

THE ASSOCIATION OF OCEANIC BOUNDARY FEATURES AND
ALBACORE TUNA IN THE NORTHEAST PACIFIC

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ABSTRACT

The distribution and apparent abundance of albacore tuna during the early season migration toward the U.S. west coast fishery are related to the oceanographic conditions of the Transition Zone and associated oceanic frontal structure. Cooperative surveys involving a National Marine Fisheries Service (NMFS) research vessel and chartered fishing vessels were conducted during 1972, 1973, and 1974, in a region centered 500 to 1,000 nautical miles offshore California. The findings show that albacore are more readily available within the Transition Zone than outside it and that year-to-year variations in ocean structure are reflected in variations in albacore distribution.

INTRODUCTION

The North Pacific albacore tuna *Thunnus alalunga* (Bonneterre) is a wide ranging species which spawns in the central subtropical Pacific, performs trans-pacific migrations, and supports important commercial fisheries in the western, central western, and eastern North Pacific. Marked variations in the distribution and apparent abundance of albacore occur in the northeast Pacific as indicated by major shifts in the location of the U.S. fishery off the Pacific west coast.

In order to evaluate factors which may affect variations in the distribution and apparent abundance of albacore in the northeast Pacific, early season surveys were conducted in 1972, 1973, and 1974, to investigate the shoreward migration of albacore tuna into the U.S. west coast fishery and the associated marine environmental factors that could influence the migration, and to examine the early season distribution and apparent abundance of albacore in the offshore area. The surveys were designed to improve our understanding of the underlying factors affecting the prediction of the onset and subsequent development of the fishery, and to examine the possibilities for fishermen to extend the albacore fishery farther offshore and to start the fishery earlier than the season usually begins. Specifically, the surveys were conducted to examine the migration patterns of albacore tuna into North American waters and the relationship of the patterns to the eastern terminus of the Transition Zone between Pacific subarctic and Pacific central waters and to evaluate the fishery potential in offshore waters.

The surveys were carried on cooperatively by the National Marine Fisheries Service (NMFS) and the albacore fishing industry through the American Fishermen's Research Foundation (AFRF).

METHODS

The general work plan employed during each of the offshore surveys involved one NMFS research vessel (Townsend Cromwell in 1972 and David Starr Jordan in 1973 and 1974) and a group of 5 to 12 commercial albacore

fishing vessels on charter to AFRF, working cooperatively to evaluate the distribution and apparent abundance of albacore in the offshore area, and to conduct concurrent oceanographic observations. The research vessel collected physical, chemical, and biological oceanographic data and conducted supplementary fishing activities, and the fishing vessels conducted exploratory fishing, fish tagging, and collected surface and subsurface temperature data. The oceanographic findings made on meridional transects were used in directing the exploratory fishing operations, particularly at the onset of each survey. And, in several instances, especially in 1973 and 1974, the findings of large bodies of fish were used to redirect the research vessel to conduct detailed oceanographic observations in the nearby vicinity.

Operations Aboard Research Vessels

Three meridional oceanographic sections were taken along 135°, 137°30', and 140° W between 31° to 41° N in 1972 and 1973; in 1974 the middle section, portions of the section along 135° W, and additional ones were taken (Figure 1). Hydrographic stations were occupied at 25 to 30 nautical-mile intervals; Figure 2 shows station positions occupied in 1973 and is typical of the station plans occupied in 1972 and 1974. Observations included 1) salinity-temperature-depth profiles to 500 or 1,000 m using a STD;¹ 2) Nansen bottle or General Oceanics rosette sampler bottle cast for collection of water samples for determination of dissolved oxygen, chlorophyll, nutrients, and salinity for STD calibration; 3) oblique zooplankton hauls to 200 m using CalCOFI 1-m plankton nets and simultaneous surface hauls with neuston plankton nets; and 4) at night stations oblique midwater trawl hauls to 200 m using an Isaacs-Kidd midwater trawl. Also, surface temperature, salinity, and chlorophyll were recorded continuously while underway. The discrete subsurface and continuous surface chlorophyll measurements were made using fluorometric methods.

Generally, 10 lines (five on Cromwell cruise in 1972) were trolled for albacore on transits between oceanographic stations during daylight hours. In some regions that were not covered by fishing vessels, trolling was carried on by the research vessel throughout daylight hours. On such fishing days, three or four expendable bathythermograph (XBT) drops were made in addition to the continuous monitoring of surface temperature, salinity, and chlorophyll.

Operations Aboard Fishing Vessels

The AFRF charter vessels which took part in the offshore surveys were all jigboats, except for two baitboats in 1973, which were outfitted to conduct either live bait fishing or jig fishing. Twelve fishing vessels participated in the operations in 1972 and 1973 and five in 1974.

The fishing vessels sailed in groups of four from San Diego, California and Astoria, Oregon at 15 to 20 day intervals during 1972 and 1973, and all vessels sailed together from San Diego in 1974. The vessels usually worked in pairs for safety reasons. A schematic diagram of the cruise tracks for the 1972, 1973, and 1974 offshore surveys is shown in Figure 3.

¹Plessey model 9006 electronic salinity-temperature-depth profiler.

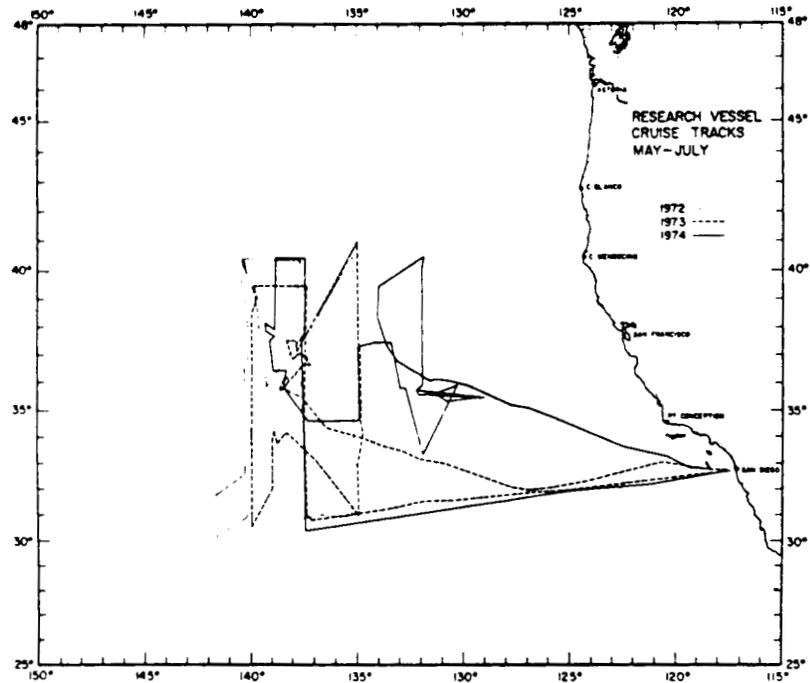


Figure 1. Research vessel cruise tracks for the 1972, 1973, and 1974 offshore research surveys.

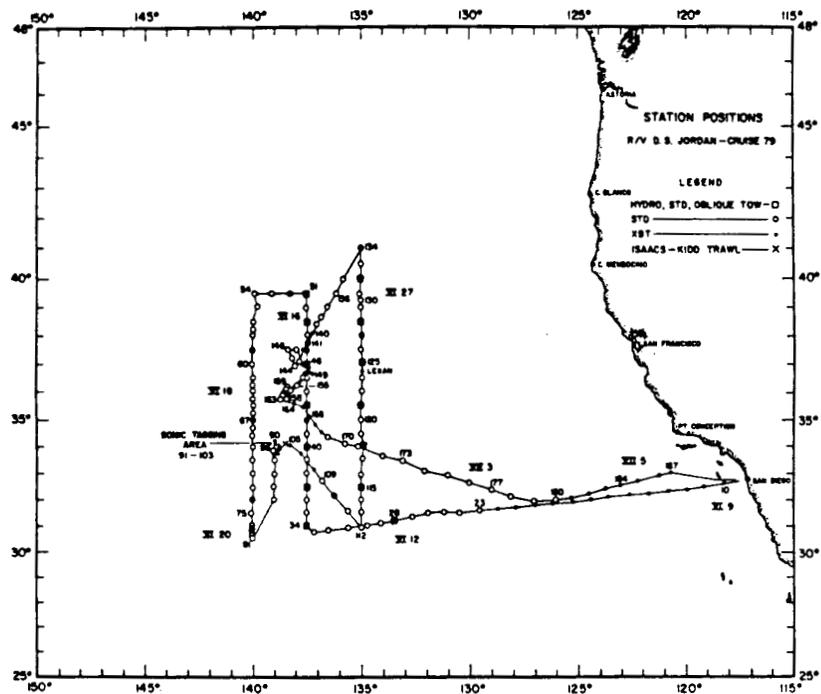


Figure 2. Track and station positions for R/V David Starr Jordan cruise 79, June 9 through July 6, 1973.

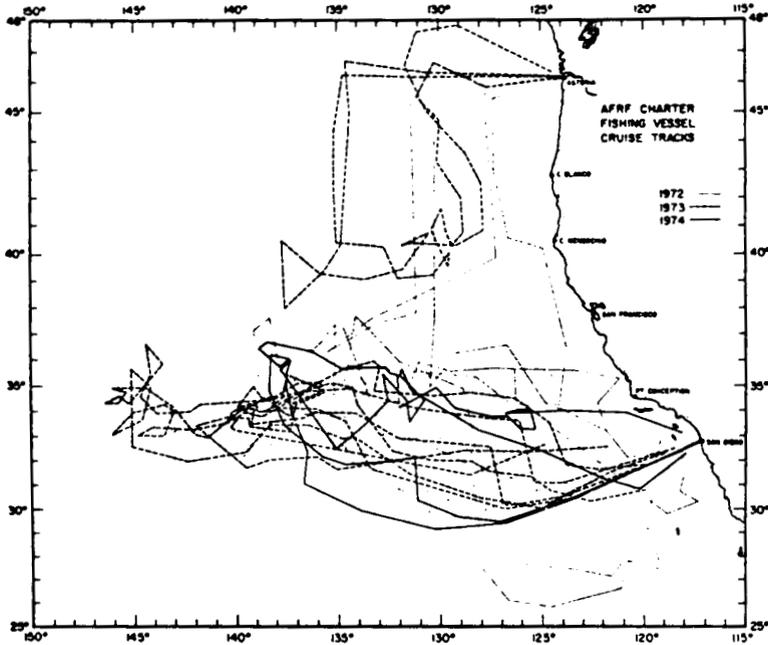


Figure 3. AFRF charter fishing vessel cruise tracks for the 1972, 1973, and 1974 offshore research surveys.

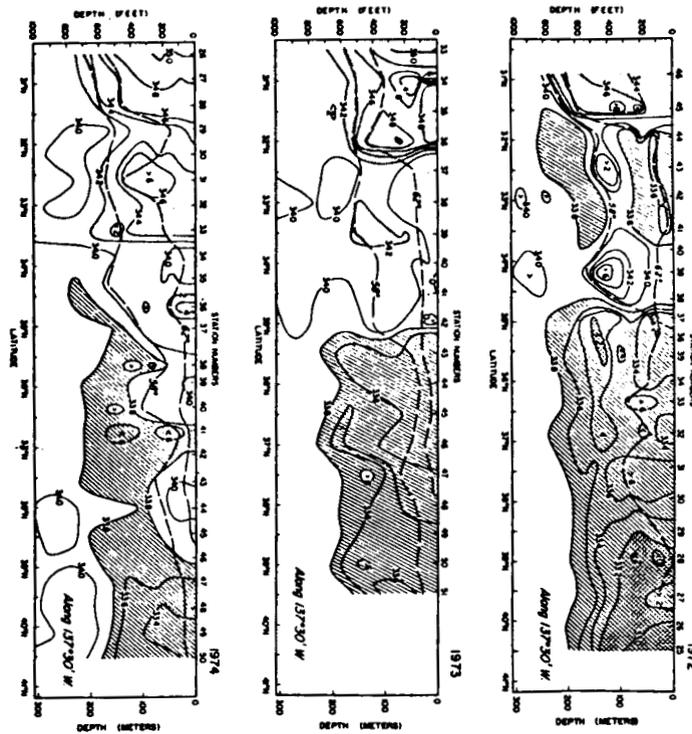


Figure 4. Vertical sections of salinity along 137° 30' W for 1972 (upper), 1973 (middle), and 1974 (lower). Salinity below 33.8% is shown hatched and salinity above 34.2% is shaded by a dot pattern. The 58° F (14.4° C) and 62° F (16.7° C) isotherms are shown by heavy dashed lines.

The fishing operations were conducted using standard commercial albacore fishing equipment employing regular commercial fishing methods. Daily records pertaining to fishing operations were maintained aboard each vessel, including the number of fish caught, the fork length of most fish caught, positions where fishing was started and ended, the amount of fishing effort expended, and fishing conditions and fish signs. In addition, sea surface temperatures, water color, sea conditions, and surface weather conditions were recorded.

Half of the fishing vessels chartered in 1972 and 1973, and all in 1974 were equipped with an XBT; generally one or two XBTs were launched each day. Sea surface temperature measurements were made using bucket thermometers.

THE DISTRIBUTION AND APPARENT ABUNDANCE OF ALBACORE IN OFFSHORE WATERS DURING SURVEY PERIODS

Over 28,000 albacore were caught by the charter and research vessels during the three offshore surveys. In 1972 and 1973 the apparent abundance of albacore was highest between 32° and 35° N and 135° and 140° W, and 32° and 35° N and 135° and 145° W, respectively. In both of these years the largest catches were made offshore of 135° W with small or no catches made in the region between the offshore area and inshore waters within 150 miles of the coast where fishing takes place during the traditional albacore fishing season. This pattern of the distribution of albacore catches appeared to be related to oceanographic frontal structure present at the time the surveys were conducted and is discussed in more detail later. In 1974, the pattern of albacore apparent abundance was similar in some respects to that observed in 1972 and 1973, and different in others. High catches were again made in the area offshore of 135° W, but over a larger latitudinal range, 31° to 36° N, and somewhat more scattered than in the two preceding years. Also, high catches were made at about 32° to 35° N, 125° W in the region between the offshore area of high catches and inshore waters where fishing normally takes place. As is discussed later, oceanographic conditions were different in 1974 than in 1973 and 1972, and the distribution of albacore catches appeared to be related to the oceanographic frontal structure prevailing at the time of the 1974 survey.

THE MARINE ENVIRONMENT

The distribution and apparent abundance of albacore in the offshore region during all three surveys were related to the oceanographic conditions of the Transition Zone waters and the development of associated oceanic frontal structure. The Transition Zone is a region of mixing between cold, low salinity subarctic waters to the north and warm, saline subtropic waters to the south. The Transition Zone waters are found in a zonal band across the North Pacific middle latitudes within the westward-flowing North Pacific Current. They are bounded by abrupt horizontal gradients in temperature and salinity. The bounding gradient region to the north is called the subarctic front and that to the south is called the subtropic front. The dynamic processes which produce and maintain the gradients also enrich these waters, which give reason why these regions are biologically important to albacore. To the east of 135° W, the North Pacific Current turns southeast and south as does the Transition Zone, and the boundary gradients begin to lose their continuity.

Temperature and salinity data are used to identify the Transition Zone as distinct from the water masses to the north and south. Three oceanographic sections of the vertical distribution of temperature and salinity along 137° 30' W taken in 1972, 1973, and 1974 are given in Figure 4. In 1972 and 1973, the

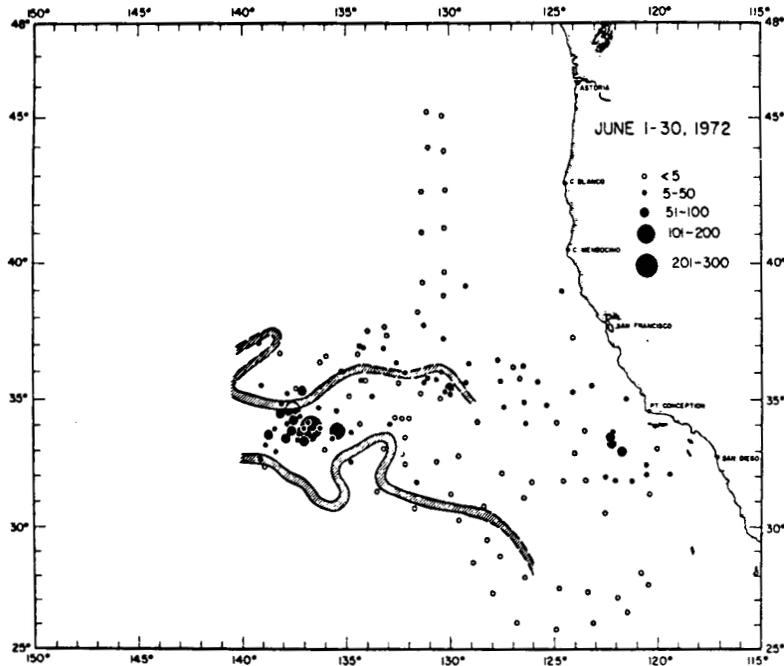


Figure 5. The standardized catch (per 150 line-hours) of albacore taken in June 1972 by the NMFS-AFRF survey plotted over a graphical depiction of the oceanic fronts that bound the Transition Zone.

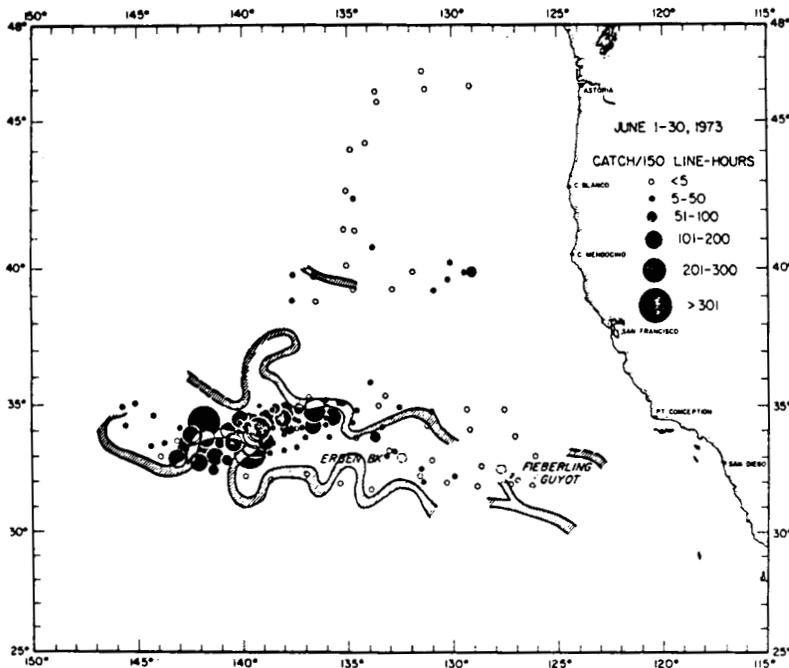


Figure 6. The standardized catch (per 150 line-hours) of albacore taken in June 1973 by the NMFS-AFRF survey plotted over a graphical depiction of the oceanic fronts that bound the Transition Zone.

boundaries of the Transition Zone were well developed and readily identifiable. The subarctic waters (shown by hatching of salinity less than 33.8‰) lie to the north of 35° N and the subtropic waters (shown by dot-shading of salinity greater than 34.2‰) lie to the south of 31°30' N and 31° N, respectively. Between these water masses is the Transition Zone, the boundaries of which are made evident by the abrupt gradients in salinity extending from the surface to depths greater than 150 m. The temperature gradients are coincident with the salinity gradients. In Figure 4, the temperature field is simplified to two isotherms. The abrupt change in depth of the 62° F (16.7° C) isotherm is coincident with the subtropic boundary and that of the 58° F (14.4° C) isotherm is coincident with the subarctic boundary. The boundaries of the Transition Zone were poorly developed in 1974. In the section taken in 1974, the salinity gradients were more diffuse and the changes in depth of the isotherms more gradual and variable.

ALBACORE CATCHES IN RELATION TO OCEANIC FRONTS

Graphical depictions of the frontal gradients that form the boundaries of the Transition Zone² and standardized albacore catches³ for June of each of the three surveys are shown in Figures 5, 6 and 7. These figures indicate that the catches were largely made within the Transition Zone in all 3 years.

During June 1972 and 1973, productive centers of fishing developed in the Transition Zone between 33° and 35° N and west of 135° W (Figures 5 and 6). These centers persisted for 2 and 3 weeks before fishing effort was withdrawn. In these years, the frontal structure was strongly developed and the Transition Zone easily identifiable. During June 1974 when the frontal structure was poorly developed and water masses boundary were less distinct, the catches were distributed over a larger range of latitude, 31° to 36° N (Figure 7). While the catches overall were substantial in 1974, they did not demonstrate the persistence in any area for more than a few days. Thus, the albacore continued to be oriented to Transition Zone waters but the influence of extensive lateral mixing between water masses and the diffuse nature of the boundary frontal structure apparently was not effective in concentrating the catches as had occurred in the previous 2 years.

The graphical depiction of frontal structure shown in Figure 7 outlines the location of the boundaries associated with Transition Zone water, however, they do not indicate the intensity of the gradients of the frontal structure. Whereas, in general, the frontal structure has been shown to have weak gradients during June 1974, one area did have abrupt gradients. The eastward protruding tongue of Transition Zone water centered at 35°30' N, 132°30' W had salinity gradients comparable to those found in previous years. Substantial catches persisted for a week in this one region.

²The temperature and salinity fields measured by the research vessel augmented by the XBT data collected by the charter fishing vessels were analyzed to delineate the frontal gradients.

³Expressed as catch per 150 line-hours, which is equivalent to fishing 10 lines for 15 hours.

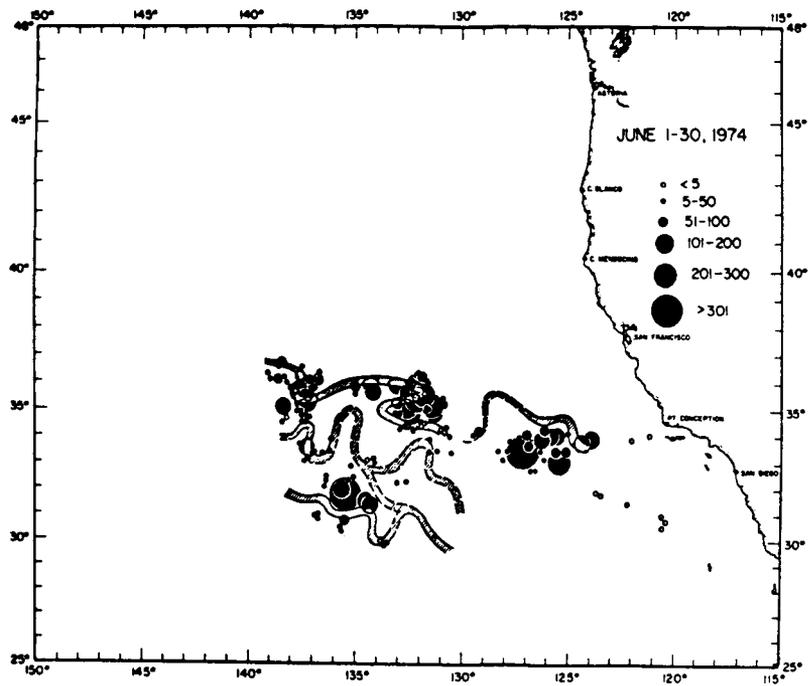


Figure 7. The standardized catch (per 150 line-hours) of albacore taken in June 1974 by the NMFS-AFRF survey plotted over a graphical depiction of the oceanic fronts that bound the Transition Zone.