Climatic Variations and the Political Economy of the Pacific Salmon Fishery

Kathleen Miller
Environmental and Societal Impacts Group
National Center for Atmospheric Research
Boulder, CO

The once-thriving commercial and sport salmon fisheries off the coasts of Oregon and Washington have been completely shut down this year. The Pacific Fisheries Management Council, which regulates fishing activity from 3 to 200 miles offshore and the state fishery agencies, which have jurisdiction inside of the 3 mile line agreed that no ocean harvest of Coho or Chinook salmon should be allowed because the Coho runs were expected to be too small to withstand any fishing pressure. While the Chinook runs were not expected to be as weak as the Coho, the two species are intermingled off the Oregon and Washington coasts and troll harvesting of Chinook inevitably increases Coho mortality. Recurring El Niño conditions have been cited as the proximate cause of the decimated Coho runs. Even the competing groups of commercial, sport and Native American harvesters who normally squabble vociferously over the division of the catch have, for the most part, agreed that complete closure of the ocean fishery is the only reasonable response to the effects of El Niño on the Coho runs.

President Clinton declared the situation a federal disaster and made $15.7 million available to assist fishermen and fishing communities in Washington and Oregon. The program includes cash grants to fishermen, a permit buy-out program and short-term employment, making it far more comprehensive and generous than the disaster loan program implemented a decade earlier in response to the effects of the 1982-83 El Niño.

Meanwhile, Canadians fishing off the west coast of Vancouver Island have continued to harvest a substantial proportion of the salmon migrating southward to spawn in rivers in Washington and Oregon. The lack of restraint shown by the Canadians in harvesting those troubled runs is linked to deadlocked negotiations over renewal of the expired Pacific Salmon Treaty. Farther north, Alaska has posted another in a string of record-breaking salmon harvests with more than 193 million salmon harvested in 1994 by the commercial fleet. In California, healthy Chinook runs have allowed an approximately normal sport and commercial salmon fishing season despite some closures and regulation changes designed to minimize the impact of the fishery on Coho populations.

The evidence suggests that ENSO-related variations in both ocean conditions and streamflows have affected the performance of some salmon stocks, but ENSO is only one thread in an intricate and rather obscure web of factors influencing the fortunes of hundreds of distinct salmon populations spawning from Alaska to California. Wild salmon stocks also have been damaged by increased fishing pressure, competition from hatchery fish and loss of spawning habitat due to dam construction and stream degradation, while hatchery salmon have, in some cases, shown poor ocean survival (Nickelson, 1986). The effects of El Niño conditions are anything but uniform across these various salmon populations. For example, while Coho and some Chinook stocks spawning from Washington southward appear to have been seriously damaged by the reduced upwelling and warm near-shore waters associated with recent El Niño events, other Chinook stocks spawning in the same areas have been less affected. The almost meteoric increase in Alaskan salmon runs since the mid-1970s may also be related to changes in ocean circulation sustained by more frequent and intense El Niños over that period, but the true causes of the phenomenal success of the Alaskan salmon fishery are not well understood.

Salmon are anadromous fish. Five species of salmon spawn in the streams of western North America, where the extent and condition of spawning gravel as well as the quality, quantity and temperature of the stream water influence the number of juveniles that will hatch and survive. After varying periods of residency in the fresh water, they return to the ocean where they mature and begin their return migration to their natal streams where they spawn and die.

To understand how better forecasts of ENSO-related oceanographic and atmospheric conditions may or may not be valuable for management of the Pacific salmon fisheries it is important to understand how those conditions and their timing can affect patterns of food availability and predation at the various life-stages of a salmon cohort as well as how streamflow conditions may affect spawning success and egg-to-smolt survival. But even a perfect understanding of the biophysical system will not ensure that improved forecasts of ENSO-related conditions will allow improved management of the resource or an increase in its socioeconomic value. That will depend on whether there is a management entity that possesses sufficient authority over the stock in question to effectively control its exploitation and whether that entity is motivated to efficiently manage the resource.

There have long been charges that inter-jurisdictional conflicts and efforts to appease various competing users of this regulated-common-property resource have resulted in an excessively costly and irrational management and harvesting system for Pacific salmon (Crutchfield and Pontecorvo, 1969; Barsh, 1977; Higgs, 1979). If the potential value of the fishery is, in fact, being dissipated by poor control of the efforts and expenditures of competing harvesters or by inefficient use of management resources, the potential social value of improved forecasts of ENSO-related conditions may be similarly squandered. Thus, the political and economic context within which management decisions are made will be at least as important as the linkages between biological and atmospheric processes in determining the value of improved forecasts of ENSO-related changes in oceanographic and atmospheric conditions.

Consider the case of the Coho stocks spawning in Washington, Oregon and California. Coho spawn in the Fall. The young hatch the following Spring and spend one year in the stream before entering the ocean as smolts. The majority return to spawn 18-20 months later. Returning adult Coho normally feed heavily in near-shore waters before ascending their spawning rivers. There is good evidence that El Niño-related reductions in food availability reduce the growth and survival of the returning adults (Pearcy, 1991). There is also evidence that Coho smolts entering the marine environment are less likely to survive when El Niño conditions are present, but there is considerable uncertainty about the source of that increased mortality -- the role of reduced food availability cannot be demonstrated, so increased predation by such warm-water species as mackerel is suspected (Fisher and Pearcy, 1988).[1] Winter flooding, which may scour salmon eggs from the gravel or low streamflows and high stream temperatures during the freshwater rearing period also reduce egg-to-smolt survival rates. Coho, thus, can be affected by ENSO-related variations in ocean conditions or in precipitation and streamflow patterns at different points in their life-cycle.

As an example, this year's Coho run (1994), is composed primarily of the offspring of fish that spawned in 1991 -- the beginning of the most recent El Niño. Widespread drought conditions impaired the stream-survival of the offspring cohort and nutrient-poor warm water conditions were still present when they entered the ocean in the Spring of 1993. Furthermore, feeding conditions do not appear to have improved appreciably since then. These multiple blows account for the small size of this year's Coho runs destined for rivers in Washington, Oregon and California.

If improved forecasts of those conditions had been available, could fishery managers have done anything differently to improve the survival of that cohort, reduce the risk of extinction of weak subpopulations or reduce the adverse impact of the small run on commercial and sport fishing interests? In the absence of a workable salmon treaty between the U. S. and Canada, it seems unlikely that the fishery agencies responsible for the Washington, Oregon and California salmon fisheries could have significantly improved the availability of the 1994 Coho cohort to Washington and Oregon harvesters and/or escapements to spawning streams.

Suppose that advanced warning of low streamflows in 1993 had allowed arrangements to be made for increased reservoir releases or modified hatchery practices that increased the survival of Coho smolts. Suppose further that advanced warning of El Niño ocean conditions could have been used to increase survival of juveniles in the marine environment -- perhaps by justifying predator control activities. Even if such actions succeeded in increasing the number of returning adults, only that part of the run approaching the coast from the south could be protected from foreign interception, while those approaching from the north would likely be siphoned off by Canadian harvesters.

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[1] Chinook smolts do not appear to be as vulnerable to the presence of warm-water conditions upon their entry into the ocean (Kope and Botsford, 1990) and because they migrate further from shore than do Coho, they are less affected by poor coastal upwelling during their period of ocean residence. Returning Chinook adults, however, also suffer increased mortality and reduced growth if El Niño conditions are present as they approach the coast.

If the Canadians had been willing to cooperate it might have been possible to ensure adequate Coho escapements, in 1994 while allowing modest sport and commercial fisheries in both Canadian and U. S. waters. Some U. S. observers argue, however, that the Canadians are playing hard-ball with the salmon stocks heading southward west of Vancouver Island because Alaskan fishing interests have shown no willingness to decrease their take of salmon spawning in the Skeena and Nass rivers of northern B.C.. (each state delegation has veto-power in the treaty negotiations and Alaska has nothing to gain by reducing its harvest of those stocks). Canadian negotiators have also argued that Washington fishermen have taken more Fraser River Sockeye than was permitted under the 1985 Salmon treaty. The El Niño weakened southward-bound Coho and Chinook runs thus represent Canada's trump card in the treaty negotiations.

Given this management setting, the full potential value of improved forecasts of ENSO-related ocean and atmospheric conditions is unlikely to be realized. It remains to be seen if the U. S. and Canada can work out a salmon treaty that would allow efficient management of each salmon population and full exploitation of the potential value of climatic information.

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Forecasting ENSO-Related Impacts for the Pacific Northwest: Can We Promise and Deliver Usable Information?

Roger S. Pulwarty
Cooperative Institute for Research in Environmental Sciences
University of Colorado
Boulder, Colorado

The Northwest Power Act of 1980, establishing the Northwest Power Planning Council (NPPC), sought to encourage conservation and efficient energy use and promote the development of renewable energy resources, assuring the Northwest of an adequate, efficient, economical supply of power. It requires the Bonneville Power Administration (BPA) to protect, mitigate, and enhance the Columbia River Basin's fish and wildlife populations, requiring that fish and wildlife receive equitable treatment with respect to power production. The Strategy for Salmon (1992), developed within the region with strong public participation, is intended to be a comprehensive plan for rebuilding healthy and genetically diverse anadromous fish populations through the basin. As envisioned it is should be independent but complementary to future measures proposed under the Endangered Species Act and may be coordinated with one or more fish and wildlife agencies.

There are, however, numerous competing interests and conflicting interpretations as to how NPPC/BPA can meet the needs of the region and return some species to harvestable levels and move others away from the brink of extinction. Planning seasonal flow requirements or providing reasonable water budgets will depend in part on the climate forecast and occurrence of periods of drought or substantial spring rainfall, and will affect definitions of 'minimum operating pool for reservoirs, total water supply available (forecast), and the balancing of energy resource acquisition costs with lost-generation opportunities caused by increased fish flows and velocities during migration periods etc. Sectors that may be climate information-sensitive may include: fish and wildlife management at the regional planning level, hydroelectric planning (power sales, purchases, generation, maintenance, transmission), shipping, recreation, pollution concentration, flood hazard adjustment, upper-basin land-use planning, alternative power strategies and conservation, irrigation (relations to Bureau of Reclamation), integrated resources planning.

In general long-range forecasting methods are chosen on the basis of their prior skill averaged over a substantial part of the U.S. or North America. There is considerable evidence that the Columbia River Basin is situated within a region that experiences a significant and delayed relation to ENSO events of both signs, associated with migration of the Aleutian Low and splitting of the westerlies over the eastern Pacific.

Changes in species composition and abundance has been noted during ENSO events, with ocean temperature increases and northward extension and shift in distributions of Jack and Pacific mackerel, predators of juvenile salmon. Longer term fluctuations in the ocean environment, such as variations in the influx of cool, nutrient rich, low salinity, subarctic water, has the potential to mask efforts in the freshwater arena possibly leading to inappropriate management conclusions regarding indications of success or failure. Since 1976 there has been a significant increase of Pacific sea surface temperatures and a splitting of the subarctic current with reduction of southward transport and concurrent salmon catch increase in the Gulf of Alaska.

The 'value' of a forecast ENSO-related impact (and seasonal forecasting in general) may be enhanced by (1) determining that decisions considered are climate-information sensitive, assessing the user goals and past use (non-use) of information, (2) assessment of desired characteristics of climate predictions (e.g. delivery, timeliness, coordination across user arenas etc), (3) identifying impediments to the use of climate predictions (4) the clarifying procedures between information availability and decision-making (see Stewart, 1994).

Specific decision-criteria will depend in part on the following general framework: selection from among competing models, balancing conflicting scientific input, revision of prior assumptions, representation and recognizing uncertainty, deciding to hold out for more information and, realizing that more information may not help. The way in which we organize the responses to these questions are framed under management goals and constraints (see Jasanoff, 1994). The need for judgement in risk assessment is often attributed to scientific uncertainty. However gaps in knowledge are not simply bridged by asking science to fill in the blanks, nor are the location of those 'blanks', in discourse necessarily dependent on the information contained in scientific predictions.

Initial problems in meeting the 'needs' of such an assessment, in the Northwest, may be met by providing or clarifying the following: the role of the media in forecast dissemination and interpretation, the role of anecdotal information as competing information, competing forecasts from different federal/state sources (e.g. River Forecast Center, SCS etc), basin and regional scale climate profile assessments, non-forecast climate data and information such as analog seasons for the one being, predicted, extremes (very dry/very wet), probabilities for future monthly-seasonal for different ranges of condition (see also Changnon, 1992), gauge assessment along different sub-basins and flow regimes on the Columbia, studies of altitudinal impacts of ENSO on precipitation and temperature, forecast of forecast skill at various lead times interpretations of probabilistic prediction, demonstrating the incorporation of information into direct impacts on specific service sectors, i.e. understanding the needs of each sector, ongoing interaction with climatologists for describing context of forecast relative to past history, possible extremes, other regions, spatially specific forecasts with empirical confirmation of relationships with ENSO events for the region concerned, a system for integrating diagnostic observations from a wide variety of data networks to improve operational decisions (increased participation), clarification of procedures from knowledge to decision-making to implementation.

Forecasting ENSO and ENSO-Related Impacts:

The following are suggested developments and/or clarifications that may help addressing degrees of uncertainty in forecasts and our understanding of ENSO, so that users can adjust for incorporation of alternatives into their preparation on an ongoing basis, i.e so we can avoid waiting for the day when 'everything' is predictable.

Develop:

- Procedures to determine, within decision time-frames (e.g. early water-year), whether a forecast is 'erroneous' or 'failing'

- produce climate-ENSO profiles for divisions: what constitutes a dry/wet season related to ENSO: storm track/numbers variations, persistence of weather regimes (and transitions) etc. How can we combine climate and weather forecast information?

- comparisons of impacts of warm/cold events. Are they mirror images of each other?

Clarify:

- relationship of forecast skill to lead-time. Are there times, close to the period forecasted when we have no (or very little) skill? Does 'greatest skill' always appears in areas expected from empirical studies? How do we forecast the expected forecast skill and confidence? How do errors in SST forecast contribute to forecast errors in CCA and AGCMs?

- For midlatitudes how many ensembles or forecast realizations are required for a stable forecast? What is the influence of event year and model choice on hindcasting?

- the role of low frequency forcing i.e. other sources of interannual variability (sea ice, snow NAO) in the forecast of ENSO-related impacts? Why is there a seasonal dependence on predictions (spring-May barrier)? Do all studies show such a barrier?

- role of Pacific SST changes since 1976. Are composites of different categories of ENSO diverse enough to interpret the forecast of impacts? What is the likelihood of an ENSO in the magnitude of 1982-83 occurring in the 'near' future (i.e before recovery or adjustment to the series of ENSO's in the past 15 years). What has the persistence of the 1992-93 event meant in terms of ocean circulation in the Pacific? What can we say about the frequency/strength of future events?

- causes and frequency of 'aborted' ENSO's. Does heat content rise in the tropical Pacific set up (probable) atmospheric states even if the event is 'aborted'?

- do coupled-model forecasts of climate anomalies associated with warm events always have the same structure (e.g. in 5000mb anomaly height fields)? Are models exciting one particular 'mode' each time? Are the forecast or specifications made for the extremes of ENSO significantly different from similar specifications (e.g for drought/flood situations) made during non-ENSO situations?

- how does a particular forecast rise to prominence (better forecast, better marketing, or both). Does consensus exist for different forecasting efforts? How is consensus built around a forecast? Are we using the 'best available' forecast? How should a 'forecast' be interpreted differently from a 'prediction'? Should we broaden the definition of a forecast to include other criteria (than skill)?

How inclusive does the ENSO 'Community' view itself? Expanding the dialogue to assess all 'decision-relevant' information available to the user. 'Incorporating' or 'building in' forecast information into a decision-making process does not automatically result from an explicit demonstration of 'value' (Stewart, 1994). The nature of information and its perceived value changes across different scales of impact, different levels of management and at points of judgement. Many post-event studies have shown where errors (or benefits) have occurred from use/non-use/unavailability of a forecast, but little has been said on the misinterpretation of forecasts. While more information may be necessary, it is not yet clear as to where available information on ENSO variability has fit into the planning process. As a result, studies of decreased resilience of salmon populations, possibly due to human-induced stress and ENSO events, have not been able to provide strong enough evidence to encourage disinvestment in fishing based on an ENSO forecast, unless a species is already felt to be at the point of collapse. 'Surprise' may not simply result from the limits to predictability of the physical event occurring (see Glantz, 1982). ENSO-forecast information may be used to assist in carrying out 'natural experiments' (e.g. of 'dry' or 'wet' periods) to test the implementation of goals of adaptive management under which the Strategy for Salmon is framed. Accounting for the variability of ENSO into decision criteria may help inform us against routinizing choices (i.e. reducing flexibility), by clarifying the probable consequences of alternative conditions and decisions from different atmospheric and oceanic conditions. Decisions occurring after a forecast is given may not be related to related to the forecast, although the forecast may be used as an excuse to pursue goals already underway. Can we identify other trends, not evident as a linear response to climate in a decision-analytic framework, that are operating when we assess the impact of climate information?
The areas of uncertainty (and our limits of confidence) may lie not only in the forecast of ENSO but in the description and forecast of social frames and responses. In general a helpful direction in ENSO-related research (broadly or even 'differently' defined) may be to test assumptions of usability of information by utilizing 'common sense' approaches (see Ludwig et al 1993). We can proceed by allowing consideration of a variety of plausible hypotheses (and presumptions) about atmospheric states of the region in response to ENSO, assessing a variety of possible strategies that have not excluded the 'surprise' element, hedge our bets, favor actions that are flexible (incremental, reversible or allow movement to a less vulnerable state), challenge our conception of 'the situation so far' by updating across different types of information trends and sources) not just the 'official' assessment), and carefully assess what

level of vulnerability we are willing to accept in different sectors and sub-basins, in order to meet the most important stated goals. To maintain credibility it suggested that the ENSO-research community keep our promises in line with the products that we can actually deliver and with concurrent assessment and discovery of the contexts involved in the communication of associated risks.

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