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An unusual ocean climate in the Gulf of Alaska during the spring of 1997 and its effect on coastal migration of Fraser River sockeye.

by

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Abstract

The migration route of Fraser River sockeye salmon (*O. nerka*) around Vancouver Island varies annually. The annual forecast of which route (northern or southern) will be favoured is the responsibility of Fisheries and Oceans Canada. Since 1976, the proportion of salmon migrating via the northern route has been highly correlated with May and June sea surface temperature (SST) at the Kains Island lightstation in Quatsino Sound on the west coast of Vancouver Island. In 1997, the daily SSTs were low in early May suggesting that most of the sockeye would return via the southern route. In mid-May, both the temperature and the salinity rose rapidly. By late May, the SSTs were higher than at any time in recorded history (since 1934). The mean SST in June was higher than any in recorded history. The forecast northern diversion for sockeye salmon in 1997 was 79%. The observed value (preliminary) of 82% is the highest on record. The Reynold's 1° latitude by 1° longitude optimally interpolated SST data for the Gulf of Alaska indicate that 1997 had the most extreme warming of the surface waters in the Gulf of Alaska in the recent 16 year history of the record. Preliminary data suggest that the average size of Fraser River sockeye in 1997 is the smallest since 1951 and may be the smallest since 1912. The duration of the Fraser River sockeye migration through coastal waters has been one of the most protracted on record. Sockeye salmon, hypothesized to be of Fraser River origin, have been found in many rivers and streams around Vancouver Island. Sockeye salmon have also been appearing in unusual abundance in Washington and Oregon.

Introduction

Sockeye salmon (*Oncorhynchus nerka*) return to the Fraser River via one of two possible coastal routes around Vancouver Island (Figure 1). The northern route begins in Queen Charlotte Sound, through Queen Charlotte Strait, Johnstone Strait, Georgia Strait to the mouth of the Fraser River. The southern route follows the west coast of Vancouver Island to Juan de Fuca Strait, Haro Strait and/or Rosario Strait to the mouth of the Fraser River. Since 1976, the preferred route has varied from approximately 20 to 80% via the northern route annually. The northern route is exclusively within Canadian waters and the southern route passes through both Canadian and American (U.S.) waters. The failure of Canada and the United States to agree on bilateral sharing of the Fraser River sockeye salmon resource in 1997 has highlighted the importance of the sockeye migration route to both nations.

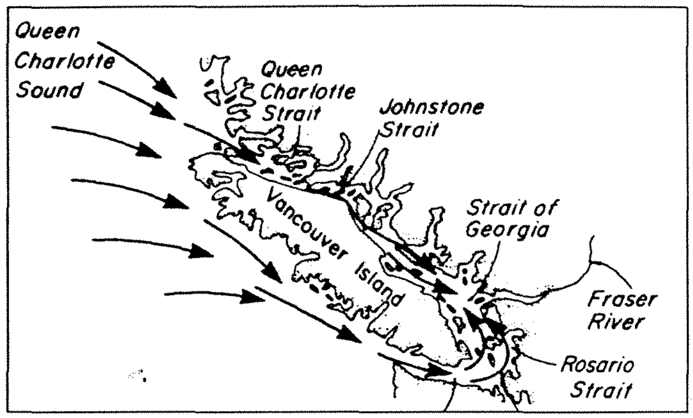

Figure 1. Sockeye salmon migration routes around Vancouver Island, B.C. (from Groot & Quinn 1987)

Fisheries and Oceans Canada provides annual pre-season forecasts of the sockeye migration route (McKinnell and Freeland, in prep.). Prior to 1977, the forecast was based largely on the magnitude of the discharge from the Fraser River (Wickett 1977). Since 1976, the sea surface temperature at the Kains Island lightstation at the mouth of Quatsino Sound on northwestern Vancouver Island has provided one of the most reliable biological indicators of the future behaviour of sockeye salmon, even though the mechanism has not been determined. During warm springs (May and June), the sockeye tend to go north. In cool springs, the sockeye go south. The forecast model is simple because the annual spring sea surface temperatures at Kains Island tend to be bimodal and so are the migration patterns. In most years, producing the forecast involves waiting until the temperature data are available to determine which state of nature appears in any given year. Unfortunately, in two of the last 21 years (1980, 1990) the relationship produced significant forecast errors.

Data and Methods

Kains Island sea surface temperature has been recorded daily by the lightkeeper at the Kains Island lightstation since 1934. The database is maintained at the Institute of Ocean Sciences in Sidney, B.C. Annual northern diversion estimates are produced by the Pacific Salmon Commission.

Fraser River sockeye northern diversion forecasts are normally issued during the first week of June and updated during the first week of July. Occasionally, interim forecasts are produced mid-month if updates are requested more frequently. The model currently in use is a GAM model (D. Welch, unpublished) that predicts northern diversion from sea surface temperatures. May sea surface temperatures are used for the June forecast and mean May + June is used for the July forecast. Only years after 1976 are included.

Gridded sea surface temperatures (Reynolds and Smith 1994) for the months of May and June in the Gulf of Alaska from 1982 to 1997 were used with the geographic information system COMPUGRID to develop isothermal contours at 8.9, 9.4 and 10.4°C. COMPUGRID (Geospatial Systems, Inc.) was used to compute the area (km^2) in the Gulf of Alaska that was less than or equal to these isotherms. The areal computations excluded the coastal waters of B.C. and southeast Alaska (waters shoreward of the islands) and they excluded Prince William Sound and Cook Inlet. The western boundary was 180°. The northern boundary (west of the Alaskan Peninsula) was the Aleutian archipelago.

The mean weight, by year, of Fraser River sockeye caught in seine gear in Area 12 and 13 (Johnstone Strait) was extracted from the Fisheries & Oceans catch statistics database (Wong 1983). The total catch of sockeye, by week, for 1952-1996 was obtained from the same database. Preliminary 1997 total sockeye catch data, by week, for Area 12 and 13 were obtained from Operations Branch, South Coast Division.

Results

In early May 1997 sea surface temperatures at Kains Island were below 10°C (Figure 2). In most years, this would result in a low mean monthly temperature and the sockeye would migrate via the southern migration route. After 9 May, the temperature rose monotonically to near 12.5°C. Temperatures this high in late May had not been observed during the period of record (since 1934). The temperature continued to rise throughout June and the mean monthly temperature for June (13.6°C) was the highest observed in the historical record (Figure 3).

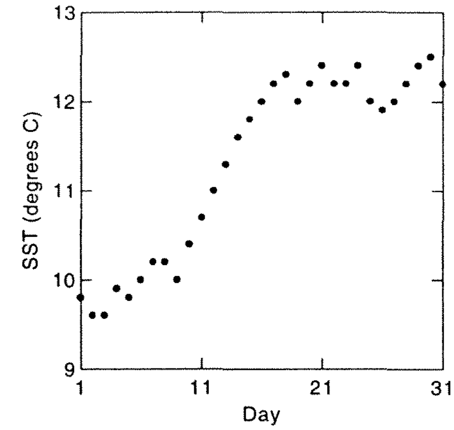

Figure 2. Daily sea surface temperature at Kains Island lightstation, Quatsino Sound, BC during May 1997.

The extreme anomaly observed at the Kains Island lightstation in 1997 was also observed in the Gulf of Alaska. The area of the Gulf of Alaska ≤8.9°C was smaller in May and June 1997 than has been observed since 1981. The area of the Gulf of Alaska ≤8.9°C in 1996 was the second smallest in the record. The area ≤8.9°C in June 1997 was 34.7% of that present in the coolest year in the series, 1987.

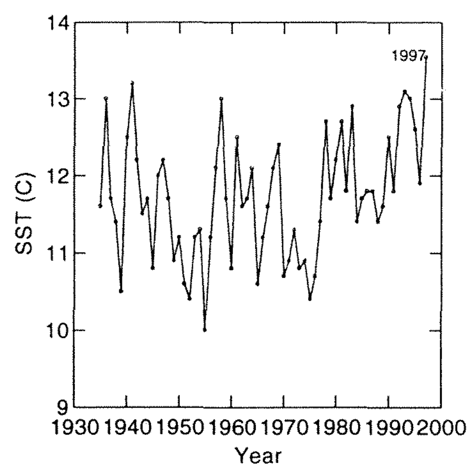

Figure 3. Monthly mean SST at the Kains Island lightstation (Quatsino Sound, B.C.).

Mean sea levels at Tofino, British Columbia were the higher in June 1997 than at any time since 1940 (Figure 4). Since 1960, peak sea levels have been coincident with major El Niño events in the tropical Pacific.

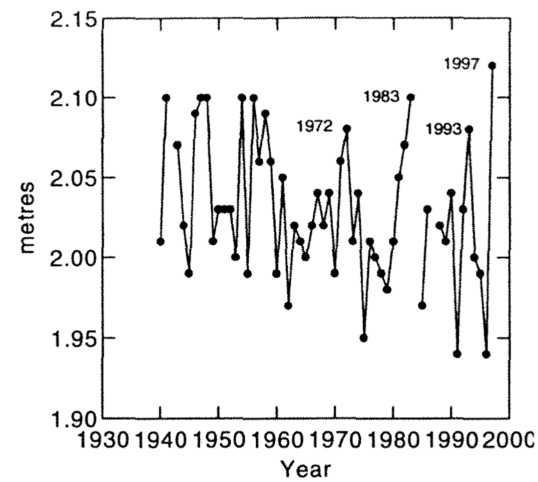

Figure 4. Mean sea level at Tofino, BC (west coast of Vancouver Is.)

There has been a significantly decreasing trend in the area of the Gulf of Alaska ≤8.9°C since 1981 (Figure 5). Bootstrap estimates of the slope and confidence intervals from a linear model suggest that the area of the Gulf of Alaska ≤8.9°C has been decreasing at an average rate of 67,085 and 83,437 km^2 per year in May and June, respectively, since 1981. The 95% confidence intervals are (-40,241 to -101,702) and (-10,742 to -160,094) for May and June respectively. Note that the 95% confidence intervals do not include 0.0.

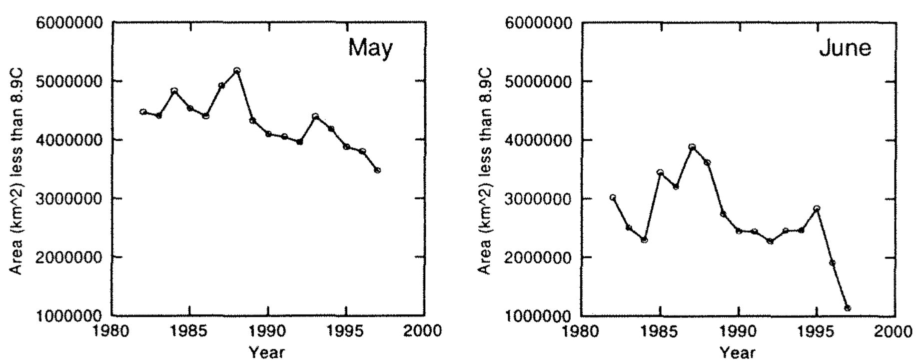

Figure 5. Area (km^2) of the Gulf of Alaska with SST less than or equal to 8.9 C (1982-1997).

The 1997 forecasts of northern diversion, abundance and run timing of Fraser River sockeye appear to have been remarkably accurate. The pre-season forecast of the Fraser River sockeye northern diversion for 1997 was 79%. The prelininary estimate of the 1997 sockeye northern diversion was 82% (Figure 6) which is the highest on record. The pre-season estimate of the total return of Fraser sockeye was 18 million. In-season estimates of run size are close to this number.

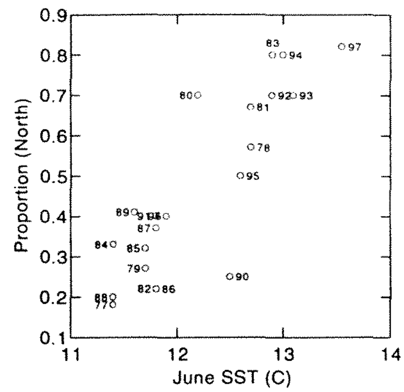

Figure 6. Proportion of Fraser River sockeye salmon returning via the northern route (1976-1997).

The migration of sockeye salmon to the Fraser River has been one of the most protracted in history (Figure 7). Sockeye were caught in unusually high abundance in pink and chum fisheries during the last two weeks of September. Anecdotal information suggests that high proportions of the sockeye caught in these fisheries were in advancing stages of sexual maturation.

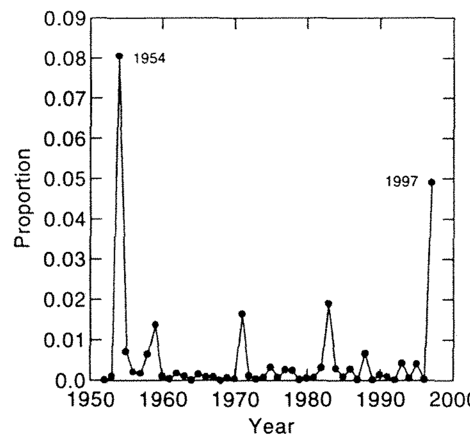

Figure 7. Proportion of the annual sockeye catch in Area 12/13 caught in the 3rd and 4th weeks of September.

Preliminary data suggest that the mean weight of sockeye salmon caught in the Area 12 (Johnstone Strait) seine fishery was 2.2 kg in 1997. This is the lowest in the 46 year history of records in the database.

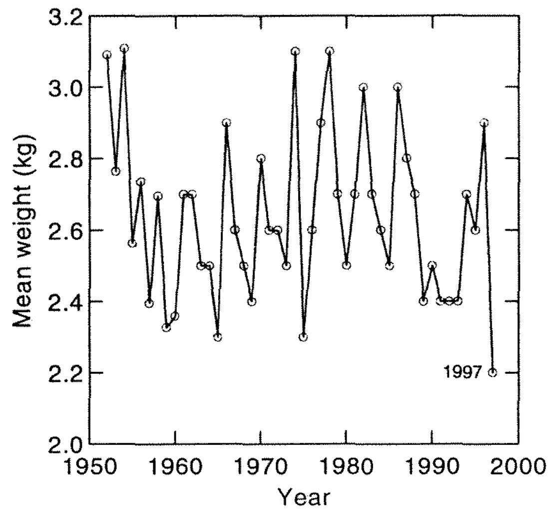

Figure 8. Mean weight of Fraser River sockeye catch (seine) in Area 12 (Johnstone Strait).

Discussion

To date, 1997 has featured extreme atmospheric and ocean climate phenomena and extreme sockeye salmon biological phenomena. Unpredicted "El Niño-like" conditions occurred in the tropical Pacific during the early spring, extreme sea surface temperatures occurred in late spring in the Gulf of Alaska and coastal BC. Fraser River sockeye were the smallest on record, with a very protracted migration through coastal waters. The migration was so protracted that some salmon appear to have have stopped migrating and entered streams and rivers along the migration route. In Johnstone Strait and on the west coast of Vancouver Island, sockeye salmon have been reported in unsual abundance in rivers and streams where they are not normally found or not normally found in abundance. U.S. biologists have reported similar findings in Washington State, Oregon, Idaho, and California (K. Kostow, pers. comm.). Some have speculated that these are Fraser River sockeye that have strayed many hundreds of kilometres from the Fraser. Equally plausible hypotheses consider the possibility that these may be local river-type populations that have experienced very good recruitment. The latter hypothesis cannot apply to those rivers that normally lack sockeye. As these extremes in climate and sockeye biology occurred within the same calendar year, it is natural to look for plausible hypotheses linking them. For the most part, the biological data are preliminary and have not been fully analyzed so any linkages are hypothetical. The abundance of Fraser River sockeye in 1997, combined with their small size, lead naturally to hypotheses concerning density-dependent growth (Peterman 1984, McKinnell 1995). Sexual maturation before the arriving at the Fraser River is a new phenomenon; perhaps suggesting an inadequate swimming speed. Warm ocean temperatures and late run timing lead to hypotheses concerning migration distance from the Gulf of Alaska to the Fraser River (Blackbourn 1987, Welch et al. 1995). If Fraser River sockeye were migrating to the Bering Sea, would we detect it?

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