jeopardize the continued existence of listed steelhead such as the B-run. The continued heavy use and release of non-native steelhead broodstocks was a key reason for this conclusion. The NMFS would like to see the hatchery program shift to using locally adapted wild brood stocks for hatchery programs and gene conservation techniques in hatchery operations.

The tribes have been strong advocates for increased hatchery production in the area where they harvest fish. The tribes have taken agencies to court over issues of wild fish protection, and just recently they went to the Oregon Legislature to exempt all Oregon rivers above Bonneville Dam from the Oregon Wild Fish Management Policy.

The 1999 fall season fishery will be another test of whether the states, tribes and federal fish management agencies can reach agreement on how to protect wild B-Run steelhead, or continue to drive them toward extinction.▲

CHANGING OCEAN CONDITIONS AND THEIR EFFECTS ON STEELHEAD

William Pearcy & Nathan Mantua

Most flyfishing magazines have weighed in with articles explaining Pacific Ocean conditions and their effects on food production for salmon and steelhead. The Osprey *recognized the need for a piece with a focus on steelhead, so we contacted two of the leading scientists in the Northwest (both are steelheaders) and asked them to collaborate on a piece just for our single-minded readers. The result is a well-rounded explanation of the recently recognized Pacific Decadal Occillation and its potential effects on steelhead ocean survival.*

From California to Southwest Alaska, and across the Pacific to the Kamchatka Peninsula, steelhead return from the ocean to their natal streams. Unlike their freshwater-resident relatives, the rainbow trout, steelhead spend 1-5 years at sea, undergoing the explosive growth that makes them among the most sought after sport fish in the world.

Life History

Our story starts with the entry of juvenile steelhead (smolts) into the ocean after rearing in fresh water. Wild fish typically live in fresh water for two years but may spend 1-4 years in streams before going to sea, with rearing times increasing from south to north throughout their range. Hatchery fish usually reach the smolt stage in a single year regardless of geographic location. Steelhead smolts migrate to the ocean during the spring of the year. Upon reaching the ocean, they remain there for a few months (half-pounders) to four years or more. One-salt fish predominate in the southern part of their range (California and southern Oregon), with 2-3-salt fish the norm from northern Oregon north. Steelhead return to freshwater streams of their origin from spring to autumn (summer runs) and autumn through the winter (winter runs). Although they may enter rivers any month of the year, steelhead usually spawn in the winter and spring. Unlike most species of Pacific salmon, steelhead can spawn more than once. Though the percentage of repeat spawners is usually low, scales recovered from some fish indicate that they have spawned up to four times.

Where Do Steelhead Go In The Ocean?

Steelhead are found over a vast region of the North Pacific. Migrating smolts are sometimes caught in coastal waters soon after they swim into the ocean. Purse seine collections off Oregon and Washington caught young steelhead along the coast mostly in May and June. After that they were rare or absent, presumably because they migrated out of the region. Other collections show that steelhead migrate long distances and are widely distributed across subarctic seas into the western Pacific. Recoveries of tagged hatchery fish show that steelhead from British Columbia and Washington are found farther to the west than those from Oregon and California. Based on catches, steelhead in the high seas generally migrate north and west in the spring and south and east during the autumn and winter.

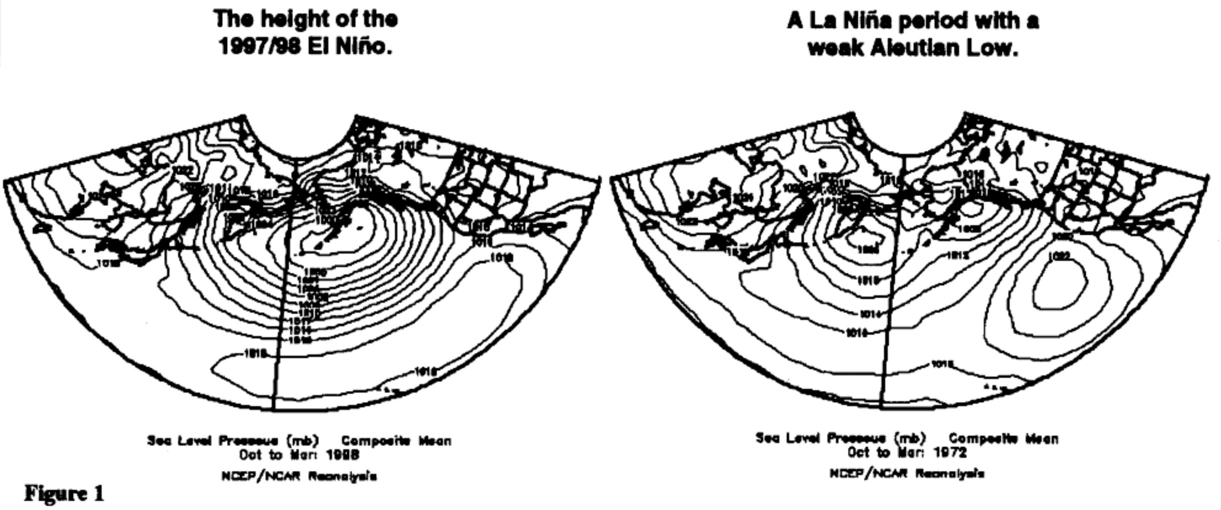
Steelhead often migrate directly into high-seas waters during their first summer in the ocean. One fish released from a hatchery in Idaho swam to the center of the Gulf of Alaska, a distance of about 890 nautical miles offshore, in only two months. Another from Oregon's Alsea River hatchery was caught south of Kodiak five months later, a distance of at least 1200 miles. These fish must be cruising at speeds of 10 miles per day or more. While most other species of Pacific salmon initially migrate along the coast of British Columbia and Alaska, juvenile steelhead appear to head directly to the open ocean.

These rapid migrations into sub-arctic waters of the North Pacific do not apply to all steelhead. Steelhead from the southern part of their range, south of the Rogue River, may not migrate to the north after entering the ocean. Instead, these fish remain in productive upwelling regions south of Cape Blanco their entire ocean life. And some steelhead from the Rogue and Klamath Rivers, for example, return as "half-pounders" after only a few months in the ocean.

Occasionally, steelhead released from a hatchery at the same time have been captured together in the high seas. Coded-wire tag recoveries of fish, up to three years after release from hatcheries, suggest that some tagged steelhead traveled together in the open ocean.

What Do Steelhead Eat In The Ocean?

Steelhead, like other Pacific salmon, feed on fish, crustaceans, squid, and other invertebrates. Small forage fish are generally the most important prey of juvenile steelhead in coastal waters, while maturing fish in the open ocean tend to feed on squid, fish and pelagic worms. Steelhead are known to feed on a wide variety of sea life, however the stomach contents of individual fish or groups of fish from the same region often consist of only a few food types. This suggests that steelhead, like other salmonids, are



The height of the 1997/98 El Niño.

Sea Level Pressure (mb) Composite Mean
Oct to Mar: 1998
NCEP/NCAR Reanalysis

A La Niña period with a weak Aleutian Low.

Sea Level Pressure (mb) Composite Mean
Oct to Mar: 1972
NCEP/NCAR Reanalysis

Figure 1

opportunists, but often selectively target the most nutritious food sources at hand. For example, in some areas of the Northeast Pacific steelhead consume mainly small squid that are very rich in lipids.

Effects of Ocean Conditions

Often summer and winter steelhead stocks have similar trends in abundance over broad regions of the Pacific coast. Moreover, year-to-year trends are often similar between hatchery and wild steelhead. Because hatchery steelhead use freshwater habitats only for a limited time compared to wild fish, and because of the similarity of trends over large geographic regions, large-scale changes in the ocean environment are thought to be a major factor in regulating steelhead abundance.

Though scientists are not entirely certain of all the factors controlling steelhead survival, several ocean-climate events are linked with fluctuations in steelhead health and abundance: El Niño/La Niña, the Aleutian Low, and coastal upwelling.

El Niño/La Niña

As many anglers are aware, El Niño gets a lot of bad press for causing warm, biologically unproductive conditions in the coastal waters of the Northeast Pacific Ocean. Especially intense El Niño events in 1982/83 and 1997/98 were connected with exceptionally warm coastal waters from Baja California to the Gulf of Alaska. Scientists have determined that El Niño plays an important role in North Pacific climate, but it is only one piece of a more complicated climate-ecology puzzle.

First, a little background information: El Niño is earth's dominant source of year-to-year climate variations. This phénomenon is understood to be a natural part of this planet's climate that spontaneously arises from interactions between tropical Trade Winds and ocean surface temperatures and currents near the equator in the Pacific. It is important to keep in mind that the "essence" of El Niño is contained within the tropics, thousands of kilometers to the south of where any North Pacific salmon ever swims. However, swings between El Niño, and its cold counterpart La Niña, have consequences for climate around the world. Simply put, massive changes in the distribution of tropical rainfall, which are directly related to changing ocean temperatures in the tropical Pacific, influence atmospheric pressure patterns, winds and storm tracks thousands of kilometers away. These changes over the North Pacific and North America are especially strong in the months from October through March. During these months, El Niño influences the character of the dominant feature of North Pacific weather, the Aleutian Low pressure cell.

Aleutian Low

The Aleutian Low is a semi-permanent atmospheric pressure cell that settles over much of the North Pacific from late fall to spring. The exact position and intensity of the Aleutian Low varies greatly from week-to-week, year-to-year, and even decade-to-decade.

An intense Aleutian Low favors northward winds along the Pacific coast, and causes relatively dry, mild winter and spring weather. In the left panel of Figure 1 is a map with contours for atmospheric sea level pressures from October 1997-March 1998, at the height of the 1997/98 El Niño. This was a period with an exceptionally intense Aleutian Low, which can be identified as the bulls-eye of low-pressure values centered over the Aleutian Islands. Northern Hemisphere surface winds blow in a direction that almost parallels the contour lines but angled slightly toward lower pressures, counter-clockwise around the lows and clockwise around the highs. Of special significance to the Pacific Northwest's coastal ocean is the fact that relatively warm northward blowing near-shore winds caused by a strong Aleutian Low tend to drive surface waters onshore (to the right of the wind direction), piling up relatively warm nutrient poor water in the coastal zone.

On the other hand, periods with a relatively weak Aleutian Low favor onshore coastal winds that move surface currents to the south. In the right panel of Figure 1 is a contour map for sea level pressures from October 1971-October 1972, a La Niña period with a weak Aleutian Low. Notice that in this year there were two relatively weak low-pressure centers in the North Pacific, one near the coast of Asia and the other in the Gulf of Alaska. Also note the strong high pressure center located off the coast of Northern California. Periods with a weak Aleutian Low typically bring relatively wet and cool winters to the Pacific Northwest region. In weak circulation periods the coastal ocean surface waters are cooler, less stratified and richer in nutrients because

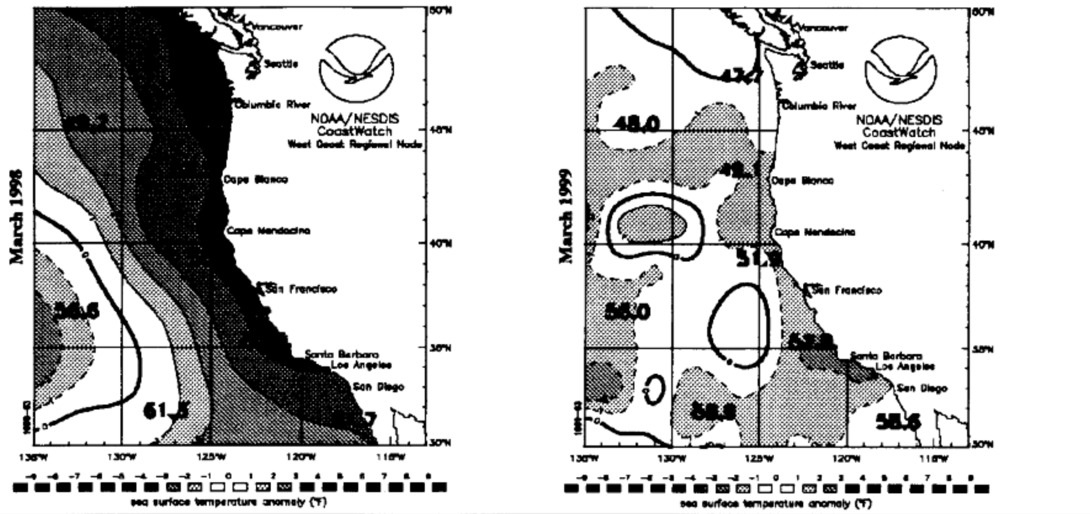


Figure 2

onshore currents are relatively weak. Off the coast of Northern California the strong high pressure cell causes southward upwelling winds even in the winter months.

Pacific climate events in the past two years have followed an often-observed pattern: the tropical El Niño favors an intense Aleutian Low, while La Niña favors a relatively weak Aleutian Low. Additionally, El Niño sends coastal currents from the tropics that travel northward along the coast of North America. These also warm and stratify the near-shore coastal waters, reinforcing the wind-driven warming and stratification brought by the intense Aleutian Low. Likewise, La Niña produces coastal currents that cool and weaken the stratification in the surface waters, reinforcing the La Niña-influenced, wind-driven cooling. In both El Niño and La Niña, the Pacific Northwest's coastal ocean is affected by changes in the oceanic and atmospheric circulation that can be traced to the equatorial Pacific—a long-range double whammy.

The maps shown in Figure 2 highlight some of the dramatic year-to-year changes that El Niño and La Niña can bring to the west coast's ocean environment. In the left panel are observed sea surface temperatures in March 1998. The contour lines and shading depict temperatures as deviations from the long-term average. Actual temperature values are shown with the larger numbers. West-coast sea temperatures were 3-to-5 degrees Fahrenheit above average in a thick layer of warm water that extended to depths of 50-to-100 meters below the surface. The wide belt of warm and sharply stratified surface waters had been present since the previous summer.

In May and June of 1998 the tropical El Niño was quickly replaced by La Niña conditions, a climatic switch that set the stage for a dramatic ocean cooling along the west coast of North America. Coastal ocean temperatures in March of 1999 (shown in the right panel) were actually a bit colder than the long term average, some 3 to 5 degrees Fahrenheit lower than those observed 12 months prior. An important factor behind this cooling was the prevalence of a weak Aleutian Low from October 1998 through April 1999. Throughout this period, North Pacific barometric sea level pressures often resembled those in the right panel of Figure 1.

Upwelling and Coastal Productivity

As the spring/summer up-welling season approaches, the coastal ocean is often primed for either rich or poor biological productivity. Clearly, the coastal ecosystem will be strongly influenced by the presence or lack of upwelling winds, but it will also depend upon the character of the preceding winter/spring Aleutian Low circulation and related ocean conditions. Following a weak Aleutian Low, cool and weakly stratified surface waters favor an especially productive food-web because upwelling winds are able to tap into the nutrient-rich subsurface waters with little resistance. Conversely, following an intense Aleutian Low, warm and sharply stratified surface waters tend to have poor biological productivity even in the presence of strong upwelling winds. The warm stratified upper ocean effectively caps the nutrient rich waters at depth. Upwelling in a sharply stratified ocean simply recycles the same depleted water in the surface layer over and over again, never replenishing the nutrients that are quickly used up by phytoplankton.

Low phytoplankton production cascades through the marine food web. Zooplankton and small fishes that feed on plankton become scarce, resulting in low food production for steelhead. For juvenile steelhead and salmon, this low productivity may result in slow growth, which can also make them more vulnerable to predation, leading to lower smolt survival rates. Also, during warm years many fishes from subtropical waters, such as mackerel, migrate into coastal waters of the Pacific Northwest from the south. These fish may compete with young steelhead and salmon for food, and in some cases even target juvenile salmonids as prey.

Pacific Decadal Oscillation

Typically, individual El Niño or La Niña events play out over the course of 8 to 14 months. However, climate records kept over the past century document decades-long warm and cool eras in the Pacific Northwest's coastal ocean that are superimposed upon the year-to-year changes associated with El Niño and La Niña. Recent research points to a second important player in North Pacific climate, the recently named Pacific Decadal Oscillation[1], or PDO.

The PDO has been described as a long-lived El Niño-like pattern of Pacific climate variability. Extremes in the PDO pattern are marked by most of the same Pacific climate changes caused by El Niño and La Niña. Two main features distinguish the PDO from El Niño. First, typical PDO "events" are much longer-lived than a typical El Niño. In this century major PDO regimes have persisted for 20-to-30 years. Second, evidence of the PDO is most visible in the North Pacific/North America sector, while secondary signatures exist in the tropics–the opposite is true for El Niño. In short, warm and cool eras of the PDO do most of the same things to Pacific climate that swings between El Niño and La Niña do, but the PDO does them for 20-to-30 years at a time.

The record of coastal sea temperatures shown in Figure 3 illustrates some of the impacts of PDO climate cycles. This data comes from the west-coast of Vancouver Island at Amphitrite Point. The record is presented in two ways: monthly deviations from the long-term mean are shown with the thin line, and 5-year running averages are shown with the thick line. The month-to-month temperature fluctuations can be as large as a few degrees, while decade-to-decade variations are more typically about +/- 1 degree Fahrenheit. Temperature records from stations along most of the Pacific Coast show the same prolonged periods of above average temperatures from 1977 to 1998 and mostly cooler than average temperatures from the mid-1940s through 1976.

Several independent studies find evidence for just two full PDO cycles in the past century: cool coastal ocean regimes for the PNW prevailed from about 1890-1924 and again from 1947-1976, while warm coastal ocean regimes dominated from 1925-1946 and from 1977 through (at least) 1998. Climate reconstructions based on tree-rings from the Pacific Northwest suggest that the PDO has been an important player in Pacific climate for at least the past few centuries, and that 20-to-30 year climate regimes are normal. Causes for PDO climate cycles are not understood.

A number of recent studies find evidence for important decade-to-decade climate impacts on Pacific salmon. Essentially, the El Niño and La Niña impacts described above appear to play out over 20-to-30 year periods because of PDO climate changes. An interesting finding is that the biologically unproductive periods in the Pacific Northwest coincide with production booms in the Gulf of Alaska. Likewise, periods with especially high coastal ocean (and salmon) production in the northwest have coincided with low-production eras in Alaska. This north-south "inverse" production pattern is thought to arise in part because a warmer, more stratified ocean in the coastal waters of Alaska benefits phytoplankton and zooplankton production.

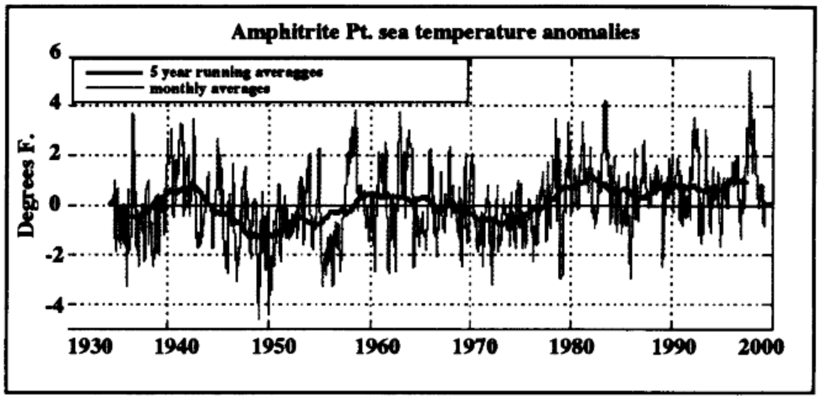


Figure 3

The cool waters in the north are most always nutrient rich, but strong stratification is needed to keep phytoplankton near the surface where the energy from the high-latitude sunshine is limited. In the Pacific Northwest's coastal ocean, lack of nutrients from increased stratification is most often the limiting factor in phytoplankton production.

Steelhead Survival Strategies In An Unpredictable World

Changes in ocean climate are nothing new; they have been a normal part of ocean ecology for centuries. Throughout their existence, Pacific salmon and steelhead and the ecological communities they are a part of have demonstrated tremendous resilience by evolving in and adapting to naturally variable environments. It is clear that wild salmonids have developed "hedging" strategies to deal with the risks they face in the unpredictable coastal ocean. Several examples are offered below.

The coastal ocean environment undergoes dramatic changes from day-to-day in response to short-lived, wind-driven upwelling events. As a means of weather and climate insurance, smolt migrations from streams to the sea take place over the course of a few weeks. An extended smolt migration period effectively increases the odds that at least some portion of each year's smolts will encounter favorable coastal ocean conditions. Hatchery releases, on the other hand, generally do not use this "hedging" strategy and smolts are released in a single pulse. If the release date happens to put smolts in the ocean when upwelling has been "just right", the payoff can be great. However, given the fact that upwelling comes in short-lived events the odds for such matching are relatively low. The pulsed-release strategy is akin to Las Vegas-style gambling.

At year-to-year time scales, a major El Niño sometimes leads to ocean changes that are so persistent that an entire upwelling season is biologically ineffective. As observed in the past few years, La Niña can turn this situation around very quickly. The big 1982-83 El Niño had obvious and drastic effects on many salmonids in the Pacific Northwest. Of the adults that returned in the fall and winter of 1983, most were skinny and very small. Steelhead and coho and chinook salmon migrating into the ocean during these years produced weak runs one and two years later. However, with a short-lived return to cooler and more favorable ocean conditions there was an El Nino rebound with generally large increases in Washington and Oregon steelhead runs from 1985 through 1988, followed by another decline. As we write this in May of 1999, there seems to be good reason to hope for a similar near-term rebound given the recent cooling trends in the coastal ocean.

Long-term sustainability is challenged when climate shifts persist for periods that exceed the length of a stock's typical generation time and when many generations are affected. Climate patterns that last 20-to-30 years, as well as longer-term cycles associated with glacial periods, result in major changes in ocean, land and in-stream climates. Recent studies have linked coast-wide salmon production cycles to the PDO, with warm eras (like 1977-1998) favoring high production in Alaska but relatively low production for many stocks in the Pacific Northwest. If history is a good guide to the future, a return to a cool PDO regime with good ocean conditions for Northwest salmon and steelhead should be expected sometime soon. Because the causes for the PDO climate cycle are unknown, it is impossible to know that a new regime has kicked in until we are several years into it.

In closing, it is important to restate the fact that poor ocean conditions are not the sole cause for the troubles now facing weakened, threatened, or endangered anadromous fish stocks in the Pacific Northwest. Steelhead and salmon have evolved with major ocean climatic fluctuations—and they have survived and flourished because of a diversity of life histories that have allowed for adaptation to a wide variety of environmental conditions. Preservation of the many different life history types of wild steelhead and salmon is essential for their future survival, and for future generations of anglers that will pursue them.

[1] The PDO label was introduced by fisheries scientist Steven Hare in 1996. At the time, he was writing his doctoral dissertation—*Low Frequency Climate variability and Salmon Production, University of Washington Press*—in which he identified and described strong connections between 20-to-30 year Alaska salmon production cycles and climate swings in the Pacific.

William Pearcy is professor emeritus at Oregon Sate University, College of Oceanic and Atmospheric Sciences. His research has earned him many awards, including the Individual Outstanding Achievement Award from the American Institute of Fisheries Research. Pearcy joined OSU in 1960, having received his doctorate from Yale University that same year. An expert on Pacific salmon, he has published more than 140 scientific papers on ecology, oceanography and general science, including biology of deep-sea fish and investigation of pollution and trace metals in the environment and the food chain. He was one of the first researchers to pinpoint ocean conditions as a cause of declining salmon stocks on the Oregon Coast. His work with the Pacific Fishery Management Council also brought attention to the serious decline in coho salmon in coastal streams. His book, "The Ecology of North Pacific Salmonids" *(University of Washington Press), is the predominant text on the subject.*

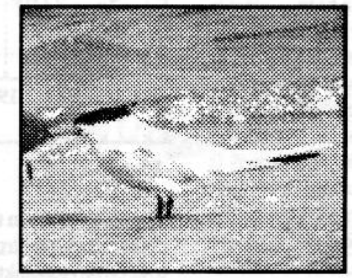
Nate Mantua is affiliate faculty at the University of Washington, Department of Atmospheric Sciences. He received a doctorate from that department in 1994. His research interests include understanding causes for climate variations like those associated with El Nino, and climate impacts on ecosystems and human activities. Recently, Mantua co-authored several articles focused on climate influences on Pacific salmon. Nate spent three

weather, cont. to page 24

AVIAN PREDATION IN THE LOWER COLUMBIA

Herb Pollard
Fisheries Biologist, NMFS

A regular contributor to The Osprey, *Herb Pollard is enjoying his new digs in Boise working at the NMFS's Snake River Research Station. He has given a couple of talks on the significant predation occurring in the lower Columbia by various sea birds, especially the Caspian Tern. Pollard explains the events leading up to the problem, and the difficulties for resource managers when bird-lovers and fish-lovers clash.*



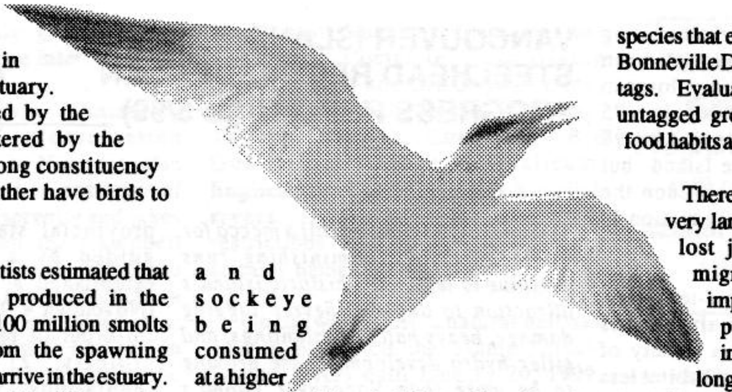
In the early 1990's, NMFS personnel at the Point Adams Field Station located in the Columbia River Estuary noted increasing numbers of Caspian Terns and double-crested cormorants nesting on man-made islands in the estuary. Because of concerns for the impacts of avian predation in the estuary and the fore-bays and tailraces of dams, a conservation measure requiring evaluation of avian predation was included in the 1995-1998 Biological Opinion on Operation of the Federal Columbia River Power System (FCRPS). As a result of the measure in the biological opinion, the Corps of Engineers and BPA have funded a research project on avian predation in the Columbia River estuary and main stem, conducted since 1996 by scientists working for the Columbia River Inter-Tribal Fish Commission and Oregon State University.

Some startling results have been presented. The following discussion summarizes some of the study results and relates the level of predation to the occurrence of smolts in the estuary.

In the past 15 years, there has been a rapid increase in the number of predatory waterbirds nesting in the Columbia River Estuary and preying on juvenile anadromous salmonids during smolt migrations. Prior to 1984, there were a few hundred double-crested cormorants and gulls reported as nesting in the estuary. The first reported nesting of Caspian terns in the Columbia Basin occurred in 1984, when a colony of about 1000 pairs nested on East Sand Island on freshly deposited dredge spoils. The tern colony has since moved to Rice Island, another man-made dredge-spoil island, and expanded rapidly to approximately 8,000 pairs in 1997 and 10,000 pairs in 1998. Cormorant nesting colonies were first reported at East Sand Island in 1987 and at Rice Island in 1988. The East Sand Island cormorant colony has grown to 5,000 pairs and is reported as the largest colony of the species on the west coast of North America. At 1,500 pairs, the Rice Island colony is the second largest colony on the west coast. There are approximately 7,000 pairs of cormorants and 10,000 pairs of gulls nesting on the man-made islands, in addition to 8,000 to 10,000 pairs of Caspian terns. Two other colonies of terns, totaling about 1,500 pairs, and several large gull colonies totaling about 70,000 pairs, have developed on islands in the upriver pools.

While some amount of avian predation is a natural component of the ecosystem of anadromous fish, the present situation is a very unnatural result of man-made habitat that has attracted species never before reported in the basin and has favored the expansion of predators at a huge cost to fish, including species listed under the Endangered Species Act. Nearly all of the pisciverous water birds are nesting on islands built by the Army Corps of Engineers during the course of maintaining the navigation channel. (Further upriver, birds are nesting on islands created during construction of dams and flooding reservoirs). Most of the predation activity in the estuary occurs around the islands and associated pile dikes. The level of avian predation has increased at an annual rate of around 30 percent for several years.

Terns, gulls and cormorants are all protected species under the Migratory Bird Treaty Act. These species may not be taken or harassed when nesting. The largest concentrations of nesting birds and the highest energy demands of the nesting adults and growing chicks exactly coincides with



the timing of the major spring smolt migrations in the Columbia River estuary. The birds are protected by the federal laws administered by the USFWS, and have a strong constituency of public who would rather have birds to watch than fish.

In 1997, NMFS scientists estimated that of 250 million smolts produced in the Columbia River basin, 100 million smolts survived migration from the spawning streams and hatcheries to arrive in the estuary. This total included about 10 million spring chinook, 64 million fall chinook, 12 million steelhead, 13 million coho and fewer than one million sockeye.

The avian predation research project provided estimates for the number of anadromous salmonid smolts consumed by the Caspian tern colony on Rice Island. Two different methods, bill loads and stomach samples, were used to assess diet composition. The diet composition data is multiplied by metabolic requirements, population size and the amount of time the birds were present to produce estimates of smolt predation. The range of estimates is 6.6 million to 24.7 million smolts consumed by the nesting adults, on the tern colony during the 100 day nesting period.

The mid-range "best" estimate from the bill-load method is 2.4 million steelhead, 3.8 million chinook, 5 million coho and 179,000 sockeye. These estimates are approximately 20 percent of the steelhead, 7 percent of the chinook, 38 percent of the coho and over 70 percent of the sockeye that were estimated to be in the estuary during the April 15-July 15 nesting period.

The research project estimates that the cormorant colonies in the estuary consumed several million additional smolts, but the data collected on cormorants was not adequate for detailed estimates. A goal for 1998 research was to estimate cormorant impacts in better detail. The 1998 project report has not been released, but the preliminary data indicated that again the tern colony took 8-25 million smolts, cormorants took 5-10 million and gulls took about a million smolts in the estuary. The combined total of smolts consumed by avian predators in the estuary in 1998 was very likely in the range of 20 to 30 million, or between 20 and 30 percent of all species. Some stocks appear to be more susceptible, with steelhead, coho and sockeye being consumed at a higher rate than chinook. Sub-yearling chinook smolts, as produced by fall-run chinook stocks, arrive later, and are not as susceptible as yearling chinook that arrive during the peak of nesting. Analysis of tag recovery data indicates that hatchery steelhead are more susceptible to avian predation than wild fish.

During the 1996 and 1997 field seasons, research personnel attached to the avian predation project collected several hundred PIT tags from the Rice Island tern colony. Most of the tags were simply picked up from the ground in visual surveys. Data from these tags was used to draw some conclusions about relative susceptibility of hatchery and wild smolts. In 1998, a more concerted effort collected over 1,000 tags from the tern colony and 1,000 tags from the cormorant colony on Rice Island, as well as several thousand PIT tags from tern colonies located in John Day and McNary pools.

NMFS personnel from the Point Adams Field station developed a mobile PIT tag detector and a device to mechanically sift the sand on the tern colony to recover tags. The mechanical sifter collected 2,000 tags and the mobile detector read about 40,000 tags buried in the sand at the Rice Island bird colonies. About half of the tags read are of 1998 releases, with some recoveries as old as 1987. This data is currently under analysis, but is expected to provide much information about the relative susceptibility of different groups of tagged smolts. Comparisons between wild and hatchery, transported and bypassed, different species and different rearing programs will be analyzed.

Because most PIT tags are placed in fish released in the Snake River, the tag analysis will provide much data about fish which pass through the federal hydropower dams. However, there are large groups of fish such as upriver bright fall chinook, coho and all species that enter the Columbia River below Bonneville Dam that are not tagged with PIT tags. Evaluation of predation impacts on untagged groups will need to rely on the food habits and metabolic requirements data.

There is no doubt, however, that a very large number of smolts are being lost just as they complete their migration to salt water. It is important to recognize that avian predation in the estuary is impacting the survivors of the long migration and passage through the FCRPS. Of around 250 million total hatchery and wild smolts produced each year, only about 100 million survive to the estuary. These are the fish which will determine the success of any recovery or mitigation action.

It is a central assumption behind most of the Columbia Basin mitigation activities that if more live smolts can be delivered to the ocean, more adults will return. For example, the whole point of collecting and transporting smolts around the dams is to get more live smolts to the estuary. The goal of the northern pikeminnow control project is to get more live smolts through the system. In 1997, only 11.8 million smolts were collected and transported. The northern pikeminnow (formerly known as the northern squawfish) control program is estimated to reduce predation on juvenile salmonids by 3 to 5 million annually. Smolt consumption estimated for the single tern colony on Rice Island is 6.7 to 24.7 million smolts. We now have very credible information that many smolts are lost to avian predation in the estuary after being safely passed through the FCRPS by ongoing mitigation programs.

In recent years, about 100 million smolts have survived passage through the river system and about one million adults have returned to the river, a gross average for the several species over several years of around one percent return. If this survival rate could be applied to the loss of 20 to 30 million smolts to avian predators then adult returns to the Columbia River are probably reduced by 200,000 to 300,000 fish annually.

An Interagency Avian Predation Working Group is developing short and long term plans to relocate the tern colony and evaluate means to reduce the impacts of avian predators. In 1999 a pilot project to attempt to relocate part of the Rice