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USE OF AGE-SPECIFIC ABUNDANCE INDICES AND EFFECTIVE EFFORT STATISTICS TO ASSESS THE NORTH PACIFIC ALBACORE STOCK

- PRELIMINARY RESULTS

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INTRODUCTION

This paper is concerned with the use of age-specific indices of abundance and effective effort statistics for estimating vital parameters of fish population dynamics and for predicting stock size and catch. It is motivated by the apparent need in tuna management analysis for a more formal way of combining information on relative stock size and age composition. Most tuna stock assessment is based on production model analyses of catch and catch-per-unit effort (CPUE) statistics. In this approach, a basic assumption is that age structure is not important. Further, the emphasis is usually on static properties of the underlying model, such as maximum sustainable yield (MSY), and little attention is paid to annual forecasts of stock size or catch.

However, in many cases age-composition estimates are available along with the catch and catch-per-effort data. These are commonly used in cohort analyses and to compute indices of reproductive potential (e.g., population fecundity) or indices of recruitment. The side information on reproductive potential and recruitment strength can be used to modify appraisals of stock condition based solely on a production model analysis and the results of cohort analysis may lead to a yield per recruit assessment and to conservation measures based on optimum harvest size. Still, it seems there is no technique now in use which fully integrates the available fishery statistics and produces both steady state information for determining general harvest strategy and short-term predictions of stock size and catch for use in tactical planning.

The approach we describe is a simple synthesis of existing theory and technique. In operation it involves the following steps at the end of each year:

(1) Compute age-specific indices of abundance, using CPUE statistics and size-composition data, and the best available growth model.

(2) Using the abundance indices and total age-specific catch data, estimate age-specific effective fishing effort.

(3) Revise estimates of mortality coefficients and coefficients of catchability using updated statistics on age-specific abundance and effective effort.

(4) Estimate spawning biomass using the latest indices of abundance and catchability coefficient estimates.

(5) Recompute estimates of parameters for spawner-recruit model, using updated estimates of recruitment and spawning biomass.

(6) Forecast recruitment for next year, using revised parameter values and estimates of spawning biomass for appropriate parent stock.

(7) Forecast abundance of other age groups using past year's age-specific abundance indices and revised estimates of mortality rates.

(8) Predict the coming year's catch using the forecasted stock size and expected fishing effort.

In the following sections we briefly outline the method and describe a trial application to North Pacific albacore, *Thunnus alalunga*. Basic equations are presented; for the most part these are conventional and fully described in the literature (e.g., Ricker 1975). In applying the technique to the albacore fishery we used catch, CPUE, and size-composition data from the major Japanese and United States fisheries over the 1955-75 period. Some fairly strong assumptions were made and several short-cuts were taken. Serious statistical problems were encountered in step (3) above, which terminated our work at this stage. These are briefly diagnosed, and comments are made concerning our intended continuation of the study.

NOTATION

Let

$N_{k,i}$ = number of fish in age group k at beginning of i^{th} year

$P_{k,i}$ = number of fish in age group k at beginning of index period for that age group in year i

$\bar{P}_{k,i}$ = average abundance of fish of age group k during their index period in year i

$U_{k,i}$ = average CPUE for fish in age group k during their index period in year i

$S_{k,i}$ = survival rate for fish in age group k during year i

$\bar{w}_k$ = average weight of individual fish of age group k during their index period

$\bar{W}_{k,i}$ = average biomass of fish in age group k during their index period in year i

$\simeq \bar{w}_k \bar{P}_{k,i}$

B_i = spawning biomass during year i

M_k = instantaneous natural mortality coefficient (annual) for fish in age-group k

λ_k = catchability availability coefficient for fish in age group k

= ratio of instantaneous fishing mortality coefficient (annual) to effective effort statistic

= $F_{k, i}/E_{k, i}$

$E_{k, i}$ = total effective effort exerted on fish in age group k in year i

$C_{k, i}$ = total number of fish of age group k caught in year i

$\varepsilon_{k,\,i}$ = effort exerted on fish in age group k during their index period in year i

$X_{k,\,i}$ = effort exerted on fish in age group k from the beginning of year i to the beginning of the index period for age group k

Δ_k = length of index period for age group k

τ_k = time at beginning of index period for age group k, relative to beginning of year

BASIC RELATIONS

We assume the exploitable population at the beginning of year i is composed of survivors from the previous year's exploitable stock and newly recruited fish. We assume the number of recruits in year i, entering the population on January 1 is

$$N_{r,\,i} = \alpha B_{i-\delta}\, e^{-\beta B_{i-\delta}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

where δ is the recruitment lag and $B_{i-\delta}$ is the spawning biomass in the parent year. For fish in the other age groups ($k > r$) we assume the initial abundance in year i is related to the initial abundance in year i-1 by

$$N_{k,\,i} = N_{k-1,\,i-1}\, e^{-(M_{k-1} + \lambda_{k-1} E_{k-1,\,i-1})} \quad . \; . \; . \quad (2)$$

Thus the rate of survival for fish in age group k-1 in year i-1 is defined as

$$S_{k-1,\ i-1} = \frac{N_{k,\ i}}{N_{k-1,\ i-1}} = e^{-(M_{k-1} + \lambda_{k-1} E_{k-1,\ i-1})} \quad . \ . \ (3)$$

At the beginning of the index period for age group k, the abundance of that group is

$$P_{k,\ i} = N_{k,\ i} e^{-(M_k \tau_k + \lambda_k X_{k,\ i})} \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (4)$$

We assume the average CPUE on fish of age group k during their index period is proportional to their average abundance during the period, i.e.,

$$U_{k,\ i} = \lambda_k \bar{P}_{k,\ i} \simeq \lambda_k P_{k,\ i} e^{-(M_k \Delta_k + \lambda_k \varepsilon_{k,\ i})/2} \quad . \ . \ . \ . \ (5)$$

To complete the set of basic equations, let $D_{k,\ i}$ be the average abundance of fish in age group k during a defined spawning period of year i.

Then

$$B_i = \sum_k v_k \bar{w}_k D_{k,\ i} \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (6)$$

where v_k is a coefficient of reproductive potential per unit biomass and $\bar{w}_k$ is average weight of an individual fish in age group k during the spawning period.

$D_{k,\ i}$ can be defined in the same fashion as $\bar{P}_{k,\ i}$ was above, i.e. $D_{k,\ i} = f\left\{\frac{U_{k,\ i}}{\lambda_k}\right\} = f\left\{\bar{P}_{k,\ i}\right\}$.

COMPUTING EFFECTIVE EFFORT

Total effective effort on age group k in year i is computed as

$$E_{k,\,i} = \frac{C_{k,\,i}}{U_{k,\,i}} \quad . \qquad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

Effective efforts for subintervals of the year, such as $X_{k,\,i}$ and $\varepsilon_{k,\,i}$, are computed analagously using subsets of the age-specific catch data.

Note that $U_{k,\,i} = \lambda_k \bar{N}_{k,\,i}$

where $\bar{N}_{k,\,i}$ is the average abundance of age group k during the year. Also, $C_{k,\,i} = \lambda_k E_{k,\,i} \bar{N}_{k,\,i} = F_{k,\,i} \bar{N}_{k,\,i}$

where $F_{k,\,i}$ is the average fishing mortality coefficient for age group k during year i.

FORECASTING ABUNDANCE AND CATCH

Given the estimate of spawning biomass for year i-δ and estimates of the parameters α and β, the abundance of recruits at the beginning of year i, $N_{r,\,i}$, may be predicted using equation (1).

The initial abundance of fish in other age groups may be estimated using the relation

$$\hat{N}_{k,\,i} = \left(\frac{U_{k-1,\,i-1}}{\lambda_{k-1}}\right) e^{-M_{k-1}(1-\tau_{k-1} - \Delta_{k-1}/2)}$$

$$\times\ e^{-\lambda_{k-1}(E_{k-1,\,i-1} - X_{k-1,\,i-1} - \varepsilon_{k-1,\,i-1}/2)} \quad \ldots \quad (8)$$

The required inputs for this predictor are the age-specific indices of abundance for the previous year, the age-specific effective effort statistics for the previous year, and estimates of the coefficients M and λ. These two coefficients are age-specific.

Once the initial population abundance is predicted, the age-specific catch for year i may be forecasted, given an estimate of expected fishing effort, i.e.,

$$\hat{C}_{k,\,i} = \left(\frac{g\,E_{k-1,\,i-1}}{M_k + g\,E_{k-1,\,i-1}}\right)\left(1 - e^{-(M_k + g\,E_{k-1,\,i-1})}\right)\hat{N}_{k,\,i} \quad . \;.(9)$$

where g is the multiplier relating last season's effort to the expected effort in season i.

ESTIMATING M AND λ

By substituting (5) in (4) an estimator for $N_{k,\,i}$ is found, leading to

$$\hat{S}_{k-1,\,i-1} = \frac{\hat{N}_{k,\,i}}{\hat{N}_{k-1,\,i-1}} \quad .$$

This is manipulated to yield the well-known result

$$-\ln\left(\frac{U_{k,\,i}}{U_{k-1,\,i-1}}\right) \simeq \ln\left(\frac{\lambda_{k-1}}{\lambda_k}\right) + M_{k-1}(1 - \tau_{k-1} - \Delta_{k-1}/2)$$

$$+ M_k(\tau_k + \Delta_k/2)$$

$$+ \lambda_{k-1}(E_{k-1,\,i-1} - X_{k-1,\,i-1} - \varepsilon_{k-1,\,i-1}/2)$$

$$+ \lambda_k(X_{k,\,i} + \varepsilon_{k,\,i}/2)$$

An estimation scheme may be developed around this equation, using ordinary multiple linear regression analysis. Since the time intervals are assumed to be the same each year, the two natural mortality terms are not separately estimable without further assumptions. The assumption we made was that $M_{k-1} = M_k = M$ for all k, i.e., that the natural mortality rate was constant.

ESTIMATING α AND β

Once the above parameters have been estimated, spawning biomass can be computed for each year. Also the recruitments may be back-estimated using

$$\hat{N}_{r,\,i} = \frac{U_{r,\,i}}{\lambda_r}\, e^{M_r(\tau_r + \Delta_r/2) + \lambda_r(X_{r,\,i} + \varepsilon_{r,\,i}/2)}$$

Once this is done, parameters of the Ricker spawner-recruit model may be estimated in the usual way with a linear regression based on the equation

$$\ln \frac{\hat{N}_{r,\,i}}{\hat{B}_{i-\delta}} = \ln\alpha - \beta\hat{B}_{i-\delta}\,.$$

DATA SOURCES

Indices of abundance were constructed using information on (1) total catch, CPUE, and size composition for the Japanese pole-and-line fishery, (2) catch, effort, and size composition for the Japanese longline fishery, and (3) catch and size composition for the U.S. west coast albacore fisheries.

The completeness and source of the data are described in Table 1. Some of the relevant statistics were available for 1976 and 1977, but not the complete set, so indices were computed only from 1955, when the pole-and-line CPUE data begin, to 1975.

INDICES OF ABUNDANCE AND INDEX AREAS

We considered two possible indices of stock abundance. (1) The number of albacore caught per vessel-day in the Japanese pole-and-line fishery, and (2) the number of albacore caught per 1,000 hooks in the Japanese tuna longline fishery. Indices were not developed using United States troll fishery data because the data series is relatively short and the availability of albacore varies markedly in time and space.

In the case of pole-and-line indices, catch rate data for 1955-69 were from vessels landing at Yaizu. This sample information was assumed to be representative of the entire pole-and-line fleet. For the 1970-75 period the pole-and-line data were taken from issues of the "Annual report of effort and catch statistics by area, Japanese skipjack baitboat fishery" published by the Fisheries Agency of Japan. The pole-and-line catch rate data were combined with length-composition statistics and with size-age relationships given by Clemens (1961), and the age-specific catch in numbers of fish was computed in such a way that the associated total weight yields equaled the figures reported at the 1977 North Pacific Albacore Workshop. [Clemens' value for the von Bertalanffy parameter t_o was increased by one year.]

Possible index areas for the Japanese pole-and-line fishery were selected as shown in Figure 1. Each area is a block of 5° lat. by 10° long. Areas PL-2 and PL-3 correspond to the Nishinoshima Area described by Shiohama (1975), areas PL-5 and PL-6 coincide with Shiohama's Izu Area, and areas PL-6 through PL-12 are in the Kuroshio Front region.

In the case of the Japanese longline fishery, nine index areas were established, areas LL-1 through LL-9, each being a band of 5° lat. These areas cover the entire North Pacific albacore longline grounds (Figure 2). In addition to the smaller index areas, we defined aggregate index areas, PL-T and LL-T. Area PL-T is composed of the pole-and-line areas PL-2, PL-3, PL-5, and PL-6. Area LL-T consists of the longline index areas LL-3 through LL-7.

ESTIMATES OF TOTAL CATCH AND EFFECTIVE EFFORT

In each index area the following computations were made: (1) First the available catch rate data were combined with the size-composition statistics to produce the average catch rates by 1-cm length interval, by quarter, for each index area.

(2) The catch rates by length class interval were converted to quarterly age-specific catch rates, by directly applying the modified Clemens growth model.

(3) Steps (1) and (2) were followed with total catch statistics in place of CPUE data, and, the quarterly catches of albacore [number of fish] by age group were computed, aggregated over the Japanese and United States fisheries.

(4) The first quarter of the year was chosen as the standard index period for the longline fishery, and the second quarter was selected for the pole-and-line fishery.

(5) In each proposed index area, the age-specific abundance indices (catch rates) during the selected indexing period were divided into the age-specific total catch estimates to produce a set of quarterly total effective effort statistics.

Figure 3 shows 21-year sequences of abundance indices, all age groups combined. Both pole-and-line and longline indices show a reduction in apparent abundance since the mid-1960's, when catch rates were relatively high. The age-specific indices of abundance are given in Tables 2 and 3. The pole-and-line indices represent area PL-T in the second quarter of the year, and the longline indices are from LL-T in the first quarter. Total age-specific catch estimates are given in Table 4. Table 5 gives the aggregate annual statistics on catch as well as the abundance indices and effective effort statistics based on both the pole-and-line and longline fisheries.

RESULTS OF REGRESSION ANALYSES

Regression analyses based on equation (10) were carried out using abundance indices and total effective effort statistics from PL-9 for age classes 2 and 3, data from PL-6 for age groups 4 and 5, and data from area LL-19 for ages 6-11. The regression analysis was also applied to the age-specific indices in area PL-T and LL-T. In most cases a complete set of 20 data points was available for the analysis; if either $U_{k, i}$ of $U_{k-1, i-1}$ was zero the particular data point was omitted.

If the data actually represent what we assumed they do in constructing the model, then the two regression coefficients (besides the constant terms) should be positive. However, these expectations were met in only 2 out of the 31 regressions we carried out. In five cases estimates of λ_k and λ_{k-1} were both negative. In the remaining 24 analyses the estimate of λ_k had a positive sign but the estimate of λ_{k-1} was negative.

These unfortunate results can be traced, at least in part, to the negative correlation between $U_{k, i}$ and $E_{k, i}$. The correlation between the two variables arises because $E_{k, i}$ is computed as in equation (7), by dividing the age-specific catch by $U_{k, i}$. The same difficulty is encountered in production model analyses when the effective effort is computed in this manner, or simply when the index of abundance is derived by dividing catch by effort and then regressed against the effort statistic.

COMMENTS ON FUTURE WORK

Our work on the age-specific abundance indices and the forecasting scheme is now halted until we solve the problem of estimating effective effort. In addition to this problem, there are other concerns needing attention:

(1) The abundance indices themselves may be questioned because of the way age composition was computed. Instead of the use of the age-length key, a short-cut procedure, we will calculate the age-specific catch by analyzing the modes of the distribution of catch by length-class interval.

(2) Because of the way total effective effort was computed, a tacit assumption in the model described here is that the average age-specific abundance during the specified index period is identical to the annual average abundance, i.e., $\bar{P}_{k,\, i} = \bar{N}_{k,\, i}$. In searching for a different effective effort measures, we hope to be able to eliminate this assumption.

(3) In outlining our forecasting scheme we neglected the effects of environmental conditions, either on stock size or expected catch.

(4) Our preliminary analysis did not consider the possibility that there is more than one stock of North Pacific albacore.

(5) In developing the pole-and-line abundance indices, we did not take into account changes in the average size of vessels in the fleet or the variation in relative fishing power of vessels

operating on different fishing grounds. Other CPUE statistics, such as catch per pole-day, may be preferable.

These are some of the considerations we will bear in mind in future exploratory work. Our objective remains to develop comprehensive and effective procedures for estimating stock condition and forecasting catch.

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Table 1.--Kinds of North Pacific albacore data used in the analysis, their completeness, and source.

Fishery	Type of data	Temporal and spatial completeness	Source
Japanese pole-and-line	Total landings	By year, 1955-75 All areas combined	Far Seas Fisheries Research Laboratory, Shimizu, Japan (FSFRL)
	Yaizu sample catch and nominal effort	By year, 1955-69 By month, Mar.-Sept. By 5° lat., 10° long. areas (25°-35°N, 130°-180°E; and 35°-45°N, 140°-180°E)	FSFRL
	Catch and nominal effort	By year, 1970-75 By month By 1° lat., 1° long. areas	"Annual Report of Effort and Catch Statistics by Areas, Japanese Skipjack Baitboat Fishery," Fisheries Agency of Japan
	Sample length composition	By year, 1955-64 By month, May-July By 10° long. bands (north of 25°N, 130°-160°E)	1955-59 in Suda (1963) 1960-64 in Koto and Hisada (1966)
		By year, 1965-71 By month, Jan.-Dec. By 5° lat., 10° long. areas (east of 120°E)	Shiohama (1973)
		1972-75 By month, Mar.-Oct. By 5° lat., 10° long. areas (east of 130°E)	FSFRL
Japanese longline	Total catch and nominal effort	By year, 1955-75 By month, Jan.-Dec. By 5° lat., 5° long. areas (east of 120°E)	"Annual Report of Effort and Catch Statistics by Area on Japanese Tuna Longline Fishery," Fisheries Agency of Japan
	Sample length composition	By year, 1955-64 By month, Dec.-Feb. By 10° long. bands (north of 25°N, 130°-180°E)	1955-59 in Suda (1963) 1960-64 in Koto and Hisada (1966)
		By year, 1965-75 By month, Jan.-Dec. By 5° lat., 10° long. areas (east of 120°E)	1965-71 in Shiohama (1973) 1972-75 from FSFRL
United States	Total landings (troll and baitboats)	By year 1955-75 By month, by state (California, Oregon and Washington)	California Department of Fish and Game, Long Beach, California (CFG) and NMFS, La Jolla, California
	Length composition (troll only)	By year, 1955-72 for California and Oregon (except 1964 for Oregon); By year, 1955-68 for Washington (several years of Washington size compositions estimated from Oregon data)	CFG Also, California data for 1955-61 published in Clemens and Craig (1965); Oregon data for 1955-60 published in Ayers and Meehan (1963); Oregon data for 1961-67 published in Meehan and Hreha (1969); Oregon data for 1968-72 published in Hreha (1974).
		1973-75 States combined	NMFS, La Jolla, California

Table 2.--Estimated age-specific abundance indices for albacore in area PL-T during second quarter (fish per vessel-day).

	Age group (years)						
Year	2	3	4	5	6	7	8
1955	--	1.17	329.74	75.87	9.88	0.21	--
1956	1.16	89.75	230.83	22.62	15.16	0.43	--
1957	6.12	58.61	124.55	91.39	14.90	0.07	--
1958	1.56	70.61	220.91	126.80	23.80	0.54	--
1959	0.02	0.63	81.45	101.25	31.76	1.54	--
1960	0.05	2.77	170.49	30.38	6.32	0.10	--
1961	7.42	--	80.15	187.58	38.76	1.86	--
1962	3.71	--	43.95	171.93	259.50	8.51	0.31
1963	--	3.17	317.00	51.98	10.13	0.19	--
1964	24.02	30.67	32.67	238.09	48.86	0.09	--
1965	275.88	88.23	60.53	329.67	78.78	5.68	--
1966	47.54	33.05	39.12	284.63	104.27	4.04	0.20
1967	5.02	27.45	22.66	237.46	86.79	15.66	1.02
1968	18.95	15.48	50.17	140.79	67.60	38.00	1.31
1968	3.47	1.69	30.86	248.41	27.32	2.18	0.74
1970	7.00	10.02	14.26	79.66	20.52	1.33	0.10
1971	2.65	7.62	39.39	127.12	53.00	11.65	0.07
1972	8.80	26.50	75.66	91.04	7.37	3.25	0.51
1973	7.49	4.72	17.10	165.61	61.38	7.72	1.77
1974	8.78	14.68	75.11	71.44	20.15	12.18	8.46
1975	12.62	37.11	57.21	83.71	20.60	3.66	0.17

Table 3.--Estimated age-specific abundance indices for albacore in area LL-T during the first quarter (fish per 1,000 hooks).

	Age group (years)									
Year	2	3	4	5	6	7	8	9	10	11
1955	0.01	0.55	0.59	2.39	1.24	0.53	0.35	0.20	0.08	0.02
1956	0.04	0.32	1.81	2.13	0.51	0.37	0.16	0.07	0.03	0.02
1957	0.04	0.64	3.27	2.88	1.47	0.92	0.34	0.11	0.07	0.03
1958	0.02	0.54	2.49	2.29	1.87	1.05	0.50	0.11	0.05	0.02
1959	--	0.23	0.76	3.48	1.81	1.00	0.72	0.31	0.09	0.02
1960	--	0.07	0.76	2.86	1.05	0.62	0.38	0.15	0.05	0.03
1961	0.01	0.12	0.49	3.83	1.14	0.81	0.35	0.10	0.04	0.01
1962	0.05	1.20	1.06	0.80	0.89	1.56	0.71	0.24	0.11	0.03
1963	0.01	0.49	1.00	1.34	0.28	0.28	0.35	0.07	0.02	--
1964	--	0.20	1.80	2.79	0.94	0.36	0.28	0.21	0.12	0.04
1965	--	0.57	1.50	1.78	0.48	0.28	0.31	0.30	0.19	0.09
1966	0.59	0.86	3.83	2.98	0.97	0.86	0.76	0.41	0.26	0.17
1967	0.35	0.86	3.45	1.91	1.77	1.28	1.07	0.59	0.31	0.13
1968	0.08	2.07	2.26	1.35	1.53	1.22	0.95	0.39	0.13	0.05
1969	--	0.14	3.08	1.21	0.73	0.85	1.07	0.66	0.18	0.02
1970	0.11	1.93	2.10	1.14	0.84	0.44	0.47	0.34	0.23	0.12
1971	0.10	0.24	0.72	1.56	0.70	0.92	0.83	0.54	0.37	0.09
1972	--	0.12	2.71	0.90	0.75	1.31	1.16	0.40	0.20	0.14
1973	--	0.01	0.84	0.78	0.90	0.94	1.06	0.58	0.25	0.13
1974	0.01	0.34	0.56	0.84	1.27	1.00	0.63	0.31	0.14	0.13
1975	--	0.03	0.38	0.54	0.41	0.66	0.71	0.42	0.32	0.18

Table 4.--Estimates of total age-specific albacore catch (10^3 fish)

	Age group (years)									
Year	2	3	4	5	6	7	8	9	10	11
1955	238	2,320	256	565	279	132	245	479	60	33
1956	153	3,200	4,101	684	328	100	38	15	8	4
1957	192	2,422	3,244	2,055	469	139	60	17	9	4
1958	174	1,878	1,746	1,121	390	149	74	18	7	3
1959	223	2,915	709	1,035	379	144	98	41	12	4
1960	13	1,610	2,701	1,063	286	122	67	29	9	4
1961	142	590	1,509	1,530	313	177	76	21	7	3
1962	402	2,926	630	437	430	204	96	34	14	4
1963	256	3,221	3,080	758	170	85	80	24	10	1
1964	412	2,141	2,102	1,295	292	50	37	28	16	6
1965	131	1,436	1,797	2,501	425	61	38	25	13	7
1966	205	1,642	1,560	1,652	514	118	85	39	22	16
1967	272	2,465	1,393	2,100	770	266	140	61	29	15
1968	202	3,027	1,480	754	529	268	141	45	16	7
1969	129	2,227	1,359	2,218	328	162	162	76	22	5
1970	614	2,561	1,849	1,079	435	109	77	46	30	13
1971	237	3,499	1,866	2,183	611	151	108	50	25	9
1972	4,072	2,539	3,128	2,442	343	234	245	99	58	29
1973	8,556	2,039	958	2,569	891	293	183	97	50	29
1974	1,435	3,832	4,985	1,382	420	260	165	83	40	35
1975	386	3,464	1,943	1,648	603	141	113	66	43	26

Table 5.--Aggregate statistics on albacore catch, catch-per-effort, and effective effort.

		Pole-line	Longline	Pole-line	Longline
	C	U	U	E	E
Year	10^3 fish	Fish/vessel-day	Fish/10^3 hooks	10^3 vessel-days	10^6 hooks
1955	4,606	417	5.97	11.0	772
1956	8,630	360	5.46	24.0	1,580
1957	8,611	296	9.75	29.1	883
1958	5,559	444	8.95	12.5	621
1959	5,560	217	8.41	25.7	661
1960	5,904	210	5.96	28.1	991
1961	4,367	316	6.89	13.8	634
1962	5,177	488	6.66	10.6	778
1963	7,684	382	3.83	20.1	2,008
1964	6,378	374	6.73	17.0	948
1965	6,435	839	5.51	7.7	1,168
1966	5,852	513	11.70	11.4	500
1967	7,512	396	11.73	19.0	641
1968	6,470	332	10.02	19.5	646
1969	6,687	315	7.96	21.3	840
1970	6,812	133	7.72	51.3	883
1971	8,738	241	6.07	36.0	1,439
1972	13,188	213	7.70	61.9	1,712
1973	15,664	266	5.50	58.9	2,848
1974	12,636	211	5.24	59.9	2,411
1975	8,432	215	3.65	39.2	2,309

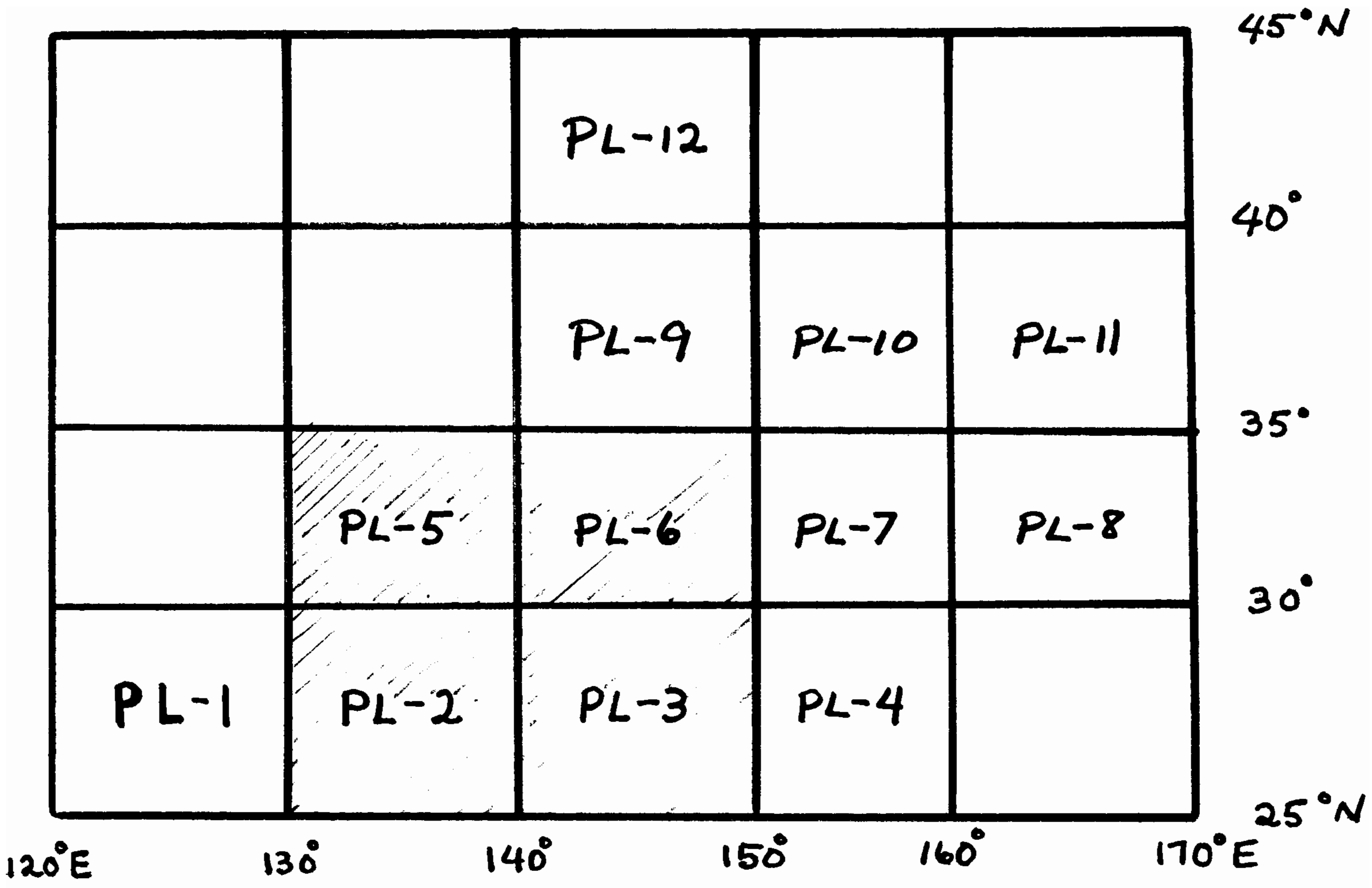


Figure 1.--Pole-and-line index areas.

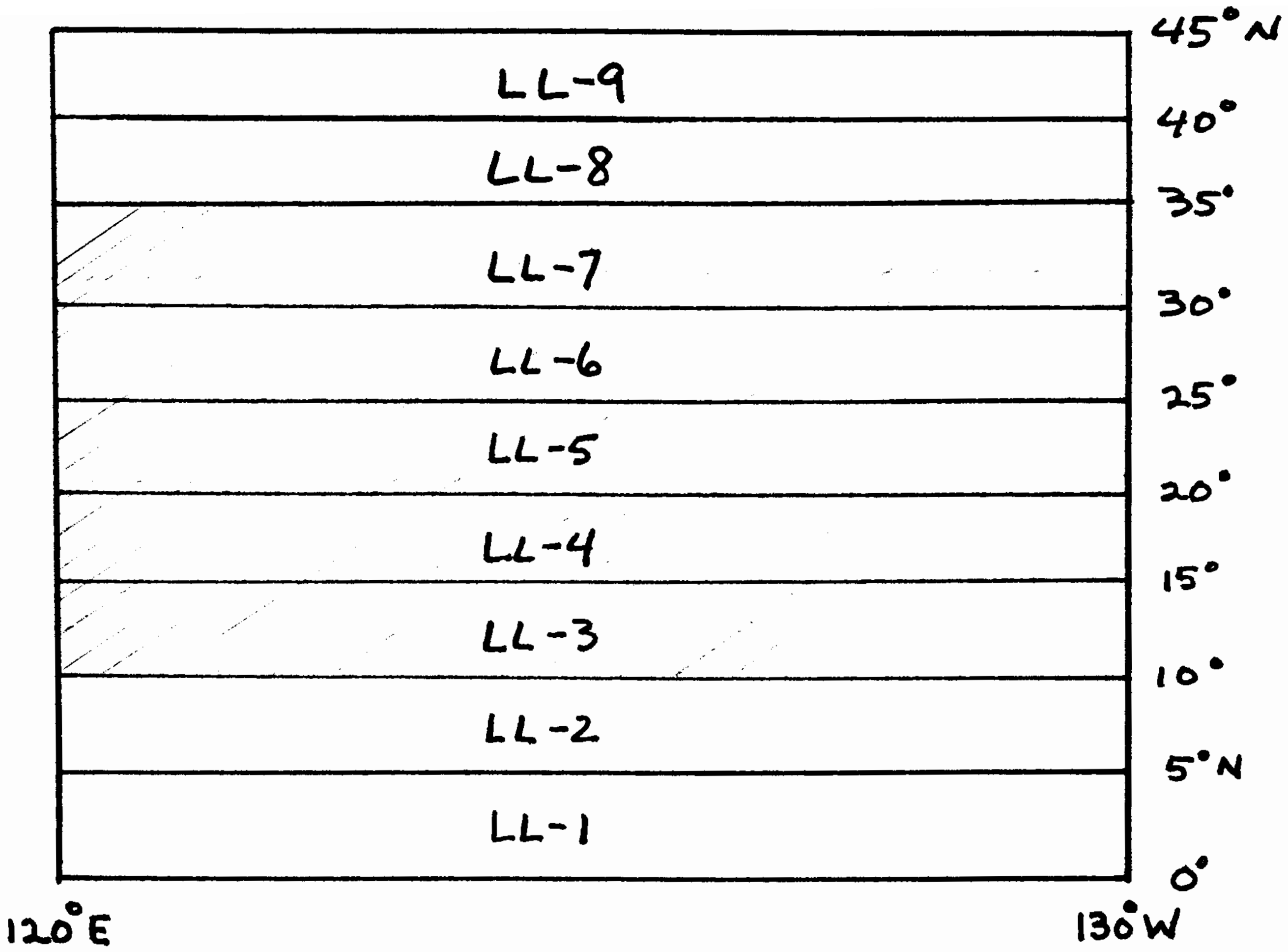
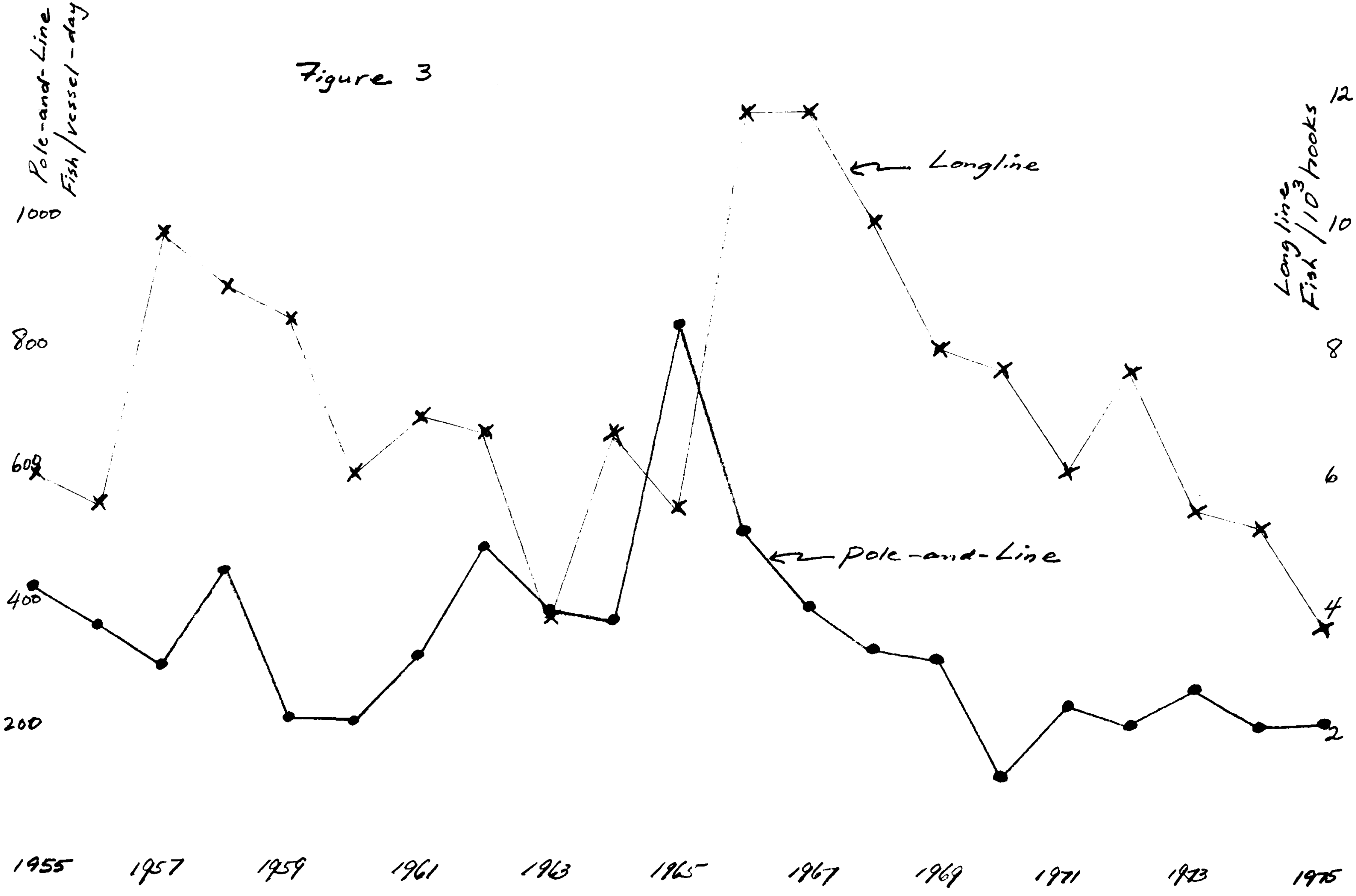


Figure 2.--Longline index areas.

Figure 3


Pole-and-Line
Fish/vessel-day
1000
800
600
400
200
Long line
Fish/10^3 hooks
12
10
8
6
4
2
Longline
Pole-and-Line
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975