on the curve get closer to the apex of the curve and; 2) The decline of the curve to the right of the apex. The gradual flattening of the curve as the apex is approached from the left indicates that the addition of specific numbers of spawners to a previous number of spawners results in the addition of proportionately fewer recruits to the total number of recruits. For example, 2,000 spawners are pre-

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dicted to produce over 7,000 recruits; but 4,000 spawners are expected to produce only 11,000. Six thousand spawners are expected to produce just over 13,000. But each additional block of 2,000 spawners adds fewer recruits to the total number of recruits than was added by the preceding block of 2,000.

At the very apex of the curve, the last spawner added to the previous total number of spawners fails to add a single additional recruit. This is the point of maximum recruitment, Rmax, and the number of spawners that produces this recruitment is Smax. After this point is reached, additional numbers of spawners actually lead to fewer total recruits; the number of recruits produced by each additional spawner becomes negative. (The Beverton-Holt equation/curve differs in this respect from the Ricker. Instead of reaching a maximum and then slowly declining, the curvature of the B-H curve keeps decreasing but remains positive and eventually effectively levels off parallel to the horizontal (x) axis.) Finally, at the point of equilibrium at the far right of the curve, where the curve intersects the straight replacement line, the total number of spawners produces just enough total recruitment to replace itself (total # spawners = total # recruits).

Maximum Sustainable Yield

Now, if a population exhibits recruitment dynamics that reflect density dependence of the kind depicted in stock-recruit curves, what proportion of the annual return can safely be harvested (killed)? If the assumption is made that the curve depicts a long-term underlying biological relationship between spawning numbers and recruitment, there then appears to be a single attractive level of harvest indicated by the curve.

Simply put, there will be one point on the curve at which the difference between the number of recruits produced by a given number of spawners and that number of spawners is greatest. This is the underlying intuition behind the concept known as maximum sustainable yield (MSY).

If we pick any point on the horizontal axis (i.e., any particular number of spawners) and draw a straight vertical line up to the curve, that portion of the vertical line lying above the straight replacement line is the harvestable fraction of the total recruitment that would be produced by that number of spawners. The one unique point on the horizontal axis for which this fraction is greatest is the MSY point. Other points may produce greater numbers of total recruits than the MSY point does, but none of these will provide as great a number in excess of the number of spawners needed to perpetually produce that total recruitment.

MSY seeks to take a constant maximum surplus from the stock annually available for harvest, and allows the minimum number of fish that is believed necessary to produce that maximum harvestable surplus to escape to spawn. If all environmental and life-history conditions pertaining to the stock are constant (average), the successful implementation of MSY will result in a perpetual motion machine in which the annual spawning escapement is always the minimum necessary to produce the maximum harvestable surplus, and that surplus will always be harvested consistently and on an annual basis. Since the assumption is that MSY harvest leaves enough stock for spawning to perpetuate this regime, theoretically, no long-term biological harm occurs.

Life History, Population Diversity and MSY

An advocate of MSY or other less intensive harvest policies must believe that escapements beyond the policy's target escapement range are biologically unnecessary to maintain the long-term health and productivity of the stock concerned. Unless such additional spawning escapements are not needed to maintain the long-term viability of the population, a harvest regime that aims to prevent such excess spawning from occurring simply cannot be described as sustainable. Advocates of MSY must make some very strong claims in this regard.

Let's begin by giving some thought to the condition of a steelhead stock under pristine and unfished circumstances. Most steelhead stocks that are subject to agency management are aggregates of sub-populations or demes. This is certainly true of winter-run steelhead stocks in Washington's Quillayute, Skagit and Queets rivers, which incorporate stocks from two or more major river tributaries. It is also certainly true of Hoh and Sauk rivers stocks, which contain sub-stocks spawning and rearing in different sections of the mainstem, and in various smaller tributaries.

The sub-stocks composing any such aggregate will each likely have different population dynamics, with differing productivity. Some, for example, will be adapted to extreme conditions that may have relatively high egg and juvenile mortality rates compared to the stocks in the more benign environments of the river basin. These sub-populations will generally have lower growth rates than the other sub-stocks; they are in this sense "less productive" stocks. But they will nonetheless still be the only extant stock capable of colonizing the more extreme habitats and conditions within the river basin.

Each sub-stock will have made adaptations to its freshwater spawning and rearing habitats in terms of their age structure, age-at-maturity, individual growth rates, and fertility/fecundity rates that will differ from those of other sub-stocks within the basin. The differences between sub-stocks with regard to these features may be subtle in many cases, but there is good reason to believe that each sub-stock has spent its evolutionary lifetime continually adjusting these age-related aspects of its population structure to the dynamics of its environment in a way that optimizes its long-term prospects for survival.

These differences among sub-populations within a river basin are among the significant aspects of population biology which advocates of MSY ignore. Most advocates, if pressed, would probably flat-out deny that such between-population differences even exist, much less that they are biologically significant.

Imagine an MSY harvest and escapement regime being imposed on such a pristine aggregate stock. The stock has a distribution of ages-at-maturity for each sex (including frequency of repeat spawning in the case of steel

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head), a distribution of juvenile survival rates, a distribution of smolt ages and associated growth rates, and a distribution of adult mortality rates. All of these aspects of the population structure of this particular aggregate stock are expressed, as it were, in the distribution of sizes, ages, and sexes of adult fish entering the river each year.

Let's attach some run size numbers to this thought exercise by assuming that the current Quillayute wild winter steelhead stock as characterized by the stock-recruit curve in Figure 1 is such a pristine stock. This stock would have an annual run/spawning population size of between 11,000 and 19,000 fish. The equilibrium spawning stock size, at which the average number of spawners that produces just enough recruits to replace itself, is somewhere in the neighborhood of 13,000. Natural, principally environmental, variability in survival across all ages and life-stages produces this range in the actual annual run size.

The structure of this population displays a schedule of mortalities across the life histories of the various component stocks organized so as to keep the stock fluctuating around the equilibrium point. Most importantly for the harvest discussion, the stock's life-history characteristics are adjusted so as to achieve and maintain a balance between juvenile and adult mortality rates, fecundities and maturation schedules. Whatever the actual rates are for the survival of age-three adults to age-four, age-four to age-five, age-five to age-six, etc., the stock is adapted and adjusted throughout its life histories so as to maintain itself within the equilibrium range of spawning run sizes.

What is the MSY harvest rate for such a pristine stock? Based on Figure 1, it is 60 percent. MSY escapement is just under 5,000, with an expected recruitment of just under 12,600, resulting in an MSY harvest of 7,600 and an MSY harvest rate (Hmsy) of 60 percent.

Note, however, that we only know what this MSY harvest rate is because we are assuming that we already know that Figure 1 is the correct curve for this stock. But if the stock is truly pristine — in undisturbed habitat and completely unfished — we have no data upon which to base an estimate for the stock-recruit function. We only get that data by fishing the stock at different levels for over several years or decades.

To initiate this MSY escapement regime, the average pristine equilibrium stock size of 13,000 must be harvested down to 5,000. Until the stock is readjusted to its new equilibrium spawning escapement regime, 8,000 fish must be harvested annually, a harvest rate of 62 percent.

Think what an additional annual mortality rate of 60-plus percent on mature adults means to the population. If the average natural mortality rate for adults between age four and age five is 20 percent, then of every 1,000 four-year olds in the ocean, 200 die, leaving 80 percent, or 800, to return to spawn as five-year olds (assuming that age five is the oldest adult age in the population). If 60 percent of these 800 are harvested, 320 remain to spawn. From the population's point of view this is identical to the situation in which only 32 percent of four-year olds survive to spawn as five-year olds. Compared to the unfished 20 percent mortality, 80 percent survival, the effective mortality rate is 68 percent, the effective survival rate 32 percent. The adult mortality rate between ages four and five has increased from 20 percent to 68 percent.

The task is to estimate a risk-averse escapement goal and harvest regime.

What might such an increase in the adult mortality rate do? We know that it selects for a younger adult population, and an earlier average age of maturity. Populations that mature earlier tend to grow faster; they have higher annual population growth rates. But, corresponding to this higher growth rate, earlier-maturing populations tend to be smaller in total population size because they are able to occupy only optimal habitats. They are less capable of filling a variety of environmental niches than older, slower-growing, more diverse populations. They are composed of fewer generations, so that each annual spawning run represents a higher fraction of the total freshwater-plus-ocean-residing population than a slower growing population composed of more generations and are more likely to be dominated by one or two age classes.

Managers and stock analysts only get an idea of how the stock responds to such low escapements by first harvesting them, and then seeing what they do. Now if — as is largely the case with West Coast steelhead populations — run size, escapement, and spawner age data are not collected until sometime after the stock has been subject to significant harvest impacts, the stock has already been adjusting its life-history characteristics to the imposition of the additional harvest-related mortality. The stock-recruit data will surely give every indication that the stock is not capable of attaining large recruitment/population sizes with significantly larger escapements than it has experienced in the recent, fished, past. This will be the case even if no detrimental changes in freshwater habitat have occurred. Habitat loss will get the full blame for this, but it will only be a part of the story, at best.

Another thing is also likely to have happened along the way that further distorts matters: The remaining aggregate stock may have become more productive at low densities than originally due to the imposition of high harvest rates on the pristine stock. The substocks best able to deal with the imposition of additional harvest-related mortality are the most productive ones occupying the most productive habitat niches. The less productive stocks that are helping the entire aggregate stock to fill all possible habitat spaces are likely to be the first to be lost.

Moreover, the life-history adjustments that are likely to be initiated in response to sudden additional adult mortality — earlier age at reproduction — are precisely the adjustments that make stocks less able to deal with environmental extremes and less-than-optimal habitats.

So, the stock-recruit curve that is based upon a decade or so of data from a stock that has been heavily fished for two or more generations will likely both under-estimate the potential of the size of the aggregate stock and will over-estimate its inherent productivity — the

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productivity that occurs at relatively low population densities. Both combine to suggest via the stock-recruit curve that the stock can sustain a low level of spawning escapement, compared to pristine conditions, which will produce a relatively high level of recruitment — as measured solely by the relative size of the difference between the excess recruitment over the escapement level of the parent stock and that parent stock escapement level itself.

Population and Ecosystem Resilience

Such an outlook reflects a mechanistic view of population and ecosystem resilience, which can be called the engineering concept of resilience. This outlook views an ecosystem or population as resilient if it can return to a desired or stable equilibrium point when disturbed from that point. In MSY harvest management, the equilibrium point is the MSY spawning escapement level, to which the system will return after overharvest if corrective measures are instituted promptly enough, due to increased productivity and recruitment at low spawning stock sizes, just as a thermostat kicks on and off to maintain the desired narrow range of temperature in a building. As long as this return of the system to the desired escapement level can happen, the system is resilient.

Instead, we need to rely on a different concept of resilience, systemic resilience. According to this concept, the resilience of a system lies in its ability to absorb disturbances and still retain its basic structure and dynamics. If disturbed too greatly, any complex system will either collapse or shift to a new structure with different internal equilibrium points or stable states. The more resilient a system is, the greater the size and/or frequency of disturbances that it can absorb without changing its overall characteristics.

The kinds of changes in population life history brought about by harvest management regimes such as MSY reduce the systemic resilience of the population and its ecosystem. The population as a system is more at-risk and less resilient even though it may appear to be relatively productive and capable of sustaining high harvest rates. This is likely to be true even though a stock managed for MSY has never experienced severe over-harvest beyond the MSY harvest rate. The "excess" components of the original native population that MSY advocates consider biologically superfluous can only be maintained at lower harvest rates. But it is the more complex population structure containing these components that provides the population with greater resilience to a wide variety of potential system disturbances than does the population simplified due to intensive harvest pressure.

One thing is reasonably certain: If significant harvest-induced changes to population structure have occurred, steelhead and salmon populations will not be able to recover their historical complexity and diversity if harvest remain high. If a population has been harvested at or near MSY for several generations, it has likely already lost some of its resilience, even if MSY escapement goals have been consistently achieved. If this level of harvest-induced mortality has selected for earlier age at reproduction, then recovery of population resilience will require more than simply greater escapements for a few years. It will probably require a significant reduction in harvest mortality for several generations.

Setting Escapement Goals

It should be obvious that harvest takes place only in order to secure or extract some kind of economic or socio-cultural gain from a fish population. It certainly does not take place for the biological benefit of the harvested population. With age-structured populations such as salmonids, harvest-derived mortality acting equally across all adult age classes, added on to natural mortality rates, will increase selective pressures towards reproduction at earlier ages. Any such tendency will be further exaggerated if harvest mortality is directed differentially toward older ages and/or larger body sizes.

We should distinguish between two general cases: Pristine, generally undisturbed populations under healthy environmental conditions; and populations that have been exposed to harvest for a number of generations and on which some run size, harvest and/or escapement data exists. In this paper I focus only on the latter.

Clearly, where substantial economic and/or social satisfaction can be derived from the fishery without lethal harvest, such as with catch-and-release regulations under most environmental conditions, no-harvest management is to be preferred. The tricky case, of course, is where some lethal harvest is desirable. Under the assumption that some stock recruit data exists, the task is to estimate a risk-averse escapement goal and harvest regime.

If there has been much harvest in the past two or more generations, the stock recruit relationship indicated by the extant data will likely reflect a population that is less resilient in the systemic sense described above than the unfished stock. Any harvest level must aim to significantly relax harvest-related selective pressures toward younger age at reproduction. But we first must use the extant data to estimate existing stock-recruit relationships. This is a kind of Catch-22 around which we must maneuver.

It will usually be possible to evaluate likely outcomes of different harvest strategies and escapement targets under each set of parameter values using extensive computer simulations. These simulations help one to imagine what would happen to the population if a particular model (e.g., Ricker or Beverton-Holt) together with a specific set of parameter values and a particular kind and amount of environmental variability were actually governing the recruitment dynamics of the population. For each model that may be considered, these simulations can be used to produce a number of decision tables that can be used to evaluate likely outcomes of management choices. Each table evaluates one kind of outcome (e.g., annual run size, annual spawning population size, or annual amount of harvest) across a range of management actions (e.g., escapement levels or harvest rates).

An example of such a decision table is given in Table 1. This table displays the predicted average annual run size over 50 years for five different hypothesized parameter values for the stock-recruit relationship for spawner escapement goals ranging from 2,000 to 17,000 in increments of 1,000. The hypothesized parameter values are chosen from a series of 1,000 "most probable" sets of

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paired a and b values based upon the available stock-recruit data using a computer-based sampling algorithm.

Essentially the computer program randomly "chooses" 1,000 likely pairs of values that might have produced the actual spawner-recruit data points observed. The P (a, b) value under each of the five sets in the table is the probability, based upon the data, that the stock-recruit dynamics of the population follow the Ricker model with those particular parameter values. So, for example, the pair of values (the hypothesis) a = 4.0, b = 8,777 (eq. = 12,250) has a probability of 0.087, based upon the fact that this pair of values occurred in 87 of the 1,000 simulated pairings. Put differently, 8.7 percent of the 1,000 simulated pairs had these particular values.

The uncertainty in the data is displayed by the range of likely pairs of values for this one particular stock-recruit model as shown in Table 1. A steelhead population whose underlying population (stock-recruit) dynamics were best characterized by the Ricker model with one of these five pairs of a and b values could have produced the actual data observed over the past 20 years. Several other pairs of values could have also produced the data.

Since we don't know for sure which set of values the population really follows, the least that we can do is evaluate what the impact of different management policies would be on the population if the population were governed by different parameter values than we think. Decision tables facilitate this kind of risk assessment.

To take an extreme example, suppose that we are interested in choosing a level of spawning escapement to achieve, on average, the largest annual run size. If we believe that the stock is very productive with a = 6.7, b = 5,635, and an equilibrium population size of 10,750, the optimal escapement goal would be 6,000 which would achieve an estimated annual run size of 14,068. If, however, the stock were really governed by dynamics more appropriately described by a = 2.7 and b = 14,414 (eq. = 14,250), an escapement goal of 6,000 would achieve an annual return of only 11,067.

Note the general difference in expected population performance between optimistic assumptions of high productivity (high a values) and conservative assumptions of relatively low a values but correspondingly higher b values (Smax) along with a higher expected equilibrium population size. Within the range of escapements considered (2,000 to 17,000), when a values are assumed to be high annual run size attains its maximum at a relatively low escapement (6,000) and falls off rapidly as escapements are increased above this optimum level.

TABLE 1.

DECISION TABLE FOR QUILAYUTE STEELHEAD
BASED UPON RICKER MODEL PARAMETER VALUES

Parameter Values and Probabilities from SIR simulation

a	**2.2**	**2.7**	**4.0**	**5.4**	**6.7**
b(=Smax)	**20798**	**14414**	**8777**	**6680**	**5635**
eq.	**16750**	**14250**	**12250**	**11250**	**10750**
P (a,b)	0.002	0.002	0.087	0.043	0.003
Cumulative P	0.011	0.046	0.536	0.923	0.99
Escapement	**Predicted Annual Run Size**				
2000	5100	5657	7248	8662	9990
3000	6686	7355	9224	10777	12188
4000	8115	8806	10708	12163	13444
5000	9398	10035	11781	12983	14007
6000	10546	11067	12515	13366	14068
7000	11568	11922	12971	13420	13777
8000	12475	12618	13200	13227	13245
9000	13273	13174	13245	12856	12559
10000	13973	13605	13144	12360	11784
11000	14573	13922	12931	11787	11164
12000	15085	14140	12632	11606	11127
13000	15520	14273	12524	11570	11089
14000	15884	14333	12496	11531	11049
15000	16182	14337	12469	11497	11018
16000	16412	14334	12450	11475	10995
17000	16544	14328	12432	11453	10972

If there is reason to believe that stock-recruit data on a population that has been subject to significant harvest mortality in the recent past will indicate that the population is more productive but has lower capacity than in its unfished condition (higher a and lower b and equilibrium population values) we should be concerned to significantly reduce harvest-related mortality in order to enable the population to regain a more complex and diverse age-structure. This will enhance and restore the systemic resilience of the population. This should further incline us to consider managing under the assumption that the population is really governed by a relatively low a value.

Much more could be said on the issue of uncertainty and setting escapement goals. It suffices for now to simply note that there are techniques for displaying, assessing, and discussing the uncertainties in steelhead population data. The use of techniques such as simulation and decision tables are advisable because no one model and no single parameterization (choice of a and b values) is obviously the preferred one in most contexts. An approach using decision tables to facilitate comparisons between expected stock performance under different assumptions regarding the basic stock dynamics enables both fisheries managers and the concerned public to visualize the uncertainties concerning the true status of the stock, and to assess what difference such uncertainties are likely to make if specific management policies, such as escapement goals or harvest rates, are implemented. Decisions made after considering uncertainties and likely impacts will more accurately reflect the amount of risk we are willing to take in managing the population.

Past harvest management (not to mention past and continuing habitat damage and hatchery practices) has altered salmonid population structure and dynamics in critical and deceptive ways. If we are aware of this, we can employ techniques for recognizing and characterizing our uncertainty about population health to help us achieve more risk-averse escapement policies and combat the dangerous and over-simplified view of salmonid populations that underlie MSY management.

Superior Steelhead

by Jon George

— *Ontario Ministry of Natural Resources* —

Introduced to the Canadian side of Lake Superior in the late 1800s, steelhead from the West Coast of the United States have thrived, adapting to local conditions and environments to develop distinct wild populations. In this article, Jon George, senior operations fisheries specialist with the Ontario Ministry of Natural Resources, gives us a fascinating account of the steelhead on his side of Gitche Gumee, including their natural history and how the Canadian government and local steelhead anglers banded together to overcome past threats from excessive harvest. The author welcomes reader comments. He can be reached at jon.george@mnr.gov.on.ca.

Steelhead anglers brave rain, sleet and snow, stand waist deep in roaring ice cold rivers and spend massive amounts of money on the finest fishing tackle in an effort to match wits with one of the most exciting salmonids in North America. To the fisheries manager, steelhead (*Oncorhynchus mykiss*) are fascinating to study. They present a complex set of life history strategies and an amazing ability to adapt and thrive, even in marginal coldwater environments. Their ability to colonize has resulted in widespread, successful introductions throughout the globe. Unfortunately, like many salmonids, wild steelhead populations are seldom abundant, making them sensitive to over fishing. Careful management of habitat and minimizing harvest are critical to maintaining healthy populations.

In the late 1800s, steelhead from the Pacific Northwest were introduced into the Great Lakes. In Lake Superior, the large headwaters of the Great Lakes system, natural reproduction and colonization of steelhead was rapid. The first stocking program in Lake Superior, initiated in 1883, was likely made up of stock from California's McCloud River. Stocks originating from Redwood Creek in California, the Willamette and Rogue rivers in Oregon and tributary streams of the Olympic Peninsula and the Columbia River in Washington made up additional plantings. By 1920, steelhead were well established along the north shore of Lake Superior. The steelhead is technically an anadromous or sea-run rainbow trout. Wild migratory rainbow trout in the Great Lakes are also called steelhead due to their appearance, life history strategies and ancestry.

In Canadian waters of Lake Superior, little management of steelhead populations was needed or, for that matter, even attempted following their introduction. Fish stocked in the late 1800's were left to fend for themselves in a remote, uninhabited wilderness. This proved to be an excellent management strategy that has enabled steelhead to thrive in most suitable tributary streams and rivers along the 800 miles (1,100 km) of rugged Lake Superior shoreline. This is virtually the only large geographic area in the Great Lakes where steelhead have been allowed to adapt to local conditions free from any negative genetic effects resulting from stocking programs.

Lake Superior separates Minnesota, Wisconsin and Michigan from Ontario, Canada by 31,820 sprawling square miles of ice-cold water, with depths plunging to 1,333 feet. It is the largest, deepest and coldest of the Great Lakes. The Canadian side is comprised of a rugged, wilderness shoreline similar to the Pacific Northwest except that it does not have high, snow capped mountains. Boreal mixed hardwood and softwood forests and muskeg wetlands cover the granite Precambrian Shield. Steep gradient streams tumble over bedrock, rock and gravel substrate and are frequently interrupted by waterfalls and long stretches of whitewater. Development is limited to small paper mill, mining and railway communities that dot the shoreline along the Trans-Canada Highway. The only major urban areas are the cities of Thunder Bay in the extreme west and Sault Ste. Marie on the southeastern shore of the lake. The climate, moderated by the waters of Lake Superior, is considered to be modified continental. Lake Superior moderates winter temperatures while having a cooling effect during the summer months. In spite of this influence, the north shore of Lake Superior has one of the harshest temperature regimes for steelhead in North America. Mean winter air temperatures range from 5 to 14 degrees Fahrenheit (–10 to –15 C) and can reach extremes of –40 F. (–40 C). Tributary streams remain ice covered from November to May.

Photo by Jon George

A tagged steelhead is released back into a North Shore stream. Data collected by volunteer anglers has played an important role in management of wild steelhead stocks.

The salmonid community of Lake Superior's north shore is a complex mixture of both native and introduced species coexisting with steelhead in both the lake and stream environments.

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Two chars, the eastern brook trout (*Salvelinus fontinalis)* and the lake trout (*Salvelinus namaycush*) are indigenous species, comprised of both resident and migratory populations. In addition, a variety of salmonids have been introduced, including brown trout (*Salmo trutta*) in the late 1800s, pink salmon (*Oncorhynchus gorbuscha*) in 1957, and coho (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*) in the late 1960s. Like steelhead, these introduced salmonids quickly colonized and are now considered established species in most of Lake Superior. This multi-salmonid community has created an attractive and diversified recreational fishery.

The life history characteristics of Lake Superior steelhead populations are similar to stocks in their native range, though survival adaptations from the original genetics have become further modified through natural selection. The result is localized populations that vary considerably, each having developed a unique set of adaptations. Spawning takes place in the spring, though mature fish may enter their home stream as early as August of the previous year. Mature steelhead migrating in the fall will generally move a considerable distance upstream before over wintering.

These early migrants are usually the first to spawn in the spring and appear to be necessary to fully seed headwater locations. Fall migrants have an advantage over spring migrants due to warmer water temperatures and more stable flow regimes. These environmental conditions create a greater window of opportunity to navigate obstacles such as waterfalls. The life history strategy of fall migration may have developed from summer run steelhead transplanted from their native environment.

Many Lake Superior tributaries also receive a fall migration of immature steelhead that have spent one or two years in the lake. These appear to be feeding migrations corresponding to freshets, preferred temperatures and the presence of salmon spawning activity. It is believed that these fish return to the lake prior to freeze-up. Spring spawning migrations usually begin in April and are over by early June, though a few adults in a scattering of tributaries migrate in March and July. These migration patterns are influenced by a variety of factors, including discharge, water temperature and geographic location. Redd construction may occur from early April to mid-June, peaking between late April and late May.

Juvenile steelhead spend one to three years in their home stream prior to migrating to Lake Superior as smolts. Two years of stream life is the dominant pattern in most small streams; three years is rare. While one-stream-year dominance is rare in most wild Great Lakes steelhead populations, several small tributaries found along the northwest side of Lake Superior have adult steelhead populations expressing a one-year smolting history of greater than 80 percent. This unique adaptation may be due to poor yearling habitat or interactions from resident fish. Another interesting life history strategy is found in tributaries that have low summer flows or dry up completely. Adults spawn in the feeder stream but the juveniles are often forced prematurely to the lake. In spite of their small size they appear to survive quite well, especially around bedrock embayments and boulder structure. The cold water temperatures of Lake Superior and the lack of inshore predators probably contribute to their survival.

North Shore steelhead have been allowed to adapt to local conditions free from the negative genetic effects of stocking programs.

Once in the lake, most steelhead remain for two years before embarking on their first spawning migration, though males often mature following only one year in the lake. In some populations, three and four lake years at first spawning are common, especially for female steelhead.

Lake Superior's steelhead appear to have evolved the ability to spawn multiple times, a characteristic that appears to be a prerequisite for optimal recruitment. Most healthy populations have repeat spawning levels for both sexes of between 50 and 70 percent. Males tend to have higher natural mortality and therefore lower repeat spawning, probably due to multiple spawning events (within the year) and the period of time spent in spawning streams. In relatively pristine populations males may spawn three to four times in successive years while females commonly have four to six spawning migrations.

While in the lake, feeding is focused primarily on terrestrial insects and freshwater shrimp (Mysis). As a result of the lake's cold and unproductive environment, growth rates of steelhead are predictably slow. Mature adults range from 12 to 16 inches (30 to 40 cm) after one lake year, 18 to 22 inches (46 to 56 cm) following two lake years and 23 to 26 inches (58 to 66 cm) after three years spent in Lake Superior. Steelhead larger than 28 inches (70 cm) are rare in most populations and are considered to be trophy quality by most anglers.

Historically, angling regulations in Canadian waters of Lake Superior were quite liberal. No closed season existed for steelhead and the bag limit was five fish without any size restrictions. This left wild stocks extremely vulnerable to over exploitation, especially during spawning migrations. Fortunately, the remote nature of the lake's north shore kept angling pressure on steelhead populations low into the early 1970s. However, during the 1970s and 1980s, the high quality angling opportunities for wild Lake Superior steelhead were realized. As fishing pressure increased, excessive harvest soon followed.

By the late 1980s steelhead anglers noted symptoms of a declining steelhead fishery. Catches were dwindling and average size was considerably reduced. The North Shore Steelhead Association (NSSA), an active angling club in Thunder Bay, Ontario, lobbied the Ontario Ministry of Natural Resources (OMNR) for a lake wide assessment of the status of steelhead stocks in Lake Superior. The result was a cooperative venture between government biologists and anglers. The assessment study solicited volunteer anglers to sample catches during the spring spawning migrations over a four year

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period — corresponding to one generation of steelhead. The volunteers were given sampling kits and collected length, sex and scale samples (to provide age estimates) from mature fish in each stream they fished. Life history strategies were extrapolated from the scale samples by sex and used to assess the health of steelhead stocks. Steelhead anglers collected close to 4,000 samples from 32 north shore streams between 1991 and 1994. Sixteen streams with the greatest sample size were used to assess the health of steelhead stocks.

The biological data collected indicated that fishing mortality was excessive, especially close to urban areas. There was a general trend of low repeat spawning corresponding with a high annual mortality rate. In several cases there were very low numbers of maiden spawners and dramatic fluctuations in year classes that were symptomatic of inadequate spawning success resulting in stock recruitment problems. In 1994, based on this information, a steelhead status report recommended maintaining an open season but restricting the bag and possession limit to one fish. An interim regulation of two fish (one over 20 inches (50 cm) and one under 20 inches (50 cm) was enacted in 1996. This was followed by the formulation of a working group made up of interested parties from along the lakeshore. Their mandate was to review the assessment data, solicit input from resource experts, obtain public input and to recommend management strategies. In the spring of 1999, the limit for steelhead was reduced to the original recommendation of a one fish bag limit for western Lake Superior (Thunder Bay to Marathon). A two fish limit was established on the eastern side of the lake from Marathon to Sault Ste. Marie. In addition, a minimal size restriction of 27 inches (69 cm) total length was deemed necessary to protect critically low populations in two urban streams located in Thunder Bay.

One particular western Lake Superior tributary, considered heavily exploited during the 1991 to 1994 lakewide assessment, was closed to public access by the landowner in 1994. The Ontario Ministry of Natural Resources took this opportunity to launch a more quantitative study to evaluate the effects of exploitation on steelhead. This was accomplished by obtaining population estimates and life histories data for at least two generations (eight years) after closure.

Volunteer anglers, in partnership with the Ontario Ministry of Natural Resources, were again called on to capture steelhead, collect biological data and apply tags and clips to the fish prior to live release. Population estimates were calculated through mark and recapture, using fin clips and tags, from one spring to the next. Life history strategies by sex were obtained from the scale samples. Each year, 250 to 350 adults (30 to 35 percent of the estimated population size) were captured, tagged or fin-clipped, biologically sampled and released. At the outset of the project in 1994, the adult population size was estimated to be 600 fish, the repeat spawning level was 30 percent and recruitment of small fish was low. By the spring of 2000, the population had risen to 1,200 adults (plus or minus 25 percent), recruitment had stabilized, 60 percent of fish had previously spawned — some as many as four to six times — and large trophy-sized fish were again present.

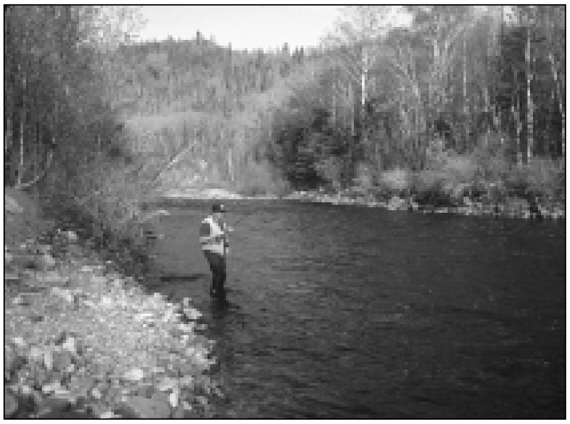

Photo by Jon George

The scenic Jackpine River is one of the best steelhead production streams on the Ontario side of Lake Superior.

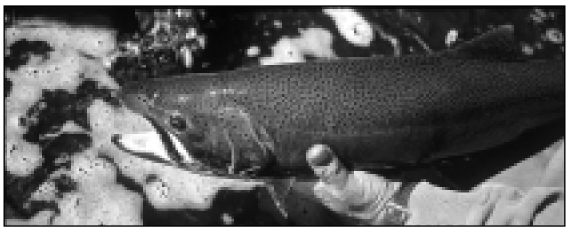

Photo by Jon George

This dark male wild North Shore steelhead sports both its spring spawning coloration and an orange Floy Tag.

Two additional bits of information that came from this study were fishing/handling mortality rates and homing of adults back to the same stream. Approximately 2,000 steelhead were angled, biologically sampled and tagged from 1994 to 2000. The mortality rate was estimated to be two percent in spite of water temperature that reached 57 F. (14 C.). Tagged steelhead were captured over a wide area of Lake Superior but the stray rate of adults to other tributaries in subsequent years was only two percent.

This quantitative study illustrated the value of restrictive harvest limits and the benefits of using volunteers. Not only did volunteers provide an inexpensive and viable method of collecting valuable data, angler involvement and input made final management decisions more acceptable to the resource users. Angler participation in the more quantitative study has resulted in solid public support for the restrictive harvest regulations that are now in place.

Steelhead are a valuable game fish in the Canadian waters of Lake Superior. Their elusive nature, reputation as an energetic fighter and potential to reach trophy sizes combine to provide a high quality angling experience to a wide variety of anglers. Thus, continued maintenance of the integrity of these wild stocks is a highly desirable goal for fishery managers. Through cooperation with anglers and the introduction of regulations based on solid scientific evidence, there is strong reason to believe that steelhead stocks in Lake Superior will continue to provide quality angling for generations to come.

Finding More Water in the Midst of Drought

by Daniel J. Rohlf

— Northwestern School of Law —

Too many demands on scarce resources is (arguably) the root cause of the Columbia River salmon and steelhead's problems. Everyone wants a piece of the Columbia and what she has to offer. But is there enough to go around? In the following essay, Daniel J. Rohlf offers some thoughts on how society just might have more of the Columbia River system's two signature resources — salmon and electricity — resources that are usually presented as nearly mutually exclusive.

Rohlf is a clinical professor of law at Northwestern School of Law, Lewis and Clark College, and Director of the Pacific Environmental Advocacy Center, both located in Portland, Oregon. This essay first appeared in the April 3, 2001 issue of The Oregonian (Portland, Ore.).

As river flows plummet and power prices climb, conflicts between two of the Northwest's signature assets – salmon and inexpensive electrical energy – are fodder for attention-grabbing headlines. But nearly lost amid the high profile fish-versus-hydropower rhetoric is public scrutiny of policy choices that hold the promise of producing both more salmon and more kilowatts.

Migrating salmon and power generators at dams both need abundant water flowing down the Columbia and Snake rivers. In addition, the region's economy and the Bonneville Power Administration — which supplies much of the Northwest's electricity as well as financing measures to protect fish — both benefit from reasonable power costs. Given these realities, it is not difficult to write a prescription that helps salmon and power consumers alike: find more water to increase river flows, and find ways to keep power prices as low as possible.

It can be done.

Surprisingly, it is indeed possible to "find" more water in the Columbia basin, even in times of dry weather. Water levels in the region's reservoirs are now at their lowest point in a quarter-century in part because federal dam operators, principally the U.S. Army Corps of Engineers, empty the reservoirs each winter to create space for capturing floodwaters that, at least this year, will never come.

While operating the reservoirs for flood control is an important duty of the Corps, the agency could make additional water available for fish and power generation by modernizing its tools for predicting weather and flood risk. Making use of new predictive technologies would allow reservoir operators to leave more water behind the dams during periods when the Northwest faces risks stemming from too little water, not too much. Modeling by experts at the Columbia River Intertribal Fish Commission indicates that modified flood control operations by the Corps could increase summer flow in the Columbia River by up to 18 percent.

Surprisingly, it is indeed possible to "find" more water in the Columbia basin.

Limiting water that is taken out of the system can also increase summer flows. During low water years, farm irrigators in the Northwest deplete summer flows by up to 22 percent in the Columbia River and by up to 41 percent in the Snake River. Though agriculture in general is a key part of the region's economy, a good deal of the water diverted away from both power turbines and salmon goes to produce very low value crops. For example, according to estimates by the Northwest Power Planning Council's Independent Economic Advisory Board, alfalfa provides an economic return of about $9 for each acre-foot of water used to grow it. Simply leaving this water in the river would produce many times that value in increased electrical generation while at the same time benefiting migrating salmon.

The federal Bureau of Reclamation supplies irrigators with vast amounts of water from the Columbia and Snake Rivers at heavily subsidized prices. It is time to re-think whether the region's salmon and power system can still afford such practices on so grand a scale, particularly in times of acute water and power shortages.

On the financial side of the equation, significant BPA rate increases imperil the regional economy and diminish BPA's ability to pay for salmon protections. Ominously, however, the agency has made clear that its rates for electricity may double beginning this fall.

In the face of this dire situation, Northwest aluminum smelters, collectively among the region's largest power users, are lobbying officials in Washington D.C. for continuation of a sweetheart financial deal which has already netted the smelters a $1.2 billion windfall while other power users suffer. Over opposition from both BPA and fish advocates, aluminum companies are attempting to secure new power contracts which would in effect require all other BPA customers to shoulder much larger rate increases in order to subsidize the smelters' lower energy costs.

The response to this audacious and one-sided proposal should be an emphatic "no."

Implementing these steps to secure additional water and minimize increases in electric rates will not take place without regional dialog, creativity, and willingness to make sometimes painful tradeoffs among alternative uses of the Columbia hydrosystem's scarce resources. But the Northwest should not miss the opportunity for serious discussion of these measures by emphasizing conflicts rather than common interests between salmon and power generation.

REDUCING THE IMPACTS OF HATCHERY STEELHEAD PROGRAMS ON WILD STEELHEAD

by Robert B. Lindsay, Ken R. Kenaston, and R. Kirk Schroeder

— *Oregon Department of Fish and Wildlife* —

Readers with an interest in the interactions and impacts of hatchery steelhead on wild populations will find this report by researchers from the Oregon Department of Fish and Wildlife enlightening. Bill Bakke of the Native Fish Society, Portland, Oregon, adapted this abridged version of the complete report. It was reviewed for accuracy by the report's authors. The complete report is titled "Reducing Impacts of Hatchery Steelhead Programs." Oregon Department of Fish and Wildlife, Information Reports, Number 2001-01, Portland, Ore. 87 pages. The entire report can be obtained by going to www.orst.edu/Dept/ODFW/ then clicking on "Information Reports."

Introduction

The persistence of hatchery programs and of productive natural populations of anadromous fish may depend, in part, on the ability of fish managers to conserve genetic resources. Native stocks have adapted to diverse natural habitats, which improves survival over a wide range of conditions. The capacity of steelhead to persist when faced with environmental change is, in part, a function of their evolutionary history. The combined evolutionary histories of many wild stocks of steelhead determine the genetic capacity of the species to cope with environmental change. Genetic resources can be lost inadvertently by fish managers through harvest regulations, hatchery programs and practices, and other traditional management activities that tend to focus on the short term. Because fish stocks removed from their natural habitat change genetically when reared in hatcheries, the only way to conserve genetic resources of steelhead, given present technology, is by maintaining wild stocks. The Oregon Department of Fish and Wildlife's Wild Fish Management Policy was adopted in 1992 out of recognition of the importance of genetic resources to the long-term health of fish species in Oregon.

People influence the genetic diversity of wild fish by altering habitats, by harvesting fish, and by stocking hatchery fish. The goal of our steelhead study was to provide information that would help decrease the risk of detrimental effects of hatchery programs on the genetic characteristics of wild steelhead. We assumed that hatchery fish would continue to be an important part of Oregon's steelhead management program.

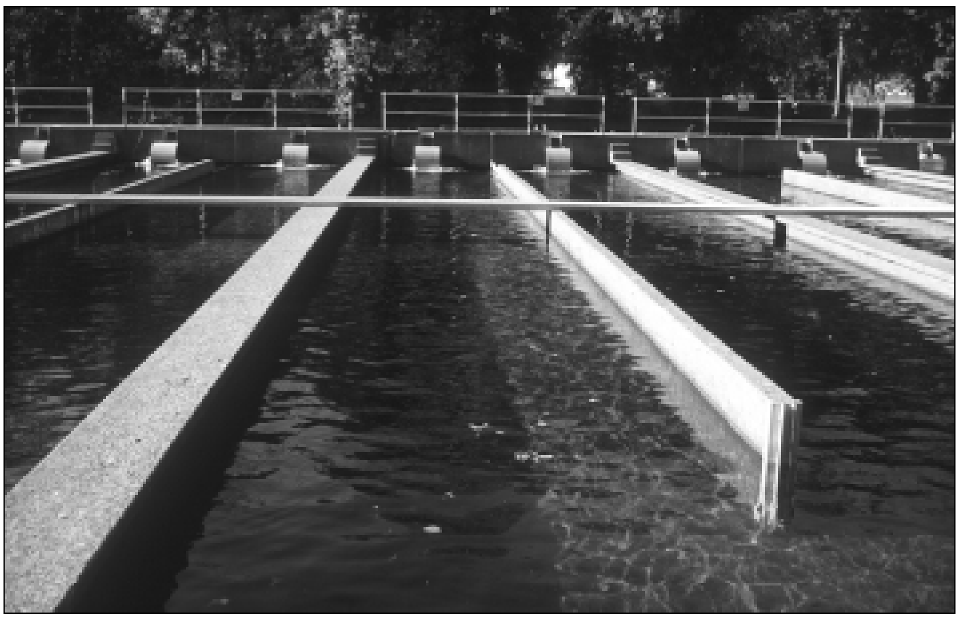

Photo by Jim Yuskavitch

The effects of mixing hatchery and wild steelhead stocks, and how to deal with those effects, have often fomented bitter and protracted scientific and political debates.

We provided information in several subject areas so managers could develop strategies to reduce genetic risk to wild steelhead populations. First, we helped identify geographic boundaries of wild steelhead populations so managers could identify streams where hatchery stocks were incompatible with wild native stocks. We also defined the magnitude of hatchery straying and the origin of these strays in coastal populations because strays constituted genetically dissimilar fish and, consequently, were restricted under the Wild Fish Management Policy. Third, we determined the percentage of hatchery fish that spawned with wild fish in selected coastal rivers and looked at methods managers could use to monitor this percentage. These data could be used to determine the status of hatchery programs relative to guidelines in the Wild Fish Management Policy. Fourth, where transplanted stocks had been used in the past, we compared the performance of hatchery adults that originated from local wild brood stock with that of hatchery adults originating from transplanted hatchery brook stock. Although the use of local brood stocks in hatcheries would reduce the risk of

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genetic impacts on wild fish, managers needed to know how the change to local brood stocks might impact sport fisheries. Finally, we investigated two strategies for reducing interbreeding of hatchery with wild steelhead on the spawning grounds. We evaluated the use of an acclimation period prior to release to cause returning adults to home to a collection site where they could be removed from the spawning population. We also evaluated sterilization as a method for producing hatchery fish that would not spawn with wild fish but would contribute to recreational fisheries.

Designation of Wild Fish Populations

Wild populations of steelhead have adapted to physical and biological conditions present within the basins in which they spawn and rear. Conservation of genetic resources requires that variation within populations and variation among populations be maintained. Eric Parkinson found significant differentiation between steelhead populations in adjacent streams in British Columbia. Steelhead stocks geographically close tend to be more genetically similar than stocks geographically distant. Some exchange between populations surely exists and is an important attribute of the species. Gary Meffe points out that "Variance among naturally isolated populations, however subtle, should be preserved and exploited through continued isolation wherever possible." Other biologists suggest that as many separate stocks be maintained as possible.

The transfer of steelhead stocks among basins is one hatchery practice that could reduce survival of wild fish because of interbreeding between locally-adapted native populations and less-adapted, transplanted stocks. The primary purpose for delineating stock boundaries was to formally identify these native populations so that steelhead management programs, especially hatchery programs, could be designed to minimize genetic risks to wild populations.

In general, all of the major basins in Oregon and in some cases subbasins within major basins were designated as separate steelhead stocks. Other ODFW reports refined this listing (see Kostow 1995) and identified management strategies for some steelhead populations (ODFW 1994).

Stray Hatchery Steelhead in Oregon Coastal Rivers

Homing to a natal site is characteristic of salmonids, but mature fish that migrate to and spawn in a stream other than their natal one are considered strays. Straying is a natural component of salmonid behavior that enables fish to colonize new habitat and to avoid locally unfavorable conditions. However, straying of hatchery fish concerns fish managers because of potential negative impacts on wild populations of interbreeding with hatchery fish.

The only way to conserve genetic resources of steelhead, given present technology, is to maintain wild stocks.

Our study...examined the degree and origin of straying of hatchery winter steelhead among several major river basins on the Oregon coast.

In Oregon coastal rivers where hatchery steelhead were released, the incidence of stray hatchery fish ranged from four to 26 percent of the total sample. The highest incidence of straying was in the Alsea River, where over 25 percent of the total catch was composed of stray hatchery fish.

Stray hatchery steelhead composed an average 22 percent of the composition of winter steelhead in five streams where no hatchery fish were released. The percentage of stray hatchery fish exceeded 10 percent in four of the five streams (Oregon's Wild Fish Policy sets a standard of 10 percent for strays when the stray fish are not native to the river where they are found). Most of the stray hatchery fish in these were from hatchery releases made in nearby rivers.

Stray hatchery steelhead increased the occurrence of hatchery steelhead in rivers where hatchery fish were released by an average of five percent. The additive percentage of straying and homing hatchery steelhead in 11 coastal rivers where hatchery fish were released composed a mean of 58 percent (range 26 to 87 percent) of the total sample. Lirette and Hooton reported in 1988 that stray hatchery steelhead accounted for an average 14 percent (range 0 to 44 percent) of the total hatchery catch in nine Vancouver Island basins.

Generally most stray hatchery steelhead in the surveyed streams were from nearby releases. Of the known strays in 16 streams, releases from adjacent streams (defined as the nearest basin receiving hatchery fish north and south of the mouth of the subject stream) accounted for 57 percent of the strays and composed the majority of strays in 10 of the 16 sampled streams.

Use of a local brood stock appeared to reduce the incidence of strays in the home or rearing basin, and in other basins. Interestingly, the return to the Alsea basin of Alsea steelhead reared and released in the Umpqua suggests some imprinting at the egg development stage or a genetic component for homing.

Steelhead transplanted from Alsea Hatchery were particularly apt to stray accounting for 84 percent of the known stray hatchery fish in the Alsea River, and composed the highest percentage of strays in other rivers compared to other releases.

Stray hatchery fish create difficulties in attempts to manage rivers for naturally producing populations. Under Oregon's Wild Fish Management Policy, only 10 percent of the naturally spawning population may be composed of genetically dissimilar fish. Stray hatchery steelhead composed 10 percent or more of the total catch in 10 of 16 Oregon coastal rivers. The genetic integrity of locally-adapted populations can decrease with rates of migration (and gene flow) from stray hatchery fish as low as five to 10 percent, especially when selection pressures maintaining local adaptations are lower than the rate of gene flow between populations.

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The National Marine Fisheries Service has used an interim straying guideline of less than five percent of the naturally spawning populations to limit the proportion of stray, non-native hatchery fish.

We believe the proportions of stray hatchery steelhead we measured in the total catch of rivers is a good measure of the interbreeding potential between the non-native hatchery fish and the naturally produced fish in those rivers. Stray hatchery fish can potentially affect wild populations through reduction in fitness of the wild populations by spreading deleterious alleles, through elimination of genetic differences between hatchery and wild populations, and through demographic effects such as harvest in mixed fisheries and competition.

In our study, the two predominant factors that contributed to straying in Oregon coastal basins were releases in nearby basins and releases of transplanted stocks. Another factor contributing to straying was steelhead returning to their rearing basin instead of their release basin.

Possible solutions to reducing the number of stray hatchery fish in problem streams include use of local brood stock, direct stream releases in tributaries to increase homing, rearing and release within natal basins, reduction in hatchery releases, or a combination of these strategies.

Overlap of Hatchery and Wild Spawners

Because fishery data were used, in part, to measure the degree of hatchery straying and the origin of strays, we wanted to know if fishery data reflected the actual proportion of hatchery fish in natural spawning populations. We also wanted to know if hatchery and wild fish overlapped in time and space during spawning. Based on the Wild Fish Policy, up to 50 percent of the natural spawning population can be hatchery-reared if native brood stock is used and wild fish are incorporated annually into the brood stock. The use of transplanted (or stray) hatchery fish lowers the percentage to 10 percent or less.

The conclusion of this part of the study showed: The hatchery and wild composition of the catch of winter steelhead in sport fisheries reflects the composition on spawning areas and is adequate to determine compliance with Wild Fish Management Policy, especially when the number of hatchery fish is far from the criteria specified in the policy. In all basins, there was considerable overlap in spawn timing between hatchery and wild steelhead although wild fish tended to spawn later and over a longer time period than hatchery fish.

Native populations of wild steelhead have evolved life history strategies that increases survival in their environment.

Use of Local Brood Stock in Hatchery Programs

The use of locally adapted native stocks in hatchery programs recognizes that these stocks are best suited for survival in natural environments and that their use in hatcheries will reduce genetic risks from interbreeding with wild stocks. Native populations of wild steelhead have evolved life history strategies, body form, and physiology that increases survival in their environment.

We compared relative return rate and contribution to fisheries between hatchery releases of a local stock with that of a transplanted stock. An unexpected difference in straying was also observed.

Relative survival from smolt-to-adult was not significantly different between the Siuslaw (native stock) and Alsea (transplanted non-native stock) smolts released into the Siuslaw River in 1991, 1993 and 1994. In addition, overall contribution to the recreational fishery in the Siuslaw River was not significantly different between the two stocks. Although not statistically different, estimated catch of Siuslaw stock in the Siuslaw River sport fishery was higher than that of Alsea stock in two of the three years sampled.

Siuslaw stock adults tended to migrate later than Alsea adults. The later migration timing shifted recreational harvest of Siuslaw fish into March compared with the Alsea stock.

The later migration timing of Siuslaw stock was related to the time eggs were collected from their parents. In all three years over 60 percent of the eggs from Siuslaw brood stock were taken after March 1, but only an average of eight percent of the eggs of Alsea brood stock were taken after that date. The egg take for the 1991 release was the latest of all three years with all of the eggs taken after March 1 and 83 percent taken after April 1. Several authors have found that migration timing is a heritable trait in anadromous salmonids.

Alsea River steelhead reared at Alsea Hatchery and released as smolts into the Siuslaw River have strayed as adults at a high rate back to the Alsea River rather than returning to the Siuslaw River. The Siuslaw stock reared at Alsea Hatchery but released into the Siuslaw River returned as adults at a higher rate than Alsea stock and resulted in a 50 percent reduction in straying back to the Alsea River. Increased homing to the Siuslaw contributed to higher catch of Siuslaw stock than Alsea stock in two of the years sampled.

Lower stray rates of the locally adapted Siuslaw stock and higher stray rates of Alsea stock into the Alsea River suggest a hereditary component in homing behavior of steelhead. Because rearing of the Siuslaw eggs differed slightly each year, we cannot rule out differences in imprinting that may have occurred prior to the eyed-egg stage. Evidence from other studies suggests a genetic component in homing of chinook and pink salmon.

Reducing Interbreeding of Hatchery with Wild Fish

We evaluated two potential management strategies that could reduce interbreeding of hatchery with wild fish.

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Acclimating hatchery juveniles at release sites prior to release to improve homing has been suggested as a strategy for segregating returning adults from wild fish. Sterilizing hatchery fish to prevent spawning with wild fish was another strategy discussed early in the development of the Wild Fish Management Policy.

Acclimation of Juvenile Steelhead

We found no difference in homing rate or in survival between hatchery steelhead acclimated in a tributary for 30 days and those trucked from the hatchery and released directly into the same tributary. Homing within the Siuslaw River was high for acclimated and direct releases, demonstrating that a tributary release strategy can be used to contain hatchery spawning escapement.

We found that acclimation of winter steelhead smolts did not increase survival over that of a direct tributary release into the Siuslaw Basin. Data on steelhead releases in British Columbia also indicated that acclimating steelhead smolts did not increase survival relative to direct release groups. Contribution to the fishery was similar between acclimated and direct release groups.

Acclimating juvenile Alsea stock steelhead in the Siuslaw basin prior to release did not reduce straying of adults to the Alsea River.

We found that Siuslaw stock steelhead, reared at Alsea Hatchery, strayed less to the Alsea basin than Alsea stock reared at the hatchery. Both stocks were released as smolts into the Siuslaw River. Straying was reduced by more than 50 percent over three years by using local Siuslaw brood stock.

The findings from our experiment do not support the use of acclimation facilities to improve homing or survival of winter steelhead. Our results show that tributary releases, when used in conjunction with a trap to collect returning adults, can be used to reduce the number of hatchery fish that spawn with wild fish while still providing fisheries.

We found no difference in the number of juvenile residuals between acclimated and direct release groups. Residualism of hatchery smolts seems to be related more to the size of the fish than to whether they are acclimated.

The purpose of attracting adult hatchery steelhead to a particular tributary ultimately is to reduce the number of hatchery fish spawning with wild fish by removing the hatchery fish.

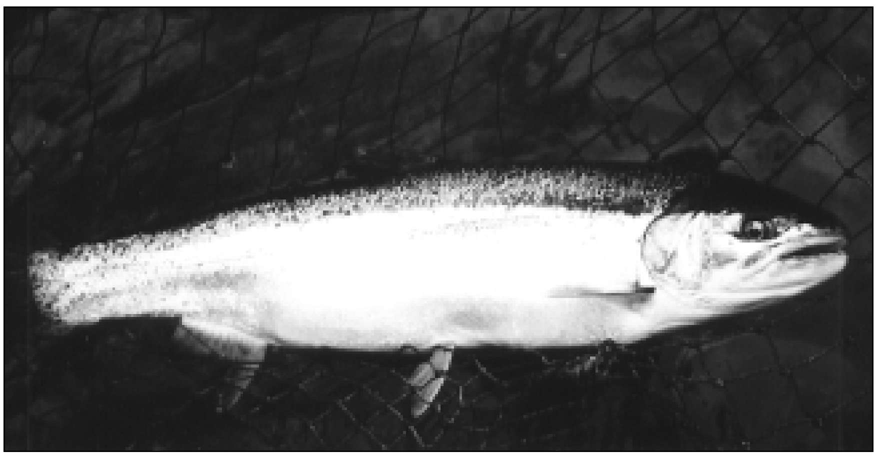

Photo by Jim Yuskavitch

Straying is a persistent problem in some river systems, bringing with it the danger that hatchery raised fish from distant river basins will spawn with the local wild steelhead population.

Recycling adult steelhead

During the last three years of our acclimation evaluation we examined the feasibility of recycling adults downstream into fishery areas of the Siuslaw River. We recycled hatchery adult steelhead through the fishery to determine if we could provide additional sport fishery benefits from these surplus fish without increasing straying to wild spawning areas.

Anglers caught an average of 10.7 percent of the steelhead recycled into downstream areas. Not all steelhead recycled are caught or return to the tributary where they were originally captured. In the three years fish were recycled, an average of only 44 percent could be accounted for in traps and in the sport fishery. Although homing accuracy for first time recycles was high, homing fidelity decreased with subsequent recycling trips. Mortality from handling fish does not explain the high number of missing fish.

Sterilization

Sterilization of hatchery steelhead was examined as a way of preventing interactions between wild and hatchery fish on spawning grounds. The objective of our work was to determine if sterilized hatchery steelhead would return at a rate high enough to provide recreational harvest while giving managers an option for reducing interactions with wild fish.

The mean smolt-to-adult return rate for three years of releases combined was 2.2 percent for control groups and 0.5 percent for sterilized groups, a four fold reduction in survival. The treatment significantly reduces return frequencies by 75 percent, 71 percent, and 80 percent for the 1990, 1991, and 1992 releases respectively. The treatment also delayed maturation. Treatment groups returned at an older age than the control groups. Adults that spent three summers in the ocean composed 51 percent of the treatment returns compared to 24 percent of the control group returns.

Treatment groups averaged 80 percent male and 20 percent female. The mean for control groups was 49 percent male and 51 percent female. Only one treatment fish appeared truly sterile.

Most of the returning fish were males that develop secondary sexual characteristics and were not sterile. The presence of gonads indicates the males would likely be sexually active. Incompletely sterilized males may compete with fertile males on spawning grounds, but most would not spawn successfully due to physiological changes. Consequently, treating hatchery steelhead ... is not an alternative for reducing hatchery fish interactions with wild stocks.

Chair's Corner, Continued

Continued from Page 3

In the fast moving environment of this year's water and power shortage, three sets of notable events have occurred since the Chair's Commentary was written a few weeks ago. B.R.

First, the Northwest Power Planning Council decided the last week of April to recommend, to the federal agencies operating the Columbia/Snake hydro system, a limited amount of spill through the lowest three Columbia River dams to assist downstream migrating salmonid smolts, but no spill through the rest of the Columbia and Snake River dams in Washington. This compromise in favor of the fish, compared to the Council's previous position, still falls far short of the spill recommended in the National Marine Fisheries Service biological opinion for recovery of Columbia system ESA listed salmon and steelhead. It is a reminder that repeated compromising of the habitat needs of the fish over the years has led to their extirpation or near extirpation in large parts of their range. When does the compromising end?

Second, Governor John Kitzhaber of Oregon addressed two important meetings in late April. One was a meeting of the Northwest Power Planning Council, the other a meeting of the federal executives who manage the Columbia hydro system operations, along with representatives of the four Northwest states and Northwest tribes. His message was consistent and forceful. He said: "The Power Planning Council recommendations and the federal agencies' plan are heavily weighted toward assuring, to the maximum extent possible, that the electricity demands of Northwest residents are satisfied ... While both plans provide electrical reliability, they fail to utilize all the tools at our disposal to continue our efforts to restore the health of the salmon and steelhead populations of the Columbia Basin." He asked for better balance between the needs of salmon and power. He urged BPA to use its extra revenues from power sales to buy more water and power from outside sources in order to make more water available for spill to aid downstream migration. He expressed reservations about relying too heavily on transporting smolts by barge or truck downstream past the dams. He also thanked the Power Council for increasing its spill plan for the Lower Columbia, saying it was a step in the right direction but didn't go far enough.

Through this developing water and power shortage, Governor Kitzhaber has been the only high level governmental or political leader to be unwavering in his continuing support for the salmon. For this, we owe him our heartiest thanks and support.

Third, two separate but complementary sets of legal actions have been initiated in the last few weeks on Snake River water allocations and ESA listed salmon and steelhead runs.

Photo by Jim Yuskavitch

Barging is likely to remain the first choice for moving steelhead and salmon smolts down the Columbia and Snake rivers this season.

(1) April 19, 2001: Four sport and commercial fishing and conservation organizations filed 60 day notice letters of intent to sue (a) the Federal Energy Regulatory Commission, which regulates the Idaho Power Company's three dam Hells Canyon Complex; and (b) the Bureau of Reclamation, which controls 11 reservoirs in the upper Snake River basin. The actions are directed to the agencies under the Endangered Species Act for failure to provide sufficient water to the lower Snake and Columbia for the downstream migration of ESA listed juvenile salmon and steelhead. Both reservoir complexes have water available, but the current federal hydro operations plan disregards the flow requirements of the fish. NMFS' Snake River biological opinion and recovery plan call for water for spill from these sources, but neither of the target agencies has completed consultation with NMFS on water requirements for the fish. A warning letter was also sent to NMFS criticizing the delay of over two years in completing the consultation and a biological opinion for operation of the Hells Canyon Complex. The notice letters to FERC and BOR request completion of consultations and biological opinions for operation of the dams which specifically address this year's low flows. Unless these actions are completed within the 60 day period, the plaintiffs intend to sue.

(2) May 3, 2001: A coalition of 13 sport and commercial fishing and conservation organizations filed suit against NMFS and its December 2000 Snake River salmon biological opinion and recovery plan, which was described by the plaintiffs as based on erroneous scientific assumptions and a lack of administration commitment to adequate funding. Todd True of EarthJustice Legal Defense Fund, attorney for the action, described the NMFS biological opinion as "a far cry from the major overhaul of the Columbia River hydro power and irrigation system that the courts called for more than six years ago." Add to that the lack of adequate funding, and the recovery plan is doomed to fail. Successful conclusion of this suit would force NMFS to redo and strengthen its recovery plan. It goes without saying that this suit could reopen the issue of lower Snake River dam breaching sooner than with the current recovery plan.

The Steelhead Committee of the Federation of Fly Fishers voted at its May 7, 2001 meeting to pursue having the Federation join both of these actions as a plaintiff. We should know the outcome of this request by about June 1.

LETTERS TO THE EDITOR, CONTINUED

Continued from Page 2

Dear Editor

Please accept the enclosed money order as a tiny token of my gratitude for still another fine issue of The Osprey.

Lee Straight
Vancouver, British Columbia, Canada

Dear Editor

On behalf of the Washington Fly Fishing Club, please find an enclosed check to help cover the continuing costs for production and distribution of your superlative Osprey.

Douglas C. Schaad, PhD
Preston Singletary
Co-Chairs, Conservation Committee
Seattle, Washington

Ready for Prime Time?

Dear Editor

Thanks for the latest issue. I especially appreciate the perspective on the Skeena, a river I have not yet been fortunate enough to fish. I note the problem of a faction wanting to kill wild steelhead as soon as the stock seems to show a temporary increase. Here in Washington we face the same problem in the Olympic Peninsula. Too bad for all of us that these resilient stocks are not fully protected for the long-term heritage value they represent to all people.

In Soverel's "endangered species," his last section on accountability raised the issue of social justice in wild salmon extinction. This is an excellent strategic direction to pursue. In my graduate studies at Evergreen College we covered environmental social justice success stories by underdogs such as Hispanic's land use in New Mexico and the United Farm Workers movement in California. One political parallel is that those movements were able to capture national attention, something the wild salmon issue has not achieved.

I was disappointed in the fall campaigns to see the Snake River dams dropped as a national issue because polls did not give it much credit outside the Pacific Northwest. I think a national campaign to achieve popular support for the recovery of a national treasure (wild salmon) could dramatically change the political situation.

Pete, are you ready to go on 60 Minutes?

Joe Jauquet
Washington

Heartening News

Dear Editor

The January 2001 issue of The Osprey had much of interest and information, like the heartening news that steelhead have been found in San Mateo Creek in 1999 after they had been declared extinct in 1991.

Now if only British Columbia commercial fishers would switch over to selective terminal fisheries, the interests of the power utilities on the North Umpqua, Columbia River and Snake River were required by regulation to manage their operations within the biological requirements of the steelhead and salmon populations of these rivers — what a banner issue that would be!

Please accept my contribution for 2001 and keep up your good work.

R.H. (Bob) Taylor
Vancouver, British Columbia, Canada

Use Us All You Want

Dear Editor

I think the January 2001 issue of The Osprey sets a record for useful content. Keep up the good work.

Jerry Reeves
Bainbridge Island, Washington

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