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Title: TACTICS OF PACIFIC NORTHWEST ALBACORE FISHERMEN - 1968, 1969, 1970

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This study examines the relationship between fishing activities of Pacific Northwest albacore fishermen and the availability of albacore. Tactical responses of troll-boat fishermen were compared to changes in daily apparent albacore abundance. Tactical responses included boat aggregation and total applied effort (number of boats) within a particular area, and net daily distances traveled by individual boats and the medial center of the fleet. Apparent abundance estimates were derived from logbook catch records collected during the 1968, 1969 and 1970 seasons.

Fishing power estimates of individual vessels allowed comparisons to be made of the most successful and least successful boats. In general, the most successful boats were larger, fished nearer the fleet center, traveled less net distance each day and caught more but smaller fish than the less successful boats. The magnitude of the

differences between the most successful and least successful boats decreased progressively from 1968 to 1970.

Apparent abundance fluctuations were synchronous in separate areas of the 1968 fishery but not in the 1969 and 1970 fisheries. Fluctuations tended to be periodic in 1969 and 1970 but not in 1968. No generalizations as to apparent abundance (patchiness, size of albacore concentrations) could be determined among years.

Fishermen responded quickly to changes in apparent abundance during 1968. Boats were highly aggregated on days of high catches, and dispersed on days of low catches. Fishermen responses during 1969 were one day out of phase with catches. Boats aggregated one day after days of high catches, indicating that fishermen experienced difficulty in staying on concentrations of fish. In 1970 fishermen experienced no difficulty in staying on fish concentrations as record daily catches were reported.

According to interviews and questionnaires, albacore fishermen rely heavily on inter-boat communications for planning their daily fishing tactics. A consequence of this reliance on radio communication appears to be a greater degree of boat aggregation and less willingness to scout in areas away from the central fleet area. Areas to the north and south of the central fleet were shown to have high estimates of albacore abundance but were exploited by very few boats. Greater dispersal of the fleet and use of several survey boats are suggested as a means of increasing the total fishing catch.

Tactics of Pacific Northwest Albacore Fishermen - 1968, 1969, 1970

by

Donald Frederick Keene

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TACTICS OF PACIFIC NORTHWEST ALBACORE FISHERMEN - 1968, 1969, 1970

INTRODUCTION

Albacore tuna, Thunnus alalunga (Bonnaterre), are distributed throughout the tropical and temperate regions of the Pacific, Indian and Atlantic Oceans. Within the major oceans, populations of albacore have been identified by serological differences (Sizuki, Morio, and Mimoto, 1959). Two distinct populations occupy the Pacific Ocean; one south of the equator and one north of the equator (Yoshida and Otsu, 1963). Suda (1963) states that albacore of the North Pacific belong to a single stock. Albacore are epipelagic fish and their distribution appears to be related to oceanic properties, particularly temperate (Blackburn, 1965; Brock, 1959) and current systems (Nakamura, 1969).

The North Pacific stock of albacore spawns in the North Equatorial Current (20° N. latitude) during the early summer months (Suda, 1963). The larval fish are thought to spend at least a year in the North Equatorial Current, although their distribution and movements are poorly known. A few one-year old fish are found in a fishery along the Japanese coast, while older fish engage in yearly trans-Pacific migrations (Clemens, 1961; Otsu and Uchida, 1963; Yoshida and Otsu, 1963). A model of the migration path is shown in Figure 1. After the fish reach sexual maturity (at about age six) migrations appear to be limited to the gyres in the western half of the Pacific Ocean.

Three fisheries dominate the exploitation of the North Pacific albacore (Figure 2). Descriptions of the Japanese longline and the Japanese pole-and-line fisheries are given in Suda (1963) and Van Campen (1960), respectively. The age and length frequencies of albacore from these fisheries (Figure 3) support the migration model in Figure 1. Younger fish predominate in the northern and eastern sectors of the fishery while older fish occur mainly in the southern and western sectors. The catch of the relatively small longline fishery of the Hawaiian Islands (Otsu, 1950) consists almost entirely of sexually mature fish (six years and older). Landings from the combined Japanese fisheries exceeds the U. S. west coast fishery by two or three times (Yoshida and Otsu, 1963).

The west coast troll-boat fleet consists of many types and sizes of vessels (Clemens, 1955). Part of this fleet begins fishing for albacore off the coast of Baja California in early summer. During the peak of the season (July, August, September) boats may be found from Mexico to the Gulf of Alaska. However, the most productive area lies between central Baja California and the Columbia River (Clemens, 1961). Troll boats range in length from about 35 feet (10.7 m) to over 75 feet (22.9 m) with a displacement of about 15 tons.

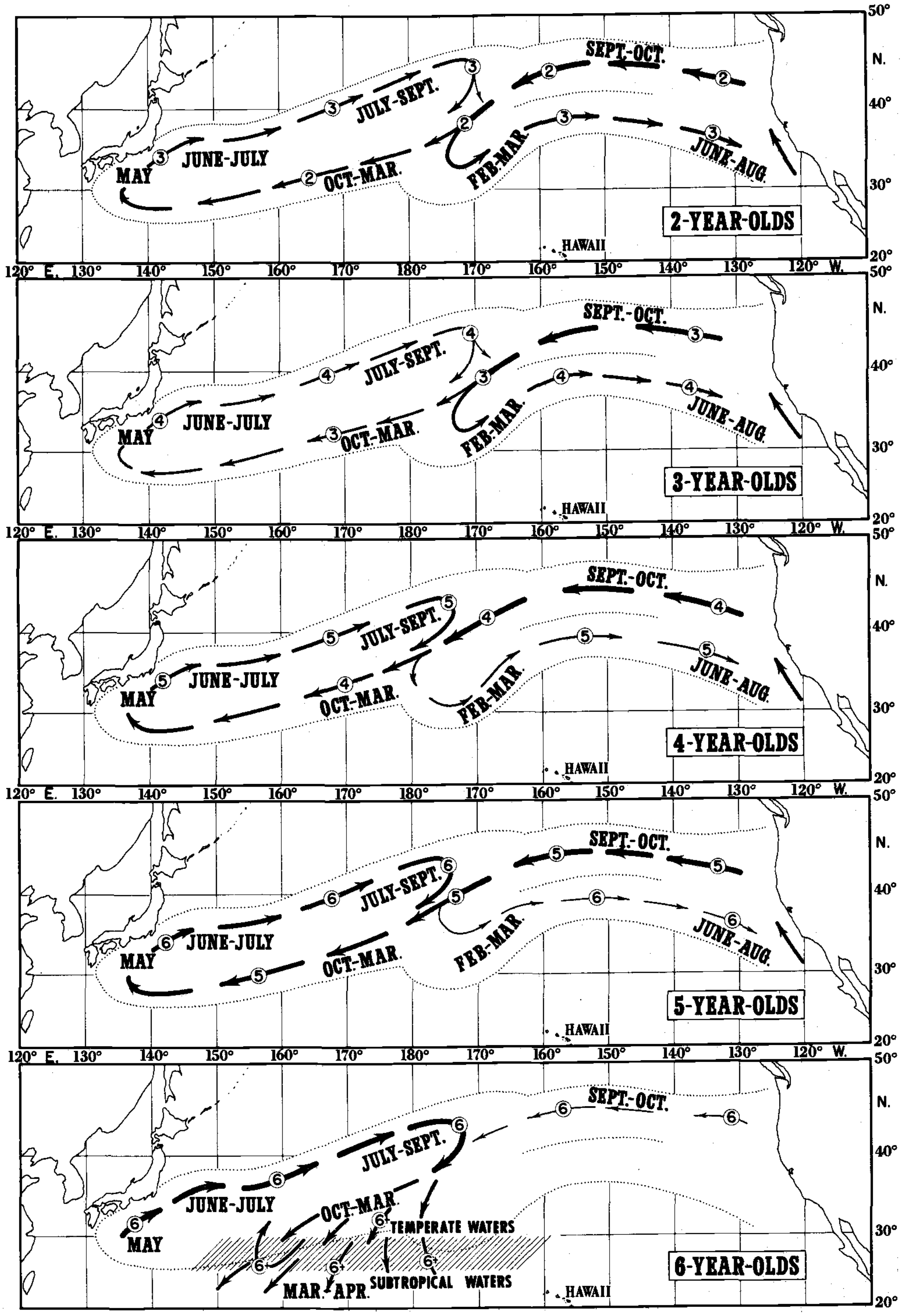

Figure 1. Model of albacore migrations in the North Pacific Ocean by age groups (ages encircled), taken from Figure 9 of Otsu and Uchida (1963).

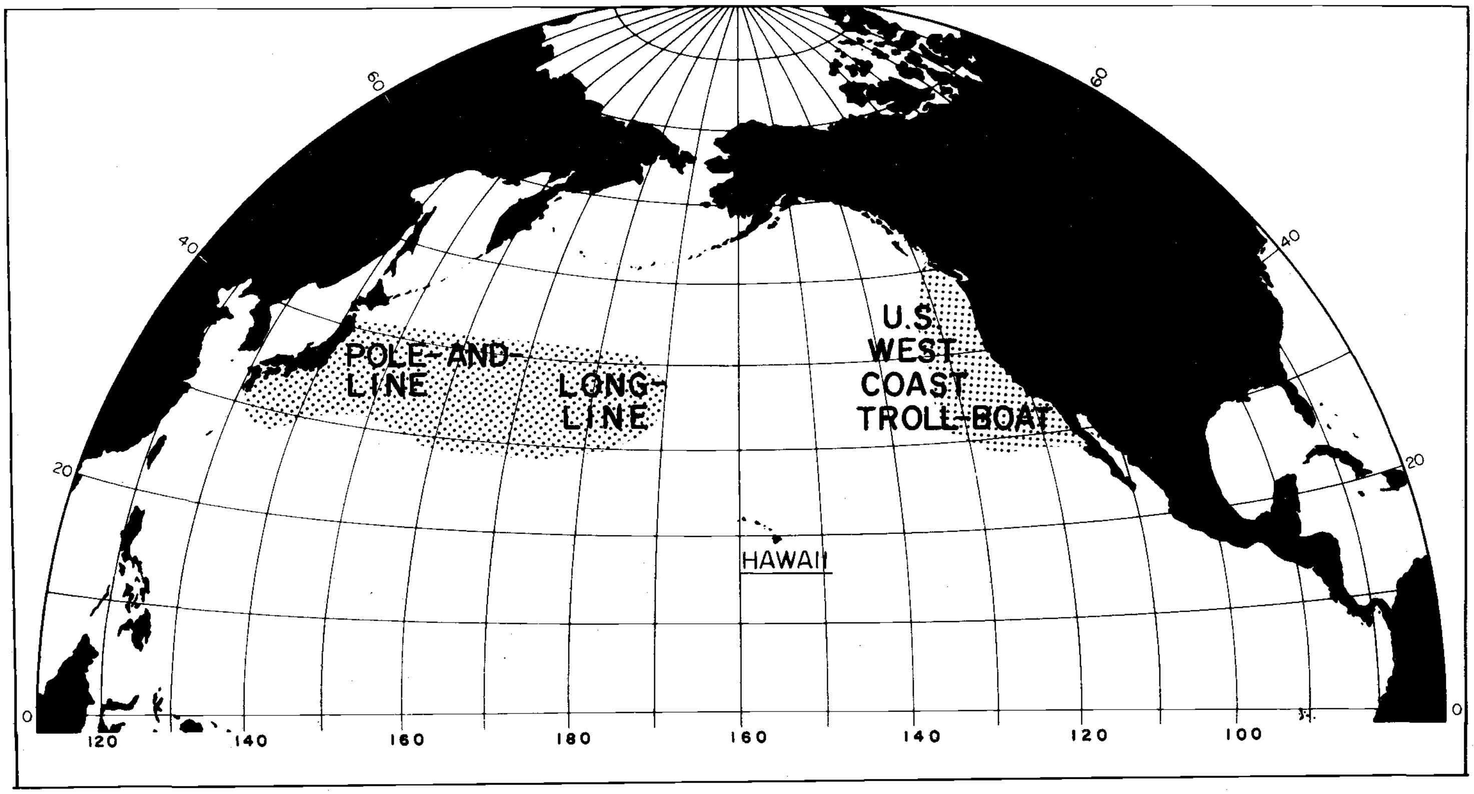

Figure 2. Approximate positions of the Japanese pole-and-line, Japanese longline, and U. S. west coast troll-boat fisheries for albacore.

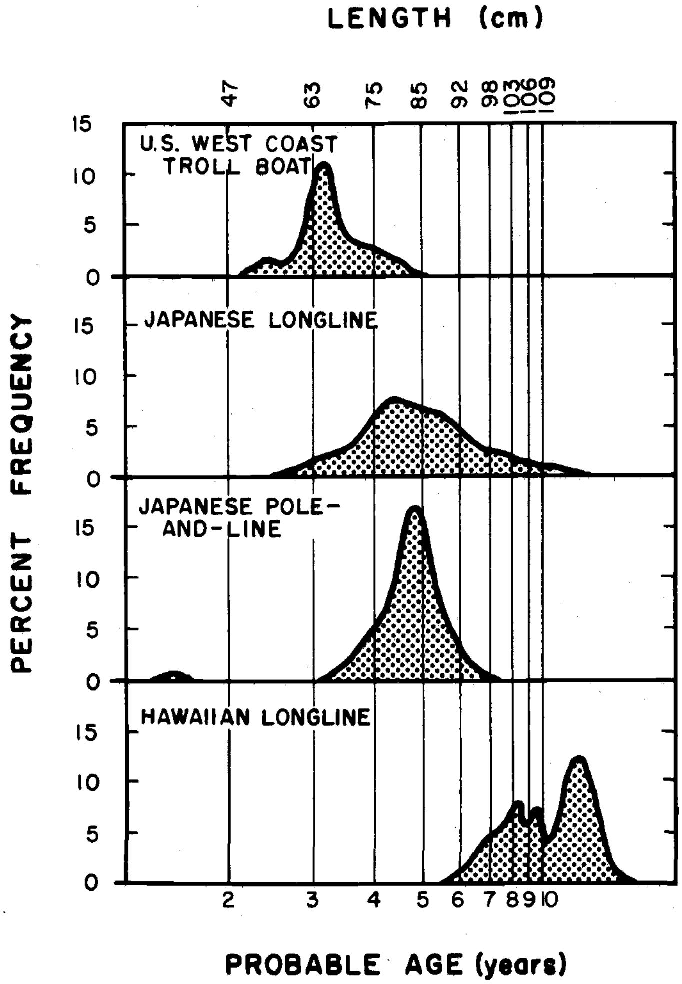

Figure 3. Age and length frequencies of albacore from the four North Pacific fisheries (after Uchida and Otsu, 1963).

Many boats, particularly those from Oregon and Washington, fish for other species (salmon, crab, shrimp) during part of the year (Roberts, 1972).

The Oregon and Washington albacore tuna fishery usually begins during July off the southern Oregon coast. It frequently represents Oregon's most valuable fishery. However, annual albacore landings fluctuate tremendously (Ayers and Meehan, 1963), ranging from a record 37.8 million pounds in 1968 (worth 7.2 million dollars to fishermen) to less than 0.5 million pounds in 1955.

In addition to annual fluctuations of albacore landings the average daily catches per boat change dramatically. Pearcy (1973) noted that 30 July 1970 catches of 800 to 1300 fish per boat day were followed on 31 July by average catches of only 50 fish. These fluctuations, both annually and seasonally, are obviously of great economic importance to the Oregon fishing industry.

Many studies have been conducted to relate fluctuations of Northeast Pacific albacore availability to environmental parameters, such as sea surface temperature (Alverson, 1961; Flittner, 1966; Johnson, 1962; Panshin, 1971), winds and coastal upwelling (Lane, 1965), surface salinity (Craig and Dean, 1968; Owen, 1968) and water transparency (Murphy, 1959). Other investigators (Iversen, 1962; Pearcy, 1973) have shown that the supply of forage organisms may be related to fluctuations in albacore availability. Blackburn

(1964) and Nakamura (1964) suggest that environmental parameters may delineate the albacore's habitat but the food supply determines the concentration and perhaps availability of fish within the habitat.

In spite of the relationships observed between albacore availability and environmental parameters and forage organisms, exceptions to these relationships occur frequently, especially in small scales of time and space (Blackburn, 1964; Hynd, 1969). Consequently there are no reliable methods of predicting when or where albacore will be available.

A very important aspect of the albacore fishery which has not been explored is the relationship between fishing activities and the availability of albacore. Fishermen are aware of daily fluctuations in local availability. If fishermen respond to changes in local availability, the rapid fluctuations of albacore availability should stimulate the development of efficient fishing strategies, much like generalized predator strategies in a patchy prey environment (Mac Arthur and Pianka, 1966; Schoener, 1971). Little is known about the responses and strategies of albacore fishermen, although search time undoubtedly represents a major portion of each fishing trip. Search time in fisheries for other than tuna species has been reported to consume over half the entire trip time (Norton, 1969; Uchida and Sumida, 1971). An optimum fishing strategy should minimize search and travel time while maximizing actual fishing time (Beverton and Holt, 1957).

Fishing activities in this study refer to responses exhibited by fishermen as they attempt to maximize their catches. Fishing activities may be considered as tactics--maximizing the catch within a particular area--or strategy--making the best choice of fishing area according to travel time, price of fish, weather, etc. (Gulland, 1969). In the west coast albacore fishery, decisions to fish the northern area off Oregon and Washington or to fish the southern area off California are considered to be strategy, whereas day-to-day decisions on where to fish within a local area are tactics. This study deals mainly with tactics--the daily fishing activities within a particular area of the fishery.

Rothschild (1970) has stated that "there is virtually no information available on the tactical aspects" of fishing, in regard to allocation of the fleet to the fishery and day-to-day guidance of vessel activities. Knowledge of tactical responses exhibited by, and available to, albacore vessels is important in effective management of the fishery.

The 1968, 1969 and 1970 albacore seasons provided an excellent series of data for examining relationships between albacore availability and fishing activities. Landings in all three years were above average. The total catch of 1968 was the highest on record, while the catch of 1969 was the second highest. Both 1968 and 1969 seasons continued into September. The 1970 season was characterized by extremely high daily catches during a very short season, beginning about 15 July and effectively ending on 4 August.

This study has two objectives. One is to examine the changes of tactical responses of albacore fishermen in relation to changes of apparent albacore abundance. Of special interest is the effect of an albacore advisory program which broadcasted information concerning sea surface temperature, fleet location and an indication of catch rates to the boats during 1969 and 1970. The second objective is to compare the characteristics and movements of the most and least successful fishermen in each year. Together the results may provide insight to improve present albacore fishing tactics for individual boats and the albacore fleet as a unit. Figure 4, a flow chart of the thesis organization, indicates the sequence of each major subject and the relationships of the subjects.

The study is limited to troll- or jig-boat fishermen who reported their daily catches and locations either in logbooks or to interviewers at dockside. Only those catch locations between 42° and 49° north latitude are included. Two responses of the fleet (an assemblage of fishing boats within an area of arbitrarily chosen size) were considered amenable to measurement with these data. The first response was the total effort applied within a particular fishing area. The second response was the degree of aggregation indicated by the mean distance separating a single boat from all other boats in the

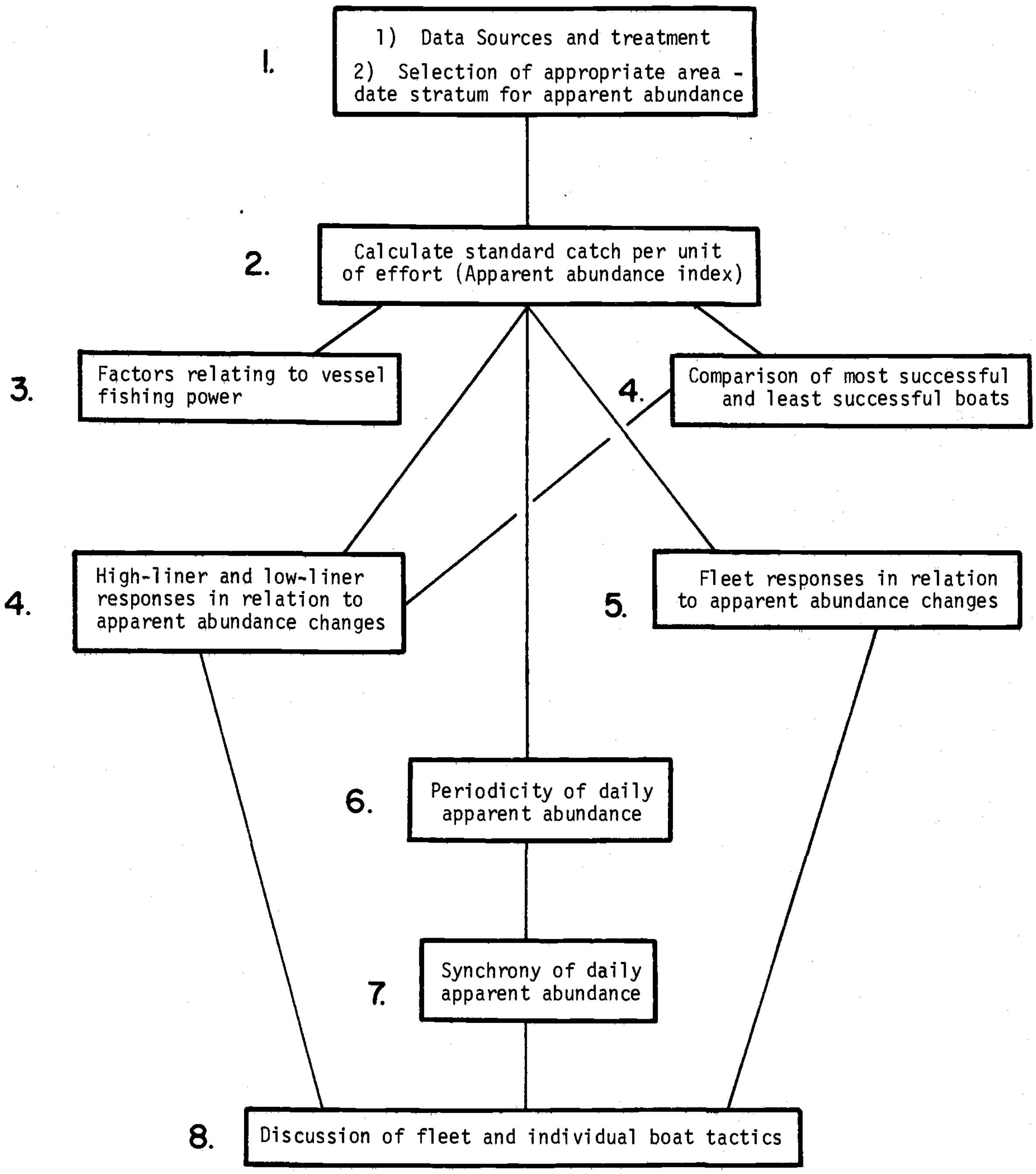

Figure 4. Outline of the thesis organization. Numbers to the left of the boxes indicate the order in which the subjects are discussed.

fishing area. No attempt was made to evaluate the effect of weather on the fishing activity, although it may have been of importance at times.

METHODS

Sources and Treatment of Data

Information on daily fish catch, location of the catch, boat length and number of lines (1970 only) was collected from three sources for the 1968, 1969 and 1970 albacore seasons; from log-books distributed by 1) Oregon State University (1969 and 1970) and 2) California Department of Fish and Game to fishermen who volunteered to submit daily information, and 3) from interviews obtained by personnel of the Oregon Fish Commission at dockside during unloading of the albacore. Careful screening avoided duplication of logbook records since vessels often submitted records to more than one source.

The number of reporting boats varied considerably between years. In 1968, 205 boats reported their daily catch and location. In 1969 and 1970, 77 boats and 113 boats, respectively, reported. The total number of boats fishing during the three years is unknown but is estimated to have been between 750 (Panshin, 1971) and 1,000.

Data from the logbooks and interview sheets were punched on computer cards. Each card contained three pieces of information: the boat number, an area-date code (signifying the 1° latitude by 1° longitude rectangle and the calendar day) and the catch of the day. There were approximately 3300 observations in 1968, 1500 in 1969 and 1000 in 1970.

A particular boat was chosen to represent the standard unit of effort. Criteria for the standard boat choice included the following: 1) it fished during all three seasons; 2) it fished in area-date strata concurrently with a majority of the fleet; 3) it fished a majority of each season; 4) it fished consistently to provide a standard, non-varying reference for the other boats.

Fishing powers[1] of all boats in the fleet were initially determined relative to the standard boat. This was accomplished using a computer program called FPOW (Berude and Abramson, 1971). A description of FPOW is given in Appendix I. The program's storage capacity was limited to 2000 catch observations from a combined total of not more than 200 distinct boats and area-data strata. Each year's data were broken up into segments short enough to satisfy this limitation. Ten segments were required in 1968, five in 1969 and three in 1970. Each segment was run independently and provided estimates of each boat's relative fishing power during the time segment.

Considerable within-season variation occurred in the average fishing power of the fleet (Table 1), suggesting that the standard boat fished inconsistently relative to the fleet. An examination of the

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[1] Fishing power is defined (Beverton and Holt, 1957; p. 172) as the ratio of the catch per unit of fishing time of a particular vessel to that of another vessel designated as the standard. It is assumed that both boats must have fished on the same density of fish during the same time interval and within the same fishing area when the ratio is determined.

Table 1. Data segments for the 1968, 1969 and 1970 seasons.

	Segment	Dates	No. of obs.	No. of boats	No. of area-dates	Average fishing power
1968	1	7-06 to 7-16	242	60	47	0.69
	2	7-17 to 7-21	320	85	34	1.14
	3	7-21 to 7-31	410	74	76	0.99
	4	8-01 to 8-04	357	109	45	0.91
	5	8-05 to 8-07	290	108	33	0.70
	6	8-08 to 8-11	310	100	39	0.88
	7	8-12 to 8-18	420	88	78	0.82
	8	8-19 to 8-24	373	82	69	1.03
	9	8-25 to 8-30	235	72	46	0.53
	10	8-31 to 9-10	385	70	113	0.99
1969	1	7-15 to 7-25	305	51	59	3.70
	2	7-26 to 8-03	374	66	60	1.01
	3	8-04 to 8-11	326	65	59	1.15
	4	8-12 to 8-18	212	56	63	1.47
	5	8-18 to 9-11	296	40	111	1.16
1970	1	7-15 to 7-22	160	52	64	0.35
	2	7-22 to 7-28	470	99	54	0.91
	3	7-28 to 9-02	262	65	86	0.67

logbooks showed that the standard boat occasionally experienced periods of very low catches (10 to 15 fish per day) while the majority of the fleet in the immediate area was catching many fish (100 to 200 per boat). This was particularly obvious during segment 1 of the 1969 season.

As a result of the standard boat's inconsistent fishing, values of standardized catch per boat day were also inconsistent between data segments. For example, if an average boat caught 100 fish on 25 July and 26 July 1969, values of standardized catch per boat day $\left(\frac{100 \text{ fish}}{\text{ave. fishing power}}\right)$ would be 29 and 99, respectively (from Table 1). Therefore a serial examination of apparent abundance could not be done without normalizing fishing power estimates of each boat in each data segment. Normalization of fishing power estimates provided a standard, non-varying unit of effort throughout the season. The average fishing power of all boats fishing during a given segment was chosen as the new standard unit of effort. This required the assumption that the fleet fished consistently throughout each season.

All boats' fishing power estimates in each time segment were normalized by subtracting the appropriate segment's average fishing power and adding unity. (By definition the standard unit of effort is 1.0). This forced the condition that each boat's fishing power estimate was now relative to the average fishing power of all boats fishing during the data segment.

Daily standardized catch per boat within each area-date stratum was determined by summing the fish catches and dividing by the summation of fishing power in that area-date stratum. The standardized catch per boat day is an index of apparent abundance, the latter being a function of the accessibility of the albacore to the boats and the vulnerability of the fish to the lures (Marr, 1951) and the true abundance of albacore.

The ten most successful and ten least successful boats (high-liners and low-liners, respectively) of each season were selected according to their average fishing power estimates throughout the entire season. High-liners and low-liners were selected who fished for at least 15 days in 1968 and 1969 or 8 days in 1970. Thus boats that fished exceptionally well or poorly for only a few days were not considered.

A New Area-Date Stratum of Apparent Abundance

Small-scale time and space information on catches and boat positions allowed a departure from the traditional time-area stratum of one month and 1° latitude by 1° longitude rectangle (Ayers and Meehan, 1963; Clemens and Craig, 1965). A mobile stratum was conceived to allow comparisons of apparent abundance and effort regardless of where the fleet moved, and without the boundary problems of fixed geodetic bounds.

The new stratum was a circular area whose center was the daily medial location of the fleet. This medial point was determined such that the fleet was equally divided in the north-south and east-west planes. Criteria for the radius of the circular area were that 1) the resulting area should be as small as possible to include a homogeneous distribution of fish, but 2) it should be large enough to accommodate a sufficient number of the boats fishing on a given day so that catch and effort could be reliably estimated, and 3) it should be large enough to give reasonable assurance that boats within the area remained in the area the entire day. Because of the lack of knowledge of small-scale albacore distributions, there was little basis for satisfying the first criterion.

Consecutively larger concentric circles were drawn around the medial point while noting the ratio of boats within each circle to the number of boats in the entire fleet. (Danils (1952) has presented theoretical considerations of sample point distributions within such circles.) During much of each season over half the boats could be found within 25 miles of the fleet's center. Exceptions occurred in each season when the fleet was highly dispersed or split into two distinct groups. Two obvious centers of boats occurred on 2, 3 and 4 August in 1968 and also 1, 2 and 8 August during 1969. During these days the northernmost center was chosen to represent the fleet center because it always contained more boats.

The third criterion suggested a radius of at least 31 miles to insure that vessels remain within the area the entire day. This figure was determined on the basis of daily distance traveled by albacore boats. (This will be reported later in the study). A circle with a radius of 31 miles was therefore used as the area size in this study. Figure 5 shows the percentage of boats that provided catch data within 31 miles of the fleet center each day during the 1968, 1969 and 1970 seasons. Only the time periods within the vertical lines will be considered for this study. Few boats reported for days outside these periods or the fleet was small and highly dispersed. The average daily percentage of those boats reporting within 31 miles of the fleet center was 46%, 57% and 65% for the 1968, 1969 and 1970 seasons, respectively. The difference between the 1968 average and the 1969 and 1970 averages was highly significant (t-test, $P < 0.01$), indicating that the 1968 fleet was more dispersed in general than the 1969 and 1970 fleets. (This was not a result of a greater number of boats reporting in 1968, because the number of boats reporting _per day_ was often greater in 1969 and 1970 than in 1968.) There was a tendency in both 1968 and 1969 for the fleet to become more dispersed as the season progressed.

Aggregation of the Boats

The index of aggregation used in this study was the mean separation distance of boats within a specified area. The index was determined by summing path distances between all boats in the area and dividing this sum by the number of path distances. This calculation required converting LORAN coordinates (given as the 2100 hours (PDT) boat positions) to latitude-longitude coordinates. Accuracy of the iterative technique used to compute the coordinates has been estimated at 10 meters (Thomas, 1965), although the absolute position accuracy varied considerably due to the precision of the Loran operator and the distance from the Loran transmitters. Boat positions reported at 2100 hours within 200 miles of the coast are estimated to be within three miles of the absolute positions.

Hunter (1966) stated that mean separation distance is preferred for measuring relative changes in spacing, but for comparison of samples containing different numbers of individuals, mean distance to nearest neighbor (Clark and Evans, 1954) should be used. I did not use mean distance to nearest neighbor because many fishermen fish together with one or more companion boats. Mean distance to nearest neighbor would thus often represent the average distance separating the same pairs of boats and would give little if any information on actual compactness of the fleet within a specified area.

RESULTS

Fishing Power versus Boat Length and Number of Lines

Sixty-six area-date strata (1° latitude by 1° longitude rectangles and one day periods) were selected to examine the relationship between the fishing power of a boat and its length and number of lines trolled. All strata had at least 20 boats reporting within them. The new mobile stratum was not used because the intent was to partition the fishery area into a number of equal quadrats; the size and location of the quadrat being of no consequence. Daily boat positions had been assigned to 1° latitude by 1° longitude rectangles by FPOW, so this stratum was used for convenience.

Fishing power estimates were then regressed on boat length and number of lines. (The data on number of lines was available only for the 1970 season.) In none of the strata, in any season, was a significant regression (F-test, $P < 0.05$) found. This indicated that no significant relationship existed between a vessel's fishing power and its length or reported number of lines trolled within a given 1° by 1° rectangle during any given day.

Because of the scatter of data for small-scale time and area strata the above conclusion did not rule out the possibility of a significant relationship between fishing power and boat length or number of lines. Therefore, a larger stratum was chosen which included all data for each year. Fishing power estimates were again regressed on boat length (1968, 1969, 1970) and number of lines (1970). The results are shown in Table 2.

Boat length was significantly related ($P < 0.05$) to fishing power of albacore boats in a time-area stratum of one season and the entire fishery, particularly in 1968. The significance of boat length as it related to fishing power was considerably less in 1969 and 1970 than in 1968, although the 1968 and 1969 regression equations were nearly identical.

Fox (1973) reported that fishing power was related to boat length in a curvilinear manner for the period of 1960 to 1970, with boats of the length class 40 to 49 feet exhibiting the highest estimates of fishing power. There was no clear indication of a curvilinear relationship in 1968, 1969 or 1970, although several very long boats (> 75 feet) generally did not have as large fishing powers as the linear relationship predicted. The sample of boats used by Fox was considerably larger (ten years) and therefore had many more observations of longer boats.

Large boats, moreover, make up a minor portion of the albacore fleet. The average length (and standard deviation) from the sample of boats in 1968, 1969 and 1970 was 49 feet (9), 49 feet (7) and 50 feet (9), respectively. Some fishermen feel that larger boats are more successful because of their increased seaworthiness and

Table 2. Regression equations and analysis of variance data for boat length (in feet) and number of lines (1970) versus boat fishing power.

1968

Fishing power = 0. 238 + 0. 014 (Boat length)
FP (40 ft. boat) = 0. 798
FP (60 ft. boat) = 1. 078

ANOVA

Source	D. F.	Sum of squares	Mean square	F value
Total	810	185. 459	0. 229	
Regression	1	13. 835	13. 835	
Residual	809	171. 624	0. 212	65. 23**

1969

Fishing power = 0. 263 + 0. 015 (Boat length)
FP (40 ft. boat) = 0. 863
FP (60 ft. boat) = 1. 163

Source	D. F.	Sum of squares	Mean square	F value
Total	271	165. 265	0. 610	
Regression	1	3. 214	3. 214	
Residual	270	162. 051	0. 600	5. 35*

1970

Fishing power = 0. 636 + 0. 007 (Boat length)
FP (40 ft. boat) = 0. 916
FP (60 ft. boat) = 1. 056

Source	D. F.	Sum of squares	Mean square	F value
Total	200	24. 777	0. 129	
Regression	1	0. 698	0. 698	
Residual	199	24. 079	0. 121	5. 76*

Fishing power = 0. 816 + 0. 018 (Number of lines)
FP (8 lines) = 0. 960
FP (12 lines) = 1. 032

Source	D. F.	Sum of squares	Mean square	F value
Total	200	24. 777	0. 139	
Regression	1	0. 110	0. 110	
Residual	199	24. 667	0. 124	0. 89 n. s.

**indicates highly significant regression ($P > 0.99$)
*indicates significant regression ($P > 0.95$)
n. s. indicates a non-significant regression ($P < 0.95$).

endurance, resulting in fewer trips to port and permitting more time on the fishing grounds. Fishermen also feel that larger boats fish the lures better in rough weather. Where smaller boats tend to jerk the lures as each wave hits the boat, larger boats push smoothly through the waves without jerking the lures.

The reported number of lines trolled in 1970 was not significantly related to fishing power. The number of lines reported varied from 6 to 14, with 10 being the mean and mode. The standard deviation was 1.0. The number of trolling lines reported on log sheets bears little resemblance to the number of lines used during varying periods of fishing activity, according to fishermen. When they are scouting or when fishing is extremely slow, all lines are trolled. When activity increases, only two or possibly three lines are pulled by each man. During periods of intense catching, each man may be kept busy with one line. When the catch rate increases, the longest lines are pulled on board first and only the short lines are fished. One fisherman stated that the number of lines used was determined primarily by the ability of the crew in avoiding tangling of lines.

I agree with Abramson's (1963) suggestion that the fishing power of individual albacore boats is related to intrinsic factors of the captain and crew, in addition to the boat's physical parameters.

A Comparison of High-liners and Low-liners

Some comparisons of high and low-liner boats are given in Table 3. Both groups fished approximately the same number of days and in the same time period each season. The difference in boat length was highly significant in all years, particularly in 1968 when high-liner boats averaged 16 feet longer than low-liner boats. In 1969 and 1970 only five feet separated the average length of high-liner and low-liner boat lengths. Seven of the 1968 high-liner boats were over 60 feet, whereas none of the 1969 and only one of the 1970 high-liner boats was over 60 feet. Essentially the same proportions of 60 feet and longer boats made up the fleet samples in each season. Low-liner boat lengths were consistently low, between 46 and 50 feet.

Both groups showed characteristic average distances from the fleet center, as shown in Table 3. The 1968 low-liners were removed from the main body of the fleet, generally located far to the south and inshore of the fleet. High-liners tended to be slightly to the south in 1968 but offshore of the main fleet center. In 1969 and 1970 both groups were located closer to the fleet center, although the low-liners were still three to four times farther away from the fleet center than were high-liners. Low-liners were consistently south of the center in all three years.

A detailed description of the location of high-liners and low-liners is presented in Figures 6, 7 and 8. The plots show where

Table 3. Comparison of high-liners with low-liners.

Average boat length (feet)		Average distance to fleet center (miles)		Average daily travel (miles)		Average relative fishing power	
High-	Low-	High-	Low-	High-	Low-	High-	Low-
			1968				
63	47**	30 SW	104 SSE	21	31**	1.61	0.65
			1969				
51	46**	5 W	22 SW	26	29 n.s.	1.57	0.46
			1970				
53	48**	8 N	25 S	27	28 n.s.	1.24	0.85

** indicates a highly significant t-test difference ($P > 0.99$);

* indicates a significant difference ($P > 0.95$)

n.s. indicates a non-significant difference ($P > 0.95$).

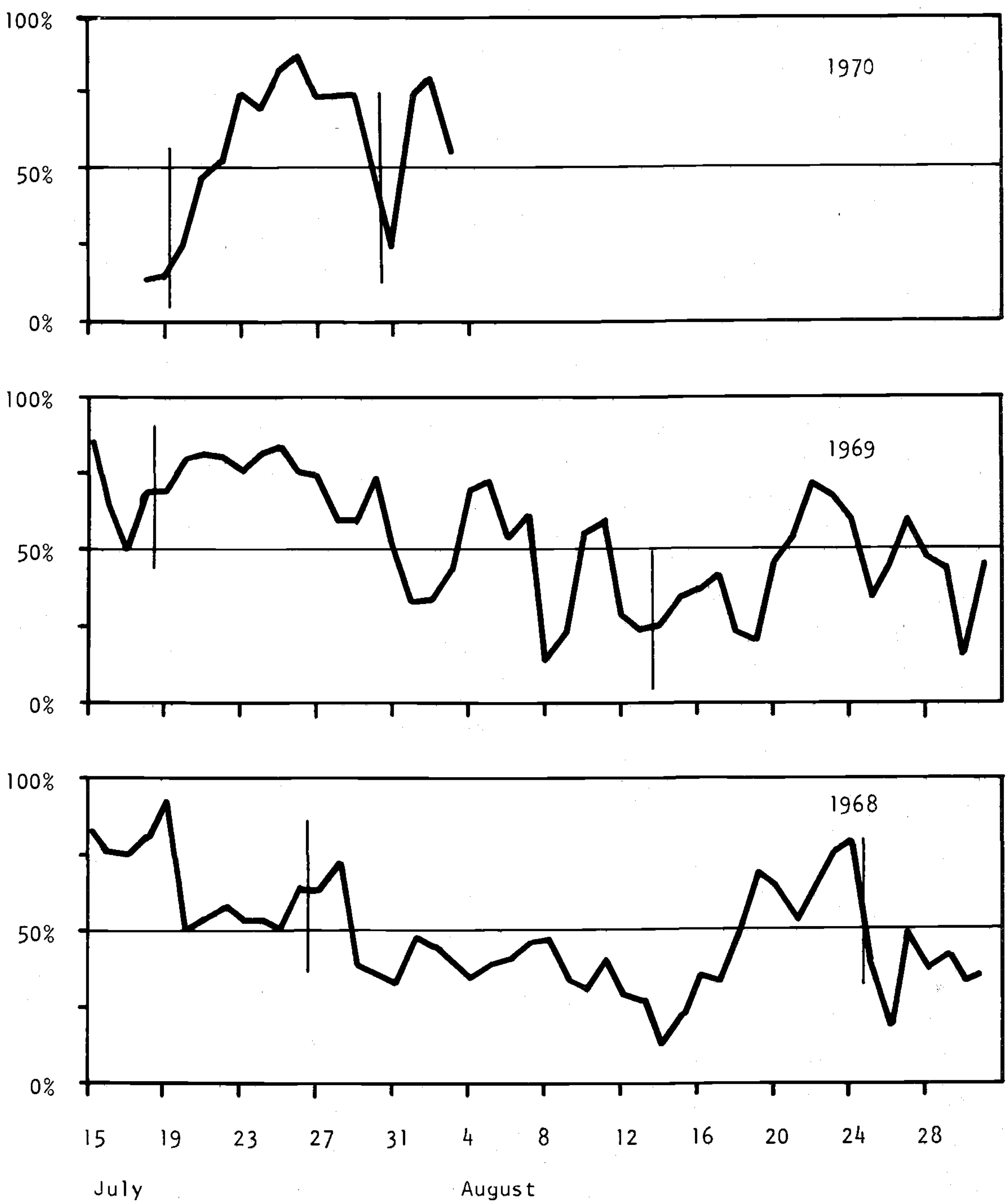

Figure 5. Daily percentage of boats within 31 miles of the fleet center; 1968, 1969 and 1970. Vertical lines on plots indicate the periods considered in detail in this study.

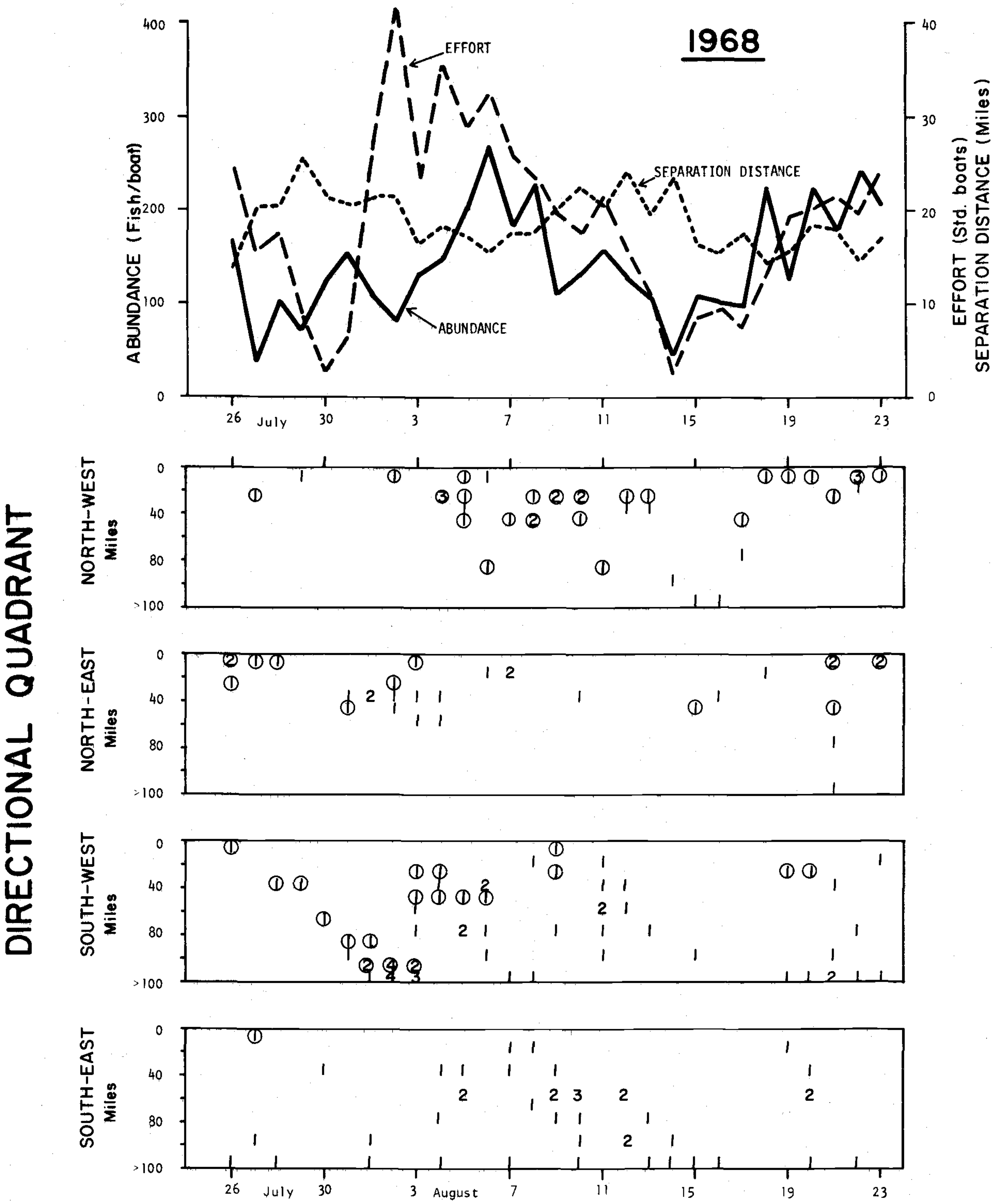

Figure 6. Locations of 1968 high-liners and low-liners relative to the medial center of the fleet. The top graph (a) indicates the corresponding levels of apparent abundance, effort and separation distance within 31 miles of the fleet center. The lower four figures show the distance of high-liners (circled numbers) and low-liners (non-circled numbers) from the medial fleet center.

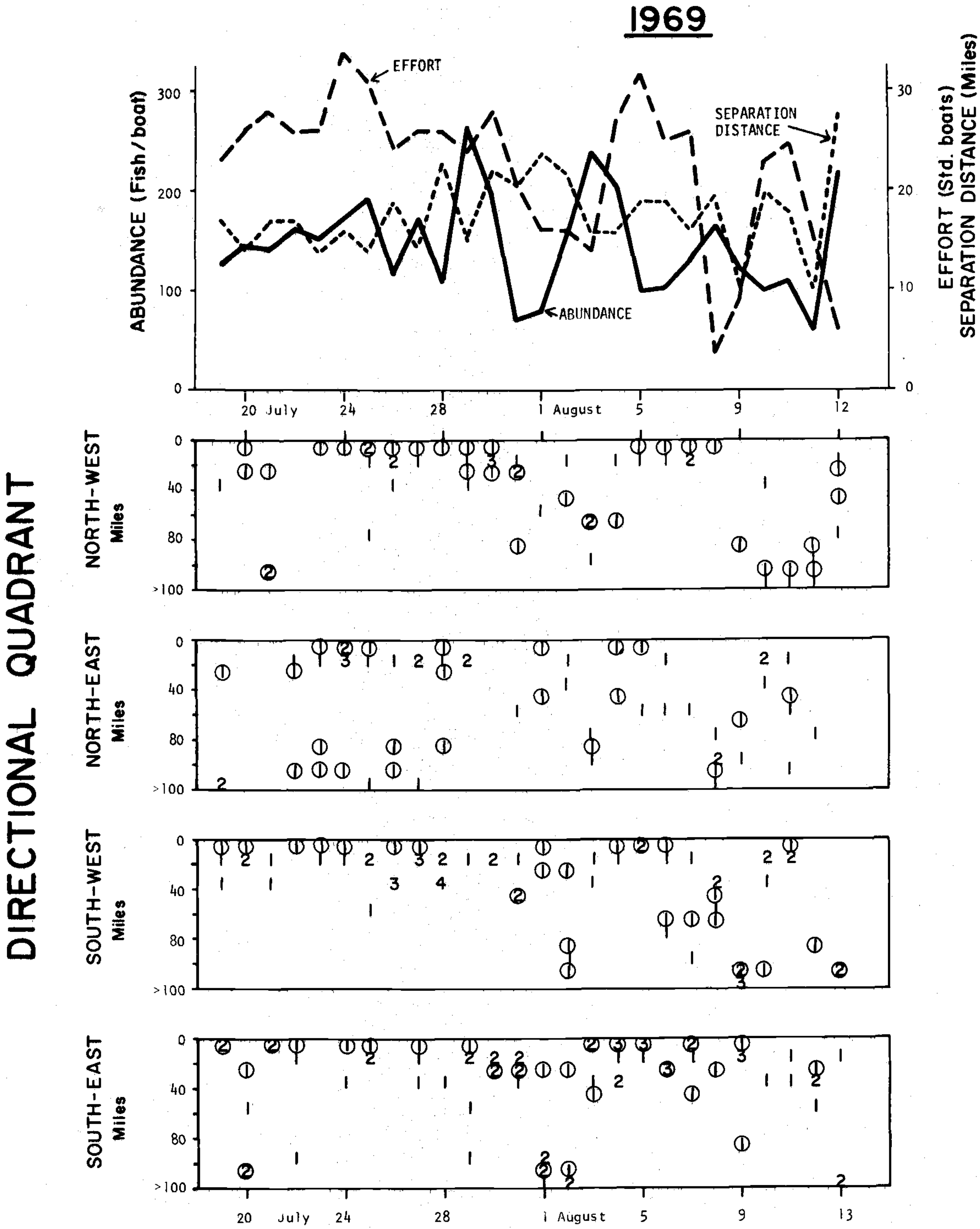

Figure 7. Locations of 1969 high-liners and low-liners relative to the medial center of the fleet. The top graph (a) indicates the corresponding levels of apparent abundance, effort and separation distance within 31 miles of the fleet center. The lower four figures show the distance of high-liners (circled numbers) and low-liners (non-circled numbers) from the medial fleet center.

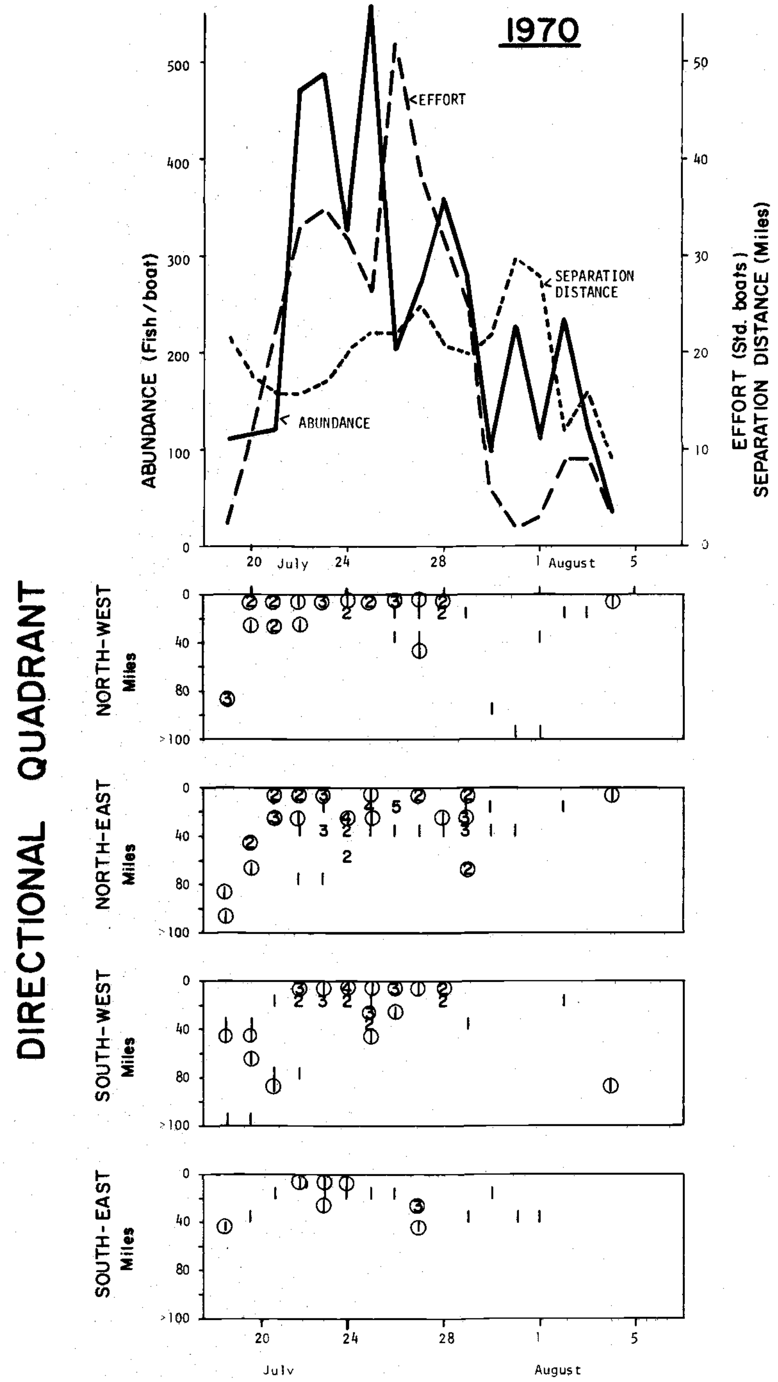

Figure 8. Locations of 1970 high-liners and low-liners relative to the medial center of the fleet. The top graph (a) indicates the corresponding levels of apparent abundance, effort and separation distance within 31 miles of the fleet center. The lower four figures show the distance of high-liners (circled numbers) and low-liners (non-circled numbers) from the medial fleet center.

these two groups fished with respect to the fleet center during periods of variable levels of abundance, effort and separation distance (shown at the top of the figures).

A very obvious separation of high- and low-liners occurred in 1968 (Figure 6). High-liners fished almost exclusively to the north-west and southwest of the fleet center. When abundance was low and effort high (26 July - 3 August) high-liners moved far from the fleet center, as seen in the south-west quadrant. During 5 and 6 August, when high catches coincided with high levels of effort, high-liners were found close to the fleet center, but not as close as during periods of low effort. Low-liners fished mainly to the south and away from the fleet center during all levels of abundance. When abundance was high (5-8 August) low-liners in the south-east quadrant moved closer to the fleet center. Later as catches declined, the low-liners moved away from the center (southeast quadrant, 9-15 August).

There was no obvious separation of high- and low-liners in 1969 (Figure 6) comparable to 1968. High-liners fished in all quadrants, as did low-liners. Some high-liners fished away from the fleet center during periods of low abundance (31 July-2 August; 5-12 August), particularly in the northwest and southwest quadrants when effort was high (10-12 August). Low-liners again fished more in the southern quadrants than did high-liners but not exclusively so and not as far as in 1968. In fact, most low-liners were located near the fleet center until all catches began decreasing after 5 August. Then, some low-liners moved away from the fleet (southwest, northeast; 10-11 August) but the majority remained near the fleet center.

The short 1970 season provided little information on the responses of high-liners and low-liners (Figure 7). As the season began (19-21 July) high-liners were fishing at some distance from the fleet center. During the period of very high catches (22-29 July) both high-liners and low-liners fished within 40 miles of the fleet center. No boat reported a location farther than 80 miles of the center during this time. There was no indication that either group dispersed in response to the high levels of effort and aggregation of boats which occurred. On 22 July when separation distance was lowest and on 26 July when effort was highest, most high-liners were fishing within 20 miles of the fleet center.

Most high-liners did not fish Oregon waters after 30 July, the day catches dropped. The low-liners that stayed were northwest of the fleet center. Catches never returned to their original high levels and on 4 August the season was essentially over for the troll boats.

Low-liners often fished in the trailing margin of the fleet during all years since the net seasonal movement of the fleet was to the north. High-liners were more centrally located in the fleet and slightly to the offshore or leading margin (Table 3). Some albacore fishermen believe that large numbers of small fish are located in the offshore fishing area. High-liners are able to exploit these fish to a greater degree because of their greater endurance and sea-worthiness. To test this hypothesis, the average weight of each fish per trip reported by high-liners during July and August was compared to the average fish weight per trip for low-liners. The results are given below.

Table 4. Average weight (pounds) of individual fish per trip taken by high-liners and low-liners during July and August.

1968		1969		1970	
High-	Low-	High-	Low-	High-	Low-
12.5	13.6	13.3	14.0	13.5	14.9
*(P <0.025)		**(P <0.005)		*(P <0.025)	

These results show that high-liners catch significantly smaller fish than low-liners. The results also support the fishermen's belief that smaller fish are found along the offshore margins of the fishery where high-liners often fish, while larger fish are found along the inshore margins of the fishery where low-liners expend more effort.

The difference between average daily net travel of high- and low-liners changed significantly within the three years (Table 3). High-liners in 1968 moved 10 miles less per day than did low-liners. In 1969 and 1970 there was no statistical difference between the average distance traveled by the two groups. Travel distances in Table 3 can be compared to the daily travel of the fleet center

(Figure 9). The fleet center moved an average of 14 miles per day in 1968, 29 miles per day in 1969, and 29 miles per day in 1970. High-liners moved in a much closer relationship with the fleet in 1968 than did low-liners. Low-liners in 1968 traveled twice as far as the general fleet, yet lagged behind the fleet's northerly movement. This was much less apparent in 1969 and 1970.

A comparison of average relative fishing powers showed that high-liners of 1968 and 1969 were about three times more successful than low-liners in catching fish (Table 3). Low-liner fishing power decreased in 1969, even though the differences between low-liner and high-liner boat lengths and daily distances traveled decreased. In 1970 low-liner fishing power increased and high-liner's decreased. This was probably due to the extremely short season on highly vulnerable fish which did not provide high-liners the opportunity to fully develop their tactics and strategies.

Two periods occurred when high-liner catches could be compared to low-liner catches within essentially the same area. Three high-liners and three low-liners fished within 12 miles of each other on 2 August 1968. The following day two of the high-liners and two of the low-liners remained in the same general area and again within 12 miles of one another. The high-liners caught nearly twice as many fish as the low-liners (Table 5). A similar situation occurred on 23 July 1970, when five high-liners and two low-liners fished all

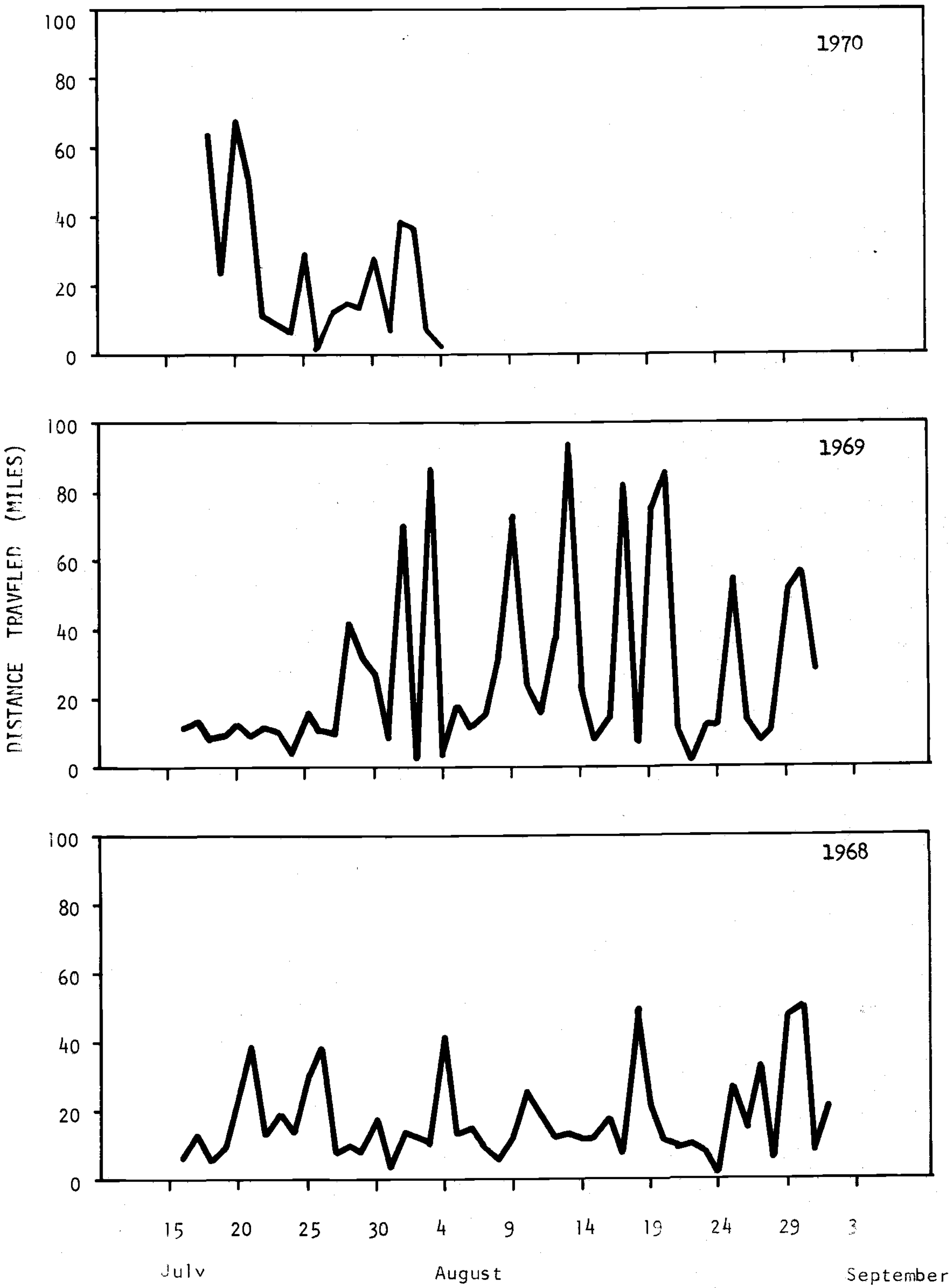

Figure 9. Net daily movement of fleet centers: 1968, 1969 and 1970.

Table 5. Catches of high- and low-liners on August 2 and 3, 1968, and July 23, 1970. Boat lengths are in parentheses.

August 2, 1968

Boat (High-)	Catch	Boat (Low-)	Catch
A (60)	515	D (45)	110
B (60)	180	E (48)	173
C (60)	300	F (54)	280
Ave =	330	Ave =	180

August 3, 1969

Boat (High-)	Catch	Boat (Low-)	Catch
A	305	D	75
B	140	E	67
Ave =	220	Ave =	71

July 23, 1970

Boat (High-)	Catch	Boat (Low-)	Catch
F (58)	654	K (54)	422
G (50)	548	L (50)	252
H (48)	563	Ave =	337
I (58)	325		
J (42)	370		
Ave =	492		

day within 10 miles of each other, according to their logbooks. The average catches of high-liners were again much larger than low-liners. These data suggest that high-liners catch more fish than low-liners, even when groups of fishermen are in the same area.

In hopes of gaining more insight as to what differences existed between high- and low-liners, a questionnaire was submitted to the ten high-liners and the ten low-liners of each year. Before the questionnaires were completed, fishermen in Newport and Astoria were interviewed to determine appropriate questions to include in the questionnaire. Questions were asked which tried to bring out possible bases for choosing one fishing tactic over another, and the aspects of a fisherman or boat which characterized the group of fishermen as being successful or not.

Of 58 questionnaires mailed, 21 fishermen responded. Eight questionnaires were returned by the post office for lack of forwarding addresses. Thirteen of the 21 respondents were high-liners; eight were low-liners. The few responding low-liners made generalizations between the two groups difficult, so all responses are presented in Appendix II. High-liner responses are listed on the left margin under each question; low-liner responses are on the right margin.

The majority of the high-liners had fished more years than low-liners (Question 1) and generally appraised their skill more highly in regard to fishing success (Question 16). Neither group felt they stayed with the fleet all season, and both felt they scouted for albacore away from the main fleet (Question 14).

The questions concerning advisory broadcasts (Questions 19-25) were intended to learn of the fishermen's evaluation of this service. Eight fishermen (including two low-liners) stated that only the less successful fishermen benefitted from the broadcasts (Question 24). None felt just the most successful fishermen benefitted. Less than one-third of the fishermen questioned said they would cooperate by reporting their locations and catches to an advisory group (Question 23). High-liners were much less cooperative than low-liners. The reasons for such a negative attitude were nearly always that the broadcasts would tend to concentrate boats in a smaller area or that the broadcasts were of no value.

Fishermen interviewed responded nearly identically as the questionnaire respondents. The value of the interviews was that each question could be answered in much greater detail and other insights presented themselves in the course of the interviews.

Spatial-temporal Responses of the Albacore Fleet

Fleet Movements

Each of the three seasons exhibited good catch rates within the same general areas off the Oregon coast. However there were significant differences between the daily changes of central fleet location and movement between the three years. Daily central fleet locations were plotted for each season as shown in Figures 10-12.

The 1968 fishery began about 90 miles off Cape Arago and progressed northward to about 100 miles off the Columbia River in the last days of July (Figure 10). For the rest of the season the fleet center was located within 70 miles of this location. During the period of interest (27 July-23 August) the fleet center movement averaged just over 14 miles per day (Figure 9).

The 1969 fishery began about 120 miles off Cape Arago and stayed within this area until 27 July, when an abrupt northern movement began (Figure 11). For the remainder of the season the fleet center oscillated between an area 100 miles west of Tillamook and an area 70 miles southwest of Vancouver Island. The average distance traveled by the fleet center from 19 July to 13 August was 29 miles per day, nearly double that of 1968.

Early fishing in 1970 occurred about 140 miles off Cape Arago until 20 July. By 21 July the fleet center had moved northward to an area 90 to 110 miles off the Columbia River (Figure 12). The fleet center remained essentially within this area for the remainder of the season. In spite of the highly localized fishery (Pearcy, 1973) average daily movement of the fleet center was 21 miles.

Each season was characterized by initial fishing off Cape Arago

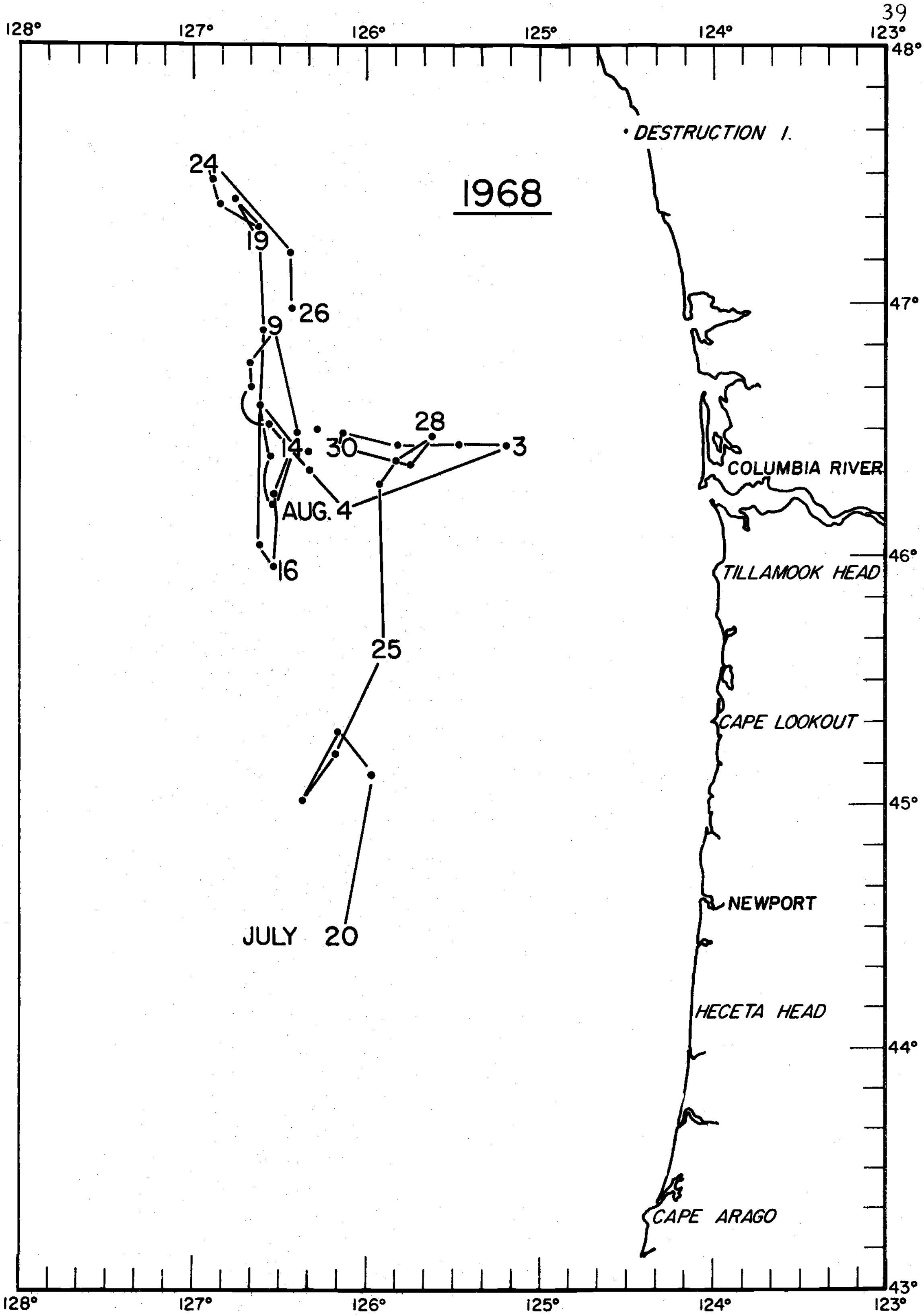

Figure 10. Medial geographic centers (every fifth day) of the 1970 fleet.

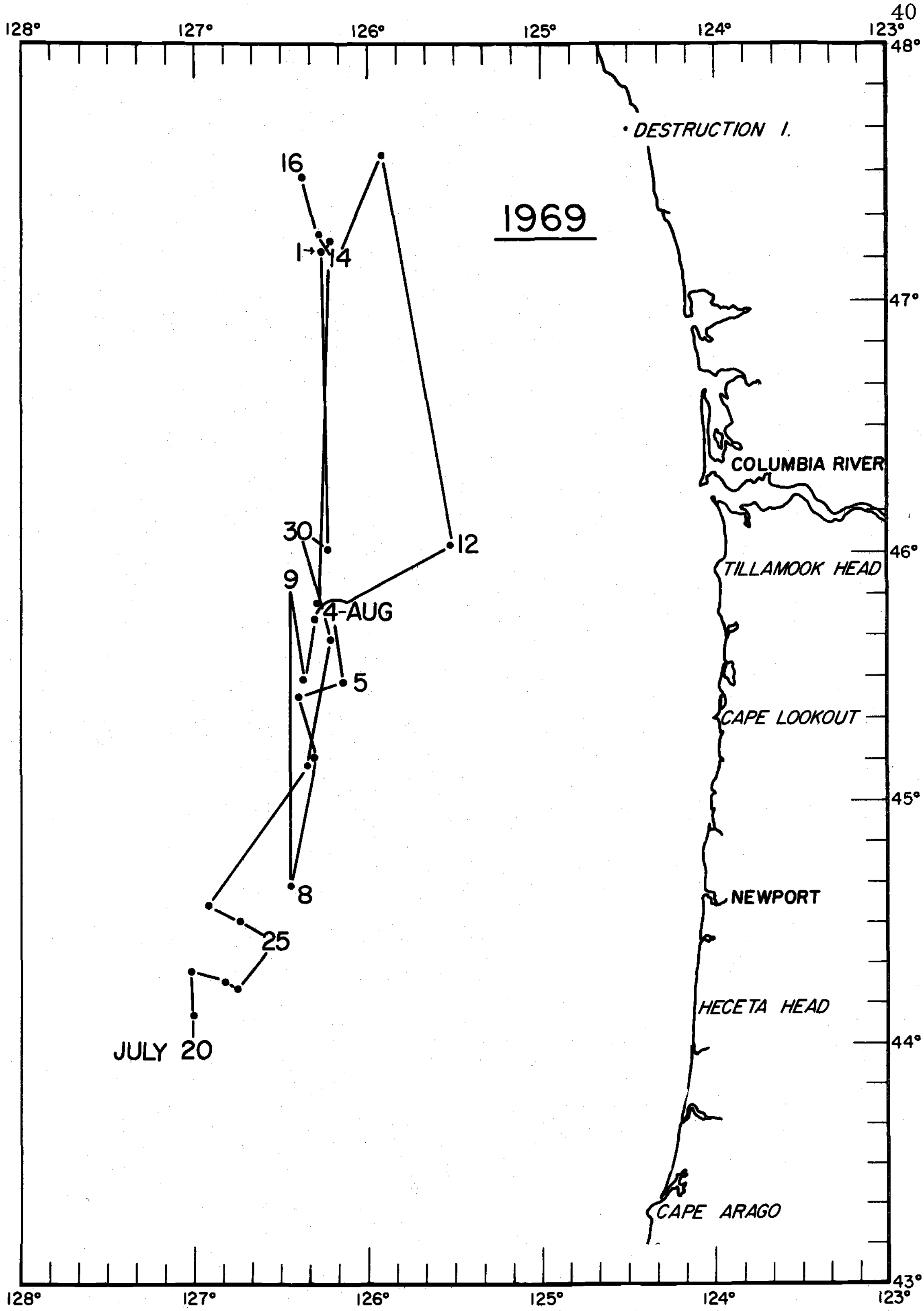

Figure 11. Medial geographic centers (every fifth day) of the 1969 fleet.

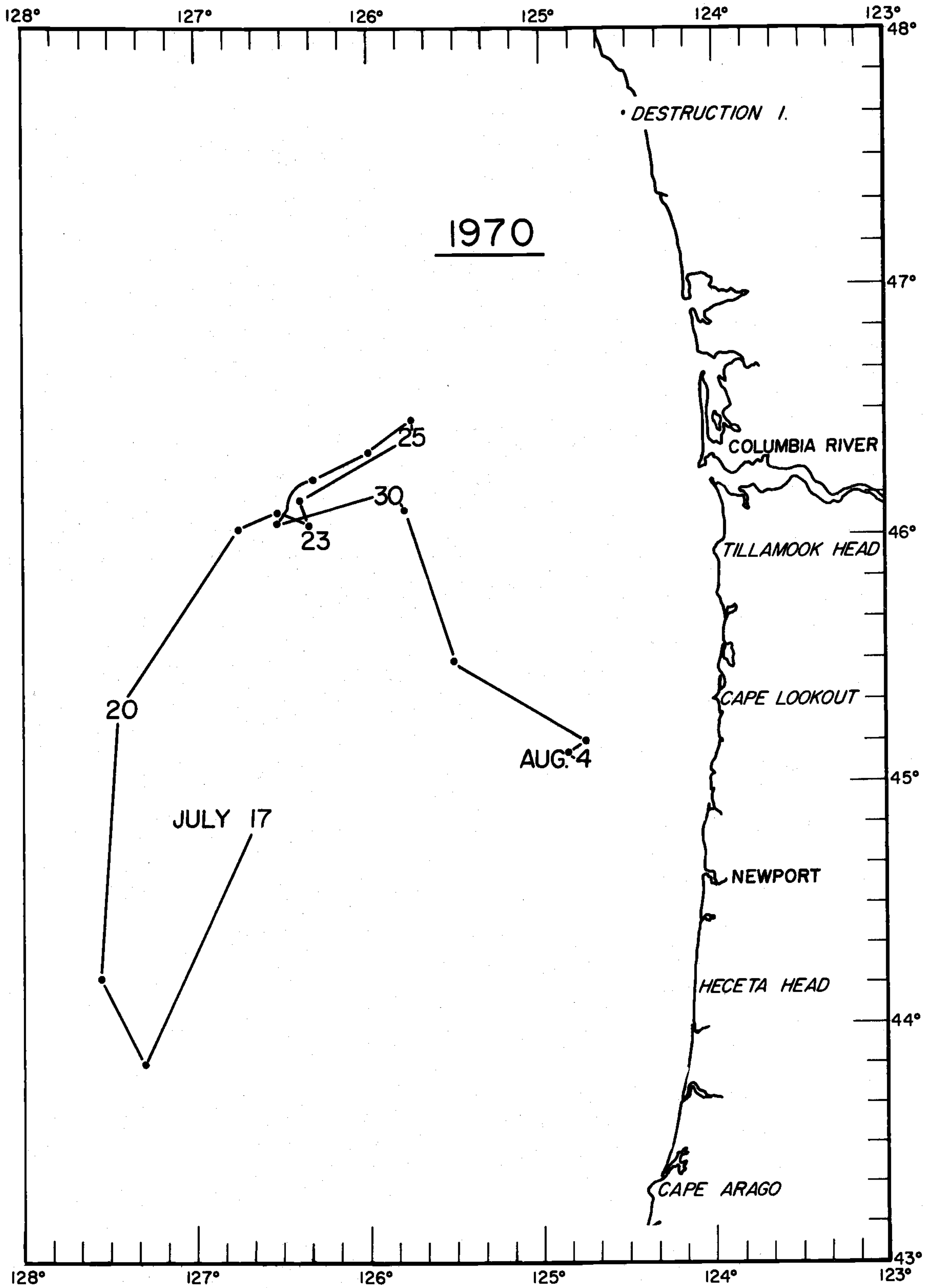

Figure 12. Medial geographic centers (every day) of the 1970 fleet.

for a short period of time, followed by a major portion of the season spent 100 to 110 miles west of the Columbia River. The fleet spent very little time in the area 110 to 150 miles off Newport during any season. Data from previous years indicate this is common pattern (Ayers and Meehan, 1963). The location of the fleet probably reflects areas of high apparent abundance.

The daily movement of the medial fleet center also differed considerably between years, as shown in Figure 9. Fleet movement was least in 1968 (14 miles per day) and much greater in 1969 and 1970 (29 miles per day). Therefore, in spite of the general similarities of the 1968, 1969 and 1970 albacore seasons, each provided different day to day situations for the albacore fishermen.

A major objective of this study was to examine the space and time scale of responses by albacore fishermen to variations in abundance. A period was selected during each season when effort was high and the fleet center was relatively stationary. These periods were: 26 July-23 August 1968; 10 July-14 August 1969; and 19 July-4 August 1970. Correlation coefficients were then calculated for effort and separation distance on day t versus abundance on days t, t-1, and t-2. This provided a means of studying the possibility that the boats were responding to a previous day's abundance. Time-lagged coefficients were computed for areas of increasing radius. The smallest area was about 100 square miles (6 mile radius).

Successive areas were increased in size by increments of 500 square miles, to a maximum area of 15,000 square miles or a radius of about 68 miles.

Correlations were made on cumulative values of effort, separation distance and abundance as the radius size was increased. Coefficients for smaller radii (6-11 miles) were more sensitive to changes in the three parameters because of the low number of boats. The majority of observations were within a 31 mile radius of the fleet center. Few observations were typically available at radii greater than about 45 miles. Daily values of apparent abundance, effort and mean boat separation distance within 31 miles of the fleet center were plotted for each season (Figures 6a, 7a, and 8a). These plots provide a comparison of this space and time scale to the scales of time lags and varying radii.

<u>1968</u>. Changes in effort and mean separation distance within 31 miles of the fleet center were often simultaneous with changes in daily albacore abundance (Figure 6a). Boats also tended to be more dispersed during periods when effort was low. Throughout the season effort and separation distance were, in general, inversely related. Prior to 6 August, effort and separation distance decreased when abundance was high, indicating the boats were searching for fish during periods of low catches.

From Figure 13a, the correlation coefficient between effort

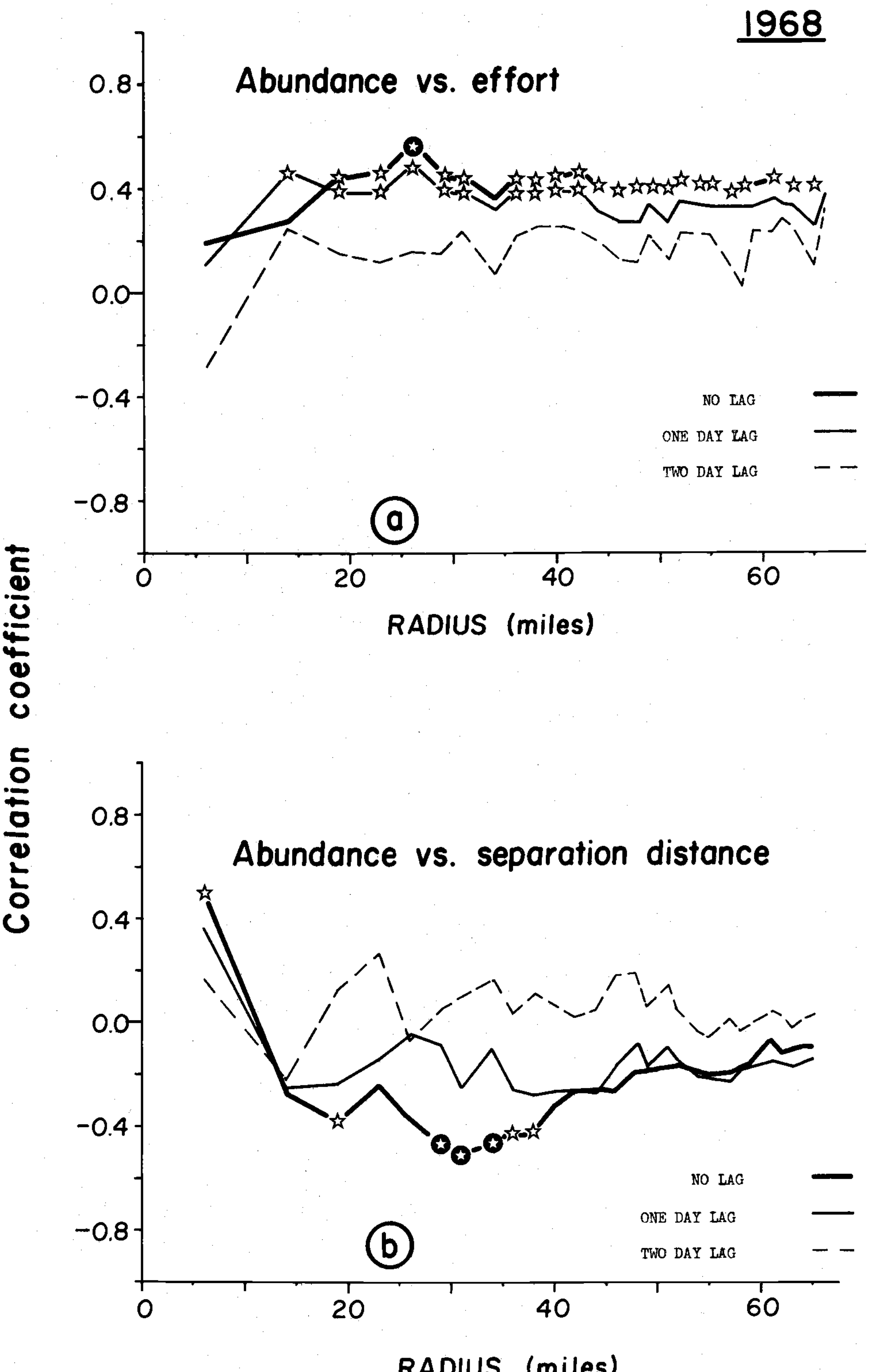

Figure 13. Correlation coefficients of apparent abundance versus effort (a) and separation distance (b) within increasing distances from the 1968 fleet center. Coefficients are shown for abundance on day t, t-1 and t-2 versus effort and separation of day t. Enclosed stars indicate a highly significant correlation (two-tailed t-test, $P < 0.01$), while open stars indicate a significant correlation ($P < 0.05$).

and abundance was greatest at a radius of about 25 miles and zero-day lag. Effort increased as abundance increased in the area of 6 to 25 miles from the fleet center. Effort of one-day lag was also closely related to abundance within a 13 mile radius. Effort of a two day lag was not related ($P > 0.05$) and showed no obvious trends.

The zero-day lag in Figure 13a did not decline with radii larger than 25 miles. This suggests that no real center of abundance occurred in 1968. On days of good catches, fish were caught with similar success over the entire area within 66 miles of the fleet center. On days of poor catches, few fish were caught anywhere and boats left the fleet, as suggested in Figure 10a.

Figures 6a and 13 suggest that during 1968 boats entered the 31 mile fleet area within one day after catches began to increase, and left this fleet area within one day after catches began to decline. Boats apparently were rapidly aware of the success, or lack of it, within the inner fleet area. When catches were low boats left the fleet area either to search out new concentrations of fish or to unload their catches in port.

Separation distance of boats was positively related to abundance with a zero-day lag in a radius of 6 miles (Figure 13b). The correlation decreased, however, with increasing radius size. Correlation coefficients were significantly negative from radii of 28 to 38 miles. Coefficients at other time lags were essentially without meaningful trends.

The significant positive relationship between abundance and separation distance at the six-mile radius (Figure 13b) was probably spurious. Few boats fished within six miles of the fleet center, particularly during periods of low abundance. Consequently nearly all the observations within this radius were from periods of high abundance. Each lag plot also showed the same trend in 1968 (and in general, 1969 and 1970).

Boats within 28 to 38 miles of the fleet center were highly aggregated on days of high catches (Figure 13b). At larger radii the correlation coefficients trended toward zero. This suggests that within a range of about 30 to 40 miles of the fleet center, boats aggregated and dispersed on days of high and low catches, respectively. This relationship did not continue beyond a range of 40 miles.

1969. Figure 7a shows daily abundance, effort and separation distances for the 1969 season. Effort and separation distance peaks were out of phase with abundance peaks by about one day throughout the season. Boats were entering the central area one and two days after high catches were experienced. Maximum effort was generally associated with declining or low catches.

Boats tended to scout during days of low catches, as evidenced by an increased mean separation distance during these periods. The peaks of separation distance occurred on days of minimum catches

(28, 31 July and 1, 5, 6 and 10 August. The maximum separation distance (28 miles) occurred on 13 August when the fleet moved rapidly northward towards Vancouver Island.

Figure 14a clearly shows that effort on day t was not related to abundance on day t. In fact, the zero-day lag coefficient dropped to and remained essentially zero at radii larger than about 20 miles. Even at radii of 6 and 11 miles the correlations were not significant ($P > 0.05$). Boats were not entering and leaving the central fleet area simultaneously during periods of increasing and decreasing catches, respectively.

Effort on day t was significantly related ($P < 0.05$) to abundance on day t-1. Highest coefficients occurred at a radius of 36 miles and gradually decreased at larger radii. A similar, but non-significant trend can be seen in the two day lag. Boats were either moving into the central fleet area one day or more after catches were made, or the large fleet of a given day was associated with reduced catches of that day. Many fishermen feel that too many boats within an area are capable of driving the albacore down, away from the jigs.

Figure 14b shows that separation distance on day t was also unrelated to abundance on day t. Separation distance was inversely related to abundance with a one-day lag within 18 to 22 miles of the fleet center. Thus, boats within about 20 miles of the center were aggregated when catches of the previous day were high, or boats

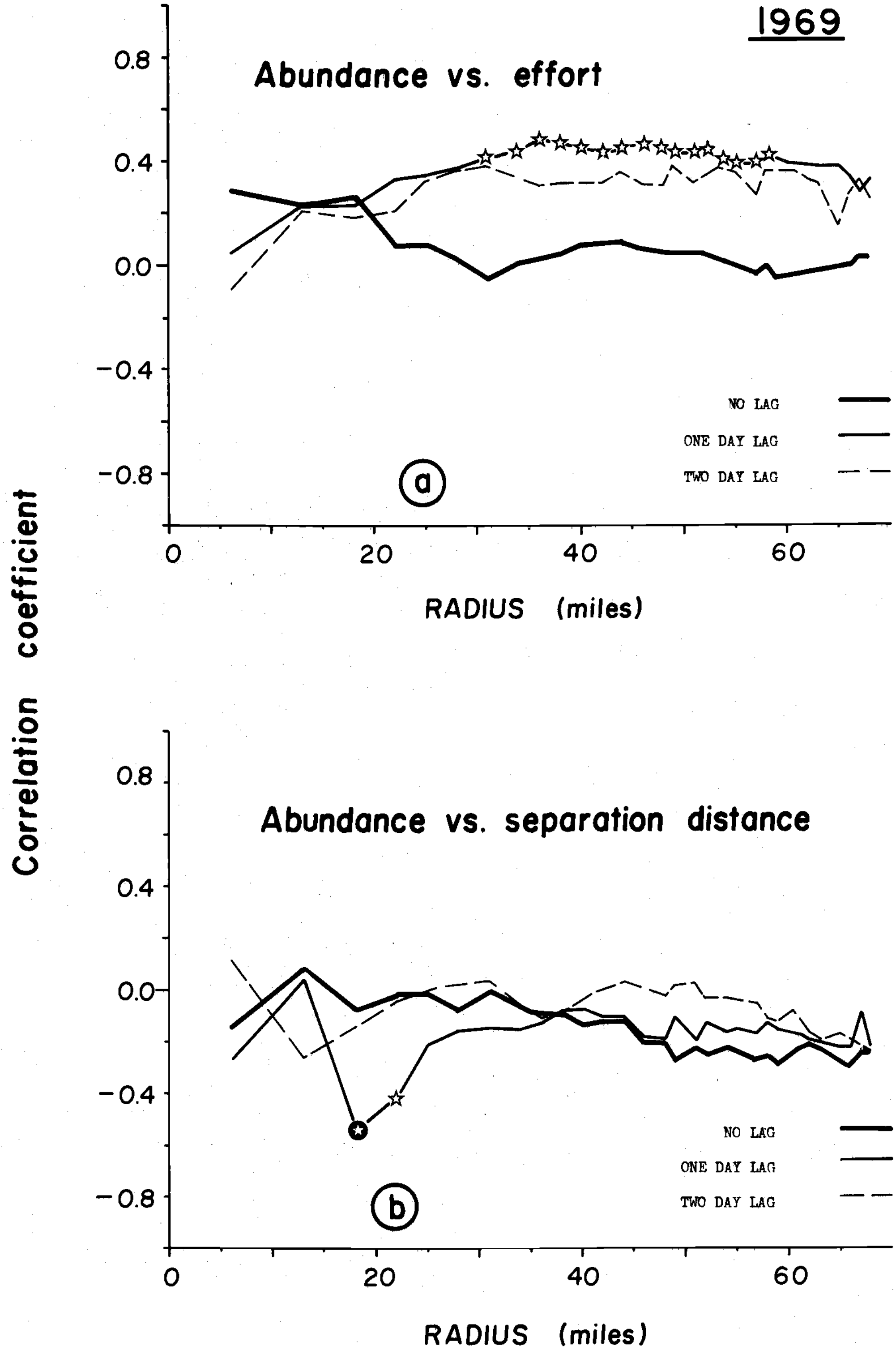

Figure 14. Correlation coefficients of apparent abundance versus effort (a) and separation distance (b) within increasing distances of the 1969 fleet center. See Figure 10 for explanation of plots.

dispersed and scouted the day after low catches were made. Beyond about 25 miles this relationship approached zero correlation.

1970. The 1970 season was very short. High catch rates occurred from 22 July to 25 July. Boats were numerous and highly aggregated within a small area about 100 miles west of the Columbia River (Figure 12).

Figure 8a indicates that effort peaks were generally in phase with abundance peaks within 31 miles of the fleet center. Separation distance within this radius did not appear to be related to abundance during the early, most productive part of the season (prior to 30 July). After the fishery declined on 31 July separation distance increased considerably as fewer boats remained in the fleet area. Those that remained were scouting since catches had decreased.

Effort within 25 miles of the fleet center increased the same day abundance increased (Figure 15a). Effort was also significantly related to the previous day's abundance within larger radii (18 to 35 miles). At radii larger than 35 miles the curves decreased and became insignificant beyond 58 miles. The center of abundance was thus defined to be within 25 miles of the fleet center. Beyond 25 miles catches apparently were smaller and boats moved into the central area during periods of high catches.

Significant relationships existed between separation distance and abundance of the same day within 18 to 25 miles of the fleet center

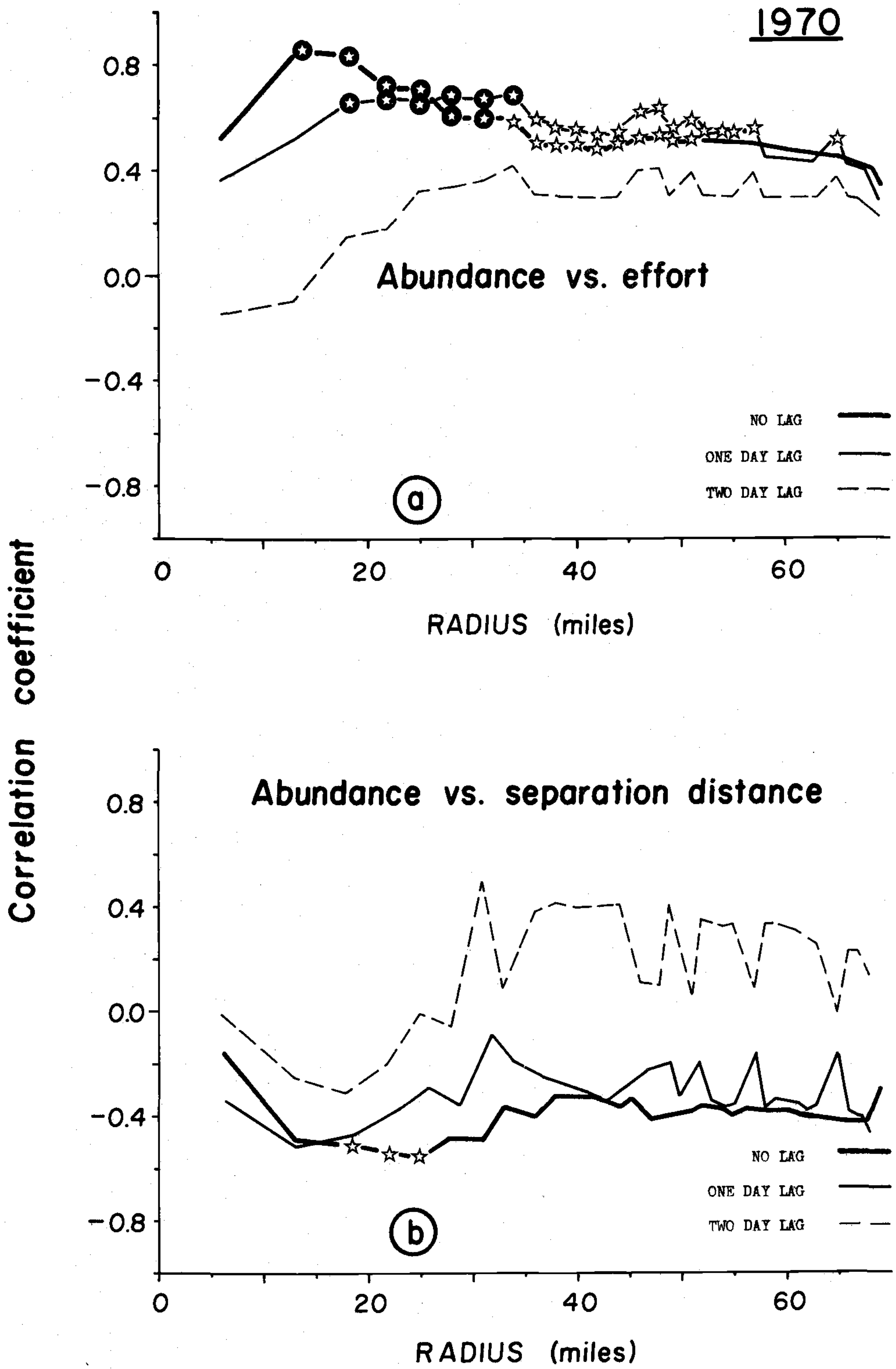

Figure 15. Correlation coefficients of apparent abundance versus effort (a) and separation distance (b) within increasing distances of the 1970 fleet center. See Figure 10 for explanation of plots.

(Figure 15b). The coefficients were not as high as one might expect in relation to the very high correlation coefficients between abundance and effort (Figure 15a). The figure suggests that boats were not highly aggregated during periods of high catches and high levels of effort.

The 1970 season was unique in that tremendous catches were made during a very few days within a very small area (Pearcy, 1973). Figure 12 illustrated that this area was on the order of 25 miles around the fleet center. Weather was favorable, the fishery was close to port and boats knew exactly where the fishery was. Little effort was made to scout during this time (Figure 15b) because fishing was good all over the local area of the fleet. This area was smaller than in previous years, suggesting the fish were more available in the area rather than being patchy over a much larger area as in the previous two years.

Two area sizes were chosen to investigate in detail the general relationships between apparent abundance, separation distance and effort. The sizes chosen were circles of 31 and 13 mile radii. The former represented an area characteristically fished by a majority of the fleet (Figure 5). The latter area represented the smallest area in which at least two boats fished during the entire period of investigation.

Figure 16 shows the relationships between apparent abundance

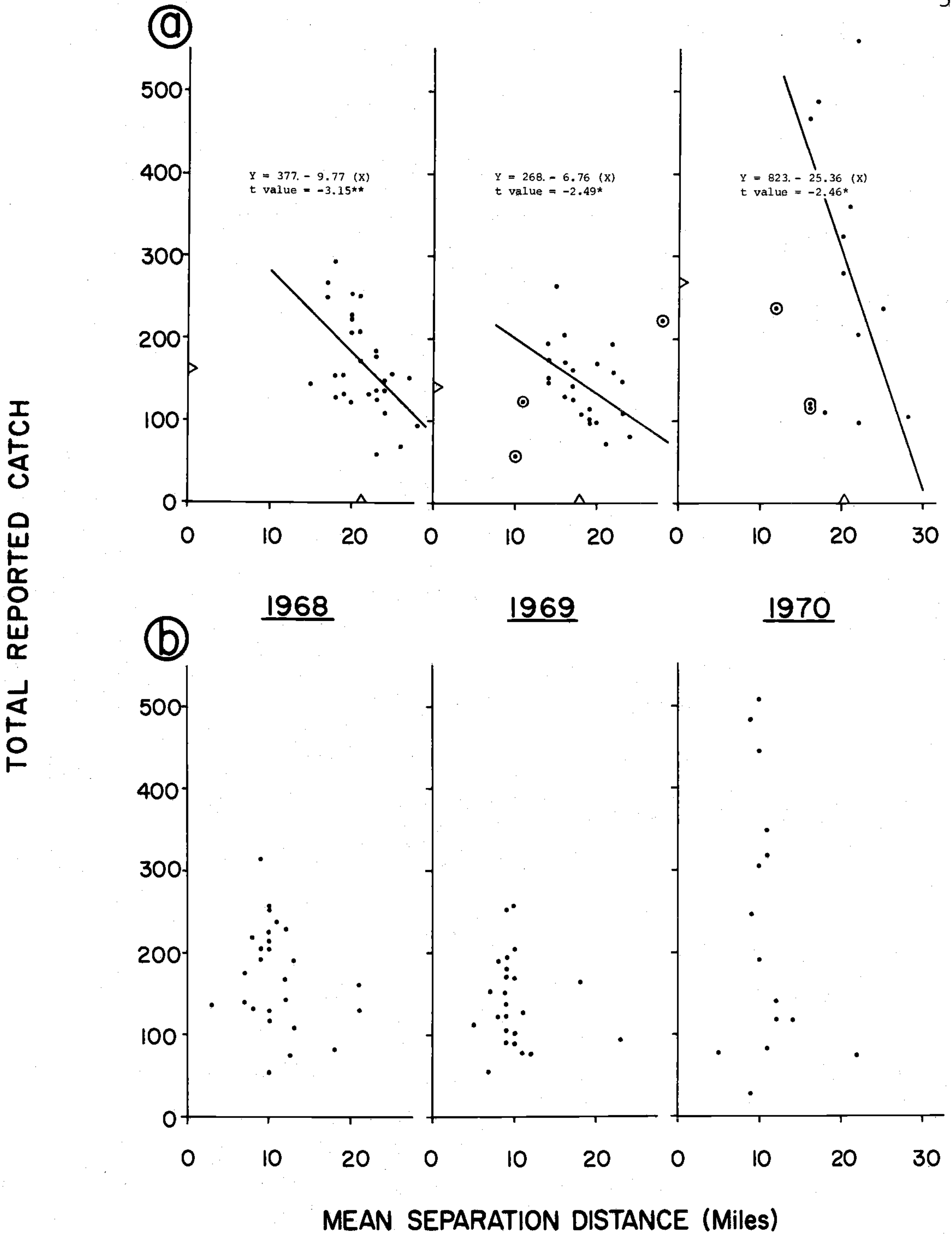

Figure 16. Relationship of apparent abundance versus mean separation distance within 31 miles of the fleet center (a) and within 13 miles of the fleet center (b) during 1968, 1969 and 1970. Circled data points were not used in least-squares determination. A double asterisk (**) indicates a highly significant regression coefficient (one-tailed t-test, $P < 0.01$); a single asterisk indicates a significant coefficient ($P < 0.05$); N.S. indicates a non-significant coefficient.

and separation distance in the two areas. In the 31-mile radius area (Figure 16a), apparent abundance was inversely related to separation distance, indicating again that boats were aggregated during days of high catches. The average separation distance in 1969 (18.0 miles, as indicated by the caret in the figure) was significantly less than that in 1968 (21.3 miles). Separation distance and apparent abundance were not significantly related within the 13-mile radius circle in any of the three years (Figure 16b).

Separation distances within 13 and 31-mile radii were also plotted versus the total reported daily catch in Figure 17. The relationships were very similar to those of apparent abundance (Figure 16). However the plots show that in 1969 separation distance was more closely related to the total catch than in 1969. This suggests that the 1969 boats were aggregating as a more cohesive unit than in 1968. As in Figure 16b, no significant relationships were found between separation distance and total catch within 13 miles of the fleet (Figure 16b).

Scattergrams of apparent abundance versus effort within 31 and 13 miles of the fleet center are shown in Figure 18. The relationships within the 31 mile radius were not as strong as for apparent abundance versus separation distance (Figure 16a). In 1969 the relationship was not significant ($P > 0.05$). This may have been caused by the boats not dispersing out of the 31 mile radius on days

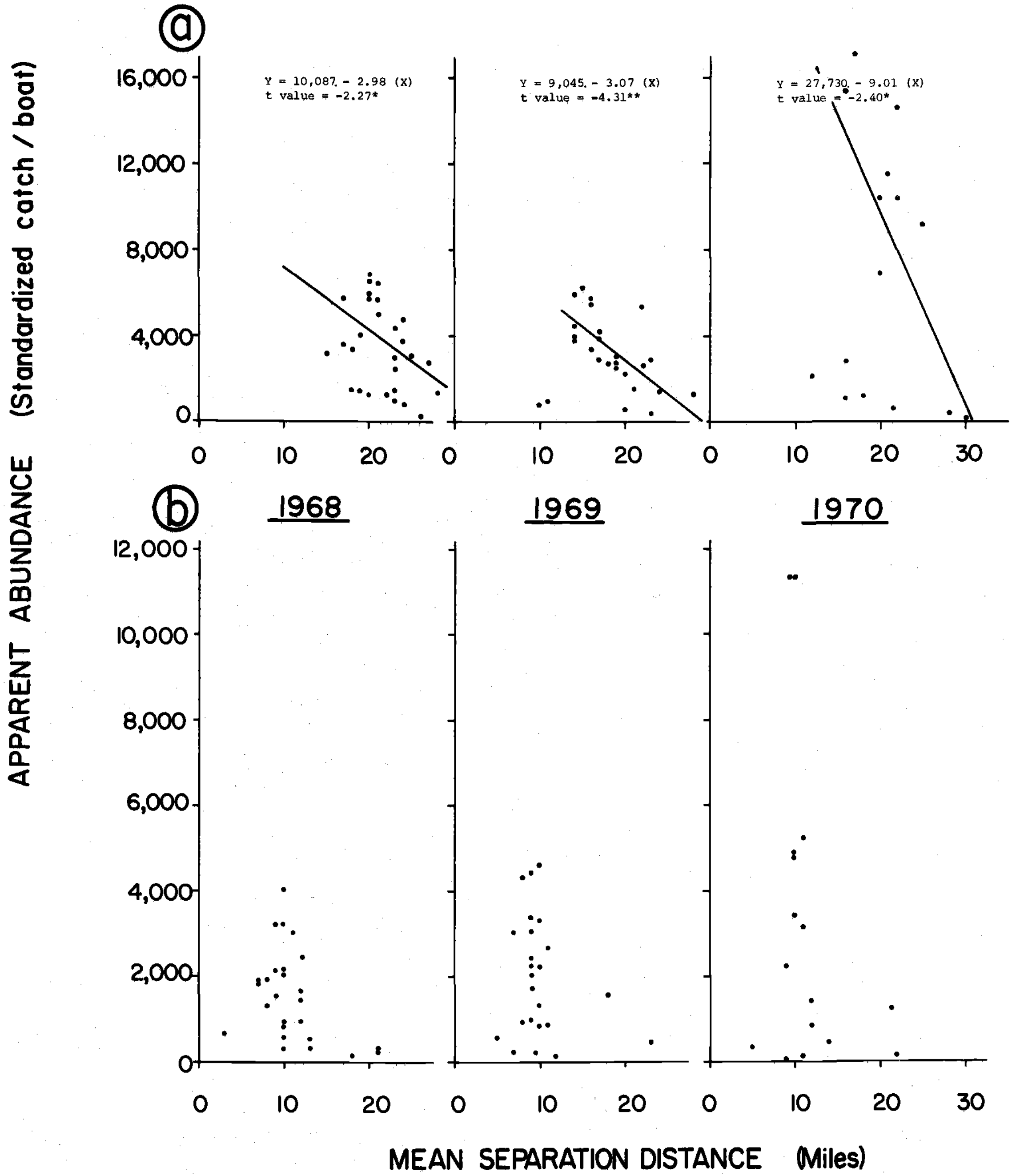

Figure 17. Relationship of total reported daily catch versus mean separation distance within 31 miles of the fleet center (a) and within 13 miles of the fleet center (b) during 1968, 1969 and 1970.

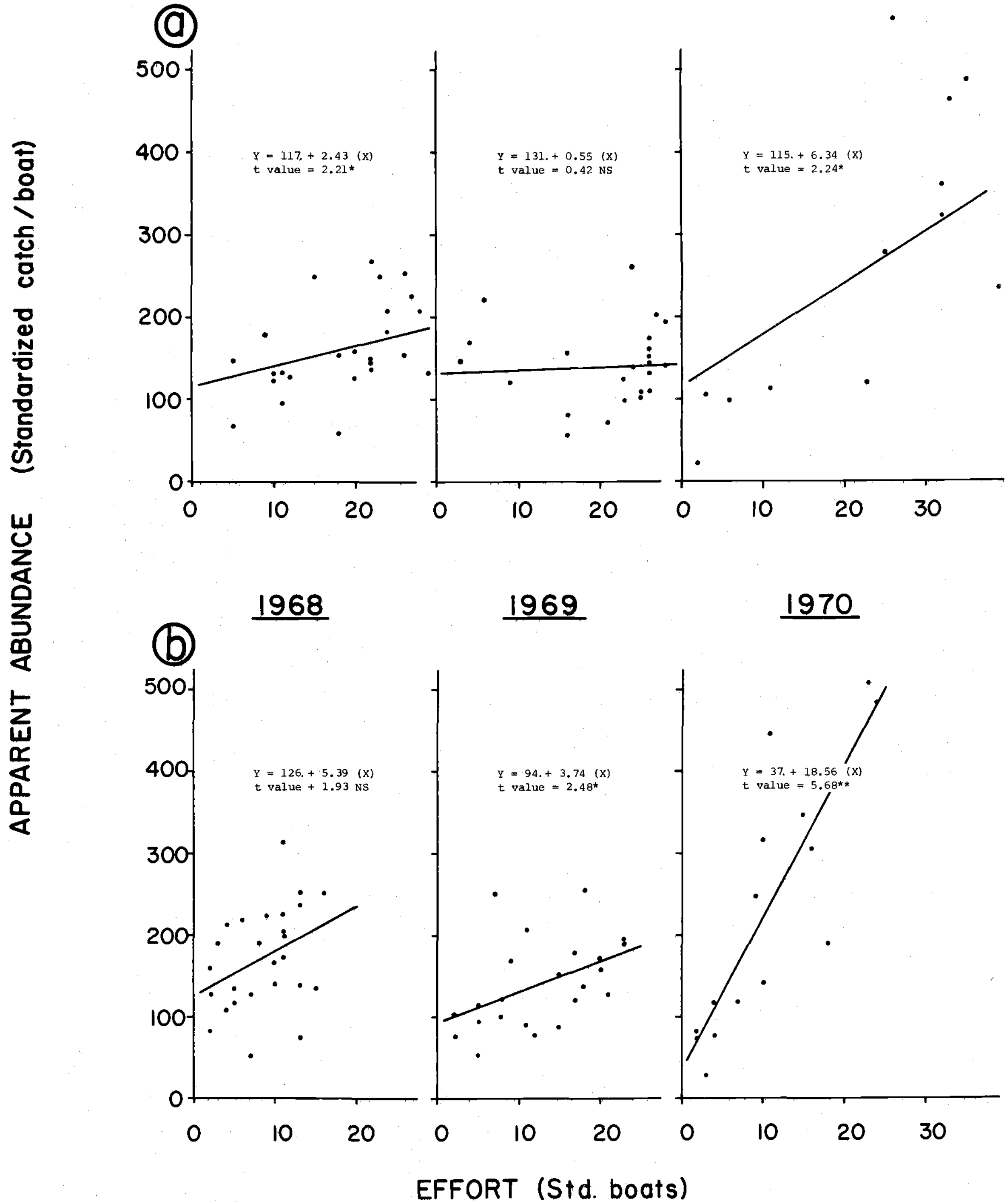

Figure 18. Relationship of apparent abundance versus effort within 31 miles of the fleet center (a) and within 13 miles of the fleet center (b) during 1968, 1969 and 1970.

of low catch rates, a condition which occurred to a much larger extent than in 1968 (see Figures 6 and 7).

Within 13 miles of the fleet center, changes in effort in 1968 were not significantly related to changes in apparent abundance. This relationship was significant in 1969 and especially 1970. Boats in 1969 and 1970 were entering the smaller area on days of high catches and leaving on days of low catches, but apparently not moving farther than 31 miles from the fleet center.

Figure 19 shows the highly significant ($P < 0.01$) relationships between effort and total reported catches within 31 miles of the fleet center. These relationships remained within the 13 mile radius. Significance levels nearly doubled in the 1969 and 1970 plots while staying the same in 1968. More boats were within the smaller radius during days of high catches in 1969 and in 1968.

Periodicity of Apparent Abundance

Figures 10, 11 and 12 showed that apparent abundance varied considerably from day to day in each season. Periodic fluctuations occurred in 1969 and to some extent, 1970. During these two years peaks of abundance appeared to be five days apart. Periodicity was not obvious in the 1968 abundance plot. Autocorrelations of the 1968 and 1969 records were run for abundance, effort and separation distance.

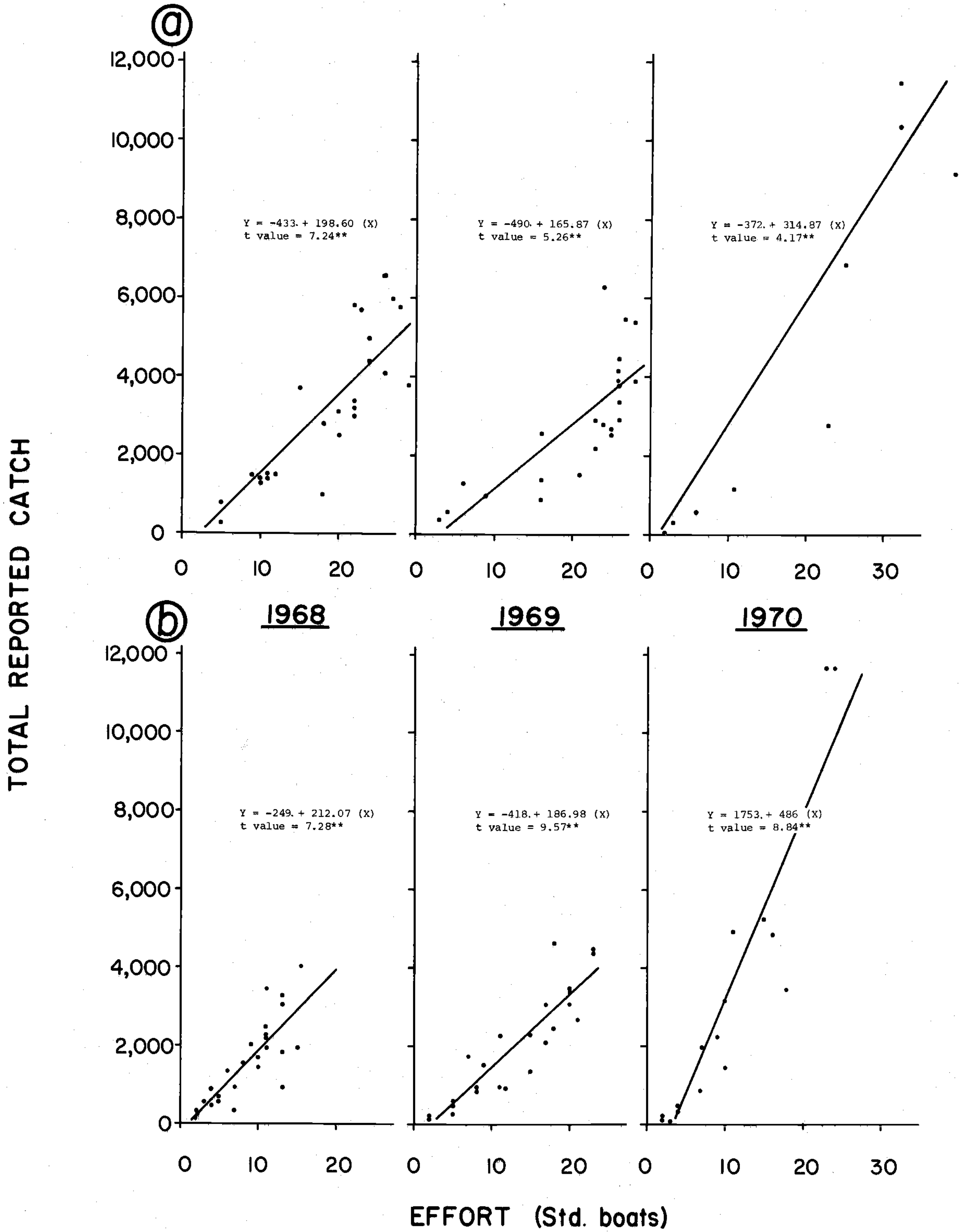

Figure 19. Relationship of total reported daily catch versus effort within 31 miles of the fleet center (a) and within 13 miles of the fleet center (b) during 1968, 1969 and 1970.

No apparent periodic trends occurred in the 1968 records (Figure 20), although high daily catches tended to be followed by lower and lower daily catches. Similar trends occurred in the effort and separation distance records. Changes in effort and separation distance were therefore related to changes in abundance as shown previously in Figures 10 and 13.

Figure 21 confirms the five-day period suggested from the 1969 abundance record in Figure 11, although it was not significant ($P > 0.05$). Autocorrelation plots of effort and abundance were similar (both had peaks at the five-day lag), but were one day out of phase (Figures 7 and 14). This provides good evidence that boats moved into and away from the central fleet area in response to changes in apparent abundance, even though the responses were one day out of phase.

Separation distance did not change in phase with effort or abundance. This suggests that even though boats moved into an area in 1969, they did not aggregate within the area as boats did in 1968. Abundance changes may have occurred so rapidly in 1969 that boats did not become fully aware of them in time to exploit the fish schools.

No autocorrelations were run for the 1970 season because it was so short.

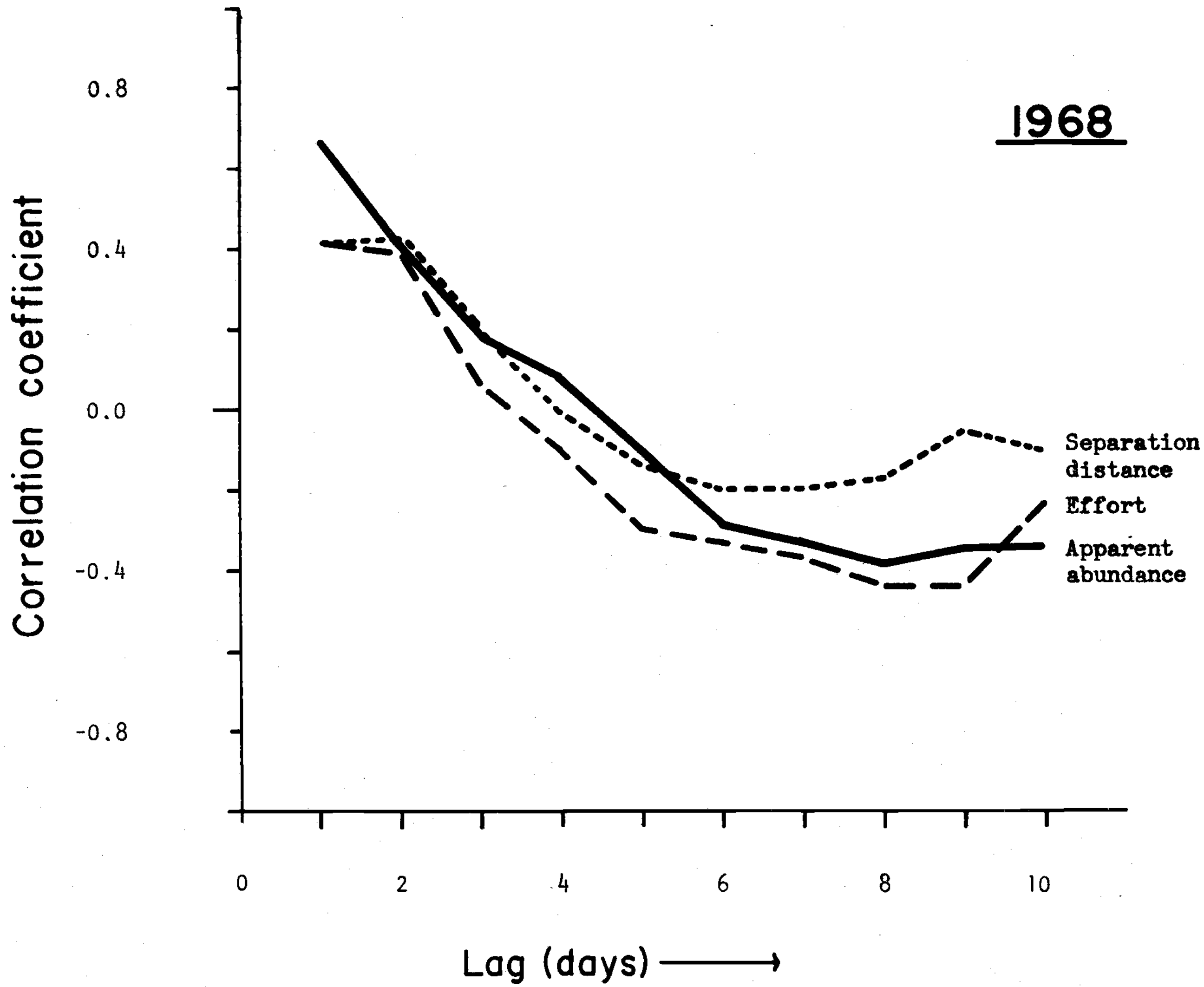

Figure 20. Auto-correlation coefficients of apparent abundance, effort and separation distance, 27 July to 24 August 1968.

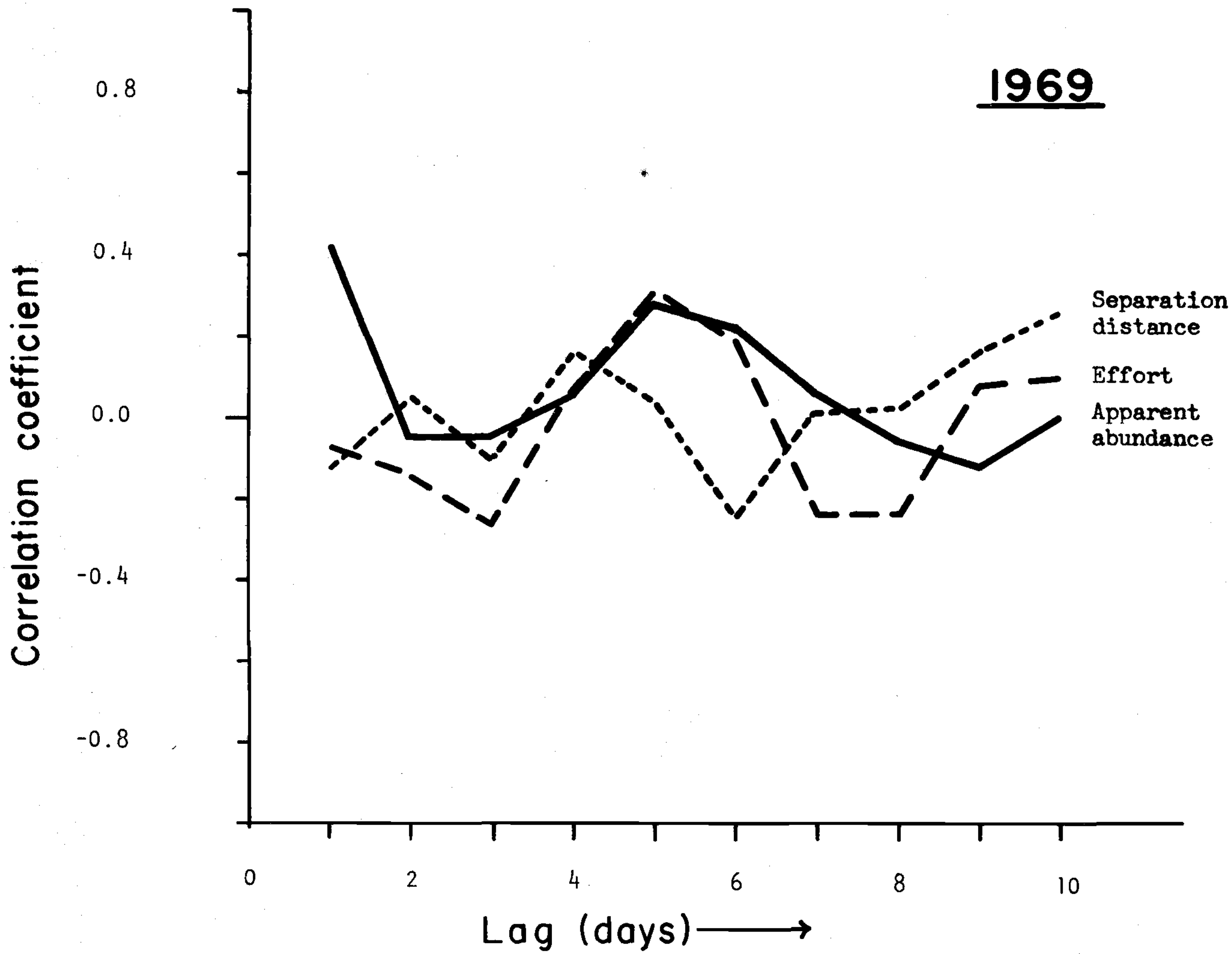

Figure 21. Auto-correlation coefficient of apparent abundance, effort and separation distance, 19 July to 13 August 1969.

Synchrony of Abundance in Separate Areas of the Fishery

The aggregation of the fleet during the three years (Figure 5) indicates that fishermen generally believe the most productive area of the fishery was close to the fleet's medial center. To examine the possibility that fishermen may have passed up large and unexploited concentrations of fish by staying with the fleet, abundances within two 31-mile radius circles, one north and one south of the 31-mile radius circle bounding the fleet center, were compared with the abundance within the central fleet circle. The two new circle centers were 124 miles apart on the 126° 30' W. longitude line, which represented the approximate axis of the fishery during the study periods (Figures 5 and 6).

Figure 22 shows the abundance in circles north and south of the 1968 fleet center, in addition to the abundance in the central fleet circle. (Abundance estimates in the north and south circles were frequently based on few observations, and are therefore less reliable in estimating true abundance in the areas.) In 1968 abundance estimates averaged higher in circles north and south of the fleet center. During days of poor catches in the central circle (11-17, 22 August) and when effort was low (13-17 August) catches to the north and south tended to be high.

Abundances in the northern and southern circles were significantly related ($P < 0.05$) as shown in Figure 23. This gives evidence

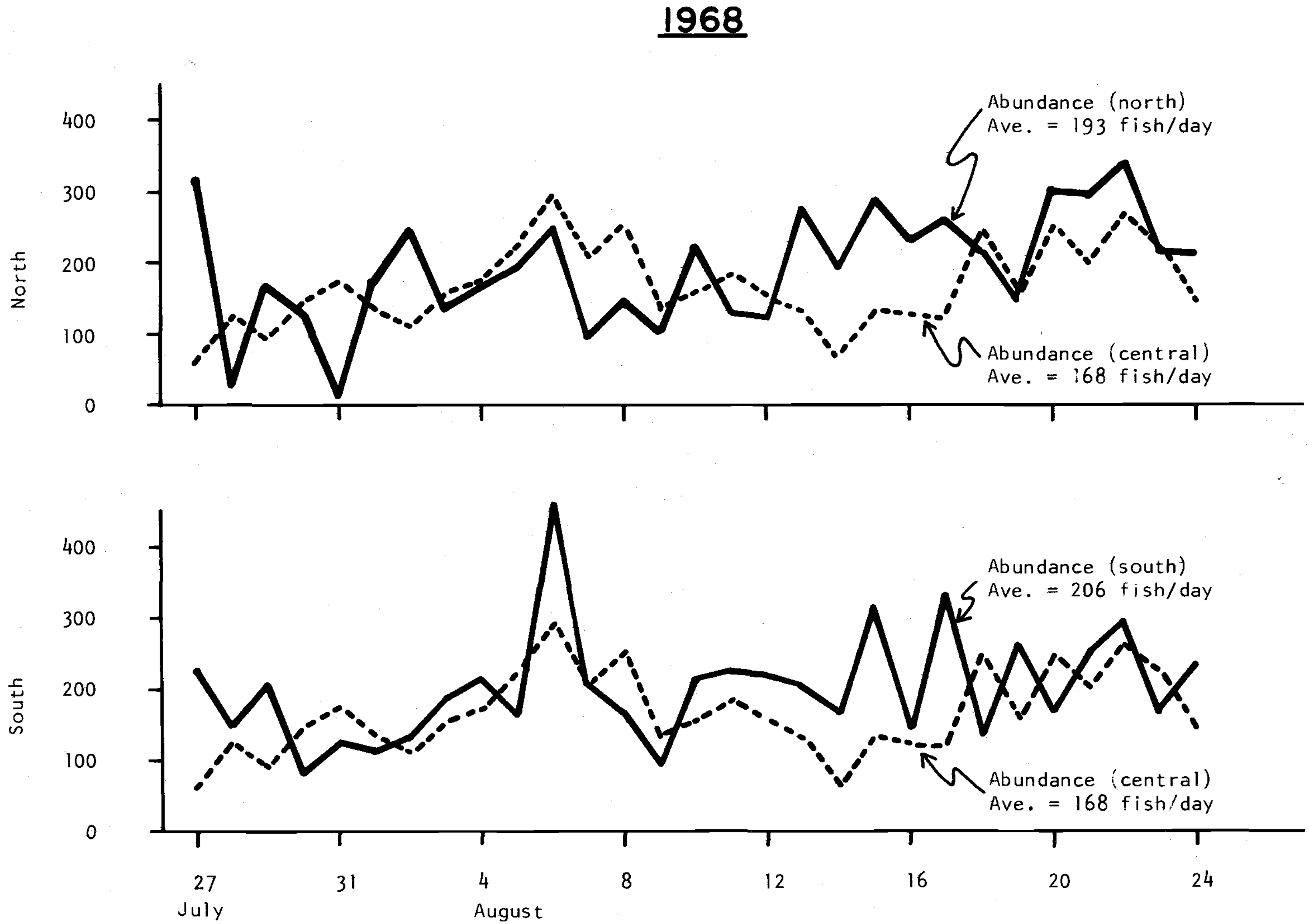

Figure 22. Apparent abundance of albacore (1968) in circular areas north (above) and south (below) of the central fleet area.

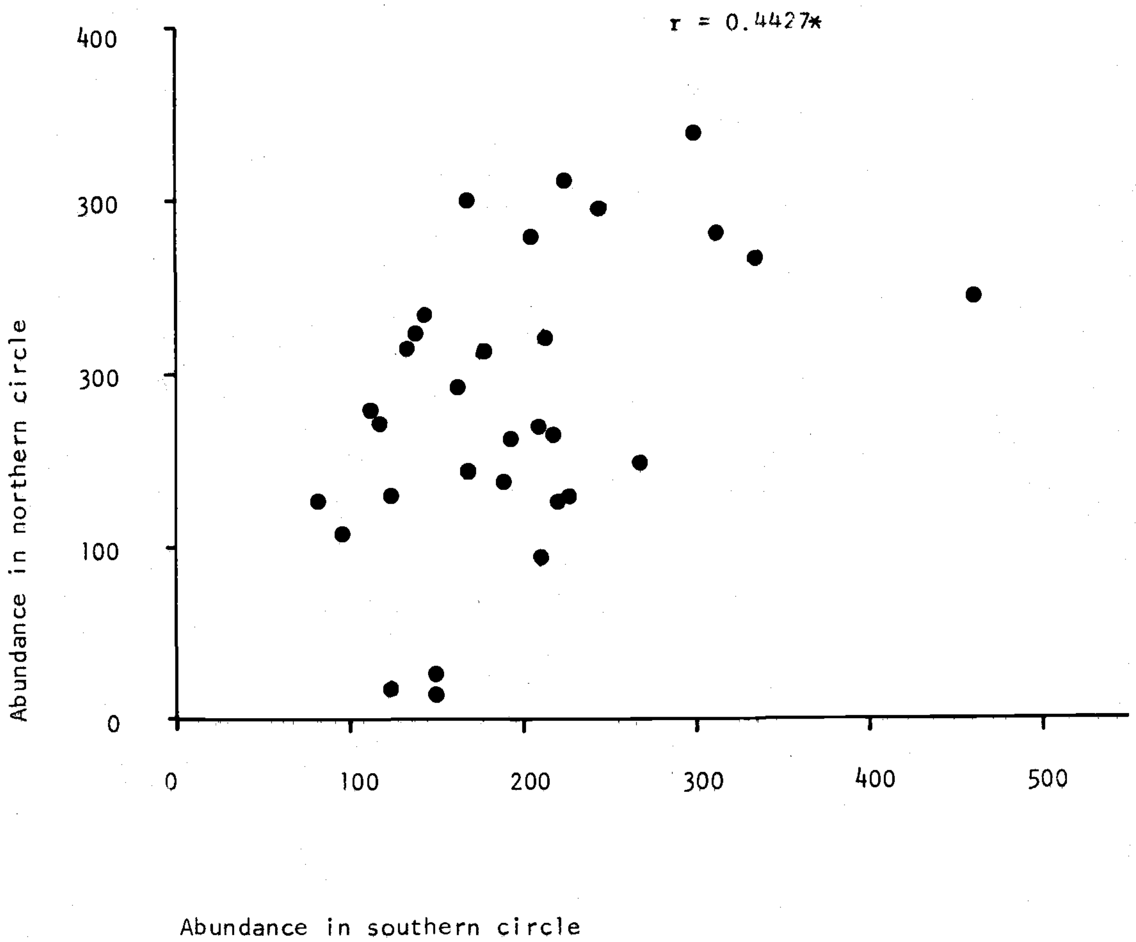

Figure 23. Scattergram of apparent abundance (1968) in northern area versus apparent abundance in southern area. A significant correlation ($P < 0.05$) existed between abundances in the two areas.

that no center of albacore abundance occurred in 1968, as suggested also in Figure 13, but rather that fish were available throughout the fishery area. Neither southern or northern abundances were significantly related to the central circle's abundance.

The 1968 fleet center appeared to move north or south (Figure 10) depending on the abundance to the north or south. During periods when abundance in the southern circle was higher than the central circle (9-17 August) the fleet center moved south. After 17 August, abundance in the northern circle increased relative to the southern and central circles and the fleet moved north. During periods of little difference in abundance among the circles, as from 26 July to 5 August, little north-south fleet movement occurred (Figure 6).

Figute 24 shows abundances in the north, south and central circles during 1969. Northern abundances were generally lower than the central area throughout the period. Abundances in the southern circle averaged 40 fish more per day than the central circle. This situation suggested that in 1969 albacore were not as scattered over the fishery area to the extent they were in 1968. In fact, boats may have been fishing too far north of the largest concentration of fish.

Unlike 1968, abundances in the northern and southern circles were not significantly related (Figure 25). Northern and southern abundances were not significantly related ($P > 0.05$) to abundances

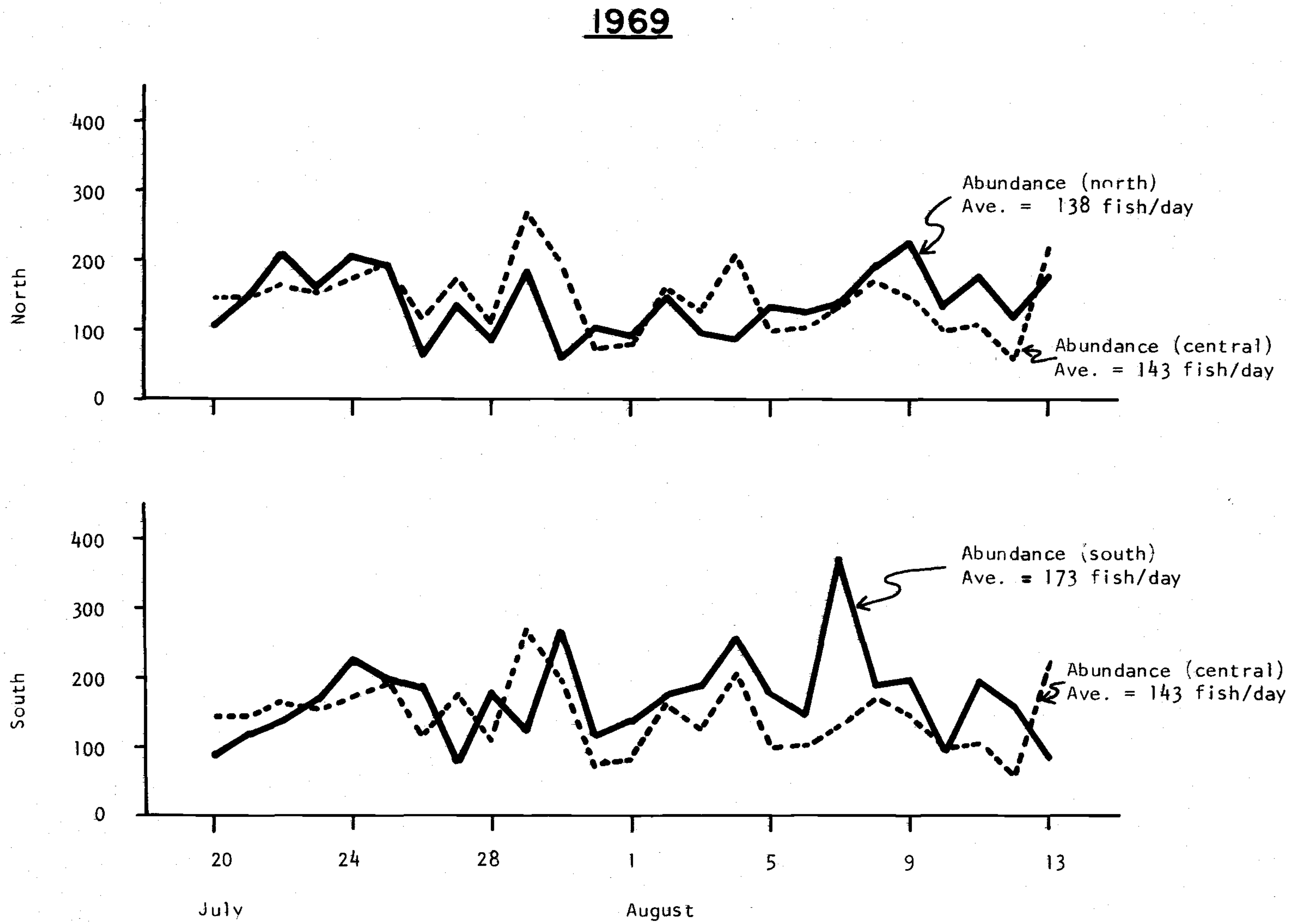

Figure 24. Apparent abundance of albacore (1969) in circular areas north (above) and south (below) of the central fleet area.

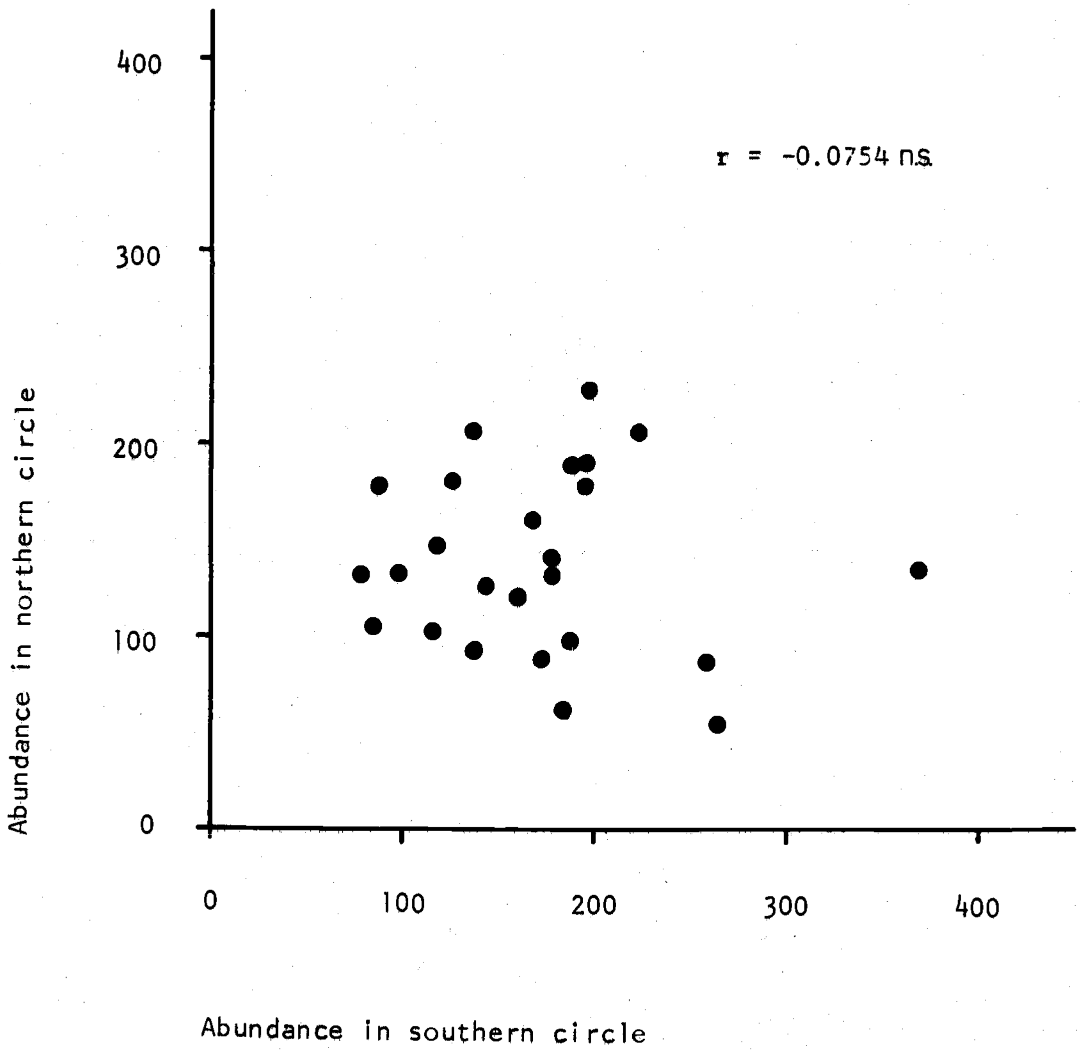

Figure 25. Scattergrams of apparent abundance (1969) in northern area versus apparent abundance in southern area. The relationship was not significant ($P < 0.05$).

in the central area, although the northern and central areas appeared related in the first half of the period (Figure 24). High abundances in the southern circle were generally associated with high levels of effort in the central area. This may have been due to the inability of the boats to respond quickly enough to rapidly changing centers of abundance by driving the fish down or otherwise inhibiting the bite when the boats aggregated within a very small area.

The 1969 fleet center generally moved in response to areas of higher abundance, as in 1968. When abundance in the southern circle increased (Figure 24), the fleet began moving south and continued to do so until 8 August (Figure 11), when abundance in the northern circle increased. From 9 August until the end of the period the fleet moved to the north. High abundances of fish were still occurring in the south, however, as on 10 and 11 August.

DISCUSSION

Similarities and Differences among Years

The three albacore seasons--1968, 1969 and 1970--were originally chosen to represent similar seasons with above average catches. Fishing tactics were then to be generalized from those observed during the three seasons. However, while the seasons were similar in some respects, they were unique in terms of daily apparent abundance fluctuations, length of season, fishery location and other characteristics. As a result, fishermen responded very differently each season.

Daily distributions of apparent abundance varied considerably between the 1968 and 1969 seasons. In 1968 albacore were found in many small concentrations scattered over the entire fishery. When catches were large in one area catches were generally large in other areas also (Figure 22). This was not the case in 1969 when albacore appeared to be more concentrated in several local areas. Large catches in one area during 1969 were sometimes, but not necessarily, associated with large catches in other areas (Figure 23). Fishermen apparently had difficulty in staying on the larger concentrations of fish (Figure 17a).

In contrast to both 1968 and 1969, albacore of the 1970 season were highly concentrated in one small area for a very short period of time. Extremely large catches were made during this period, but afterwards albacore were not available to the troll boats, although bait boats had good success later in the season (Pearcy, 1973).

In general fishing boats were more aggregated in 1969 and 1970 than in 1968 (Figure 5). During periods of high apparent abundance, boats in 1968 were most aggregated within 28 to 38 miles of the fleet center (Figure 13b). In 1969 and 1970 boats were most aggregated within 18 to 22 and 13 to 25 miles of the fleet center respectively (Figure 14b, 15b). Boat aggregation thus appeared to be inversely related to the areal size of albacore concentrations. Maximum boat aggregation occurred during 1970 when fish were most highly concentrated, while minimum boat aggregation occurred in 1968 when fish were least concentrated spatially.

Movements of the fleet and individual boats also differed markedly between 1968 and 1969. The fleet moved very slowly northward in 1968 (Figure 10) while mean separation distance of boats was high. The least successful fishermen were located far from the fleet center. In 1969 the fleet center moved rapidly north and south (Figure 11). Aggregation was greater in 1968 and low-liners were closer to the center of the fleet. A much greater part of the 1969 fleet was moving farther and more rapidly each day than in 1968. This is also shown in Figure 9.

The 1970 fleet movements were similar to those of 1969 in that the fleet center moved rapidly but unlike the north and south movements of 1969, the 1970 movements were more east and west (Figure 12). The majority of the fish were caught in a small area off the mouth of the Columbia River. Large boats (longer than 60 feet) were associated with more successful fishermen in 1968. The advantage enjoyed by these larger boats was probably their greater endurance and sea-worthiness which allowed them to fish longer during periods of good catches with less concern about inclement weather. In 1969 and 1970 larger boats were not necessarily more successful than smaller boats, as the majority of high-liners were under 60 feet in length.

In summary, the distribution, abundance and behavior of albacore varied greatly between the three years. Generalizations have little meaning and no confidence can be placed on extensions of the generalizations to seasons other than those studied. Because of these variations, fishing tactics of fishermen must be flexible enough to allow for the changes.

Tactics of Albacore Fishermen

Tactics of albacore fishermen can be differentiated into tactics of individuals and tactics of the collection of boats (fleet) within a given area. Tactics of individual fishermen include the methods and means which the fisherman believes are useful in locating and exploiting the largest concentrations of most available fish. Movements of the albacore fleet are unintentional for the most part, being the additive and integrated collection of individual fishermen's tactics.

The Pacific Northwest albacore fisherman fishes primarily as an individual, although he may be associated with other boats. It is his intent and to his advantage to maximize his own daily catch rather than the fleet's daily catch or even the daily catch of the small group of boats he is closely associated with. In this regard an albacore fisherman can be considered as a single predator searching for concentrations of prey. On the other hand, most fishermen are part of the fleet (Figure 2) or at least a small group of cooperating boats and rely on communications with other boats to evaluate and modify their individual tactics. Therefore, the fleet may be considered as an aggregation of predators searching for prey concentrations.

The probability (Ps) of a single predator (fisherman) finding a concentration of prey (albacore) according to Koopman (1956) is

$$Ps = 1.0 - \exp[-2(R)\, Vt/A]$$

where R is the visual range of the fisherman into the ocean, V is the constant speed of the boat, t is the time interval and A is the area of search. Olsen (1956) pointed out that if the width of the fish concentration is much greater than R, the finding of a fish school becomes more a matter of "just bumping into it."

From the above equation an albacore fisherman can increase his searching success in several ways. One is by increasing his speed (Saila, 1962), assuming the albacore will strike at his lures equally well. Success can also be increased by increasing the sight range, R. Directional sonar, for example, may increase the fisherman's sight range.

The actual sight range of albacore fishermen into the water is essentially zero. They rely on the sight range of albacore to see the lures. An albacore is "sighted" when it strikes at a lure. Thus, the fisherman's sight range (without electronic devices) can be considered to be the sight range of the albacore. Widening the area on either side of the boat which is swept by the lures, may increase searching success by effectively extending the albacore's sight range. This could be accomplished by lengthening the spar poles from which the lures are trolled.

The probability of finding fish concentrations may also be increased by reducing A, the area to be searched. The only means of accomplishing this is to reduce the area searched <u>per boat</u> by increasing the number of boats searching. For each boat to benefit requires cooperation between boats by reporting their location and catch so that each boat is aware of the apparent abundance of albacore in the area searched by the other boats. This cooperating fleet then acts as an aggregation of predators.

Aggregations of predators in the ocean are generally considered inefficient if their sight ranges overlap because efficiency is reduced (Brock and Riffenburgh, 1960). This obviously is not the case with albacore fishermen, as their effective sight ranges are very short compared to the distances separating boats while fishing. Brock and Riffenburgh (1960) state that an aggregation of predators with overlapping sight ranges can be advantageous in the special case where, within a given range, a predator can see other predators feeding but cannot see the schooled prey.

Albacore fishermen do take advantage of this situation. When an albacore strikes at a lure, the fisherman generally turns his boat around to make another pass over the area of the strike. This maneuver is watched for continually by fishermen on other boats. When one boat swings around, other boats may begin to move towards the circling boat.

Fishermen also watch for aggregations of other predators--birds--feeding on the surface. Flocks of birds (petrels and terns) are often attracted to areas where albacore drive their prey into surface waters. Albacore may indicate their own presence, at times, by breaking the surface in pursuit of prey.

Radio Communications

By far the most important and most used method of communication among fishermen is listening to radio broadcasts between boats. Albacore fishermen work together in small groups to a great extent. Every fisherman interviewed and all questionnaire respondents (except one) stated that they exchanged information and fished together with other boats. For example, albacore tuna fishermen from Newport, Oregon, keep in radio contact and exchange information on daily position and success. In larger ports, such as Astoria, small groups of five to ten boats work together and travel as a unit.

Cooperation within these groups is very strong. Each boat communicates by radio with the other boats in the group throughout the day. When a concentration of albacore is found, the successful fisherman informs the others in his group and they move to the albacore concentration.

In an attempt to increase the fishermen's availability to information regarding weather, sea-surface temperatures, catch success and fleet location, an Oregon State University Sea Grant program initiated daily broadcasts through the Astoria Marine radio-telephone frequency in 1969 and 1970 (Panshin and Burdwell, 1970). Broadcasts were made at 10:15 PM each evening and repeated at 10:15 AM the following morning. Information for each evening's broadcast was collected throughout the day from scientific organizations and calls from co-operating fishermen in the fleet.

Not all fishermen felt this advisory service was beneficial. Albacore fishermen believe that too many boats within an area drive the fish down from the surface waters, or otherwise cause a decrease in the catch rate. For this reason, efforts may be made within each group to conceal the true content of radio communications regarding their catches and locations. On the other hand, fishermen attempt to listen to broadcasts from other groups to effectively increase their knowledge of where fish are, or are not, being caught.

The Sea Grant albacore advisory broadcasts provided each fisherman with additional information on which to plan his following day's fishing location. One consequence of such advisory broadcasts in Australia was that fishermen tended to aggregate in areas of reported high catches (Hynd, 1969), which was the purpose of the broadcasts. However, if fishermen aggregated to the point that catch rates or total daily catch began to decline, the broadcasts may have performed a disservice to the fishermen.

The possibility exists that the Oregon Sea Grant advisory broadcasts resulted in fishermen aggregating where fishing was good the previous day (Figures 4, 11). Fishermen may not have been aware of the time delay (usually one day) between the receipt and dissemination of information by the broadcast personnel. Furthermore, fishermen had no way to evaluate the source of the broadcast information; whether it was reported by one boat or many, or by low-liners or high-liners. Fishermen may have relied too much on the broadcasts as a source of information of albacore locations.

Distances traveled by the medial fleet center each day in 1969 (Figure 6) show clearly that the fishermen were receptive to moving considerable distances each day. Figure 8 illustrates that fleet movements were oscillatory, in that the fleet returned to areas it had left several days previously. Many of these oscillations occurred when apparent abundance fluctuations were not excessive (2-13 August). In comparison, 1968 fleet movements were slow (Figure 6) and in general, progressed steadily to the north throughout the season (Figure 7).

The data presented in this thesis have shown that in 1969 and 1970 albacore fishermen were more aggregated than in 1968 (Figures 5, 16, 17). This increased aggregation was not associated with lower catch rates which would have suggested that the aggregation of boats was driving fish down or otherwise reducing the catch rate. Boat aggregation may have affected catch rates within smaller local areas, but there was no evidence that this effect occurred within 13 or 31 miles of the fleet center (Figures 16, 18).

The results also showed that areas to the north and south of the main fleet area sometimes had higher average levels of apparent abundance than the central fleet area (Figures 22 and 24). This indicated that while aggregation may not have reduced the catch rates in the central fleet area, it may have inhibited exploitation of greater fish concentrations located away from the fleet area.

Tactical Considerations

Most of the fishermen who were interviewed were aware that fish concentrations existed away from the central fleet area, but stated that they were usually reluctant to move unless a very reliable source reported fish in a distant location. Even from a reliable source, reports of major fish concentrations did not always provide sufficient reason to leave the central fleet area. The final decision to leave required consideration of several other factors which included those listed below.

The distance to be traveled A good catch rate usually lasts for only a few days. If a boat required a full day's travel, the "bite" may have been off before he arrived.

The catch rate in his present location If the catch rate was greater than 150 fish per day, most fishermen remained in their present location, traveling less than 30 miles per day (Appendix II).

Time of day Fishermen feel that if an area of high catch rate is reported early in the morning there is little hope that the fish will still be biting in the evening or the following day. If the area is reported late in the day, fishermen are more inclined to travel at night, as they feel the fish will be available the next morning. Laurs (1972) has found some evidence that albacore swimming speeds are greatly reduced at night, which may be the basis of the fishermen's observation.

Number of boats already in the reported new area Fishermen stated that too many boats within a small area somehow reduces their individual catches (Appendix II). Therefore, the number of boats reported already in the area is considered before moving. Large aggregations of boats discourage a fisherman from moving.

Weather Weather plays a dominant role in the determination of fishing strategy, particularly for smaller boats. Flittner (1970) reported that a typical albacore troller is hampered by sustained winds of 22-28 knots and seas of 1.2 to 2.4 meters. If the reported new area experienced bad weather, or if a boat had to travel against strong winds there was less justification for leaving the present area.

Available fish storage on board Occasionally boats approached their storage capacity of fish when a new area was reported. The captain then determined whether to stay in the present area for an extra day or so or to move to the new area, possibly staying fewer days before running into port.

These factors represent a portion of the considerations involved in the daily strategy or decision-making process of fishermen.

Advisory broadcasts attempted to provide the fisherman with more information upon which to make his decision. However, much of the information came from within the central fleet area and little catch information was available from areas away from the central fleet. Because boats were more aggregated in 1969 and 1970, most boats were aware of the broadcast information before advisory broadcasts were made. Furthermore, some fishermen felt maximum catch rates were often reported in the broadcasts, rather than more representative estimates of catch success. As stated previously, the majority of albacore fishermen said they would not cooperate with advisory broadcasters by submitting daily information as to their catch and location (see Appendix II). They felt that boats were too aggregated now and as a result, some areas of good fishing remained unexplored and unexploited.

Not all of the aggregation of effort was due to advisory broadcasts. Several fishermen are known as high-liners and many boats try to be in the same area as the high-liners. In fact the predominant strategy of many albacore fishermen is to follow these high-liners and capitalize on their fish-finding ability. One fisherman stated that his crew's most important function was to recognize a high-liner's radio broadcasts and to carefully monitor the content of the messages.

A common suggestion presented by fishermen was to continue the radio broadcasts by advisory programs but limit the information to weather and ocean conditions. They felt that information regarding albacore concentrations could be better provided by three or four survey boats sampling systematically and simultaneously throughout the fishery area. These boats could make regular and frequent broadcasts to the general fleet and thus reduce the tendency of boats to aggregate in small areas.

Survey boats could provide fishermen with reliable and nearly unbiased estimates of albacore concentrations over a much larger portion of the fishery area. High-liners could still employ their superior "skill" or tactics of catching more fish per day, while the majority of the fleet more efficiently exploited widespread albacore concentrations. Moreover, survey boats could also provide oceanographic data outside the small area of active fishing and in the areas of low as well as high catch rates. Such data on ocean conditions and albacore catches may lead to better understanding of the causative factors associated with fluctuations of agundance in time and space.

We also need knowledge about factors which affect or control small-scale distributions of albacore. Better ways to estimate abundance must be found before more effective tactics can be proposed or variable concentrations of fish can be predicted. Progress has been slow because of the difficulties of sampling patchy parameters and highly mobile fish. Cooperative programs with fishermen have good potential for providing much of this knowledge.

Implications to the Fishery

This thesis has been concerned primarily with identifying characteristics of successful fishermen and with suggesting means of increasing the potential catch of albacore. However, there is another aspect of the fishery which must be considered, namely conservation of this living resource. The fate of over-exploited fish populations of the past is all too-well known. It is therefore appropriate to suggest how the results of this thesis may be useful in attempts to conserve the North Pacific albacore stock.

If catch per unit of effort is to be used as an index of stock abundance, relationships must be determined between different types of effort (i.e. longline, pole-and-line, and troll-boat). Furthermore, each effort type must be standardized to adequately and consistently reflect the true amount of effort being expended in a particular fishery.

Definition of such a standard unit of effort remains a problem in the troll-boat fishery.

In several fisheries there is an obvious relationship between fishing power and a class or type of boat (Broadhead, 1962; Gulland, 1956). Fox (1973) has suggested that fishing power of troll boats can be related to boat length. This thesis has shown that boat length is not related to fishing power during small intervals of time (less than one year). This was particularly obvious in 1969 and 1970 when the average boat length of the most successful fishermen differed from the least successful fishermen's boat length by only five feet (Table 3).

A parameter which should be included in a standard unit of effort is time, specifically it's allocation during fishing activities. The high catch rates of 1970 (occasionally over 1000 fish per day [Pearcy, 1973]) provide an example of the significance of time. Each fish has to be hauled on board individually by the crew. (The typical crew size of an albacore troll boat is two, but varies from one to more than five). For one man to land 1000 fish would require the fisherman to haul in slightly more than one fish per minute for 16 hours; obviously a nearly impossible task. Even two men would experience difficulty catching this number of fish, such that the task would probably represent their endurance rather than an estimate of typical effort. Fishermen are also limited by the number of lines they can handle at varying catch rates and by their speed of landing a single fish.

Therefore, the number of fish caught each day will depend on the number of fishermen actually fishing, the rate at which each fisherman can land a single fish, and the density and vulnerability of albacore.

Holling (1959a, 1959b) has shown that for predators which must handle each prey individually, the number of prey captured is a function of the prey density as well as the time required to handle each prey. At high levels of prey density, handling time per prey becomes increasingly significant and eventually limits the catch per unit of time. Similar studies could be conducted for the troll boats as predators in an effort to more accurately estimate albacore density. The handling times, or catching rate of fishermen, could be determined by observing the fishing operations at sea.

Beyond providing accurate estimates of effort and abundance, research in fishery science should provide guidelines for the rational utilization of this renewable resource. Although no estimate of stock size has been attempted for the North Pacific albacore (Yoshida and Otsu, 1963) the stock is not considered over-exploited (Frey, 1971). Over a decade ago, several authors suggested that albacore were under-exploited by the troll-boat fishery and that considerable expansion could be made without damaging the stock (Clemens, 1961; Johnson, 1962). These authors based their conclusions on observations that albacore were often present in great numbers but were not available to the fleet. The results of this thesis appear to support this contention since the albacore fleet was shown to aggregate to such a degree that areas of higher apparent abundance were left unfished by the majority of the fleet. However, there are other factors which must be considered.

The consequences of increasing the harvest by increasing the availability of albacore to the troll-boat fishery may not be desirable. From data of Laurs (1973) the U. S. west coast albacore landings have been increasing about 3% per year and more boats continue to enter the fleet. As pointed out by Frey (1971) and Uchida and Otsu (1961), the troll-boat fishery depends primarily on one or two age groups. Heavy exploitation of these age groups could conceivably reduce the production of the total fishery and the number of spawners for the future. Rothschild and Yong (1970) have shown that the Japanese longline catch (i. e. spawners) decreased during the period of 1949-1961, but these authors were not able to show a concurrent relationship to the U. S. troll fisheries. Although no evidence has been found for a relationship between the size of the spawning group and the size of the recruit group (Suda, 1959), such a relationship must exist at some minimum spawning group size.

Gulland and Boerema (1973) discuss management guides for fisheries which show large changes in year-class strength, such as albacore. They argue that the most advantageous objective to achieve a maximum sustained yield is to define a constant fishing mortality (i.e. amount of standard units of effort) in fisheries which do not exhibit marked density-dependent changes in natural mortality or growth. Royce (1972), however, points out the economic problems that occur in most fisheries; during periods of good catches, there is a tendency to overcapitalize the fishery. Later, as catches decline, effort remains high for several years and inflicts a greater than optimum fishing mortality. Clark (1973) has demonstrated that exploiters may consider over-exploitation, even to extinction, to be more profitable than conservation of some fish stocks. Clark urged continual public surveillance and control of the yield and condition of fish stocks.

The diversity of the Pacific Northwest albacore fleet (Roberts, 1972) may serve to reduce fishing mortality of albacore during years of low abundance, since the small boats can easily gear up for salmon, another valuable northwest species available during the albacore season. Occasionally, however, all commercial species are scarce and boats either move to other areas of abundance or absorb the loss by not fishing. If this latter condition persists for several years, some fishermen may leave the fleet permanently. Likewise, when a year-class appears to be very abundant, more fishermen enter the fleet and effectively harvest the additional numbers of fish.

An example of the difficulties and complexities of interpreting albacore statistics is provided by the albacore fishery of the North Atlantic Ocean, the home of an albacore fishery very similar to the albacore fishery in the North Pacific. Troll boats fish for two- and three-year old albacore in the Bay of Biscay off France and Spain, while Japanese, Chinese and Korean longliners fish for mature albacore farther offshore. Dao (1973) has compared catches of immature fish taken by troll boats with catches of mature fish taken by longliners. He found an inverse relationship (correlation coefficient of 0.853 with 7 d.f.) between the catch per unit of effort of troll boats and the number of hooks placed by longliners four and five years previously. On the other hand, Beardsley (1971) stated that the maximum sustainable yield from the North Atlantic longline fishery could not be estimated (up to 1968) with conventional population models because the population abundance, represented by catch per unit of effort, had not declined sufficiently to allow a description to be made of the population dynamics. Beardsley suggested that increased longline fishing would result in increased yield with no major decline in the catch per unit of effort. The apparent disparity between these two views illustrates a familiar problem in marine fisheries, namely that each fishery is complex and that simple models cannot be extended to explain most variations.

It is in this perspective that the North Pacific albacore may represent either a near-maximally exploited stock, or may have the capacity to support additional yield. The answer may lie in data which have been collected for years by several nations. However, it has been less than two years since a cooperative exchange of catch and effort statistics between nations has begun (R. M. Laurs, pers. comm.). Improvement of these statistics and continued anlaysis may provide insight into the management of this very important food source.

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APPENDICES

APPENDIX I

Estimation of relative fishing power of albacore boats.

The abundance of a marine fish stock must be inferred by statistical means. The parameter most often used to estimate abundance is the catch per unit of effort. The obvious assumption is made that the catch per unit of effort is proportional to the true abundance of fish. The basic modeling relating catch to fish abundance is

$$C_{ij} = q_i \cdot f_{ij} \cdot \overline{P}_j \cdot \varepsilon ij \qquad \text{(Beverton and Holt, 1957)}$$

or

$$\frac{C_{ij}}{f_{ij}} = q_i \cdot \overline{P}_j \cdot \varepsilon ij \qquad (1)$$

where C_{ij} = the catch of the ith fishing treatment in the jth area-date stratum

q_i = the catchability coefficient of the ith treatment.

f_{ij} = the amount of fishing effort by the ith treatment in the jth area-date stratum.

$\overline{P}j$ = the average fish density in the jth area-date stratum.

eij = the log-normally distributed random error term.

The ith fishing treatments may be different individual vessels, vessel types, vessel characteristics (horsepower, length, etc.) or gear types (number of troll lines, etc.) or any other classification of fishing treatment. Individual vessels will be the treatments in this study to allow an examination of other vessel characteristics in relation to individual fishing power. Each treatment is assumed to be independent of the other treatments and between area-date strata. Furthermore, the unit of effort is assumed to operate independently and is constant through the area-date strata.

Transforming the model to a logarithmithic scale we have

$$\ln \left(\frac{C_{ij}}{f_{ij}}\right) = \ln q_i + \ln \overline{P}_j + \ln \varepsilon ij$$

which may be written as

$$Y_{ij} = \alpha_i + \beta_j + \varepsilon_{ij}. \qquad (2)$$

This results in a linear two-factor analysis of variance model which Robson (1966) suggested for estimating the relative fishing power (catchability) of fishing vessels. More recently a computer program called FPOW was written by Berude and Abramson (1972) which utilized Robson's model to estimate relative fishing power, relative population density (abundance), confidence intervals and corrections for bias in the parameter estimates. The following description of the program is from Fox (1971).

The parameters α_i and β_j of equation (2) cannot be estimated directly because the model design matrix is singular and no solution exists. By standardizing these parameters estimates of relative catchability and relative abundance can be obtained as

$$\rho i = \frac{q_i}{q_s} \quad \text{and} \quad D_j = \frac{\overline{P}_j}{P_s}$$

where the s denote the treatment and area-date selected as the standard. Standardized fishing effort was obtained by

$$f_{sj} = \Sigma \rho i \cdot f_{ij}$$

such that $C_j = q_s \cdot f_{sj} \cdot \overline{P}_j$,

which provided the standardized catch for the particular fishing treatment.

To obtain the estimate of the relative abundance of fish equation (2) can be rewritten as

$$Y_{ij} = \alpha s + \beta s + (\alpha i - \alpha s) + (\beta j - \beta s) + \acute{\varepsilon}_{ij}$$

or $$Y_{ij} = \mu + \acute{\alpha} i + \acute{\beta} j + \acute{\varepsilon}_{ij} \qquad (3)$$

where $\mu = \alpha s + \beta s$, $\acute{\alpha} i = (\alpha i - \alpha s)$ and $\acute{\beta}_j = (\beta_j - \beta_s)$.

The design matrix for equation (3) is not singular and therefore the parameters μ, $\acute{\alpha}_i$ and $\acute{\beta}_j$ are estimatable.

FPOW provides estimates of relative fishing power and relative abundance as

$$\hat{\rho}_i = e^{\hat{\alpha}' i}$$

$$\hat{D}_j = e^{\hat{\beta}'_j}$$

where $\rho_s = 1$ and $D_s = 1$ by definition. Because the estimates are logarithms they are biased (Laurent, 1963). FPOW provides an approximate correction for this bias using a Taylor series expansion of the estimate about its true value. The program also computes the 95% confidence intervals about the estimates of $\hat{\rho}_i$ and $\hat{D}_j$.

The final output of the program provides the desired parameter of apparent relative abundance in each 1° latitude x 1° longitude rectangle with appropriate confidence intervals. This parameter is of interest in itself to provide information for an examination of the spatial distribution of albacore abundance over the area of the fishery and the temporal trends of albacore abundance throughout the fishing season.

APPENDIX II

Questionnaire submitted to high-liners and low-liners. Questions marked with an asterisk (*) distinguish between years, as in question 1.

	High-liners	Low-liners
*1	How many years have you fished commercially?	
	1968) 13, 45, 50	11, 36
	1969) 8, 24, 25, 25, 34	15, 15, 16, 27
	1970) 6, 18, 26, 46, 49	20, 27
*2.	How many years have you fished commercially for albacore?	
	8, 25, 28	11, 27
	8, 24, 25, 25, 28	10, 13, 16, 27
	3, 8, 26, 30, 36	9, 18
*3.	Have you used the same boat during all the years you fished for albacore?	
	Yes - 2, No - 1	No - 2
	No - 5	Yes - 1, No - 3
	No - 5	Yes - 1, No - 1
4.	If you have changed boats, what is the biggest advantage your new boat had over your old boat?	
	Comfort - 4, Endurance - 5	Comfort -2, Capacity - 3
	Greater Capacity - 4, Size - 3	Better equipped - 5, Sea-worthy - 1
	Seaworthiness - 4	
5.	Do you fish only for albacore or do you fish for other species of fish too?	
	Salmon - 6, Crabs - 2	Salmon - 7, Bottomfish - 1
	Others - 4, Only albacore - 1	Albacore only - 1, Crabs - 1
6.	What percentage of your income is from albacore, roughly?	
	60-70% - 3	60-70% - 2
	70-80% - 5	70-80% - 5
	80-90% - 1	100% - 1
	90-100% - 2	
7.	a) Do you feel your present boat is just right for catching albacore?	
	Yes - 7, No - 3	Yes - 2, No - 5
	b) or would you make changes, such as new prop, hydraulics, length, capacity, etc.?	
	Prop reduction - 1	Size - 4, Capacity - 4
	Size - 1	Endurance - 1
	Bait tank - 1	

8. Are there one or more major characteristics that describe the "ideal" albacore boat, besides the captain and crew? If so, what are they?

Size - 4, equipment (radios) -4 Endurance - 3, Seaworthiness - 4 Quiet - 2, Refrigeration - 1	Schooner style - 1, size - 4 equipment - 4, endurance - 1 seaworthiness - 3

Please answer the following questions as they applied to the 1968, 1969 or 1970 seasons off Oregon and Washington.

*9. As you leave port for an albacore fishing trip, what information do you use to tell you where to fish?

1968) Water Temp. and Color - 1, Radio - 1, Birds - 1, knowledge from previous years - 1	Dock talk - 1, Radio - 2
1969) Radio - 6, Experience - 3	Radio - 6, Water Temp. - 1, Luck - 1
1970) Water Temp. and Color - 2 Experience - 4, Radio - 4	Experience - 1, Radio - 1, Dock Talk - 1, Research Boat Reports - 1

10. Do you and one or more boats fish together, exchanging information?

Yes - 12, No - 2	Yes - 5, No - 0, Occasionally - 3

Do you think more fish are caught by each boat using this fishing method?

Yes - 11, No - 0, ? - 2	Yes - 5, No - 0, Usually - 2

11. From your experience do you think the fleet stays pretty much on the major concentrations of albacore throughout the season?

Yes - 9, No - 3, ? - 1	Yes - 8, No - 1

12.

a) Do you find albacore to be mostly in one location? Yes - 2, No - 10	Yes - 1, No - 4 Sometimes - 3
b) or do you find albacore scattered over the grounds? Yes - 7, No - 0, Sometimes - 4	Yes - 4, No 0, Sometimes - 3

13. Do you find that when the albacore fishing is good in one area that it's good in other areas too, say within 100 miles?

Yes - 4, No - 0, Sometimes - 9	Yes - 4, No - 1, Sometimes - 3

*14. a) Do you try to stay with the fleet during the whole season?

Yes - 0, No - 3, Sometimes - 0	Yes - 0, No - 1, Sometimes - 1
Yes - 0, No - 4, Sometimes - 0	Yes - 0, No - 4, Sometimes - 0
Yes - 3, No - 2, Sometimes - 0	Yes - 0, No - 2, Sometimes - 0

b) or do you scout out albacore away from the main fleet?

Yes - 3, No - 0, Sometimes - 0	Yes - 1, No - 0, Sometimes - 1
Yes - 5, No - 0, Sometimes - 0	Yes - 3, No - 0, Sometimes - 1
Yes - 3, No - 0, Sometimes - 2	Yes - 0, No - 1, Sometimes - 1

c) Do you feel you risk lower catches when you leave the area of the fleet?

Yes - 1, No - 2, Sometimes - 0	Yes - 1, No - 1, Sometimes - 0
Yes - 1, No - 2, Sometimes - 2	Yes - 1, No - 3, Sometimes - 0
Yes - 2, No - 2, Sometimes - 1	Yes - 1, No - 1, Sometimes - 0

d) What determines whether you stay with the fleet or not?

Scores in the fleet - 3,	Scores in the fleet - 2,
Fleet size - 1	Fleet size - 1
Scores in the fleet - 0	Scores in the fleet - 2
Fleet size - 3	Fleet size - 1
Scores in the fleet - 3	Scores in the fleet - 2
Fleet size - 2	Fleet size - 1

15. a) On days when fishing is poor, do boats tend to scatter?

Yes - 12, No - 0	Yes - 8, No - 0

b) On days when fishing is good, do boats tend to concentrate on the fishing grounds?

Yes - 11, No - 0	Yes, 7, No - 0

c) When the boats are concentrated, do your catches decline with time?

Yes, 12, No - 0	Yes - 7, No - 0

d) Do you feel this drives the fish down, or slows the bite?

Yes - 9, No - 0, Sometimes - 1	Yes - 7, No - 0

e) Is the duration of the bite dependent on the number of boats in the area?

Yes - 6, No - 2, Sometimes - 5	Yes - 2, No - 2, Sometimes - 3

16. Roughly, what percentage of a trip's success is due to

a) your skill at finding fish?

0 to 24% - 2	0 to 24% - 4
25% to 49% - 2	25% to 49% - 1
50% to 74% - 6	50% to 74% - 2
75% to 100%-0	75% to 100%-0

b) your crew's efforts and abilities?

0 - 24% - 5	0 - 24% - 4
25 - 49% - 0	25 - 49% - 0
50 - 74% - 0	50 - 74% - 0
75 - 100%- 0	75 - 100%- 0

c) luck?

0 - 24% - 2	0 - 24% - 3
25 - 49% - 3	25 - 49% - 0
50 - 74% - 5	50 - 74% - 2
75 - 100%- 0	75 - 100%- 0

d) your boat?

0 - 24% - 3	0 - 24% - 3
25 - 49% - 2	25 - 49% - 1
50 - 74% - 2	50 - 74% - 2
75 - 100%- 1	75 - 100%- 0

e) other?

Other boats, good information	Persistence, hard work determination

17. In regard to staying in an area or leaving it, on the average how many miles do you travel on days when your daily catch is:

a) Less than 50 fish?

50 - 99 - 1	0 - 49 - 1
100 - 149 - 4	50 - 99 - 1
150 - 200 - 0	100 - 149 - 0
	150 - 200 - 1

b) More than 100 but less than 150?

0 - 24 - 1	0 - 24 - 3
25 - 49 - 3	25 - 49 - 0
50 - 75 - 1	50 - 75 - 0

c) More than 150 fish but less than 250?

0 - 9 - 1	0 - 9 - 4
10 - 19 - 0	10 - 19 - 0
20 - 30 - 3	20 - 30 - 1

d) More than 250?

0 - 9 - 1	0 - 9 - 5
10 - 19 - 1	10 - 19 - 0
20 - 30 - 2	20 - 30 - 0

18. Do you have any problems in finding a crew?

Yes - 2, No - 11	Yes - 1, No - 6

19. During 1968 did you receive any daily information on albacore fishing from government or other organization's radio broadcasts?

Yes - 3, No - 9	Yes - 3, No - 4

20. During 1969 and 1970 did you listen to the OSU Albacore Central broadcasts at 10:15 a. m. and 10:15 p. m. ?

Yes - 6, No - 7	Yes - 6, No - 2

21. Did you use the information from the Albacore Central broadcasts in planning your fishing location for the next day?

Yes - 4, No - 9	Yes - 4, No - 4

22. How could a daily radio broadcast be improved over those in 1969 and 1970?

a)	More weather information	6	7
b)	More oceanographic information	3	3
c)	More locations of high fish catches	5	2
d)	Other _____		

Aircraft coverage; survey boats; broadcasts are useless	More of everything; broadcasts are always out of date; broadcasts are a waste of time and money.

23. a) Would you cooperate by reporting your location and catch to a central agency?

Yes - 2, No - 11	Yes -4, No - 2

b) If not, why?

Research has produced nothing; It concentrates boats in one area while leaving other areas unfinished; good boats already know what is going on; doesn't like being a "target."	Does no good; fleet is too big now; wastes fishing time while writing; let others do it.

24. Who do you feel benefits from albacore advisory broadcasts?

a)	the whole fleet	6	6
b)	yourself	0	1
c)	just the less successful fishermen	6	2
d)	just the most successful fishermen	0	0

[one respondent felt the broadcast personnel benefited the most.]

25. If you benefited from the 1969 and 1970 broadcasts, how did you benefit?

a)	saved searching time	1	3
b)	found better fishing grounds	0	2
c)	more aware of weather conditions	6	4
d)	other	0	0
e)	didn't benefit	5	2

26. Do you wish to have a copy of the results of this questionnaire sent to your address?

Yes - 10, No - 2	Yes - 8, No - 0

[At least five boats stated that survey boats working throughout the season over the entire fishing area would be of greater benefit than daily broadcasts based on fishing boat reports.]