PROGRESS REPORT
on
OCEANOGRAPHY

By

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Introduction

The oceanographic studies being conducted under the supervision of the American Section of the International North Pacific Fisheries Commission are directed towards accomplishing five primary objectives: first, to define the oceanic salmon environment in order to delineate the extent of the region of investigations; second, to discover within the general environment oceanographic properties or discontinuities that might contribute to a separation or isolation of stocks or races of salmon; third, to determine the effects of annual fluctuations in oceanographic conditions on the extent and position of these areas in order eventually to permit a prediction of their general geographical locations; fourth, to discover in these specific areas features conducive to large populations of salmon; and fifth, to reveal in the specific or general environment continuity of water properties at the surface or at depth that could serve as a path to a migrating population.

Methods

As in previous years, the oceanographic observations were made from chartered fishing vessels, and the stations occupied were dependent on the fishing plan. The field work was similar to that of 1958 and consisted of hydrographic casts to 1000 meters at the location of fishing sets, and casts to 300 meters between sets, resulting in observations at approximately 30-mile intervals along the cruise track. A total of 161 stations were
occupied north and south of the Aleutian Islands. The locations are shown in figure 1.

Vertical plankton hauls from 150 meters to the surface using a \( \frac{3}{4} \) meter #6 mesh net and surface plankton tows using the modified (3' opening) Isaacs-Kidd trawl were also made at fishing locations. This year no difficulty was experienced in towing the trawl at speeds of 6 to 8 knots and good samples were obtained. Drift bottles with attached hooks to permit capture in fishing nets were released at various locations.

This year, since space for chemical analyses is not available on the small vessels, we experimented with a conductivity-thermistor cell which is towed astern of the vessel and provides a continuous record of the surface temperature and salinity. The cell, designed and constructed by the Fisheries Instrumentation Laboratory, will require further modifications and improvements before it can be considered operational. However, other agencies have shown an interest in the instrument and a workable model will probably be available next season.

Salmon Environment South of the Aleutian Islands in 1958

As we have gradually extended the southern limit of our observations from 50°W in 1957, to 49°W in 1958 and to 48°W in 1959 the basic structure of the Subarctic Water south of the Aleutians has become clarified. In summer, we are able to identify three different types of environments in the upper 300 meters which are continuous within the area of our investigations, 160°W to 175°E. Because of the uniformity of water properties
Shallow cast (50-325 meters)  
1000 meter cast

Figure 1.—Location of oceanographic stations, 1959 (MV Pioneer □, MV Tordenskjold △)
at the surface, it is necessary to identify these environments below a depth of 50 meters. The water structure below this depth reflects the surface currents. These three environments, denoted A, B, and C, are schematically illustrated in vertical profile by figure 2.

Type A, existing adjacent to the Aleutian chain, is characterized by extensive mixing and sinking which results in a depression of the isopleths of the various constituents. This environment is associated with the Aleutian Current which flows westward out of the Gulf of Alaska along the chain and at depth, except at the surface near the passes through the chain, is warmer, more dilute, and richer in dissolved oxygen than the environment to the south. Then too, the vigorous mixing of this water prevents the formation of a temperature minimum or sharp halocline usually found in Subarctic Water.

The second environment, Type B, is indicated by an upwelling or vertical movement and is shown by a rise of the isopleths resulting in a ridge or plateau-like structure. This can be considered a frontal or transition zone between the westward flowing Aleutian Current and the eastward flowing current to the south. The upward vertical movement establishes a shallow, sharp halocline and results in the formation of a cold stratum or temperature minimum at a depth of 75-100 meters below which the temperature rises to approximately 4.0°C. Formation of this cold stratum by winter-overturn has been discussed in previous reports. The latitudinal extent of this environment varies from approximately 150-200 miles at 160°W to 50 miles at 175°W. The absence of any
Figure 2. Model of subarctic water structure south of Aleutian Islands.
appreciable longitudinal pressure gradient along the ridge from 160°W to 175°E indicates there is very little net movement of this water.

The third environment within the Subarctic region, before encountering the warm, saline Central Pacific Water, is identified by a depression of the isopleths of salinity and dissolved oxygen and the presence of a cold stratum existing at 150-200 meters which is colder than the stratum existing at the shallower depth in the frontal zone. This water is flowing eastward and is believed to originate in the Oyashio Current, where the extremely cold winter surface temperatures permit winter-overtures to extend to a greater depth than in the Gulf of Alaska. An indication of the intrusion of this water from the westward is shown by a horizontal plot of temperatures at 100 meters shown in figure 3.

Vertical profiles of temperature along 165°W in 1957, 1958, and 1959 (figure 4) have been constructed to show the relative positions of the two cold strata and the similarity of the temperature structure for these years. Although the presence of the cold stratum associated with the Type C environment was indicated south of 51°N in 1957 and 1958, it was not clearly identified until 1959 when observations extended to 48°N. Then too, the temperature minimum associated with the frontal zone environment (Type B), although clearly evidenced in 1957 and 1959, was absent in 1958.

Figure 5, vertical profiles of temperature, salinity, dissolved oxygen and sigma-t along 160°W in August 1958, clearly shows at depth the features of the three environments: the depression of the isopleths
Figure 3.--Temperature (°C) at 100 meters, May-August 1958
Figure 4. Vertical profiles of temperature along 165°W.
between 54°N and the land; the predominant plateau-like feature from 54°N to 51°N; and the depression of the isopleths southward of 51°N coincident with the cold stratum, (less than 4.0), indicated by shading.

Continuity of these three environments along the chain to 175°W is shown in figure 6 by similar vertical profiles in July 1958. However, at this longitude the plateau-like structure has been greatly compressed latitudinally. Also evident is the presence of a vertical movement of the deeper water extending to the surface which could serve to replenish nutrients to the surface layers. The oxygen maximum near the surface south of the ridge implies high phytoplankton productivity.

This surface penetration ceased abruptly in August, as shown in figure 7. An intrusion of warm dilute surface water has suppressed the ridge to a depth of 75 meters, resulting in surface conditions similar to those shown at 160°W in figure 5. The source of this surface dilution is indicated in figure 8, a plot of salinity at 10 meters in the Aleutian area, which shows the sharp, tongue-like salinity gradient extending from the Gulf westward along the Aleutian chain. Although the surface features in this area are considerably altered in the summer, the basic features of the three environments are still evidenced at depth.

The latitudinal extent of the three water types in 1958 are indicated in figure 9. The relationship between the vertical structure of these environments and the surface currents is seen by comparing the boundaries in figure 9 with the plot of the anomaly of dynamic height shown in figure 10. The surface currents relative to the 300 meter level clearly show the more intense westerly flow along the Aleutian chain separated
Figure 5. Vertical profiles along 160°W in August 1958 (MV Pioneer, MV Hugh M. Smith)
Figure 6. Vertical profiles along 175° W in July 1958 (MV Pioneer, MV Attu)
Figure 7. Vertical profiles along 175°W in August 1958 (MV Pioneer, MV Attu, MV Hugh M. Smith)
Figure 8.—Salinity (‰) at 10 meters, July-August 1958.
Figure 9.--Approximate north-south boundaries of the three environments south of Aleutian Chain in 1958.
Figure 10.—Anomaly of dynamic height (ΔD), θ/300 decibars.
from the eastward flow to the south by the central region (shaded) in which there is little net motion.

**Relationship to salmon catch**

It has been shown in early spring that the region south of the Aleutian chain is a potential upwelling area serving to replenish vital nutrients to the surface layer and thus permit considerable productivity. The oceanographic ridge or upwelling area separates two current systems: the Aleutian Current to the north flowing westward along the Aleutian chain, and what must be considered an extension of the Oyashio Current flowing eastward south of the ridge. The relationship between these systems and salmon catches in May and June 1959 along 175°E and 180° have been investigated.

Figure 11 shows vertical profiles of temperature and salinity, and the results of the gill net fishing on 175°E in May. The thin vertical lines have been inserted at 49°30'N to denote the approximate northern edge of the eastward flowing current. Immediately apparent is the decrease in catches at 49°N and 50°N of red and chum salmon compared to those at 48°N and 51°N. However, more striking is the decrease in the average fork length of the red salmon south of 49°N from the relatively constant average fork lengths of the catches to the north. The large catch of pink salmon at 48°N is of particular interest. However, later in the season large numbers of pink salmon were caught to the northward and in the Bering Sea.

Somewhat similar fishing results were obtained along 180° in June,
Figure 11. Comparison of salmon catch with temperature and salinity profiles along 175° E (MV Pioneer May 20-25, 1959)
as shown in figure 12. Southward of the superimposed line denoting separation of the current systems, the average fork length of red salmon dropped from 549.9 mm. to 445.6 mm., and the pink catch rose from 10 to 145 fish per set.

These salmon have not been identified by the various racial techniques. However, if subsequent analysis shows different stocks of red and chum salmon in these current systems, we can draw two conclusions. The absence of any major difference in salinity or temperature values at the surface implies that the direction of the current or the identity of other constituents in the water, or both, are important factors in the distribution of salmon in this region in early spring.
Figure 12. Comparison of salmon catch with temperature and salinity profiles along 180° longitude (MV Tordenskjold June 1959)
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