AN ABSTRACT OF THE THESIS OF

Robert N. Nishimoto for the degree of Master of Science
in Oceanography presented on June 1, 1984.
Title: Time Series Analyses of Daily Albacore Catches and Upwelling Indices off Oregon and California

Redacted for privacy

Abstract approved:
William G. Pearcy

Daily commercial albacore catches made by U. S. trollers fishing off central California and Oregon are correlated with daily upwelling indices and predictive catch models are developed.

Models predicting total catch/day and catch/boat/day are formulated for the region off central California in 1961 to 1963 and off Oregon in 1967 to 1969. These models explain 28 to 91% of the variances in expected catches one day in advance for the years studied. The total catch/day models are better predictors than the catch/boat/day models, indicating that the behavior of albacore fishermen is important in developing predictive catch models when catch records are used.

The statistically significant terms of catches lagged to upwelling indices in the models recur at one to three, six to nine and 13 to 14 days off Oregon, and at less than five days off central California. The reason for the long lags off Oregon may be due to active and relaxed cyclical upwelling events. The lags of less than five days in both locations may be associated with the delay of upwelling after

the onset of northerly or northwesterly winds. The relationships between daily catches and daily upwelling indices off Oregon and central California indicate that albacore catches and fishing success are affected by pulses of upwelling.

Catches as functions of catches, when present in the models, are positive and significant at lags of one day and either positive or negative at lags of two days or more. These values suggest that albacore catches probably remain high for one day after the start of good fishing.

Time Series Analyses of Daily Albacore Catches and Upwelling Indices off Oregon and California

by

Robert N. Nishimoto

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed June 1, 1984

Commencement June 1985

APPROVED:

Redacted for privacy

Professor of Oceanography in charge of major

Redacted for privacy

Head of College of Oceanography

Redacted for privacy

Dean of Graduate School

Date thesis is presented June 1, 1984

Typed by researcher for Robert N. Nishimoto

ACKNOWLEDGEMENTS

Many individuals provided assistance in completing this thesis and I wish to thank them: Mr. Andrew Bakun and Mr. Anthony Majors for making the upwelling indices and albacore catch data available; Dr. Roy Mendelssohn for suggesting the use of a multiple time series computer package, aiding in the analyses and commenting on the thesis; Dr. R. Michael Laurs and my graduate committee members, especially Dr. William G. Pearcy, for their support and comments on the thesis.

TABLE OF CONTENTS

INTRODUCTION 1

THE ALBACORE 3
    Distribution and Oceanography 3
    Movements in the North American Fishery 4

THE NORTH AMERICAN FISHERY 7
    Fishing Methods 7
    Spatial and Temporal Distribution 7

COASTAL UPWELLING 10
    Mechanisms 10
    Oceanographic Effects 10
    Seasonality off the North American West Coast 11

MATERIALS AND METHODS 12
    Locations and Years of Study 12
    Catch Information 12
    Upwelling Indices 14
    Analysis and Modeling 14

RESULTS 31

DISCUSSION 47

CONCLUSION 51

LITERATURE CITED 52

APPENDIX 59

LIST OF FIGURES

Figure		Page
1.	Schematic model of albacore movement off the Pacific coast as suggested by U. S. Navy picket vessel catch data, 1960-65 (Flittner 1970).	5
2.	Albacore landings by year and area, 1961-70.	9
3.	Locations used for correlation study. Closed circles are positions where upwelling indices were computed. Stippled areas are locations of catch data.	13
4a.	Daily upwelling index at 36° N lat., 122° W long. and total albacore catch/day between 35-37° N lat. from the California coast to 125° W long., July 24 - October 6, 1961.	17
4b.	Daily upwelling index at 36° N lat., 122° W long. and albacore catch/boat/day between 35-37° N lat. from the California coast to 125° W long., July 24 - October 6, 1961.	18
4c.	Daily upwelling index at 36° N lat., 122° W long. and total albacore catch/day between 35-37° N lat. from the California coast to 125° W long., August 6 - October 30, 1962.	19
4d.	Daily upwelling index at 36° N lat., 122° W long. and albacore catch/boat/day between 35-37° N lat. from the California coast to 125° W long., August 6 - October 30, 1962.	20
4e.	Daily upwelling index at 36° N lat., 122° W long. and total albacore catch/day between 35-37° N lat. from the California coast to 125° W long., August 13 - October 31, 1963.	21
4f.	Daily upwelling index at 36° N lat., 122° W long. and albacore catch/boat/day between 35-37° N lat. from the California coast to 125° W long., August 13 - October 31, 1963.	22
4g.	Daily upwelling index at 45° N lat., 125° W long. and total albacore catch/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 9, 1967.	23

LIST OF FIGURES Continued

Figure | Page
4h. Daily upwelling index at 45° N lat., 125° W long. and total albacore catch/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 14, 1968. 24

4i. Daily upwelling index at 45° N lat., 125° W long. and albacore catch/boat/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 14, 1968. 25

4j. Daily upwelling index at 45° N lat., 125° W long. and total albacore catch/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 17, 1969. 26

4k. Daily upwelling index at 45° N lat., 125° W long. and albacore catch/boat/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 17, 1969. 27

LIST OF TABLES

Table		Page
1.	U. S. west coast albacore landings (in million pounds), 1961-70.	8
2.	Summary of upwelling locations, dates and numbers of days used in correlating total catch/day and catch/boat/day to daily upwelling index.	16
3a.	Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1961.	32
3b.	Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1961.	33
3c.	Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1962.	34
3d.	Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1962.	35
3e.	Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1963.	36
3f.	Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1963.	37

LIST OF TABLES Continued

Table		Page
4a.	Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1967.	38
4b.	Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1968.	39
4c.	Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1968.	40
4d.	Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1969.	41
4e.	Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1969.	42

TIME SERIES ANALYSES OF DAILY ALBACORE CATCHES AND UPWELLING INDICES OFF OREGON AND CALIFORNIA

INTRODUCTION

The traditional fishery for albacore, Thunnus alalunga (Bonnaterre), along the North American west coast extends from late spring to early fall within 400 km of the coast (Laurs et al. 1976) and occurs during the coastal upwelling season (Reid et al. 1958; Bakun 1973). High albacore catches are often made in association with horizontal thermal gradients or discontinuities (Alverson 1961; Laurs and Lynn 1977; and others) which can develop during coastal upwelling (Owen 1968; Smith 1968). Lane (1965) said that a relationship existed between daily albacore catches and five-day averages of wind and sea temperatures off Oregon and concluded that predictions of upwelling off Oregon could aid fishermen.

The possibility that upwelling affects tuna catches was also indicated by Blackburn (1969) who found yellowfin (Thunnus albacares) and skipjack (Katsuwonus pelamis) tunas associated with forage, water temperature and upwelling off Baja California and by Forsbergh (1963) who found that the correlation between skipjack tuna catches and zooplankton volumes was nearly significant in the Gulf of Panama.

Because of these findings, my hypothesis is that the fishing success and availability of albacore off the North American west coast are related to variations in coastal upwelling. Since catches depend largely on availability of fish (Owen 1968; Flittner 1970), predictions of changes in availability can be important in increasing fishing efficiency and may be useful in determining the status of the resource.

Upwelling indices, albacore caught by trolling off California and Oregon and multiple time series analysis are used to develop this hypothesis. Time series analyses have been used by Mendelssohn (1981) to forecast catch and effort in the skipjack fishery off Hawaii and by Roy and Mendelssohn (1983) to relate skipjack and yellowfin tuna catches with environmental variables in the Gulf of Guinea.

THE ALBACORE

Distribution and Oceanography

Albacore are highly migratory, pelagic fish which, in the North Pacific Ocean, are found from Baja California to the Gulf of Alaska in the east and the equator to approximately 45° N lat. in the west (Yoshida and Otsu 1963). Their distribution is thought to be affected by water temperature and forage (Blackburn 1965).

Albacore are caught in surface water temperatures ranging between 14° C and 23° C (Laevastu and Rosa 1963), but best catches off North America are made in surface temperatures of 15.6° to 19.4° C off California (Clemens 1961) and 14.4° to 16.1° C off Oregon, Washington and British Columbia (Partlo 1950; Powell and Hildebrand 1950; Powell et al. 1952).

Alverson (1961), Laevastu and Rosa (1963), Owen (1968), Pearcy and Mueller (1970), Duclos (1973), Uda (1973), Laurs et al. (1977), Laurs and Lynn (1977), and Laurs et al. (1984) have shown that temperature fronts and/or coastal upwelling affect albacore catches. Temperature gradients cause aggregation of tunas (Laevastu and Rosa 1963) possibly because food organisms are concentrated near temperature fronts.

Albacore are opportunistic feeders and feed on many small animals that are available. In the eastern North Pacific forage organisms are, primarily, micronektonic cephalopods, crustaceans and fishes (Powell and Hildebrand 1950; McHugh 1952; Powell et al. 1952; Pinkas et al. 1971).

Water clarity is also important to the distribution of albacore (Murphy 1959; Pearcy 1973) because these fish are believed to be visual feeders. Powell and Hildebrand (1950) found albacore in the clear water on the warm side of oceanic fronts and indicated that the distribution may be related to temperature rather than water clarity. Laurs (1983), however, postulated

> ". . . that water clarity's effect on the tuna's ability to see its prey may play a key role in the mechanisms underlying the aggregation of tunas on the warm, clear side of ocean surface thermal fronts."

Laevastu and Rosa (1963) reported that the optimum transparency for tunas is 25 to 35 m.

The Columbia River plume which is present off Oregon during the albacore season is important to the distribution of albacore off Oregon (Owen 1968; Pearcy and Mueller 1970). Dissolved oxygen and water masses also affect the distribution of tunas (Blackburn 1965).

Movements in the North American Fishery

The movements of albacore in the North American fishery are similar to the schematic diagrams of Flittner (1970)(Figure 1). Two substocks are present (Laurs 1983). One substock enters the fishery off Baja and southern California beginning in late June and early July, moves northward during the seasonal warming of sea-surface temperatures and moves offshore between Cape Mendocino and Point Conception, California in December (Clemens 1955). The seasonal change in sea temperatures is important in the northward movement of these albacore (Clemens and Craig 1965).

The fishery in the Pacific Northwest which is comprised of the second substock begins off northern California and southern Oregon in

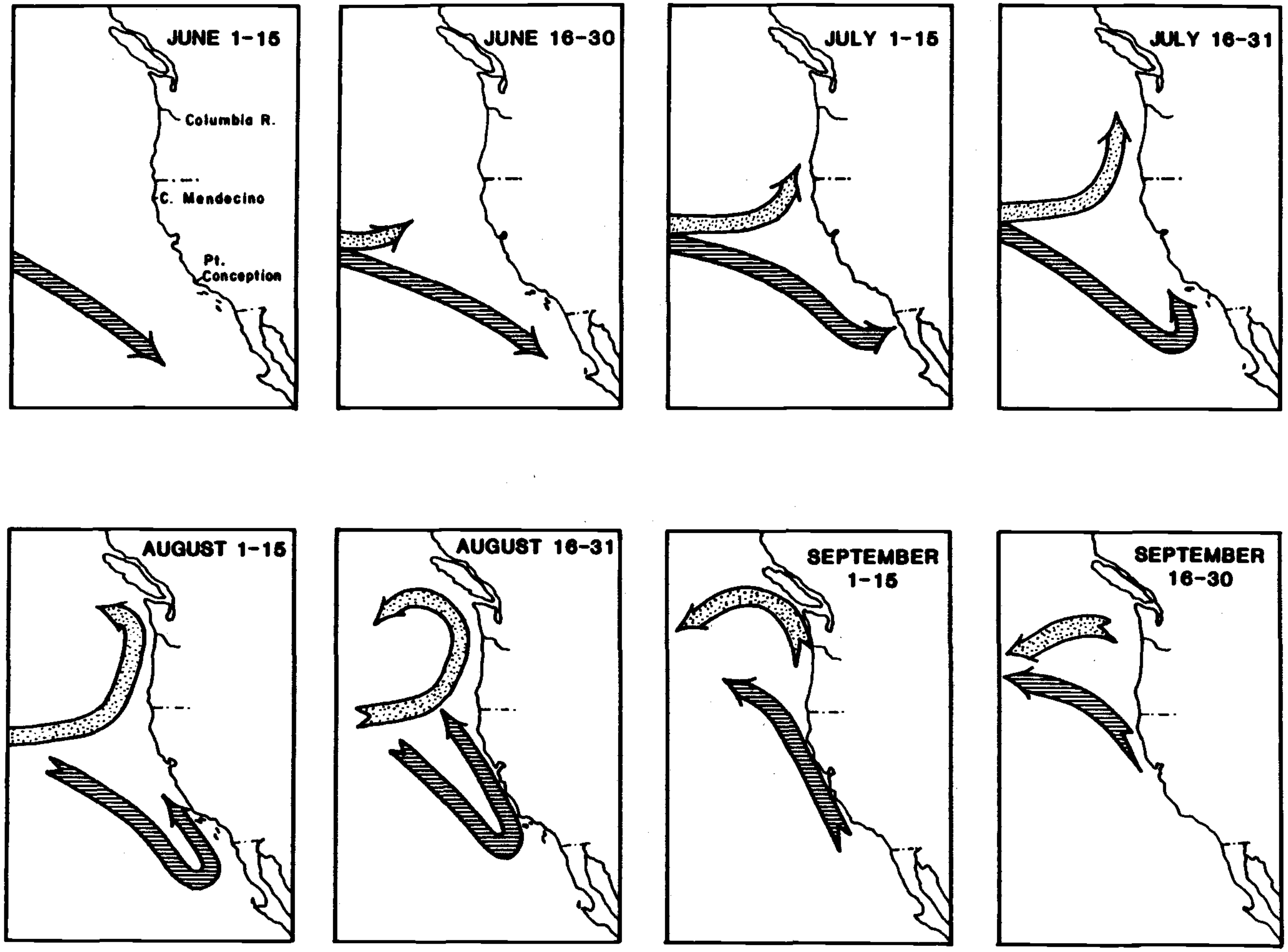

Figure 1. Schematic model of albacore movement off the Pacific coast as suggested by U. S. Navy picket vessel catch data, 1960-65 (Flittner 1970).

mid-July and moves northward to the area of Vancouver Island-Queen Charlotte Islands, British Columbia in late August and September before moving to the west (Laurs et al. 1976). Generally, albacore are not landed in Oregon and Washington after October (Powell and Hildebrand 1950).

The fishing season usually ends in the northern ranges of both substocks, but tagging studies by the National Marine Fisheries Service (NMFS) in LaJolla, California show that in some years albacore move south as well as offshore during late season. Also, tagging results (Clemens 1961) and findings of researchers at the NMFS in LaJolla indicate that there is little intermingling between substocks during the same season after they enter the coastal fishery.

THE NORTH AMERICAN FISHERY

Fishing Methods

Trolling and pole-and-line gears (Dotson 1980) are used as the primary methods of fishing. Approximately 75% of the annual albacore catches from 1942 to 1961 were made by trolling while nearly all of the remaining 25% were made by pole-and-line (Clemens and Craig 1965). Trolling became more important from 1962 to 1980 as the annual troll catches, including albacore caught in the mid-North Pacific, increased to 80 to 98% of the total North American commercial landings (Majors et al. 1983).

Occasionally, commercial catches are also made by purse seiners off southern and Baja California. And, in the 1980's, a few fishermen tried gillnets during spring to fall and conducted exploratory longline fishing in offshore waters during the winter (Laurs et al. 1981, 1982; Laurs and Dotson 1983).

Spatial and Temporal Distribution

The coastal fishery extends from central Baja California to British Columbia from the coast to approximately 400 km offshore (Laurs et al. 1976). Since the early 1970's, however, U. S. and Canadian fishermen have operated from the west coast of North America to the International Dateline from spring to fall.

The coastal fishery is characterized by geographical variations in catch location within and between seasons, but the environmental or biological factors that cause these shifts are still undetermined.

Table 1 and Figure 2 show the changes in geographical distribution and yearly variations of albacore landings from California and Oregon-Washington for 1961 to 1970. The total landings range from 32.8 to 60.8 million pounds with better landings off California in 1961 to 1965 and off Oregon and Washington in 1967 to 1969. Landings are nearly equal from California and Oregon-Washington in 1966 and 1970.

Table 1. U. S. west coast albacore landings (in million pounds), 1961-70 (Bell 1971; Heimann and Carlisle 1970; Hreha 1974; Lyles 1965, 1966, 1967, 1968, 1969; Meehan and Hreha 1969; Pinkas 1970; Power 1963; Power and Lyles 1964; U. S. Department of Commerce 1971; Wheeland 1972, 1973).

Year	California*	Oregon and Washington*	Total
1961	29.0	3.8	32.8
1962	36.6	9.3	45.9
1963	48.9	11.9	60.8
1964	42.6	5.5	48.1
1965	23.0	14.2	37.2
1966	17.5	19.8	37.3
1967	15.5	32.9	48.4
1968	12.3	43.6	55.9
1969	11.7	36.4	48.1
1970	28.5	27.6	56.1

*Albacore caught off Washington and Oregon, but landed in California have been added to the Oregon and Washington landings.

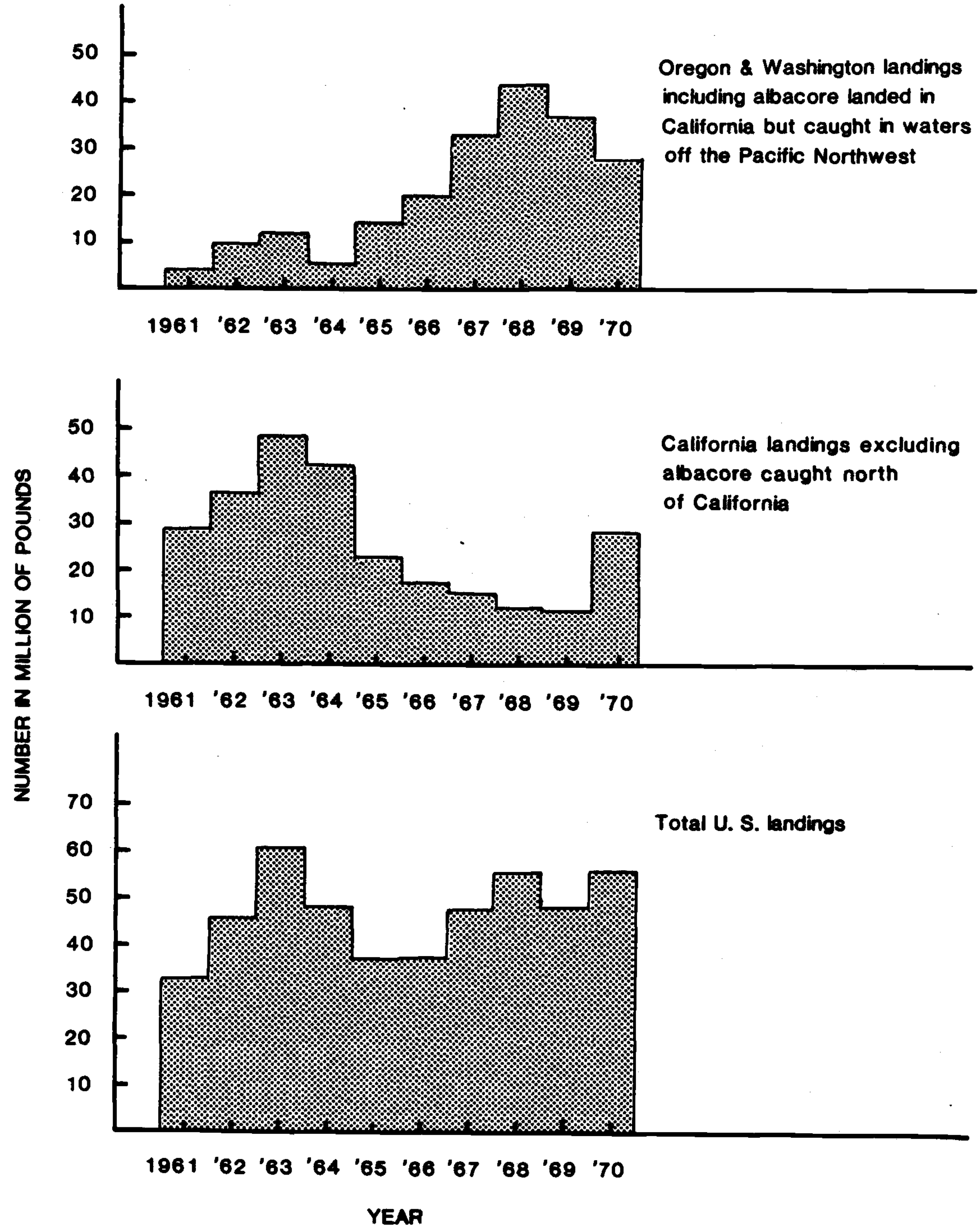

Figure 2. Albacore landings by year and area, 1961-70.

COASTAL UPWELLING

Mechanisms

The physical processes of coastal upwelling are reviewed by Smith (1968). The nearshore surface waters are displaced offshore and are replaced by sub-surface waters (Sverdrup et al. 1942). Coastal upwelling is most prevalent in eastern boundary currents and is caused, mainly, by wind stress on the sea surface (Smith 1968). Topography and geostrophic currents (Stommel and Wooster 1965) and onshore flow at the sea floor due to bottom friction (Hsueh and O'Brien 1971) can also cause and contribute to coastal upwelling.

Oceanographic Effects

The effects of coastal upwelling extend to about 100 km offshore (Yoshida 1955) and the upper 200-300 m (Sverdrup et al. 1942), but short-term upwelling is limited to shallower depths (Halpern 1976). Rises in thermocline depth, development of large horizontal temperature gradients and changes in density, salinity, oxygen saturation, phosphates and sea level are associated with upwelling (Smith 1968).

The horizontal temperature gradients become more prominent soon after the cessation of northerly winds (Stevenson et al. 1974; Halpern 1976; Brink 1983). Laurs et al. (1977) found that thermal fronts associated with upwelling off central California were not apparent within two days after the subsidence of upwelling.

The increase in nutrients in the photic zone results in higher primary production and, subsequently, increased production of higher trophic levels (Cushing 1969).

Seasonality off the North American West Coast

According to Reid et al. (1958) the most intense periods of upwelling along the west coast of North America occur from April to August when northerly or northwesterly winds prevail. The intensity of upwelling progresses northward during spring and summer and is strongest from May to July off California and in August off Oregon. Upwelling, however, may occur from Baja California to central California during all months, off northern California during March to October, and off Oregon during April to September (Bakun 1973).

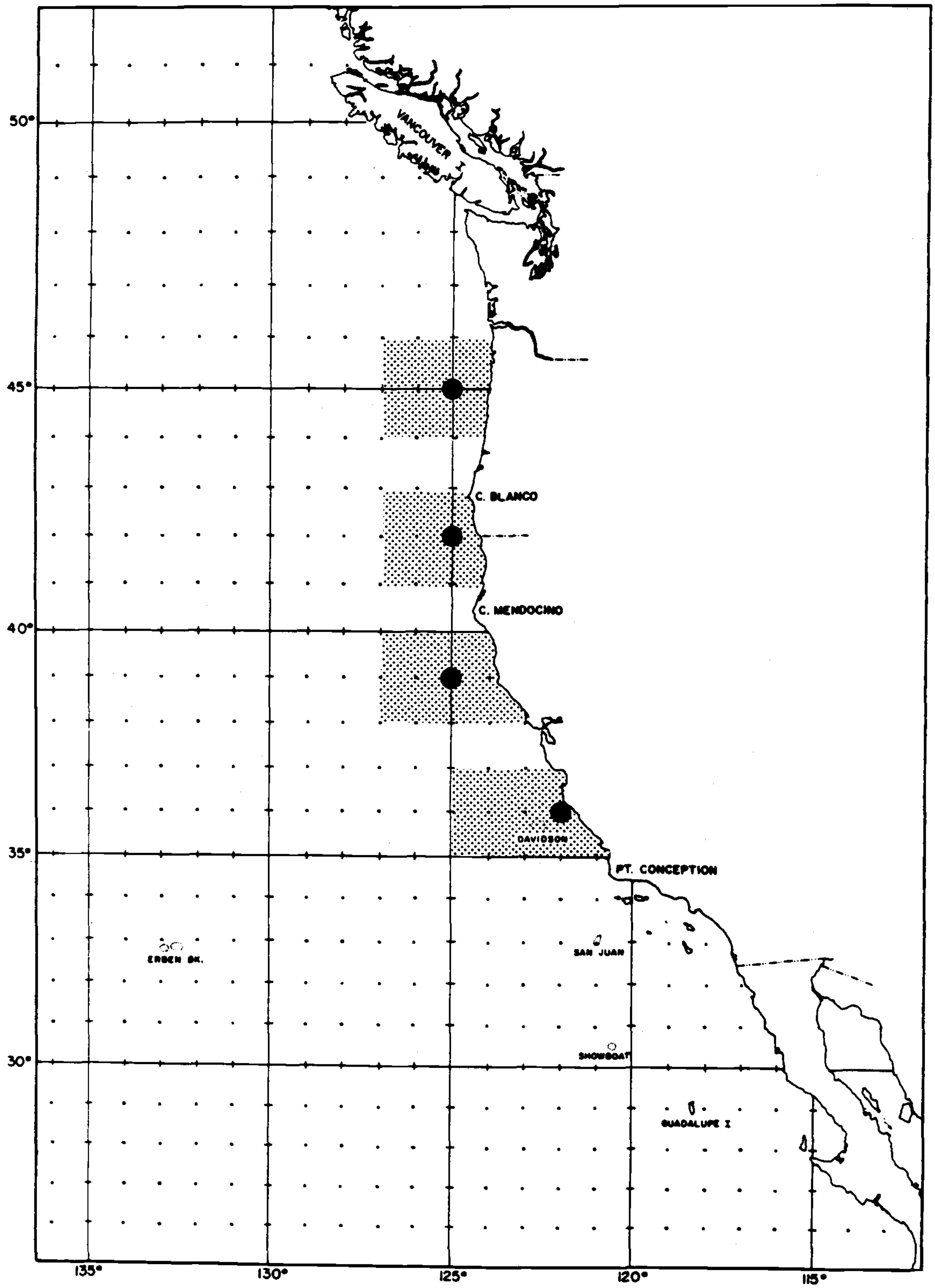

Figure 3. Locations used for correlation study. Closed circles are positions where upwelling indices were computed. Stippled areas are locations of catch data.

portions of the same catch data at adjacent upwelling locations in Figure 3.

Upwelling Indices

The weekly, semimonthly and monthly upwelling indices are from Bakun (1973). The daily upwelling indices were computed by the Pacific Environmental Group of the NMFS in Monterey, California according to the method by Bakun (1975) using wind-based parameters compiled by the Meteorology International Incorporated (Caton et al. 1978). Daily wind stresses on the sea surface were computed in the four areas shown in Figure 3 and daily Ekman transports perpendicular to the coast were derived.

The amount of water transported zonally, in metric tons/sec/100 m of coastline, is used as an index of upwelling or downwelling (Appendix). The positive values are upwelling and the negative numbers are downwelling. According to Bakun (1973) these indices are indicators of relative fluctuations of upwelling intensity and not quantitative measures of absolute magnitude.

Analysis and Modeling

The Wisconsin Multiple Time Series-1 (WMTS-1) computer package developed by the Department of Statistics at the University of Wisconsin in Madison is used to analyze the data. Significant correlations of daily catches and daily upwelling indices and predictive catch models are determined from the WMTS-1.

Because of the data requirements of the WMTS-1, two of the four areas originally selected for analysis were eliminated. The

$$\phi_p(B)z_t = \Theta_q(B)a_t$$

where ϕ_i and Θ_j = k x k matrices of parameters; p and q are orders in the model; ($z_t = Z_t - \eta$) = vector of deviations from some origin η which is the mean if the series is stationary; Z_t = data vector at time t; a_t = similar dimensioned random Gaussian vector; and

$$\phi_p(B) = I - \phi_1 B - \ldots . - \phi_p B^p$$

and

$$\Theta_q(B) = I - \Theta_1 B - \ldots . - \Theta_q B^q$$

are matrix polynomials in B, the backward shift operator where $BZ_t = Z_{t-1}$.

Table 2. Summary of upwelling locations, dates and numbers of days used in correlating total catch/day and catch/boat/day to daily upwelling index.

Year	Upwelling Location	Dates of Sampling	No. of Observations
1961	36° N lat., 122° W long.	July 24 - October 6	75
1962	36° N lat., 122° W long.	August 6 - October 30	86
1963	36° N lat., 122° W long.	August 13 - October 31	81
1967	45° N lat., 125° W long.	July 15 - September 9	57
1968	45° N lat., 125° W long.	July 15 - September 14	62
1969	45° N lat., 125° W long.	July 15 - September 17	65

The modeling procedure consists of three steps: Identification, estimation and diagnostic checking.

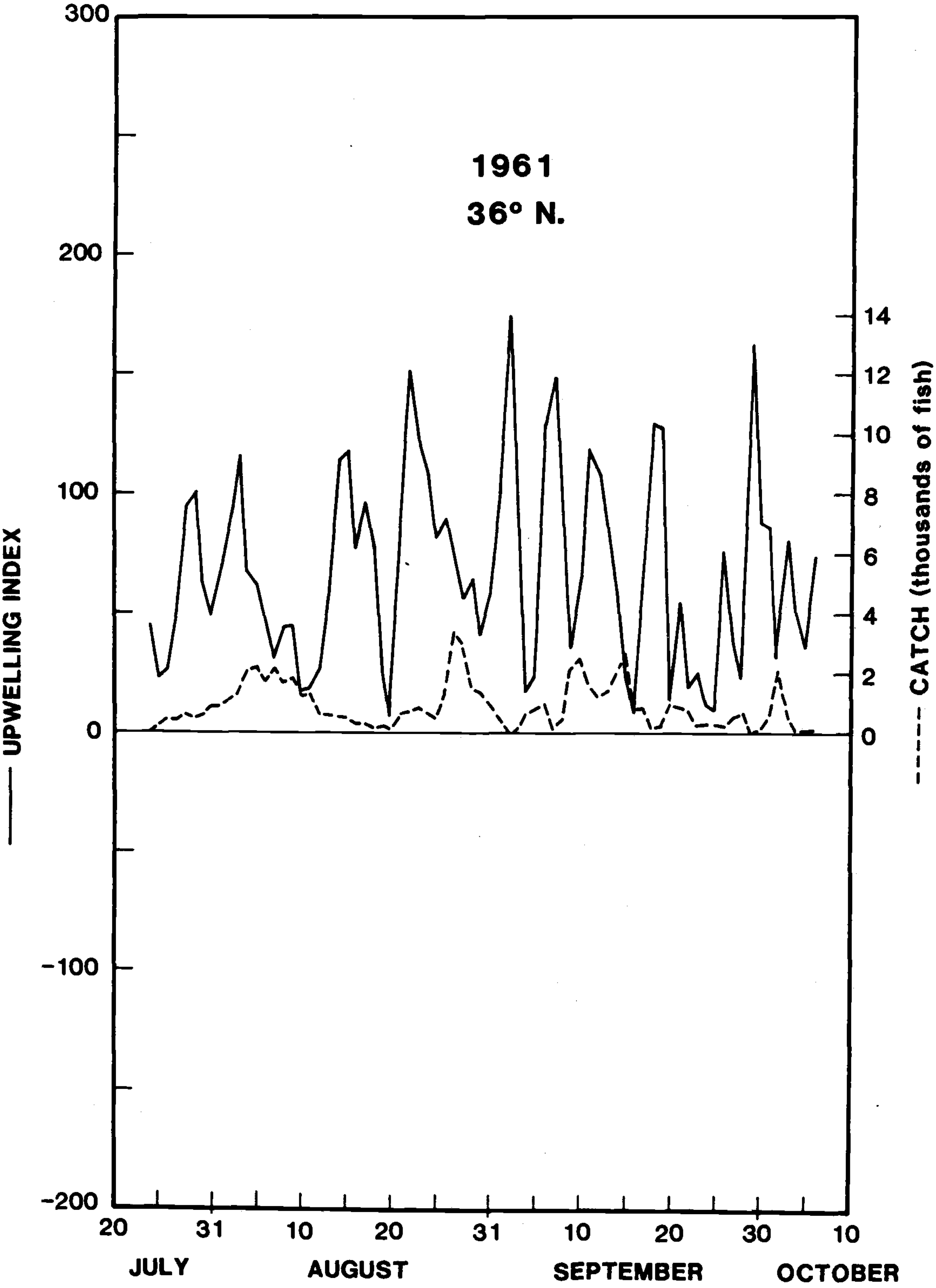

Figure 4a. Daily upwelling index at 36° N lat., 122° W long. and total albacore catch/day between 35-37° N lat. from the California coast to 125° W long., July 24 - October 6, 1961.

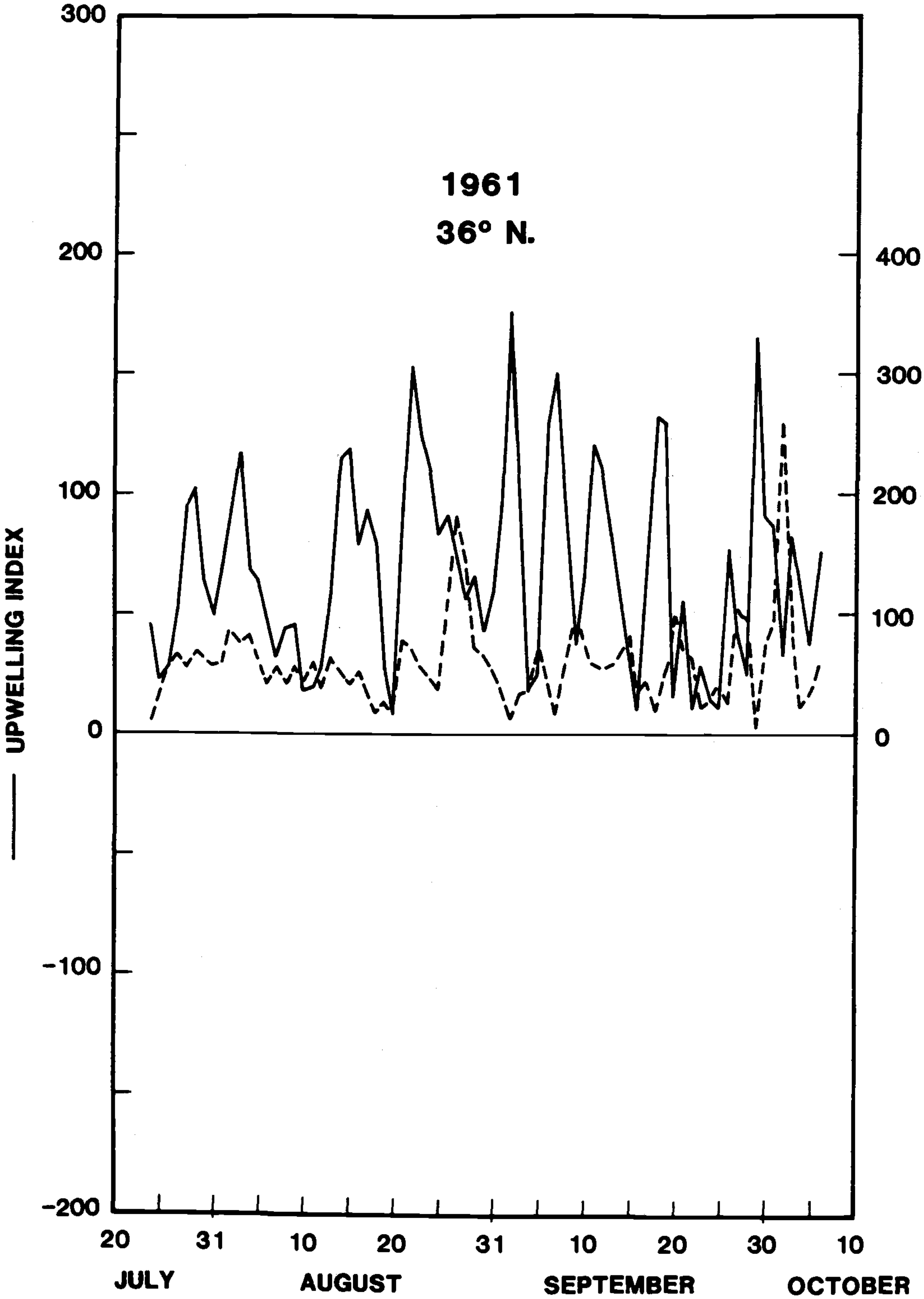

Figure 4b. Daily upwelling index at 36° N lat., 122° W long. and albacore catch/boat/day between 35-37° N lat. from the California coast to 125° W long., July 24 - October 6, 1961.

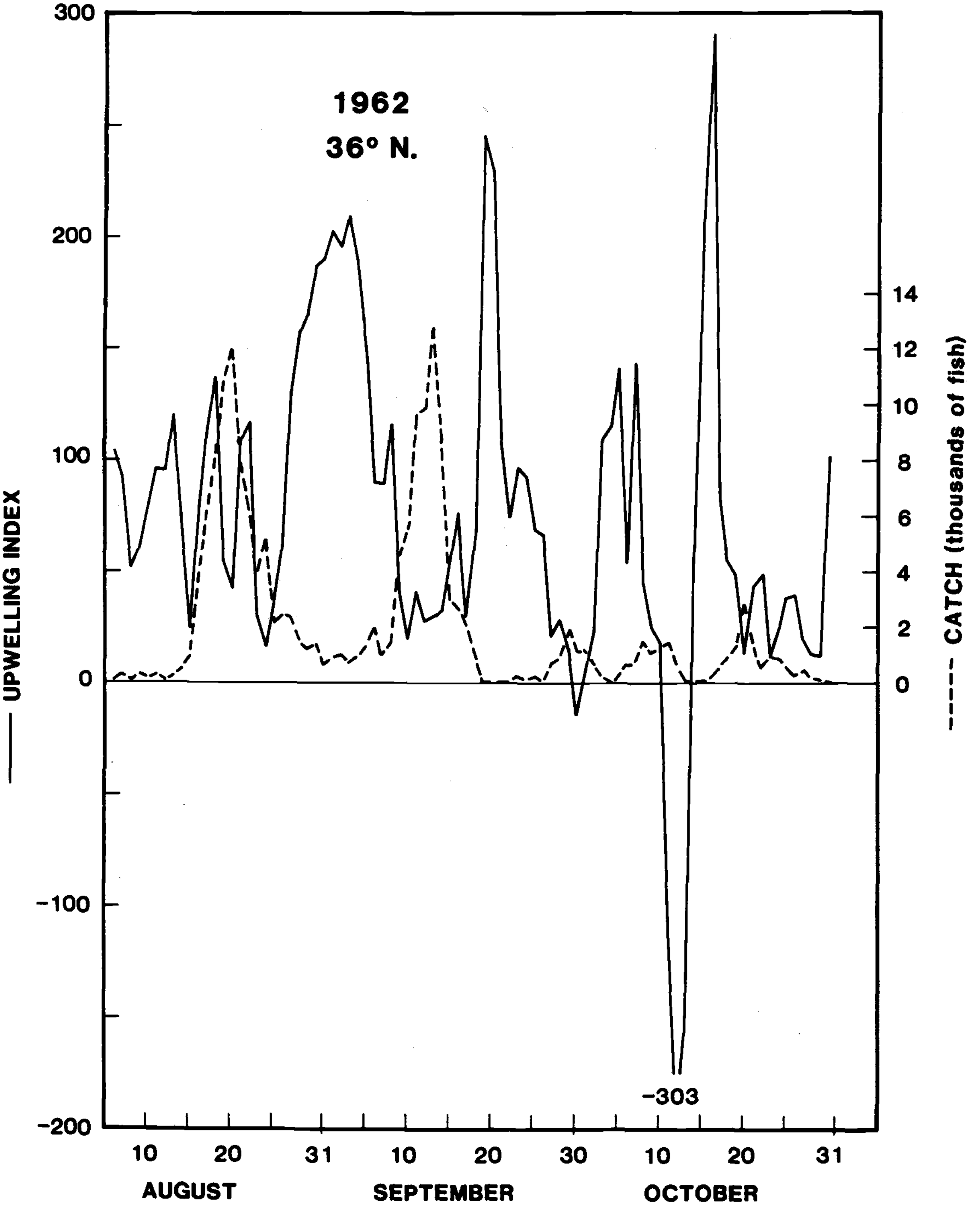

Figure 4c. Daily upwelling index at 36° N lat., 122° W long. and total albacore catch/day between 35-37° N lat. from the California coast to 125° W long., August 6 - October 30, 1962.

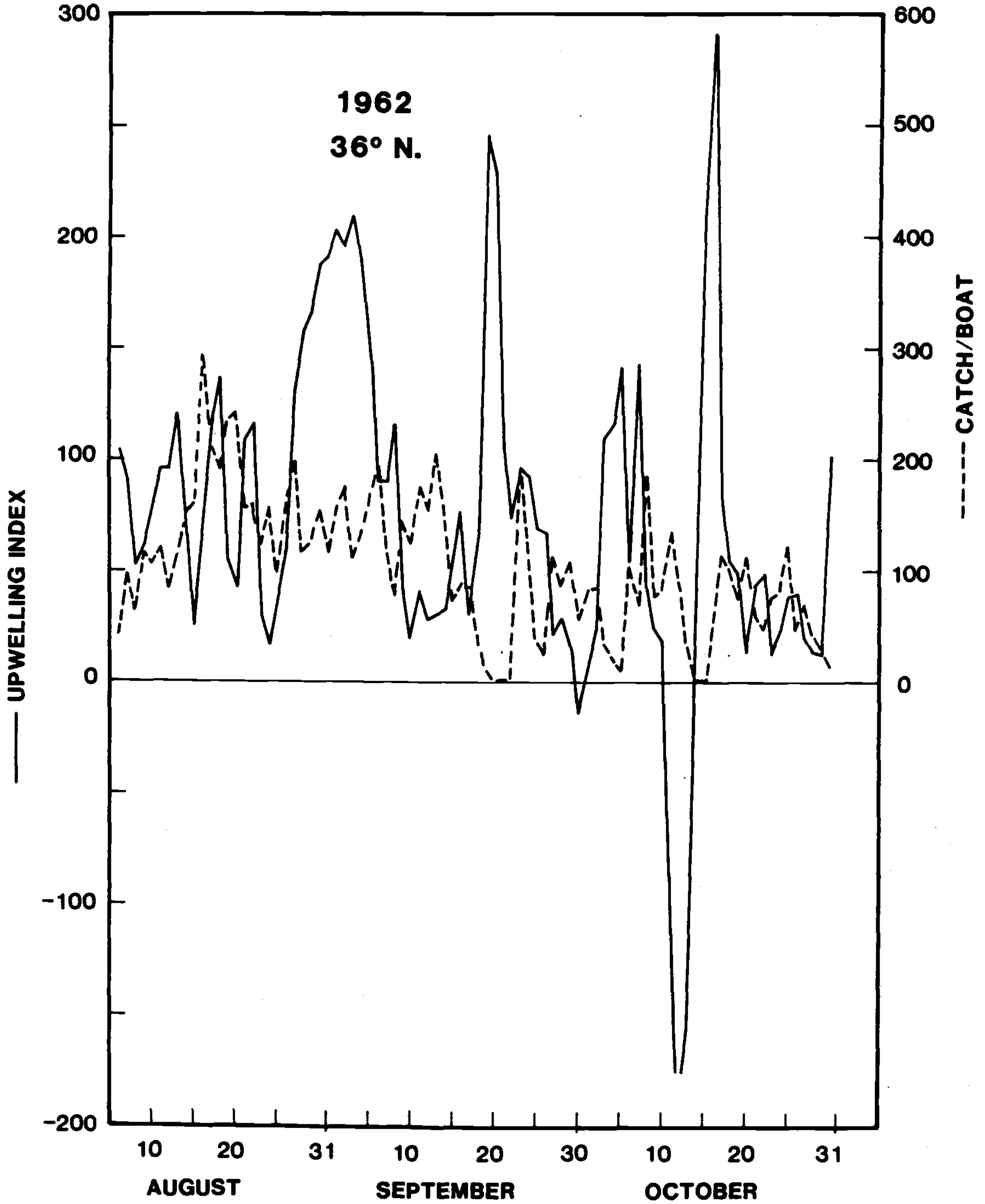

Figure 4d. Daily upwelling index at 36° N lat., 122° W long. and albacore catch/boat/day between 35-37° N lat. from the California coast to 125° W long., August 6 - October 30, 1962.

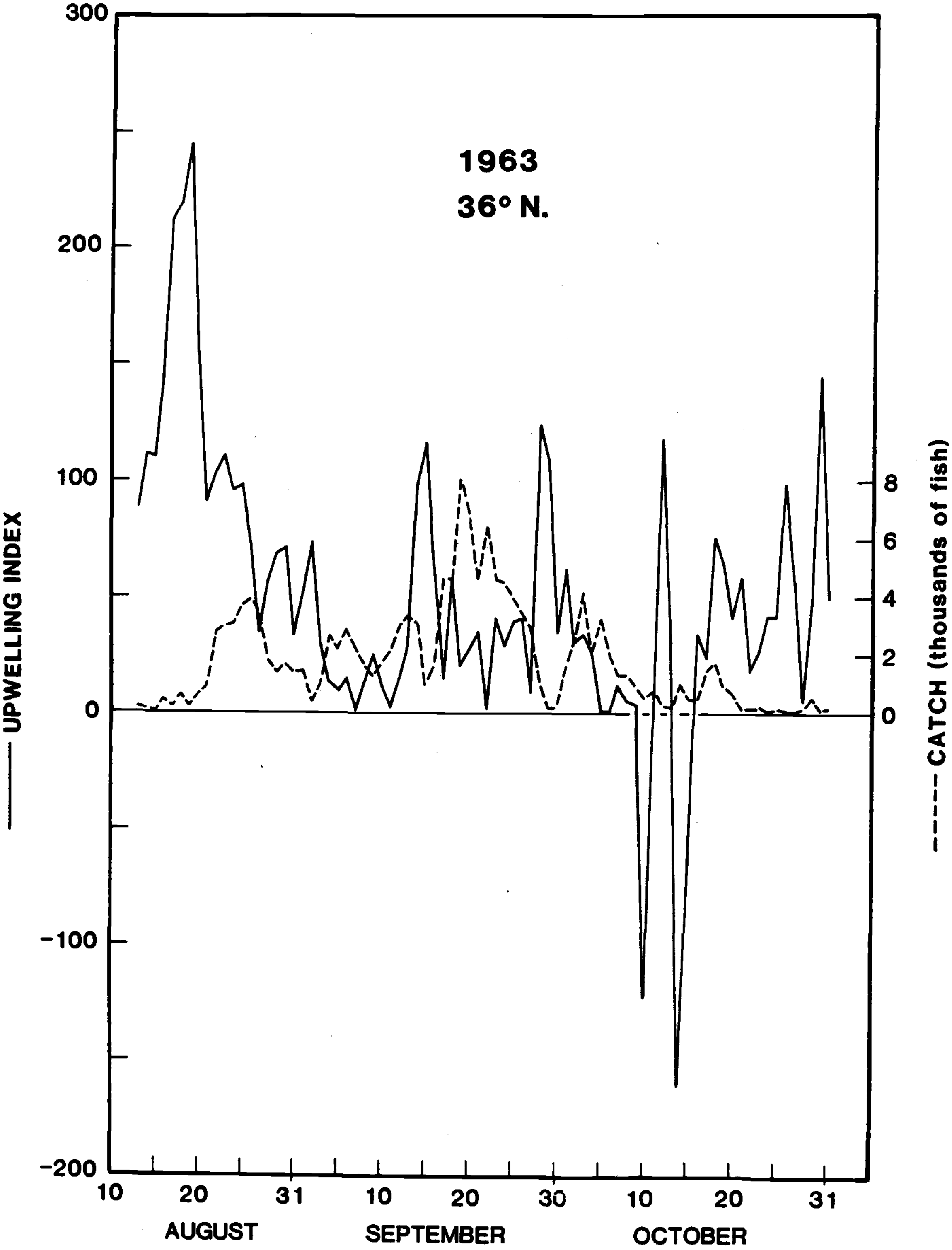

Figure 4e. Daily upwelling index at 36° N lat., 122° W long. and total albacore catch/day between 35-37° N lat. from the California coast to 125° W long., August 13 - October 31, 1963.

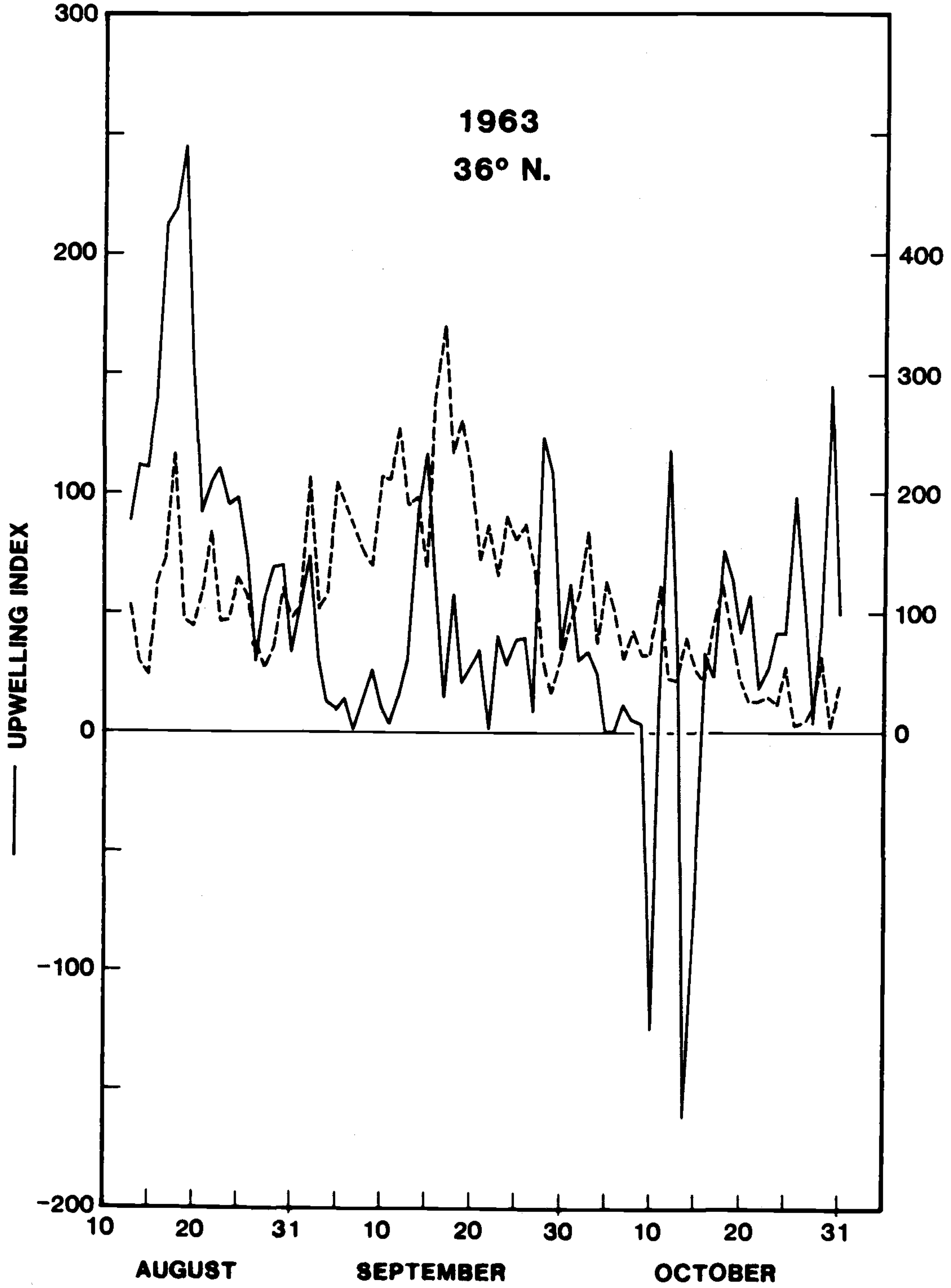

Figure 4f. Daily upwelling index at 36° N lat., 122° W long. and albacore catch/boat/day between 35-37° N lat. from the California coast to 125° W long., August 13 - October 31, 1963.

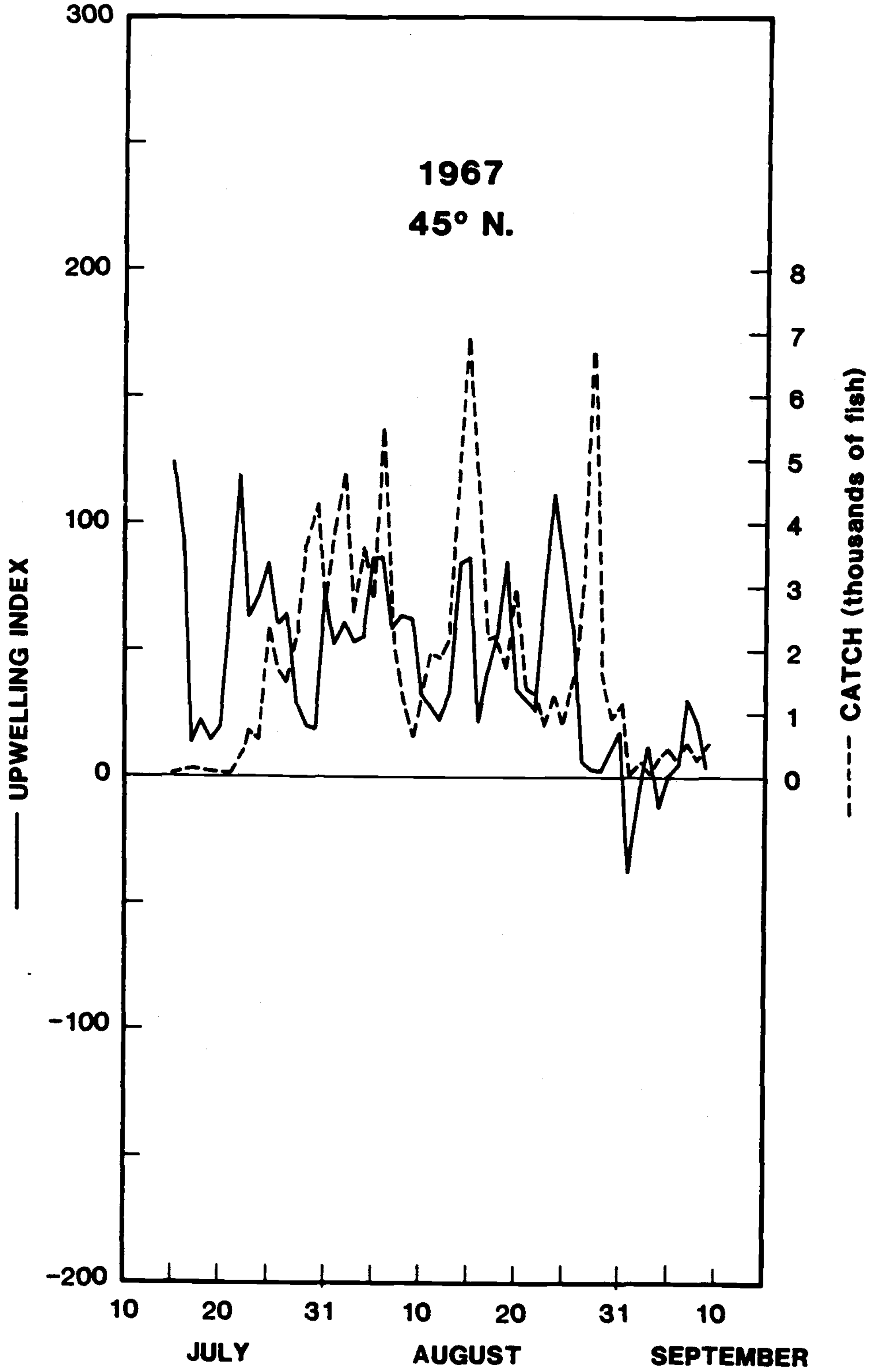

Figure 4g. Daily upwelling index at 45° N lat., 125° W long. and total albacore catch/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 9, 1967.

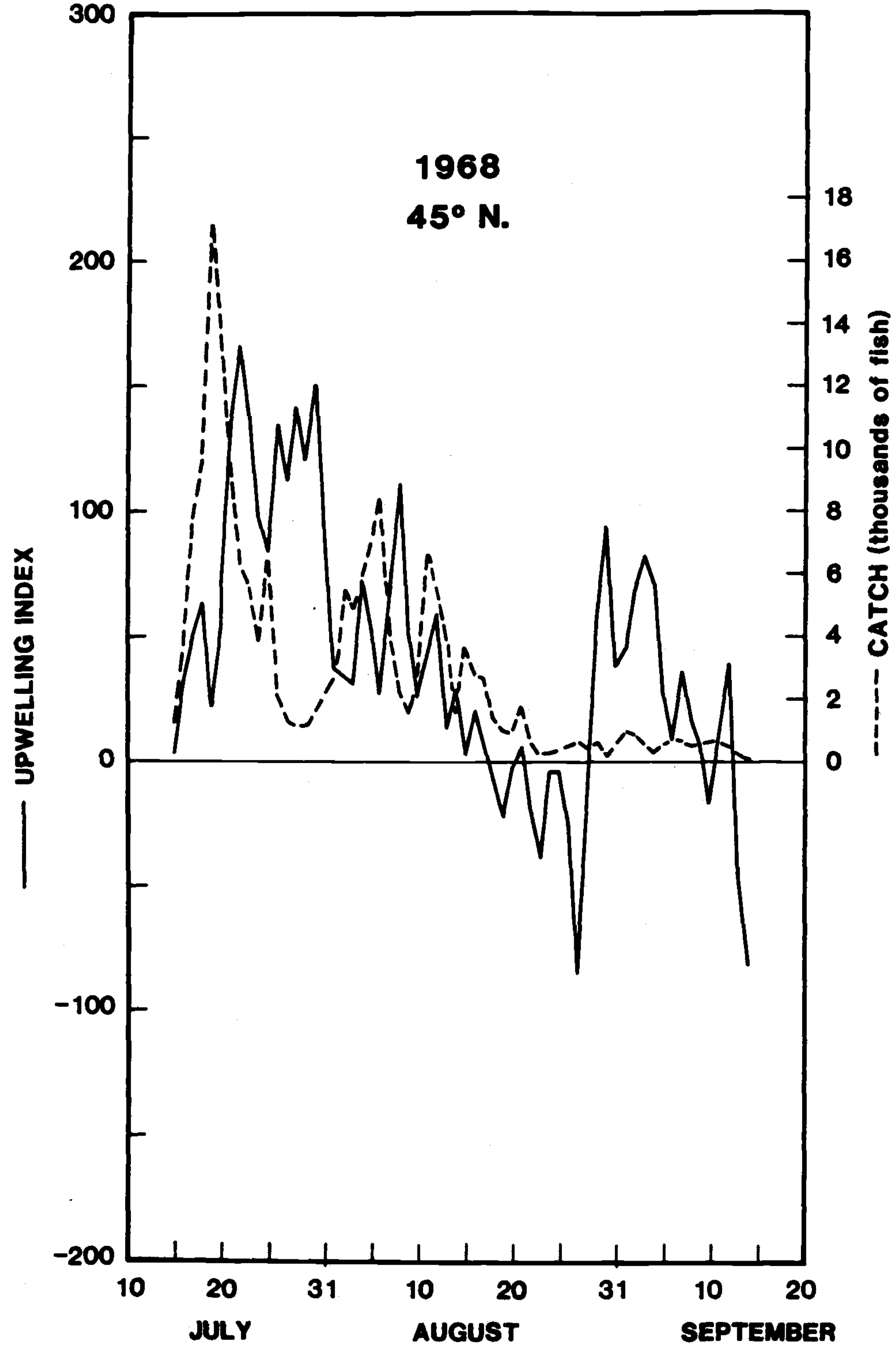

Figure 4h. Daily upwelling index at 45° N lat., 125° W long. and total albacore catch/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 14, 1968.

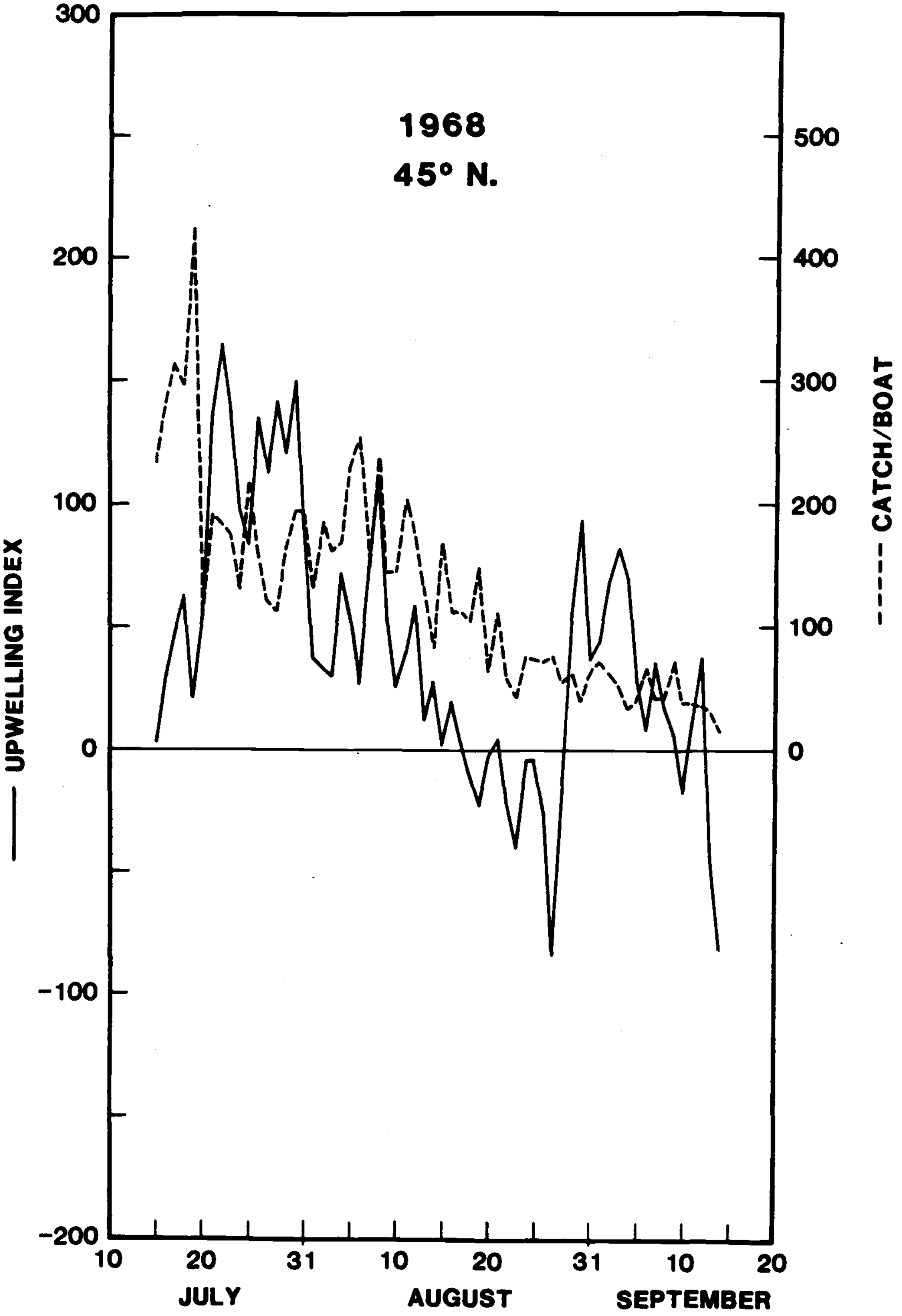

Figure 4i. Daily upwelling index at 45° N lat., 125° W long. and albacore catch/boat/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 14, 1968.

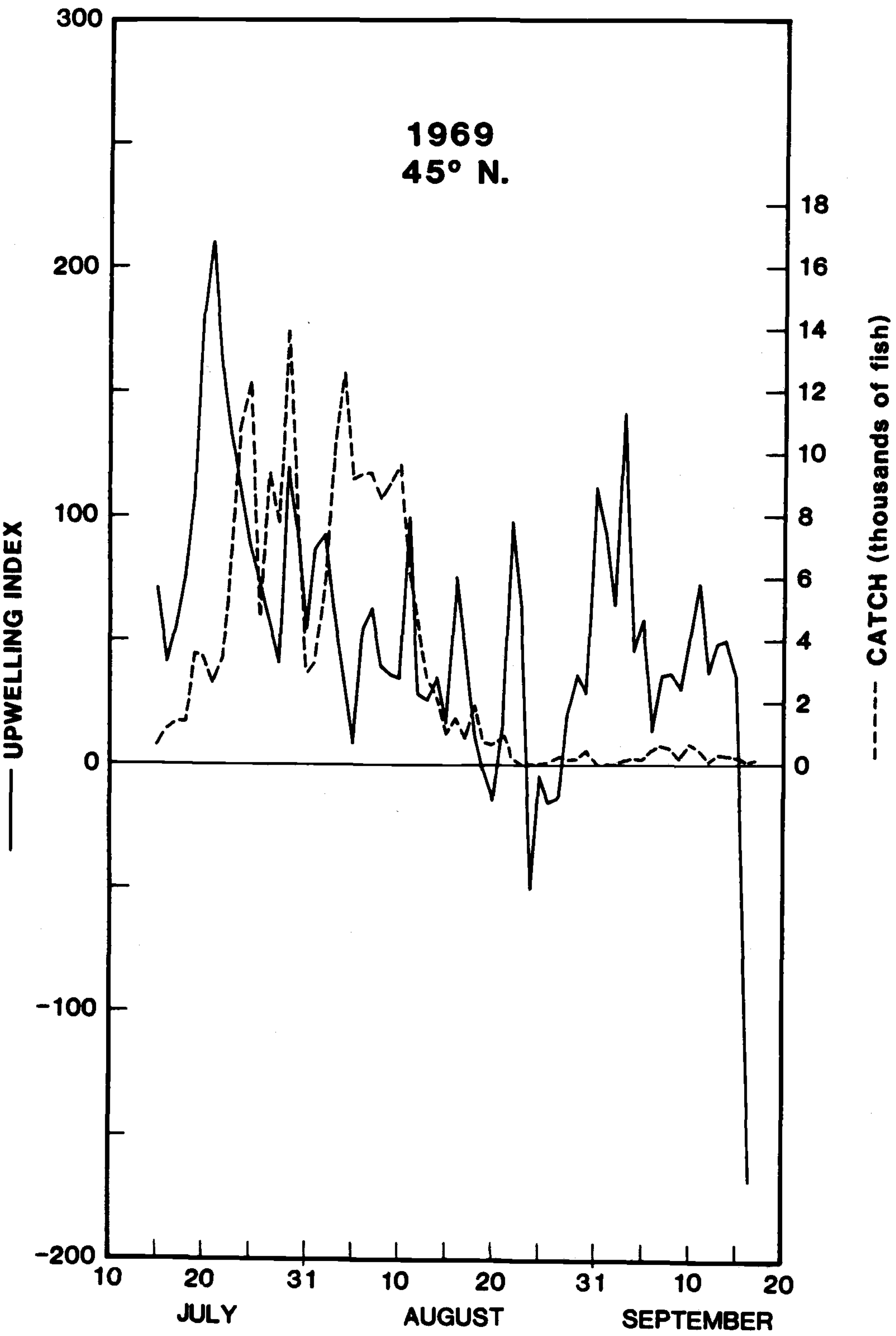

Figure 4j. Daily upwelling index at 45° N lat., 125° W long. and total albacore catch/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 17, 1969.

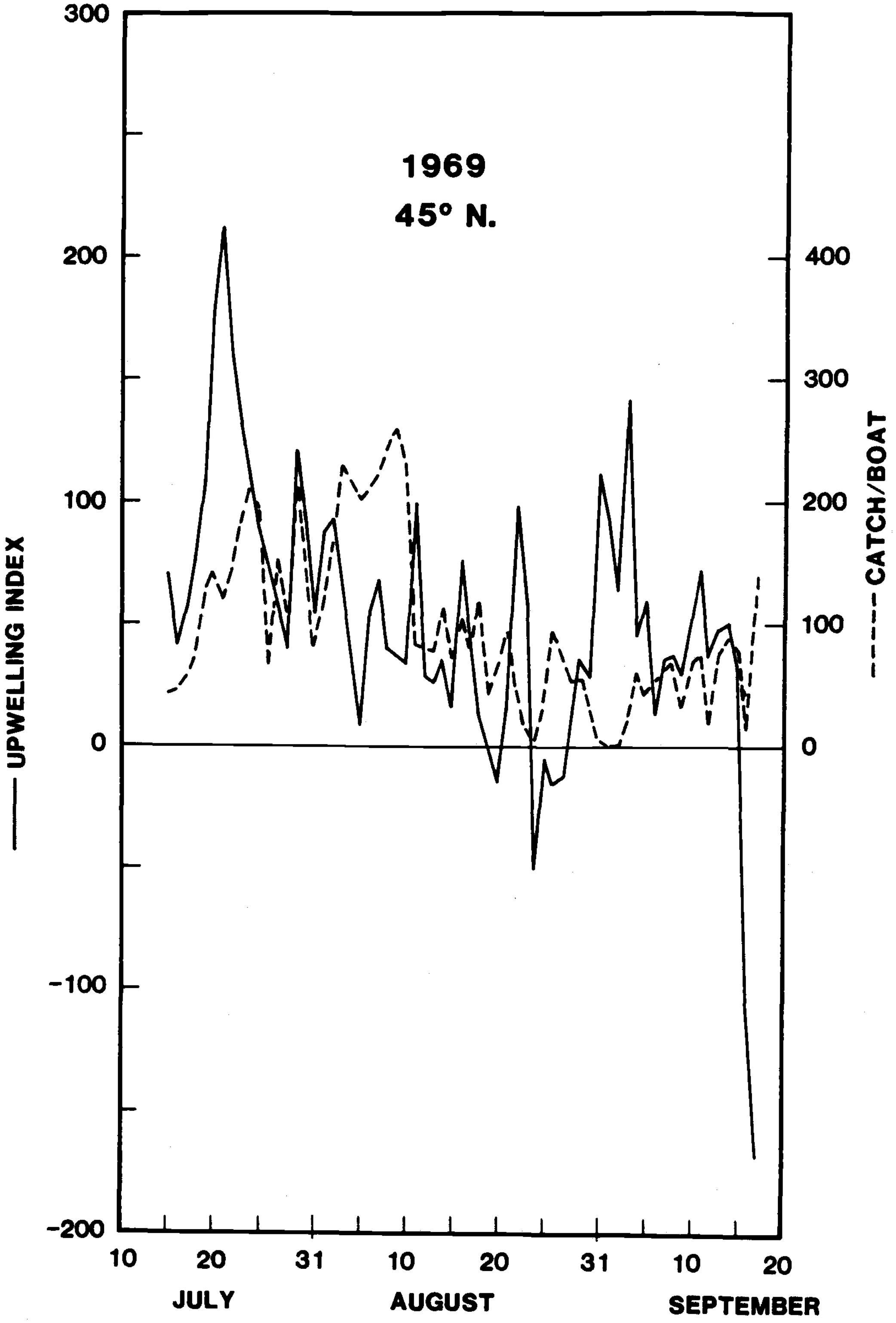

Figure 4k. Daily upwelling index at 45° N lat., 125° W long. and albacore catch/boat/day between 44-46° N lat. from the Oregon coast to 127° W long., July 15 - September 17, 1969.

The identification step is used to determine which of the three time series modeling schemes, moving average (MA), autoregressive (AR), or autoregressive-moving average (ARMA), will best describe the data and to determine, tentatively, the maximum orders p, q of the models; the estimation step involves maximum likelihood estimates of the parameters of the chosen models and checking stage; and the diagnostic checks are made on the residual series to test for misspecifications in the models.

The models which will best explain the data are determined by examining the patterns of significant lags in the cross-correlation and generalized partial correlation matrices. Cross-correlation matrices were calculated for total catch/day and daily upwelling index and for catch/boat/day and daily upwelling index at lags of 36 and 15 days for 1961 to 1963 and 1967 to 1969, respectively. The lags in days were selected based, mainly, on the lengths of the data series and to ensure that all significant correlations of daily catches and daily upwelling indices would be included in the models. Each year was run independently, but all data for each year were included in the calculations.

The generalized cross-correlation matrices are found by fitting multivariate AR models of increasing order to the data by ordinary multivariate least squares. The standardized values of the lag j parameter matrix, when all lags greater than j are assumed to have parameter values of zero, are used in the estimate of the generalized partial correlation matrix. Residual variances and χ^2 statistics are given to test the statistical significance of the generalized partial correlation matrices.

For all six years the cross-correlation matrices had several significant lags ($>2n^{-1/2}$ and $<-2n^{-1/2}$) and some sinusoidal patterns of significant and non-significant correlations. The generalized partial correlation matrices tended to have single significant lags ($\gtrless \pm 2$ SE). These patterns of significance in the cross-correlation and generalized partial correlation matrices suggested that the data were best described by AR models.

If the data could be best explained by MA models, there would have been single significant peaks in the cross-correlation matrices and several lags in the generalized partial correlation matrices. If the data could be explained by an ARMA model, both the cross-correlation and generalized partial correlation matrices would have several significant lags.

After estimating the form and order of the models from the cross-correlation and generalized partial correlation matrices, an iterative procedure was used to estimate the significant parameters of the models. The diagonal elements of the residual covariance matrices were used to determine the improvements of the fit in the models with each iteration. At each iteration, only possible significant parameters from the residual cross-correlation matrices were retained and added to the models. The non-significant parameters were removed. The procedure ended when the estimated models contained only significant parameters and the residual cross-correlation matrices showed no lack of fit. Overfitting and underfitting of the models were also used to test the stability of the models. Maximum likelihood estimates of the parameters and their standard errors were calculated.

The final forms of the models were checked further by examining the normalized residuals for each series. This allowed for checks that the residuals were symmetrical with mean near zero and that there were no significant trends or outliers that could seriously affect the analyses.

RESULTS

A preliminary study was conducted to examine correlations between catches and upwelling indices in four areas off California and Oregon (Figure 3) for July 1 through October 31, 1961 to 1970. Standard correlation coefficient tests were made between catch/boat and daily upwelling indices, and between total catch and upwelling indices for monthly, semimonthly, weekly and daily time periods. No statistically significant correlations were found even when catches were lagged to upwelling indices in the weekly and daily tests.

Since the daily graphs seemed to show positive relationships between catches and upwelling indices (Figures 4a-k) and since correlations between catches and upwelling indices may not be independent, the WMTS-1 was used.

Figures 4a-k are graphs of total catch/day with daily upwelling indices and catch/boat/day with daily upwelling indices for the areas surrounding 36° N lat., 122° W long. and 45° N lat., 125° W long. These graphs show that catches tend to increase after pulses of high upwelling. The changes in intensity of upwelling, however, do not always produce proportionate changes in catches nor do catches always increase after increases in upwelling indices.

Tables 3a-f and Tables 4a-e present predictive catch models and summaries of the final statistics from the WMTS-1 for central California and Oregon, respectively. The models are composed of significant correlations of daily catches and daily upwelling indices and their maximum likelihood parameter estimates. These

Table 3a. Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1961.

MODEL

Total catch/day = 0.665CC(t-1) + 6.471CU(t-3) - 3.540CU(t-10)

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Total catch/day constant	314.480	168.869
Upwelling index constant	41.073	12.531
Reg. autoregress.(1,C,C)[1]	0.665[2]	0.091
(1,U,U)	0.526	0.115
(2,U,U)	-0.285	0.115
(3,C,U)	6.471[2]	1.608
(10,C,U)	-3.540[2]	1.475

ERROR COVARIANCE MATRIX

	Total catch/day	Daily upwelling index
Total catch/day	265181.	
Daily upwelling index	-3037.39	1373.32

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Total catch/day	.07	514.96
Daily upwelling index	-.03	37.06

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 53%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or total catch/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between total catch/day lagged to total catch/day of one day earlier.

[2] Parameter estimates included in model.

Table 3b. Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1961.

MODEL

$$\text{Catch/boat/day} = 0.478CC(t-1) + 0.221CU(t-1) - 0.310CC(t-2) + 0.259CU(t-3) - 0.182CU(t-10)$$

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Catch/boat/day constant	28.728	13.747
Upwelling index constant	43.931	12.564
Reg. autoregress.(1,C,C)[1]	0.478[2]	0.107
(1,C,U)	0.221[2]	0.093
(1,U,U)	0.525	0.116
(2,C,C)	-0.310[2]	0.105
(2,U,U)	-0.324	0.114
(3,C,U)	0.259[2]	0.092
(10,C,U)	-0.182[2]	0.091

ERROR COVARIANCE MATRIX

	Catch/boat/day	Daily upwelling index
Catch/boat/day	994.04	
Daily upwelling index	-308.24	1372.98

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Catch/boat/day	.01	31.53
Daily upwelling index	-.01	37.05

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 28%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or catch/boat/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between catch/boat/day lagged to catch/boat/day of one day earlier.

[2] Parameter estimates included in model.

Table 3c. Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1962.

MODEL

Total catch/day = 1.167CC(t-1) - 0.330CC(t-2)

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Total catch/day constant	175.580	217.119
Upwelling index constant	29.169	8.690
Reg. autoregress.(1,C,C)[1]	1.167[2]	0.106
(1,U,U)	0.955	0.107
(2,C,C)	-0.330[2]	0.106
(2,U,U)	-0.372	0.107

ERROR COVARIANCE MATRIX

	Total catch/day	Daily upwelling index
Total catch/day	1658150.	
Daily upwelling index	-1437.56	3293.15

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Total catch/day	-.26	1287.69
Daily upwelling index	.01	57.39

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 80%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or total catch/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between total catch/day lagged to total catch/day of one day earlier.

[2] Parameter estimates included in model.

Table 3d. Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1962.

MODEL

Catch/boat/day = 0.598CC(t-1)

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Catch/boat/day constant	30.452	11.610
Upwelling index constant	28.483	8.673
Reg. autoregress.(1,C,C)[1]	0.598[2]	0.090
(1,U,U)	0.968	0.106
(2,U,U)	-0.375	0.106

ERROR COVARIANCE MATRIX

	Catch/boat/day	Daily upwelling index
Catch/boat/day	2157.99	
Daily upwelling index	-318.92	3294.34

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Catch/boat/day	-.00	46.45
Daily upwelling index	-.02	57.40

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 78%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or catch/boat/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between catch/boat/day lagged to catch/boat/day of one day earlier.

[2] Parameter estimates included in model.

Table 3e. Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1963.

MODEL

Total catch/day = 0.830CC(t-1) + 5.068CU(t-5)

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Total catch/day constant	-6.930	200.291
Upwelling index constant	21.836	6.666
Reg. autoregress.(1,C,C)[1]	0.830[2]	0.064
(1,U,U)	0.312	0.115
(5,C,U)	5.068[2]	2.544

ERROR COVARIANCE MATRIX

	Total catch/day	Daily upwelling index
Total catch/day	904567.	
Daily upwelling index	-11560.8	1975.00

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Total catch/day	.20	951.09
Daily upwelling index	-.01	44.44

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 70%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or total catch/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between total catch/day lagged to total catch/day of one day earlier.

[2] Parameter estimates included in model.

Table 3f. Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 36° N lat., 122° W long., 1963.

MODEL

Catch/boat/day = 0.534CC(t-1) + 0.247CC(t-2) + 0.292CU(t-2) + 0.240CU(t-18)

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Catch/boat/day constant	3.111	11.008
Upwelling index constant	22.309	6.750
Reg. autoregress.(1,C,C)[1]	0.534[2]	0.114
(1,U,U)	0.282	0.118
(2,C,C)	0.247[2]	0.111
(2,C,U)	0.292[2]	0.113
(18,C,U)	0.240[2]	0.089

ERROR COVARIANCE MATRIX

	Catch/boat/day	Daily upwelling index
Catch/boat/day	1734.90	
Daily upwelling index	-332.81	1993.64

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Catch/boat/day	.01	41.65
Daily upwelling index	.00	44.65

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 65%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or catch/boat/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between catch/boat/day lagged to catch/boat/day of one day earlier.

[2] Parameter estimates included in model.

Table 4a. Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1967.

MODEL

$$\begin{aligned}\text{Total catch/day} = {} & 32.012CU(t-1) - 0.328CC(t-4) + 23.633CU(t-6) \\ & - 0.300CC(t-9) + 34.537CU(t-9) + 22.746CU(t-13) \\ & + 18.169CU(t-14)\end{aligned}$$

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description		Final Est.	Est. SE
Total catch/day constant		-2168.85	881.831
Upwelling index constant		-1.519	8.740
Reg. autoregress.	(1,C,U)[1]	32.012[2]	6.684
	(1,U,U)	0.684	0.111
	(4,C,C)	-0.328[2]	0.151
	(6,C,U)	23.633[2]	6.772
	(9,C,C)	-0.300[2]	0.119
	(9,C,U)	34.537[2]	6.923
	(9,U,U)	0.259	0.123
	(13,C,U)	22.746[2]	7.790
	(14,C,U)	18.169[2]	7.283

ERROR COVARIANCE MATRIX

	Total catch/day	Daily upwelling index
Total catch/day	1371270.	
Daily upwelling index	-18.31	551.41

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Total catch/day	1.68	1171.01
Daily upwelling index	-.00	34.48

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 53%

---

[1] (1,C,U)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or total catch/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CU(t-1). This means that the correlation is between total catch/day lagged to daily upwelling index of one day earlier.

[2] Parameter estimates included in model.

Table 4b. Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1968.

MODEL

$$\text{Total catch/day} = 0.543CC(t-1) + 13.178CU(t-3) + 16.418CU(t-7) - 10.558CU(t-8) + 11.028CU(t-14)$$

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Total catch/day constant	-66.916	206.819
Upwelling index constant	0.918	6.076
Reg. autoregress.(1,C,C)[1]	0.543[2]	0.103
(1,U,U)	0.616	0.106
(3,C,U)	13.178[2]	4.975
(4,U,U)	0.288	0.114
(7,C,U)	16.418[2]	5.646
(8,C,U)	-10.558[2]	4.488
(14,C,U)	11.028[2]	3.365

ERROR COVARIANCE MATRIX

	Total catch/day	Daily upwelling index
Total catch/day	827143.	
Daily upwelling index	865.80	898.94

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Total catch/day	.02	909.27
Daily upwelling index	-.00	29.98

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 91%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or total catch/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between total catch/day lagged to total catch/day of one day earlier.

[2] Parameter estimates included in model.

Table 4c. Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long. 1968.

MODEL

$$\text{Catch/boat/day} = 0.265CC(t-1) + 0.200CU(t-1) + 0.301CC(t-2) + 0.217CC(t-3) - 0.482CU(t-6) + 0.625CU(t-7)$$

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Catch/boat/day constant	4.378	8.048
Upwelling index constant	3.809	5.658
Reg. autoregress.(1,C,C)[1]	0.265[2]	0.104
(1,C,U)	0.200[2]	0.081
(1,U,U)	0.822	0.081
(2,C,C)	0.301[2]	0.098
(3,C,C)	0.217[2]	0.070
(6,C,U)	-0.482[2]	0.122
(7,C,U)	0.625[2]	0.112

ERROR COVARIANCE MATRIX

	Catch/boat/day	Daily upwelling index
Catch/boat/day	673.87	
Daily upwelling index	9.18	1074.10

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Catch/boat/day	-.01	25.96
Daily upwelling index	-.00	32.77

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 90%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or catch/boat/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between catch/boat/day lagged to catch/boat/day or one day earlier.

[2] Parameter estimates included in model.

Table 4d. Total catch/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1969.

MODEL

$$\text{Total catch/day} = 0.684CC(t-1) + 0.226CC(t-4) - 0.147CC(t-8) + 17.306CU(t-14)$$

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Total catch/day constant	-487.771	336.182
Upwelling index constant	10.881	8.485
Reg. autoregress.(1,C,C)[1]	0.684[2]	0.076
(1,U,U)	0.648	0.139
(4,C,C)	0.226[2]	0.079
(8,C,C)	-0.147[2]	0.070
(14,C,U)	17.306[2]	4.831

ERROR COVARIANCE MATRIX

	Total catch/day	Daily upwelling index
Total catch/day	2294000.	
Daily upwelling index	17175.4	1877.50

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Total catch/day	.11	1514.60
Daily upwelling index	-.00	43.33

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 85%

---

[1] (1,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or total catch/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-1). This means that the correlation is between total catch/day lagged to total catch/day of one day earlier.

[2] Parameter estimates included in model.

Table 4e. Catch/boat/day model, parameter estimates, estimated standard errors, error covariance matrix, means and standard deviations of residual series and percent variance in catch data explained in the model for the area surrounding 45° N lat., 125° W long., 1969.

MODEL

Catch/boat/day = 0.347CC(t-5) + 0.450CU(t-7) + 0.451CU(t-14)

MODEL SUMMARY WITH MAXIMUM LIKELIHOOD PARAMETER ESTIMATES

Parameter Description	Final Est.	Est. SE
Catch/boat/day constant	2.773	8.739
Upwelling index constant	9.806	8.590
Reg. autoregress.(1,U,U)	0.673	0.143
(5,C,C)[1]	0.347[2]	0.081
(7,C,U)	0.450[2]	0.099
(14,C,U)	0.451[2]	0.087

ERROR COVARIANCE MATRIX

	Catch/boat/day	Daily upwelling index
Catch/boat/day	853.70	
Daily upwelling index	162.84	1878.33

SUMMARY STATISTICS OF RESIDUAL SERIES

Series	Mean	Standard Deviation
Catch/boat/day	-.00	29.22
Daily upwelling index	.01	43.34

PERCENT VARIANCE IN CATCH DATA EXPLAINED IN THE MODEL: 72%

---

[1] (5,C,C)=(day lagged, series, series lagged). Lag in days, series is daily upwelling indices (U) or catch/boat/day (C) and series lagged is C or U. The parameter estimates are from correlations between C and C, C and U, and U and U at the reported lags and are listed in the model, for example, as the parameter estimate and CC(t-5). This means that the correlation is between catch/boat/day lagged to catch/boat/day of five days earlier.

[2] Parameter estimates included in model.

models explain 28 to 91% of the variances in the actual total albacore catch/day and catch/boat/day for the six years studied.

The predictive models may show a value, e.g. 0.555(t-5), as part of the entire model and this means that the parameter estimate (0.555), which is significant at the five percent level in a t-test, is a function of the relationship between catch and the catch (CC) of five days earlier (t-5). Similarly, the term CU indicates that daily catch is a function of daily upwelling index. The sum of each parameter estimate times the daily catch or daily upwelling index of the lag indicated gives expected catch. The catch prediction, therefore, can be due primarily to past catches or past upwelling indices depending on the strength of the variables of daily catch and daily upwelling index included in the models.

The upwelling index and catch constants listed under parameter description in the tables are mean levels of catch and upwelling indices. Since the models are stationary, the means are equivalent to a zero value. The process is assumed to be at equilibrium about these constant means (Box and Jenkins 1970).

The final residual covariance matrix and summary statistics of the residual series are used as diagnostic tests for the model fit. The percent variance of catch is determined from the catch values in the covariance matrices by substracting the residual covariance matrix from the sample covariance matrix and dividing by the sample covariance matrix. The summary statistics test whether the assumptions of the models are met.

The parameter estimates of daily catches as functions of their lagged values and daily catches as functions of lagged daily upwelling indices were simultaneously estimated in the models. The models can reveal if lagged values of catch are better predictors than upwelling indices of present catch.

The terms "model" and "significant" in this and subsequent sections mean the predictive catch models developed by the WMTS-1 and statistical significance.

Tables 3a-f show predictive catch models, parameter estimates, error covariance matrices, summary statistics of residual series, and percent variance of catch explained in the models off central California. A one-day forecast explains 53%, 80% and 70% of the variances of the actual total catch/day and 28%, 78% and 65% of the catch/boat/day for 1961, 1962 and 1963, respectively.

In the total catch/day models, total catch/day as functions of daily upwelling indices are significant when catches are lagged to upwelling indices of three and 10 days earlier in 1961 and five days earlier in 1963. The 10-day lag in 1961, however, is negative. Total catch/day is not significantly related to daily upwelling index in 1962. The total catch/day values which can predict total catch/day are significantly correlated at one-day lag in all three years and there is also a negative relationship at lag of two days in 1962.

Catch/boat/day is affected by daily upwelling index when catches lag upwelling indices by one, three and 10 days in 1961; and two and 18 days in 1963. The 10-day lag is negative in 1961. Catch/boat/day is not significantly related to daily upwelling index in 1962. Catch/boat/day as functions of catch/boat/day are significant at lags of one day in all years and two days in 1961 and 1963. The two-day lag in 1961 is negative.

The relationships of daily upwelling indices to daily upwelling indices are listed for information only and are not included in the models. They are, however, included in the modeling procedure to ensure that each series is reduced to "white noise". Daily upwelling indices in both the total catch/day and catch/boat/day models are significant at lags of one and two days in 1961 and 1962 and one day in 1963, but the two-day lags in 1961 and 1962 are negative.

Catch models, parameter estimates, error covariance matrices and summary statistics for the models off Oregon are shown in Tables 4a-e. A one-day forecast explains 53%, 91% and 85% of the variances of total catch in 1967, 1968 and 1969, respectively. The catch/boat/day models explain 90% of the variance in 1968 and 72% in 1969.

The total catch/day models show significant total catch/day terms which lag upwelling indices at one, six, nine, 13 and 14 days in 1967; three, seven, eight and 14 days in 1968 with the eight-day lag being negative; and at 14 days in 1969. Total catch/day values lagged to total catch/day are negatively affected at lags of four and nine days in 1967; the one-day lag in 1968 is positive; and in 1969, the one and four-day lags are positive while the eight-day lag is negative.

Catch/boat/day terms lagged to daily upwelling indices in the catch/boat/day models are significant at lags of one, six and seven days in 1968; and seven and 14 days in 1969. The six-day lag in 1968 is negative. Catch/boat/day values related to themselves are significant at lags of one to three days in 1968 and five days in 1969. A model for 1967 was not generated.

The upwelling indices which predict upwelling indices in the total catch/day models are significant at lags of one and nine days in 1967; one and four days in 1968; and at one day in 1969. The catch/boat/day models have significant upwelling index related to upwelling index at lags of one day in 1968 and 1969.

DISCUSSION

Assuming that the distribution of tunas is, mainly, affected by water temperature and forage (Blackburn 1965), the short-term changes in concentration of forage near upwelling fronts may affect the distribution of albacore. Albacore that migrate to the North American fishery are immature (Otsu and Uchida 1963); therefore, their movements to and in the North American fishery are probably one for feeding rather than reproduction. Pearcy (1973) suggested that the disappearance of saury (Cololabis saira) affected the availability of albacore off Oregon in 1970.

Laurs (1983) said that because albacore spend much of their time at temperatures below which most of the albacore catches off North America are made, the effect of water clarity on the aggregations of albacore near oceanic fronts is probably more important than the thermal-physiological requirements of the albacore. When albacore catches were plotted on satellite images showing ocean temperatures and water color, Laurs et al. (1984) found that fishing effort and albacore catch rates, based on logbook records, were highest in the warmer, clear waters near the temperature and color boundaries believed to be associated with upwelling.

Results from the study show that daily catches correlated to daily catches are generally present in the models at lags of one day and are always positive. This indicates that when high catches are made, similar catches can be expected for at least one more day. The lags of two days and longer, when present, are positive or negative and do not follow any pattern. Similarly, daily upwelling indices show significant correlations with daily upwelling indices of the previous day, but are not always correlated for more than one day. The reason for the significant one-day lags for daily catches related to daily catches and daily upwelling indices related to daily upwelling indices is probably due to fishing and weather conditions remaining similar for more than one day.

There are differences between the predictive catch models off central California and Oregon, notably in the relationship between daily catch and daily upwelling index. These differences may be explained by the response of albacore to changes in the environment associated with upwelling and the behavior of fishermen to fishing reports.

The Oregon models generally show significant relationships between daily catches lagged to daily upwelling indices at one to three, six to nine and 13 to 14 days. This pattern follows cyclical upwelling events which average about eight days off Oregon (Peterson et al. 1979) and the one to three days necessary for upwelling to develop after the onset of northerly winds (Panshin 1971; Halpern 1976).

Off central California the significant correlations of daily catch lagged to daily upwelling index generally recur at less than five days and correspond to the time required for upwelling to develop after the onset of northerly or northwesterly winds. The relationships between daily catch and daily upwelling index off central California and Oregon suggest that the availability of albacore in both of these areas is affected by pulses of upwelling.

The absence of recurring predictive relationships between daily catches lagged to daily upwelling indices at greater than five days in the central California models may be due to the lack of persistence in upwelling in the area. Parrish et al. (1981) mentioned that maximum upwelling off the North American west coast occurs between Cape Blanco and Point Conception, but upwelling is probably not as persistant in this location as the study area off Oregon.

Interestingly, the 1962 models off central California only consist of daily catch lagged to daily catch terms. Strong upwelling or downwelling of approximately six, seven and 13 consecutive days (Figures 4c-d and Appendix) may have masked any possible significant correlations between daily catch and daily upwelling index in this series.

The study also shows that the models predict catches more accurately for Oregon than central California and more accurately for total catch/day than catch/boat/day in both areas.

The Oregon models are probably better predictors of catch because of the persistent nature of upwelling events off Oregon and because of the Columbia River plume. When upwelling ceases or is weak off Oregon, the Columbia River plume becomes more evident (Pearcy and Mueller 1970) and strong temperature gradients and differences in turbidity between the Columbia River plume and the surrounding water mass exist. Under these circumstances albacore may be concentrated at the temperature fronts associated with the Columbia River plume (Owen 1968; Pearcy and Mueller 1970). The Columbia River plume may add to the predictability of albacore catches in the Oregon models because of its persistence during the albacore season.

Albacore catches used in this study are dependent on records kept by fishermen and the behavior of these fishermen appears to affect the predictability of catches in the models. Albacore fishermen tend to aggregate in areas of good fishing (Pearcy and Mueller 1970) and they are aware of the locations in which albacore catches are high. Therefore, when weather conditions are good and albacore are present, fishermen tend to concentrate in areas of good catches. Consistent reactions by fishermen to reports of good catches and their aggregation in these areas may be the reason for the total catch/day models being better predictors than the catch/boat/day models off Oregon and central California.

CONCLUSION

The WMTS-1 computer package is used to develop predictive albacore catch models by relating daily troll-caught albacore to themselves and to daily upwelling index. Catches off Oregon are predicted from daily upwelling indices of approximately one to three, six to nine and 13 to 14 days earlier, while upwelling indices of less than five days are important in predicting catches off central California. These relationships indicate that upwelling affects albacore catches and that pulses of upwelling are more favorable for catching albacore than consistently high levels of upwelling.

Daily catches lagged to daily catches of the previous day are important in estimating total catch/day and catch/boat/day in the models and an understanding of the behavior of the fishermen is important in developing catch models when catch data are used.

LITERATURE CITED

ALVERSON, D. L.
1961. Ocean temperatures and their relation to albacore tuna (Thunnus germo) distribution in waters off the coast of Oregon, Washington and British Columbia. J. Fish. Res. Board Can. 18:1145-1152.

BAKUN, A.
1973. Coastal upwelling indices, west coast of North America, 1946-71. U. S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-671, 103 p.

BAKUN, A.
1975. Daily and weekly upwelling indices, west coast of North America, 1967-73. U. S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-693, 114 p.

BELL, R. R.
1971. California marine fish landings for 1970. Calif. Dep. Fish Game, Fish Bull. 154, 50 p.

BLACKBURN, M.
1965. Oceanography and the ecology of tunas. Oceanogr. Mar. Biol., Annu. Rev. 3:299-322.

BLACKBURN, M.
1969. Conditions related to upwelling which determine distribution of tropical tunas off western Baja California. Fish. Bull., U. S. 68:147-176.

BOX, G. E. P., and G. M. JENKINS.
1970. Time series analysis forecasting and control. Holden-Day, Inc., San Francisco, 553 p.

BRINK, K. H.
1983. The near-surface dynamics of coastal upwelling. Prog. Oceanogr. 12:223-257.

CATON, F. G., M. J. CUMING, and B. R. MENDENHALL.
1978. A northern hemisphere history of marine wind-based parameters. Meteorol. Intl. Inc., Monterey, 106 p., Appen. A1-A9.

CLEMENS, H. B.
1955. Catch localities for Pacific albacore (Thunnus germo) landed in California, 1951 through 1953. Calif. Dep. Fish Game, Fish Bull. 100, 28 p.

LITERATURE CITED Continued

CLEMENS, H. B.
1961. The migration, age, and growth of Pacific albacore (Thunnus germo), 1951-1958. Calif. Dep. Fish Game, Fish Bull. 115, 128 p.

CLEMENS, H. B., and W. L. CRAIG.
1965. An analysis of California's albacore fishery. Calif. Dep. Fish Game, Fish Bull. 128, 301 p.

CUSHING, D. H.
1969. Upwelling and fish production. FAO Fish. Tech. Pap. 84, 40 p.

DOTSON, R. C.
1980. Fishing methods and equipment of the U. S. west coast albacore fleet. SWFC-TM-NMFS-8, 126 p.

DUCLOS, F. H.
1973. Albacore fishery in the Bay of Biscay - influence of temperature on the displacement of schools. Third Reunion, Permanent Committee for Research and Statistics (SCRS), Intl. Comm. Conserv. Atl. Tuna (ICCAT), Madrid, Nov. 20-28, 1972, 52 p.

FLITTNER, G. A.
1970. Forecasting availability of albacore tuna in the eastern Pacific Ocean. P.116-129. In T. Laevastu and I. Hela (editors), Fisheries Oceanography. Fishing News (Books) Ltd., London.

FORSBERGH, E. D.
1963. Some relationships of meteorological, hydrographic, and biological variables in the Gulf of Panama. (In Engl. and Span.) Inter-Am. Trop. Tuna Comm. Bull. 7, p. 1-109.

HALPERN, D.
1976. Structure of a coastal upwelling event observed off Oregon during July 1973. Deep-Sea Res. 23:495-508.

HEIMANN, R. F. G., and J. G. CARLISLE, JR.
1970. The California marine fish catch for 1968 and historical review 1916-68. Calif. Dep. Fish Game, Fish Bull. 149, 70 p.

HREHA, L. H.
1974. Oregon albacore tuna fishery statistics, 1968-72. Fish Comm. Oreg. Data Rep. Ser. 5, 120 p.

HSUEH, Y., and J. J. O'BRIEN.
1971. Steady coastal upwelling induced by an along-shore current. J. Phys. Oceanogr. 1:180-186.

LITERATURE CITED Continued

KEENE, D. F., and W. G. PEARCY.
1976. Comparison of the most successful and least successful west coast albacore troll fishermen. Fish Bull., U. S. 74:973-982.

LAEVASTU, T., and H. ROSA, JR.
1963. Distribution and relative abundance of tunas in relation to their environment. FAO Fish Rep. 6:1835-1851.

LANE, R. K.
1965. Wind, nearshore ocean temperature, and the albacore tuna catch off Oregon. Fish Comm. Oreg. Res. Briefs 11:25-28.

LAURS, R. M.
1983. The North Pacific albacore--an important visitor to California Current waters. Calif. Coop. Oceanic Fish. Invest. Rep. 24, p. 99-106.

LAURS, R. M., H. B. CLEMENS, and L. H. HREHA.
1976. Nominal catch-per-unit effort of albacore, Thunnus alalunga (Bonnaterre), caught by U. S. jig vessels during 1961-70. Mar. Fish. Rev. 38:1-32.

LAURS, R. M., and R. C. DOTSON.
1983. Exploratory longline fishing for albacore tuna in eastern North Pacific waters during November-December 1982. SWFC-Admin. Rep. LJ-83-05, 71 p.

LAURS, R. M., P. C. FIEDLER, and D. R. MONTGOMERY.
1984. Albacore tuna catch distributions relative to environmental features observed from satellites. Deep-Sea Res. 31:1-15.

LAURS, R. M., and R. J. LYNN.
1977. Seasonal migration of North Pacific albacore, Thunnus alalunga, into North American coastal waters: distribution, relative abundance, and association with Transition Zone waters. Fish. Bull., U. S. 75:795-822.

LAURS, R. M., R. LYNN, R. DOTSON, R. NISHIMOTO, K. BLISS, and D. HOLTS.
1982. Exploratory albacore longline fishing in the eastern North Pacific during winter 1982. SWFC-Admin. Rep. LJ-82-06, 79 p.

LAURS, R. M., R. J. LYNN, R. NISHIMOTO, and R. DOTSON.
1981. Albacore trolling and longline exploration in eastern North Pacific waters during mid-winter 1981. SWFC-TM-NMFS-10, 40 p., Appen. 1-52.

LITERATURE CITED Continued

LAURS, R. M., H. S. H. YUEN, and J. H. JOHNSON.
1977. Small-scale movements of albacore, Thunnus alalunga, in relation to ocean features as indicated by ultrasonic tracking and oceanographic sampling. Fish. Bull., U. S. 75:347-355.

LYLES, C. H.
1965. Fishery statistics of the United States 1963. U. S. Fish Wildl. Serv., Bur. Commer. Fish., Stat. Digest 57, 522 p.

LYLES, C. H.
1966. Fishery statistics of the United States 1964. U. S. Fish Wildl. Serv., Bur. Commer. Fish., Stat. Digest 58, 541 p.

LYLES, C. H.
1967. Fishery statistics of the United States 1965. U. S. Fish Wildl. Serv., Bur. Commer. Fish., Stat. Digest 59, 756 p.

LYLES, C. H.
1968. Fishery statistics of the United States 1966. U. S. Fish Wildl. Serv., Bur. Commer. Fish., Stat. Digest 60, 679 p.

LYLES, C. H.
1969. Fishery statistics of the United States 1967. U. S. Fish Wildl. Serv., Bur. Commer. Fish., Stat. Digest 61, 490 p.

MAJORS, A. P., A. L. COAN, JR., N. BARTOO, and F. MILLER.
1983. Summary of the 1982 North Pacific albacore fishery data. SWFC-Admin. Rep. LJ-83-14, 40 p.

MC HUGH, J. L.
1952. The food of albacore (Germo alalunga) off California and Baja California. Bull. Scripps Inst. Oceanogr. Univ. Calif. 6:161-172.

MEEHAN, J. M., and L. H. HREHA.
1969. Oregon albacore tuna fishery statistics, 1961-67. Fish Comm. Oreg. Data Rep. Ser. 1, 143 p.

MENDELSSOHN, R.
1981. Using Box-Jenkins models to forecast fishing dynamics: identification, estimation, and checking. Fish. Bull., U. S. 78:887-896.

MURPHY, G. I.
1959. Effect of water clarity on albacore catches. Limnol. Oceanogr. 4:86-93.

OTSU, T., and R. N. UCHIDA.
1963. Model of the migration of albacore in the North Pacific Ocean. Fish. Bull., U. S. 63:33-44.

LITERATURE CITED Continued

OWEN, R. W., JR.
1968. Oceanographic conditions in the northeast Pacific Ocean and their relation to the albacore fishery. Fish. Bull., U. S. 66:503-526.

PANSHIN, D. A.
1971. Albacore tuna catches in the northeast Pacific during summer 1969 as related to selected ocean conditions. Ph.D. Thesis, Oregon State Univ., Corvallis, 110 p.

PARRISH, R. H., C. S. NELSON, and A. BAKUN.
1981. Transport mechanisms and reproductive success of fishes in the California Current. Biol. Oceanogr. 1:175-203.

PARTLO, J. M.
1950. A report on the 1949 albacore fishery (Thunnus alalunga). Fish. Res. Board Can. Nanaimo Biol. Sta. Circ. 20, 9 p.

PEARCY, W. G.
1973. Albacore oceanography off Oregon - 1970. Fish. Bull., U. S. 71:489-504.

PEARCY, W. G., and J. L. MUELLER.
1970. Upwelling, Columbia River plume and albacore tuna. Proc. Sixth International Symposium on Remote Sensing of Environment, p. 1101-1113, Univ. Mich., Ann Arbor.

PETERSON, W. T., C. B. MILLER, and A. HUTCHINSON.
1979. Zonation and maintenance of copepod populations in the Oregon upwelling zone. Deep-Sea Res. 26A:467-494.

PINKAS, L.
1970. The California marine fish catch for 1969. Calif. Dep. Fish Game, Fish Bull. 153, 47 p.

PINKAS, L., M. S. OLIPHANT, and I. L. K. IVERSON.
1971. Food habits of albacore, bluefin tuna, and bonito in California waters. Calif. Dep. Fish Game, Fish Bull. 152, 105 p.

POWELL, D. E., D. L. ALVERSON, and R. LIVINGSTONE, JR.
1952. North Pacific albacore tuna exploration - - 1950. U. S. Fish Wildl. Serv., Fish. Leafl. 402, 56 p.

POWELL, D. E., and H. A. HILDEBRAND.
1950. Albacore tuna exploration in Alaskan and adjacent waters - - 1949. U. S. Fish Wildl. Serv., Fish. Leafl. 376, 33 p.

POWER, E. A.
1963. Fishery statistics of the United States 1961. U. S. Fish Wildl. Serv., Bur. Commer. Fish., Stat. Digest 54, 460 p.

LITERATURE CITED Continued

POWER, E. A., and C. H. LYLES.
1964. Fishery statistics of the United States 1962. U. S. Fish Wildl. Serv., Bur. Commer. Fish., Stat. Digest 56, 466 p.

REID, J. L., JR., G. I. RODEN, and J. G. WYLLIE.
1958. Studies of the California Current system. Calif. Coop. Oceanic Fish. Invest. Prog. Rep., 1 July 1956 to 1 January 1958, p. 27-56.

ROY, C., and R. MENDELSSOHN.
1983. Environmental influences on tuna catches in the Gulf of Guinea. Am. Inst. Fish. Res. Biol. Briefs 12(6):2-3.

SMITH, R. L.
1968. Upwelling. Oceanogr. Mar. Biol., Annu. Rev. 6:11-46.

STEVENSON, M. R., R. W. GARVINE, and B. WYATT.
1974. Langrangian measurements in a coastal upwelling zone off Oregon. J. Phys. Oceanogr. 4:321-336.

STOMMEL, H., and W. S. WOOSTER.
1965. Reconnaissance of the Somali Current during the southwest monsoon. Proc. Natl. Acad. Sci. 54:8-13.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING.
1942. The oceans; their physics, chemistry, and general biology. Prentice-Hall, Inc., Englewood Cliffs, 1087 p.

TIAO, G. C., and G. E. P. BOX.
1981. Modeling multiple time series with applications. J. Am. Stat. Assoc. 76:802-816.

UDA, M.
1973. Pulsative fluctuation of oceanic fronts in association with tuna fishing grounds and fisheries. J. Fac. Mar. Sci. Technol., Tokai Univ. 7:245-265.

U. S. DEPARTMENT OF COMMERCE.
1971. Fishery statistics of the United States 1968. Natl. Oceanic Atmos. Adm., Natl. Mar. Fish. Serv., Stat. Digest 62, 578 p.

WHEELAND, H. A.
1972. Fishery statistics of the United States 1969. Natl. Oceanic Atmos. Adm., Natl. Mar. Fish. Serv., Stat. Digest 63, 474 p.

LITERATURE CITED Continued

WHEELAND, H. A.
1973. Fishery statistics of the United States 1970. Natl. Oceanic Atmos. Adm., Natl. Mar. Fish. Serv., Stat. Digest 64, 489 p.

YOSHIDA, H. O., and T. OTSU.
1963. Synopsis of biological data on albacore *Thunnus germo* (Lacépède), 1800 (Pacific and Indian Oceans). *FAO Fish. Rep.* 6:274-318.

YOSHIDA, K.
1955. Coastal upwelling off the California coast. Rec. Oceanogr. Works Jpn. 2:8-20.

APPENDIX

Appendix 1a. Albacore catches, number of boats that reported catches and upwelling indices used in study for 1961. Upwelling indices are from 36° N lat., 122° W long.; catches are from 35-37° N lat. from the central California coast to 125° W long.

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Jul 24	10	1	10.0	45
25	205	3	68.3	23
26	413	7	59.0	27
27	402	6	67.0	51
28	626	11	56.9	95
29	470	7	67.1	101
30	606	10	60.6	64
31	881	15	58.7	50
Aug 1	828	14	59.1	70
2	1109	13	85.3	91
3	1226	16	76.6	116
4	2034	25	81.4	68
5	2181	35	62.3	63
6	1676	41	40.9	47
7	2130	40	53.2	32
8	1687	38	44.4	44
9	1814	32	56.7	45
10	1268	32	39.6	18
11	1308	22	59.5	19
12	540	14	38.6	27
13	637	10	63.7	58
14	592	11	53.8	115
15	444	10	44.4	118
16	305	6	50.8	79
17	347	10	34.7	93
18	181	10	18.1	78
19	222	9	24.7	27
20	143	8	17.9	9
21	690	9	76.7	93
22	761	11	69.2	152
23	826	15	55.1	124
24	716	15	47.7	110
25	532	14	38.0	84
26	1257	12	104.8	90
27	3441	19	181.1	74
28	2969	21	141.4	57
29	1579	22	71.8	65
30	1407	22	64.0	43
31	902	18	50.1	59

Appendix 1a Continued

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Sep 1	560	15	37.3	96
2	32	3	10.7	175
3	98	3	32.7	98
4	684	19	36.0	18
5	1743	24	72.6	24
6	990	22	45.0	129
7	196	12	16.3	150
8	483	8	60.4	94
9	2173	22	98.8	37
10	2229	30	74.3	65
11	1624	28	58.0	120
12	1269	23	55.2	110
13	1396	24	58.2	81
14	2020	30	67.3	59
15	2688	33	81.5	26
16	829	24	34.5	10
17	811	19	42.7	70
18	229	13	17.6	132
19	340	7	48.6	129
20	994	10	99.4	16
21	855	12	71.2	55
22	804	13	61.8	21
23	297	14	21.2	27
24	364	13	28.0	14
25	284	7	40.6	11
26	221	8	27.6	77
27	519	5	103.8	43
28	680	7	97.1	25
29	18	7	2.6	165
30	70	1	70.0	91
Oct 1	556	6	92.7	87
2	2077	8	259.6	34
3	501	6	83.5	82
4	43	2	21.5	55
5	64	2	32.0	38
6	231	4	57.8	76

Appendix 1b. Albacore catches, number of boats that reported catches and upwelling indices used in study for 1962. Upwelling indices are from 36° N lat., 122° W long.; catches are from 35-37° N lat. from the central California coast to 125° W long.

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Aug 6	42	1	42.0	104
7	294	3	98.0	93
8	127	2	63.5	52
9	349	3	116.3	60
10	214	2	107.0	80
11	361	3	120.3	96
12	169	2	84.5	95
13	236	2	118.0	120
14	461	3	153.7	74
15	963	6	160.5	26
16	3275	11	297.7	79
17	6082	29	209.7	112
18	8040	42	191.4	137
19	10835	46	235.5	55
20	11621	48	242.1	42
21	7582	48	158.0	108
22	6100	38	160.5	117
23	3949	32	123.4	30
24	5207	33	157.8	16
25	2202	23	95.7	35
26	2506	16	156.6	62
27	2369	12	197.4	129
28	1549	13	119.2	157
29	1267	10	126.7	165
30	1376	9	152.9	187
31	766	7	109.4	190
Sep 1	949	6	158.2	202
2	1036	6	172.7	196
3	782	7	111.7	209
4	962	7	137.4	189
5	1334	8	166.8	143
6	1980	10	198.0	90
7	1005	9	111.7	89
8	1372	18	76.2	116
9	4716	33	142.9	40
10	5834	46	126.8	20
11	9676	56	172.8	41
12	9903	63	157.2	28
13	12785	63	202.9	31
14	8481	57	148.8	33
15	3165	43	73.6	50

Appendix 1b Continued

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Sep 16	2784	31	89.8	76
17	2020	24	84.2	30
18	911	19	47.9	69
19	68	5	13.6	245
20	-	0	-	230
21	-	0	-	110
22	-	0	-	74
23	197	1	197.0	96
24	103	1	103.0	92
25	161	4	40.2	69
26	66	3	22.0	67
27	760	7	108.6	21
28	972	11	88.4	28
29	1992	18	110.7	16
30	1147	19	60.4	-13
Oct 1	1169	14	83.5	4
2	766	9	85.1	23
3	206	6	34.3	110
4	20	1	20.0	116
5	22	2	11.0	141
6	624	6	104.0	54
7	798	11	72.5	143
8	1487	8	185.9	46
9	1132	15	75.5	25
10	1252	15	83.5	18
11	1459	11	132.6	-118
12	723	8	90.4	-303
13	32	1	32.0	-158
14	-	0	-	55
15	-	0	-	205
16	103	2	51.5	290
17	583	5	116.6	83
18	931	9	103.4	56
19	1355	18	75.3	48
20	2806	25	112.2	14
21	1505	23	65.4	44
22	646	13	49.7	49
23	988	13	76.0	13
24	910	11	82.7	24
25	612	5	122.4	38
26	288	6	48.0	39
27	418	6	69.7	20
28	180	4	45.0	13
29	108	4	27.0	12
30	16	1	16.0	101

Appendix 1c. Albacore catches, number of boats that reported catches and upwelling indices used in study for 1963. Upwelling indices are from 36° N lat., 122° W long.; catches are from 35-37° N lat. from the central California coast to 125° W long.

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Aug 13	218	2	109.0	89
14	119	2	59.5	112
15	49	1	49.0	111
16	514	4	128.5	141
17	289	2	144.5	213
18	697	3	232.3	219
19	289	3	96.3	245
20	712	8	89.0	155
21	946	8	118.2	92
22	2877	17	169.2	104
23	3068	33	93.0	111
24	3164	33	95.9	96
25	3648	28	130.3	98
26	3972	34	116.8	73
27	3416	44	77.6	36
28	1879	35	53.7	57
29	1353	19	71.2	69
30	1705	14	121.8	71
31	1461	15	97.4	34
Sep 1	1501	8	187.6	54
2	416	4	104.0	74
3	1038	9	115.3	31
4	2728	13	209.8	13
5	2287	13	175.9	10
6	2881	15	192.1	15
7	2262	13	174.0	2
8	1667	11	151.5	13
9	1258	9	139.8	26
10	1712	8	214.0	12
11	2116	10	211.6	4
12	3048	12	254.0	16
13	3433	18	190.7	30
14	3130	17	184.1	99
15	1115	8	139.4	117
16	1692	6	282.0	64
17	4778	14	341.3	15
18	4722	20	236.1	58
19	8123	31	262.0	21
20	6867	32	214.6	27
21	4678	32	146.2	35
22	6419	37	173.5	2
23	4669	35	133.4	41
24	4543	25	181.7	29
25	4035	25	161.4	39

Appendix 1c Continued

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Sep 26	3453	20	172.6	41
27	2971	21	141.5	9
28	1121	18	62.3	124
29	140	4	35.0	109
30	383	6	63.8	36
Oct 1	1659	18	92.2	62
2	2608	22	118.5	31
3	4234	25	169.4	34
4	2032	26	78.2	25
5	3246	25	129.8	1
6	2013	20	100.6	1
7	1315	21	62.6	12
8	1324	15	88.3	6
9	804	12	67.0	4
10	590	9	65.6	-123
11	859	7	122.7	11
12	387	8	48.4	118
13	259	6	43.2	31
14	1061	13	81.6	-160
15	543	10	54.3	-67
16	525	12	43.8	34
17	1446	15	96.4	24
18	1742	14	124.4	76
19	959	13	73.8	65
20	717	16	44.8	42
21	141	5	28.2	58
22	137	5	27.4	19
23	182	6	30.3	27
24	73	3	24.3	42
25	112	2	56.0	42
26	20	3	6.7	99
27	9	1	9.0	57
28	136	7	19.4	5
29	499	8	62.4	46
30	19	2	9.5	145
31	80	2	40.0	50

Appendix 1d. Albacore catches, number of boats that reported catches and upwelling indices used in study for 1967. Upwelling indices are from 45° N lat., 125° W long.; catches are from 44-46° N lat. from the Oregon coast to 127° W long.

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Jul 15	18	1	18.0	124
16	69	1	69.0	92
17	106	1	106.0	14
18	76	3	25.3	21
19	25	1	25.0	14
20	80	2	40.0	19
21	2	1	2.0	67
22	293	2	146.5	118
23	741	2	370.5	64
24	626	4	156.5	71
25	2364	9	262.7	84
26	1685	14	120.4	60
27	1429	18	79.4	64
28	2163	12	180.2	30
29	3631	13	279.3	20
30	4219	17	248.2	19
31	2874	22	130.6	71
Aug 1	3938	29	135.8	52
2	4794	29	165.3	61
3	2603	23	113.2	53
4	3599	22	163.6	55
5	2813	20	140.6	87
6	5465	22	248.4	87
7	2237	23	97.3	59
8	1309	18	72.7	64
9	611	10	61.1	63
10	1322	7	188.9	34
11	1953	10	195.3	28
12	1887	15	125.8	23
13	2235	28	79.8	33
14	4852	35	138.6	85
15	6953	34	204.5	86
16	4843	35	138.4	22
17	2182	38	57.4	41
18	2226	29	76.8	57
19	1743	26	67.0	85
20	2920	23	127.0	35
21	1410	17	82.9	31
22	1267	15	84.5	26
23	831	16	51.9	77
24	1314	13	101.1	111
25	844	13	64.9	87

Appendix 1d Continued

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Aug 26	1490	13	114.6	58
27	3059	16	191.2	6
28	6707	18	372.6	3
29	1675	15	111.7	2
30	967	14	69.1	10
31	1169	13	89.9	18
Sep 1	64	5	12.8	-37
2	205	1	205.0	-4
3	-	0	-	12
4	342	4	85.5	-12
5	419	5	83.8	1
6	255	4	63.8	5
7	542	5	108.4	31
8	233	4	58.2	22
9	468	7	66.9	4

Appendix 1e. Albacore catches, number of boats that reported catches and upwelling indices used in study for 1968. Upwelling indices are from 45° N lat., 125° W long.; catches are from 44-46° N lat. from the Oregon coast to 127° W long.

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Jul 15	1656	7	236.6	4
16	3667	13	282.1	30
17	7522	24	313.4	49
18	9560	32	298.8	63
19	17010	40	425.2	22
20	5688	49	116.1	55
21	9205	48	191.8	136
22	6352	34	186.8	166
23	5698	32	178.1	139
24	3932	30	131.1	98
25	6355	29	219.1	84
26	2138	13	164.5	135
27	1340	11	121.8	113
28	1120	10	112.0	142
29	1135	7	162.1	122
30	1580	8	197.5	150
31	2119	11	192.6	90
Aug 1	2653	20	132.6	38
2	5449	29	187.9	34
3	4860	30	162.0	31
4	5644	33	171.0	72
5	6964	30	232.1	54
6	8481	33	257.0	28
7	3805	23	165.4	74
8	2396	10	239.6	112
9	1622	11	147.5	53
10	2663	18	147.9	27
11	6704	33	203.2	40
12	5451	31	175.8	59
13	3840	29	132.4	14
14	1691	19	89.0	28
15	3734	22	169.7	3
16	2800	25	112.0	20
17	2689	24	112.0	4
18	1477	14	105.5	-8
19	1051	7	150.1	-22
20	924	14	66.0	-2
21	1730	15	115.3	6
22	595	10	59.5	-21
23	278	6	46.3	-39
24	314	4	78.5	-4
25	383	5	76.6	-4

Appendix 1e Continued

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Aug 26	505	7	72.1	-25
27	625	8	78.1	-83
28	453	8	56.6	-9
29	636	10	63.6	55
30	206	5	41.2	94
31	661	10	66.1	38
Sep 1	933	13	71.8	45
2	832	13	64.0	68
3	588	11	53.5	82
4	305	9	33.9	71
5	560	14	40.0	29
6	757	11	68.8	9
7	649	15	43.3	36
8	494	11	44.9	18
9	882	12	73.5	7
10	640	16	40.0	-16
11	594	15	39.6	12
12	422	11	38.4	39
13	103	3	34.3	-46
14	18	1	18.0	-81

Appendix 1f. Albacore catches, number of boats that reported catches and upwelling indices used in study for 1969. Upwelling indices are from 45° N lat., 125° W long.; catches are from 44-46° N lat. from the Oregon coast to 127° W long.

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Jul 15	631	15	42.1	71
16	1185	26	45.6	42
17	1374	25	55.0	56
18	1371	19	72.2	76
19	3597	29	124.0	109
20	3466	24	144.4	178
21	2637	24	109.9	211
22	3366	23	146.3	160
23	6879	37	185.9	134
24	10884	50	217.7	110
25	12297	66	186.3	89
26	4823	70	68.9	74
27	9519	63	151.1	59
28	7839	72	108.9	41
29	13945	61	228.6	120
30	8247	50	164.9	96
31	2894	35	82.7	55
Aug 1	3309	28	118.2	88
2	5969	37	161.3	93
3	10366	45	230.4	61
4	12674	58	218.5	37
5	9205	87	105.8	9
6	9416	82	114.8	55
7	9470	76	124.6	68
8	8634	58	148.9	40
9	9131	57	160.2	37
10	9737	72	135.2	35
11	6412	77	83.3	100
12	4111	51	80.6	29
13	2862	36	79.5	27
14	2219	20	111.0	36
15	1079	14	77.1	17
16	1572	15	104.8	76
17	872	11	79.3	47
18	1926	16	120.4	13
19	760	17	44.7	-1
20	706	11	64.2	-14
21	1014	11	92.2	16
22	292	6	48.7	98
23	31	2	15.5	64
24	-	0	-	-50
25	40	1	40.0	-4

Appendix 1f Continued

DATE	TOTAL CATCH	NO. BOATS	CATCH/BOAT	UPWELLING INDEX
Aug 26	95	1	95.0	-15
27	230	3	76.7	-13
28	163	3	54.3	21
29	224	4	56.0	36
30	484	6	80.7	29
31	12	2	6.0	112
Sep 1	-	0	-	94
2	-	0	-	65
3	110	5	22.0	142
4	241	4	60.2	46
5	217	5	43.4	59
6	470	8	58.8	14
7	597	9	66.3	36
8	499	7	71.3	37
9	239	7	34.1	30
10	692	10	69.2	48
11	511	7	73.0	73
12	137	8	17.1	38
13	374	5	74.8	48
14	365	4	91.2	50
15	308	4	77.0	35
16	29	1	29.0	-102
17	135	1	135.0	-168