THE NORTH PACIFIC ALBACORE—AN IMPORTANT VISITOR TO CALIFORNIA CURRENT WATERS

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ABSTRACT

The North Pacific albacore, *Thunnus alalunga,* is a highly migratory species, valuable to domestic and foreign fisheries. Albacore are found off the west coast of North America from about central Baja California to British Columbia, Canada, from late spring through fall. U.S. fishermen traditionally harvested the resource with surface gear within a few hundred miles of the shore until the mid-1970s, when an increasing number of West Coast- and Hawaiian-based jig vessels began operating from slightly west of the date line eastward across the North Pacific. A U.S. longline subsurface fishery also appears to be developing during winter beyond 1200 miles off southern California. The albacore is also highly sought after along the U.S. west coast by a large number of sportfishermen.

At the present time none of the North Pacific albacore fisheries is under management. Statistics and analysis currently available indicate that the resource is healthy. Recent estimates of MSY range from about 92,000 MT to 166,000 MT. Since the early 1960s, total catches for all fisheries harvesting albacore in the North Pacific have fluctuated; during the past decade they have ranged from about 70,000 MT to 124,000 MT.

Results from recent tagging studies suggest (1) that there are at least two substocks of fish constituting the North Pacific albacore population and (2) that these substocks have different migratory patterns. Off North America the separation in the proposed substocks occurs at Cape Mendocino, California, near 40°N. The proposed northern substock of fish makes trans-Pacific migrations between the eastern and western North Pacific, resulting in an exchange of fish between the northern area of the U.S. fishery and the Japanese livebait and gill net fisheries, and the longline fishery west of 180°. The proposed southern group of fish appear to enter the U.S. fishery south of about 40°N and are also fished by the longline fisheries east of 180°.

The migration, distribution, availability, and vulnerability of albacore are markedly influenced by oceanographic conditions in the North Pacific, notably by oceanic fronts. Recent research using acoustic telemetry methods to determine the location and swimming depth of free-swimming albacore, in conjunction with oceanographic observations made by ship and satellite suggests that water clarity's effect on the tuna's ability to see its prey is an important mechanism underlying the aggregation of tuna in the vicinity of oceanic fronts.

RESUMEN

Thunnus alalunga, albacora del Pacífico Norte, es una especie que efectúa amplias migraciones, manteniendo pesquerías nacionales y extranjeras de elevado valor económico. *T. alalunga* se encuentra desde finales de primavera hasta finales del otoño en aguas de las costas occidentales de Norte América, aproximadamente desde la parte central de Baja California (México) hasta la Columbia Británica (Canadá). Los pescadores de los Estados Unidos utilizan artes que operan en aguas de superficie, abarcando una zona que se extiende varios cientos de millas mar afuera; pero desde mediados de la década de 1970-1980, aumentaron los barcos al curricán en la costa del oeste y los de base en Hawaii, y así esta pesquería va avanzando en el Pacífico progresivamente hacia el este desde los 180° de longitud. Los Estados Unidos pescan con palangre durante el invierno, abarcando aguas más profundas, extendiéndose a más de 1200 millas del Sur de California. El albacora es también muy apreciado en la pesca deportiva, que opera a lo largo de las costas occidentales de los Estados Unidos.

Hasta ahora ninguna de las pesquerías de albacora ha sido sometida a regulaciones. Las estadísticas y análisis de los datos parecen indicar que esta pesquería logra mantenerse en buenas condiciones. Estimaciones recientes indican que las reservas de estas poblaciones alcanzan de las 92,000 a las 166,000 Toneladas métricas. Desde principios de la década de 1960-1970, las capturas totales, incluyendo todas las pesquerías de albacora en el Pacífico septentrional, han fluctuado oscilando durante la década pasada entre 70,000 hasta 124,000 Toneladas métricas.

Los resultados obtenidos mediante marcado de peces sugieren que en el Pacífico Norte hay dos poblaciones de albacora, las cuales presentan distintas rutas migratorias. La separación de estas propuestas pobla-

[Manuscript received May 13, 1983.]

ciones en la zona de América del Norte, se presenta en las inmediaciones de Cabo Mendocino, California, aproximadamente a los 40°N. Los peces de la propuesta población nórdica efectuan migraciones transoceánicas entre el Pacífico oriental y occidental, resultando así un intercambio de peces entre la pesquería del norte de los Estados Unidos y las pesquerías japonesas con cebo vivo y trasmallos y la pesquería con palangre al oeste de 180°. El propuesto grupo meridional de peces entran al parecer la pesquería de los Estados Unidos al sur de los 40°N, y también se pescan con palangre al este de los 180°.

La migración, distribución, presencia y vulnerabilidad del albacora se ven influidas notablemente por las condiciones oceanográficas del Pacífico Norte, principalmente por los frentes oceánicos. Investigaciones recientes utilizando métodos telemétricos acústicos para determinar la distribución y localización en profundidad del albacora, en conjunción con observaciones oceanográficas efectuadas desde barcos y satélites, revelan que el comportamiento de agrupación de estos peces en las inmediaciones de los frentes oceánicos está condicionada más por el alimento que por los mecanismos termo-fisiológicos.

INTRODUCTION

Albacore tuna, *Thunnus alalunga* (Bonneterre), is a highly migratory tuna that supports important U.S. commercial and recreational fisheries and several foreign fisheries in the North Pacific. Over the past decade fisheries operating on North Pacific albacore have expanded, and research has yielded new information about this valuable resource. The purpose of this paper is to give an overview of the catch, effort, and catch-per-unit-effort trends of fisheries harvesting the North Pacific albacore and to provide information on the condition of the stock. Also, results from selected research investigations dealing with albacore oceanography and biology will be given.

FISHERIES HARVESTING NORTH PACIFIC ALBACORE

Japan and the U.S. account for the majority of the catches of North Pacific albacore—approximately 70% and 28%, respectively, from 1961 through 1978. Canada, Korea, and Taiwan each land about 0.5% to 1% of the total catch.

Historically, the Japanese have had two distinct fisheries harvesting albacore—a pole-and-line surface fishery operating during spring and summer and a longline subsurface fishery operating during winter. In 1978 a third Japanese fishery gained importance with the dramatic expansion of summer gill net fishing targeted on albacore.

For several decades the pole-and-line fishery extended eastward from near the coast of Japan to about 150°E; however, in the early 1970s it was expanded to east of the date line. The Japanese longline fishery is executed across much of the North Pacific, and by 1981 gill net operations had spread almost entirely across the North Pacific to within several hundred miles of the North American coast.

The U.S. fishery for albacore, which began in the early 1900s, uses surface trolling and pole-and-line fishing gears (Dotson 1980). The fishing takes place during summer and autumn in waters within a few hundred miles of the coast between central Baja California and British Columbia. Major geographical variations in the location of the fishing occur; during some periods it is centered in waters off the Pacific Northwest, during others, off southern-central California (Laurs et al. 1976). These geographical shifts in the location of the fishing have been linked to variations in environmental conditions (Clark et al. 1975). In 1975 the U.S. troll fleet began a broad extension of its operating range (Laurs and Nishimoto 1977). In recent years 75 to 100 vessels have started to fish near the date line about May, and to operate eastward across the mid-North Pacific to end the season in autumn off the coast of the U.S.

Recently, the U.S. albacore industry conducted a series of exploratory fishing operations to evaluate the feasibility of a winter U.S. longline fishery for albacore in the eastern Pacific (Laurs et al. 1981). The results of the experiments are encouraging, and a number of vessels have indicated a desire to participate in this new albacore fishery for the U.S.

CATCH, EFFORT, AND CATCH-PER-UNIT-EFFORT TRENDS

Catch Trends

Estimated annual catches of North Pacific albacore by country and gear type are given in Figure 1 for years 1961-79 (Bartoo and Kume 1982a) and in Table 1 for years 1962-81 (Bartoo and Kume 1982b). Since the early 1960s, total catches of North Pacific albacore fluctuated annually, but showed an increasing trend until 1976, when a peak of nearly 124,000 MT was recorded. During the early and middle 1970s, the increased catches reflected a rapid development of the Japanese pole-and-line fishery. In 1977, the catch declined by 40% compared to the average of the preceding 6 years; the decline was due primarily to the sharply reduced Japanese pole-and-line catch. Catches in 1978 recovered to the 1974-77 average of 97,000 MT, but in 1979 the catch again declined, mainly because the U.S. catch fell to its lowest point in nearly 40

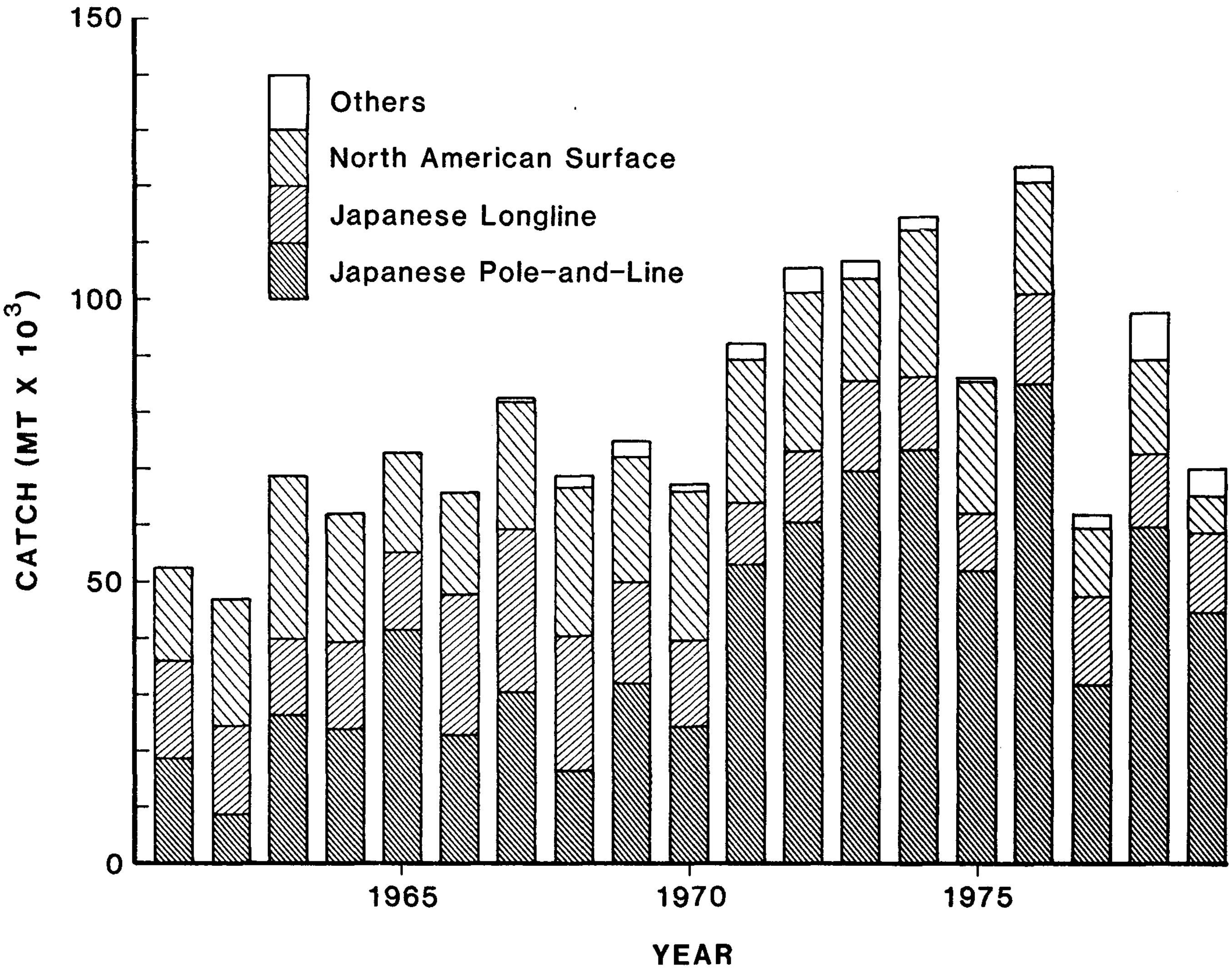

Figure 1. Annual catches of North Pacific albacore in the Japanese pole-and-line, Japanese longline, and North American surface fisheries, 1961-79 (Bartoo and Kume 1982a).

years—a little more than 7,000 MT. In 1980, the total catch increased to over 74,000 MT. It appears that the 1981 total catch was about 76,000 MT. The 1981 Japanese pole-and-line catch of albacore declined to about 26,000 MT, its lowest level since 1970, but this was offset by a dramatic increase in the Japanese drift gill net catch to nearly 20,000 MT.

Effort Trends

Effort trends within the U.S. troll fishery and the Japanese pole-and-line and longline fisheries are shown in Table 2 (Bartoo and Kume 1982b). The U.S. troll effort has remained rather stable except for 1972 and 1979 when the amounts of effort exerted were high and low, respectively. Effort by the Japanese longline fishery, the longest historical series available, shows considerable variability, but is relatively constant in the late 1970s at a level corresponding to about 75% of that in the 1960s and about 150% of that in the early 1970s. The Japanese pole-and-line effort increased substantially in the 1970s—primarily as the result of larger vessels entering the fishery—to levels almost triple those of the 1960s. In recent years the number of vessels in the 100 to 200 gross ton class, which account for more than 80% of the Japanese pole-and-line albacore catch, has declined (Bartoo and Kume 1982b). However, the number of large (greater than 100 gross tons) drift gill net vessels has been increasing, and the gill net fishery has expanded its operations farther eastward, with some fishing as far east as 135°W[1].

[1]Bartoo, N. 1982. United States albacore surface fishery catch distribution determined from logbook records. Seventh North Pacific Albacore Workshop. Working Paper NPAL/82/12, 26 p.

TABLE 1
Catches for North Pacific Albacore in Metric Tons, 1952-81

	Japan					Taiwan & Korea	United States				Canada	
Year	Pole-and-line	Long-line	Gill net	Other gear	Total	Longline	Baitboat	Jigboat	Sport	Total	Jigboat	Grand Total
1952	41,386	26,687		237	68,710			23,843	1,373	25,216	71	93,997
1953	32,921	27,777		132	60,830			15,740	171	15,911	5	76,746
1954	28,069	20,958		38	49,065			12,246	147	12,393	—	61,458
1955	24,236	16,277		136	40,649			13,264	577	13,841	—	54,490
1956	42,810	14,341		57	57,208			18,751	482	19,233	17	76,458
1957	49,500	21,053		151	70,704			21,165	304	21,469	8	92,181
1958	22,175	18,452		124	40,731			14,855	48	14,903	74	55,708
1959	14,252	15,502		67	30,121			20,990	—	20,990	212	51,323
1960	23,156	17,369		76	42,601			20,100	557	20,657	5	63,263
1961	18,636	17,437		268	36,341		2,837	12,054	1,355	16,246	4	52,591
1962	8,729	15,764		191	24,684		1,085	19,753	1,681	22,519	1	47,204
1963	26,420	13,464		218	40,102		2,432	25,142	1,161	28,735	5	68,812
1964	23,858	15,458		319	39,635	26	3,411	18,389	824	22,624	3	62,283
1965	41,491	13,701		121	55,313	16	417	16,461	731	17,609	15	72,953
1966	22,830	25,050		585	48,465	16	1,600	15,169	588	17,357	44	65,882
1967	30,481	28,869		520	59,870	17	4,113	17,814	707	22,634	161	82,682
1968	16,597	23,961		1,109	41,667	15	4,906	20,441	951	26,298	1,028	69,008
1969	32,107	18,006		1,480	51,593	21	2,996	18,826	358	22,180	1,365	75,157
1970	24,376	15,372		956	40,704	23	4,416	21,039	822	26,277	354	67,358
1971	53,198	11,035		1,262	65,495	24	2,071	22,496	1,175	25,442	1,587	92,548
1972	60,762	12,649	1	921	74,333	25	3,750	23,600	637	27,987	3,558	105,903
1973	69,811	16,059	39	1,883	87,792	35	2,236	15,652	88	17,976	1,270	107,073
1974	73,576	13,053	224	1,065	87,918	40	4,777	20,177	739	25,693	1,207	114,858
1975	52,157	10,060	166	402	62,785	28	3,243	18,926	1,243	23,412	101	86,326
1976	85,336	15,896	1,070	1,394	103,696	37	2,700	16,314	766	19,780	252	123,765
1977	31,934	15,737	688	1,039	49,398	561	1,497	10,012	619	12,128	53	62,140
1978	59,877	13,061	4,029	3,209	80,176	53	950	15,700	871	17,512	23	97,773
1979	44,662	14,249	2,856	1,280	63,047	81	303	6,253	75	6,631	289	70,050
1980	46,743	14,660	2,986	1,516	65,988	—	382	7,599	174	8,155	212	—
1981	26,000	—	20,000	—	—	—	—	—	—	15,838	200	—

Remarks:
1. Figures for 1979-81 are preliminary.
2. Japanese longline catches for 1952-60 exclude minor amounts taken by vessels under 20 gross tons. Longline catches in weight are estimated by multiplying annual number of fish caught by average weight statistics.
3. Japanese pole-and-line catches include catches by research vessels.
4. United States jigboat catches include minor amounts taken by baitboats not submitting logbooks.
5. Jigboat catches for years 1952-60 include baitboat catches.
6. United States sport catch is a minimum estimate based on partial coverage.
7. Grand totals omit unknown but minor catches by longline and pole-and-line vessels of the Republic of Korea.

Catch Rate Trends (CPUE)

Nominal catch-per-unit-effort (CPUE) data for the U.S. troll fleet for 1961-70 are given in Laurs et al. (1976), and CPUE statistics for the major North Pacific albacore fisheries for 1961-81 are shown in Table 3 (Bartoo and Kume 1982b) and for 1961-79 in Figure 2 (Bartoo and Kume 1982a). CPUE within the U.S. troll fishery showed no apparent upward or downward trend from 1961-70, but declined from 1971-80. CPUEs in 1979 and 1980 were the lowest observed since records began. However, in 1981, CPUE increased to more than double the value for 1980. The catch rates over the long term have varied, being highest in the late 1960s when effort was unusually variable.

CPUE within the Japanese longline fishery showed a steady decline from the early 1950s through 1960, increased substantially through 1966, and then declined through 1971. Since then the trend in catch rate has been stable.

CPUE of the Japanese pole-and-line fishery showed a slight decreasing trend from 1962-80, except for relatively high values from 1970-76. A peak catch rate of 8 MT/fishing day was reported in 1974. The catch rate reached a low of about 3 MT/fishing day in 1977, then increased slightly before dropping to about 3 MT/fishing day again in 1981.

Condition of the Stock

In 1974 the Southwest Fisheries Center and the Far Seas Fisheries Research Laboratory in Shimizu, Japan, informally agreed to exchange research results

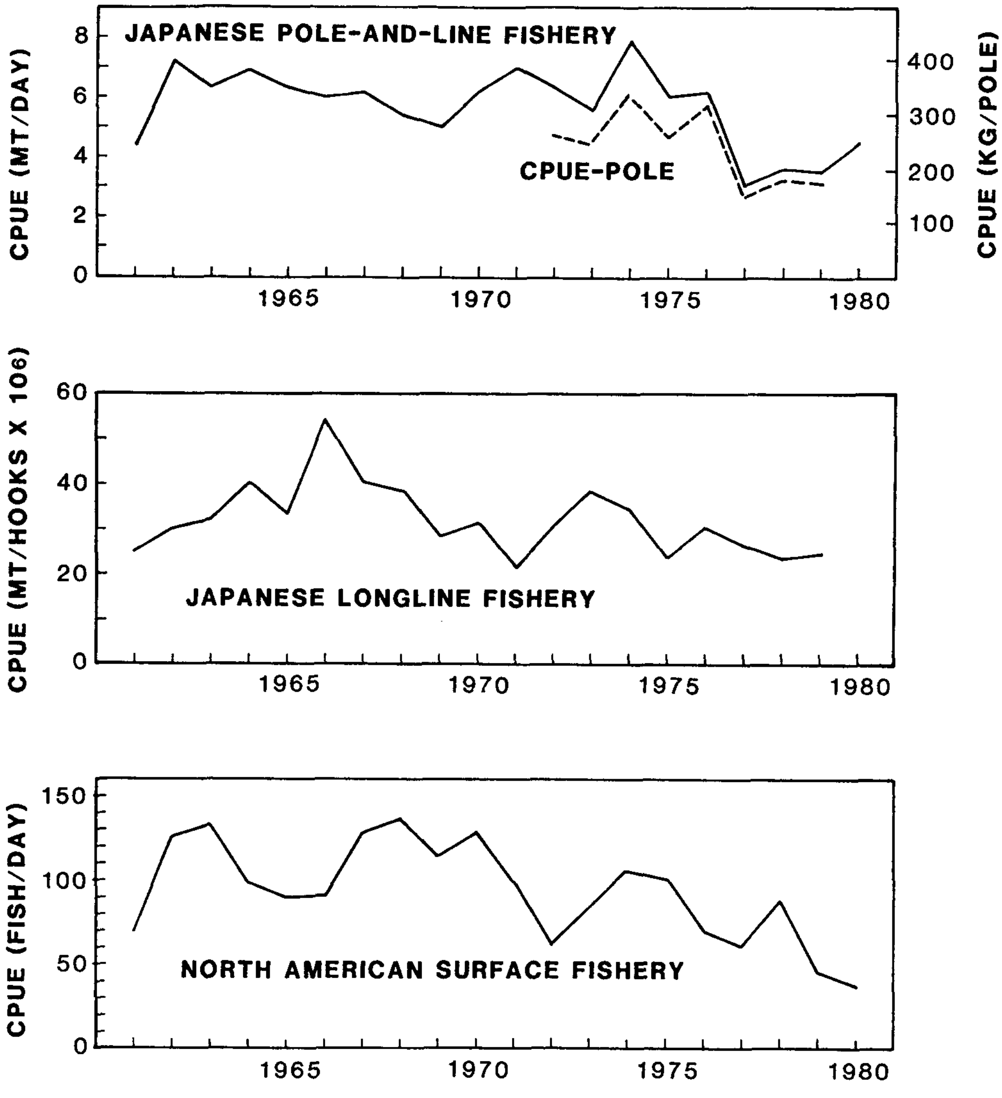

Figure 2. Annual catch rates of North Pacific albacore in the Japanese pole-and-line, Japanese longline, and North American surface fisheries, 1961-80 (Bartoo and Kume 1982a).

concerning the North Pacific albacore resource. In 1982 this agreement was extended to include the Pacific Biological Station at Nanaimo, Canada. There have been seven North Pacific Albacore Workshops held with scientists from the U.S. and Japan; in some cases scientists from Canada, Taiwan, and Korea participated. One of the objectives of the workshops is to share information for appraising the condition of the North Pacific albacore resource.

At the 1982 workshop a paper was presented on results of production model analyses based on updated abundance indices and effective effort statistics, and assuming a single stock[2]. The estimates of MSY ranged from 92,000 MT to 166,000 MT, depending largely on the assumed shape of the equilibrium yield-effort relationship. This range of estimates is consistent with results presented at past workshops. Participants at the workshop cautioned that critical assumptions underlying production model analyses may be difficult to satisfy when applied to albacore.

According to the report of the Seventh North Pacific Albacore Workshop (Bartoo and Kume 1982b),

> "Based on statistics and analyses currently available, the stock appears to be healthy. However, close monitoring is required, especially in view of increased effort in the drift gill net fishery, about which very little is known, and because of the declining catch-per-unit-effort in the major fisheries. Reliable assessment of the North Pacific albacore stocks remains a crucial task, beset by numerous problems. In particular, the measurement of effective effort is necessary, but is exceedingly difficult in the surface fisheries,

[2]Kume, S. 1982. An approach to evaluate the stock status of North Pacific albacore by production model analysis. Seventh North Pacific Albacore Workshop. Working Paper NPAL/82/11, 6 p.

TABLE 2
Estimated Effective Effort by Fishery for North Pacific Albacore, 1961-81

Year	Japan longline (hooks x 10^6)	Japan[1] pole-and-line (days)	Japan[1] pole-and-line (poles x 10^3)	U.S.[1] effort (days)
1952	283.0			
1953	311.1			
1954	409.6			
1955	395.3			
1956	389.1			
1957	346.4			
1958	384.3			
1959	373.7			
1960	455.5			
1961	432.0	4,235		25,255
1962	309.0	1,209		27,464
1963	259.0	4,200		31,456
1964	232.4	3,478		30,355
1965	242.7	6,628		24,945
1966	276.8	3,843		25,756
1967	434.8	5,005		26,453
1968	355.8	3,108		29,175
1969	361.2	6,447		28,528
1970	253.2	3,958		20,165
1971	255.2	7,631		44,015
1972	186.7	9,695	227.8	67,319
1973	173.5	12,685	287.8	32,031
1974	153.8	9,421	226.4	39,748
1975	158.1	8,766	204.5	35,449
1976	227.2	13,921	278.9	38,445
1977	256.2	10,609	203.4	32,292
1978	252.8	16,725	321.9	32,111
1979	278.7	12,761	252.3	17,924
1980	203.0	*	*	28,418
1981	*	*	*	20,945

[1]Japanese pole-and-line days are not the same as U.S. effort days.
*Data not available.

where oceanographic processes and weather conditions strongly influence fish availability and catchability. Further, stock recruitment processes are not understood, and many questions about stock structure remain unanswered. As pointed out in past workshops, these subjects should be placed high on the research agenda of the participating laboratories. In the meantime, sensitivity analyses are needed to better define the robustness of current assessment procedures and the direction and magnitude of possible biases."

STOCK STRUCTURE AND MIGRATION PATTERNS

There is a growing body of evidence (Brock 1943; Laurs and Lynn 1977; Laurs and Wetherall 1981) that North Pacific albacore are not as homogeneous as usually assumed (Clemens 1961; Otsu and Uchida 1963). Results from recent tagging studies (Table 4) suggest that at least two substocks constitute the North Pacific albacore population and that these substocks have different migratory patterns (Laurs and Nishimoto 1979). Fish belonging to a proposed northern substock migrate between the eastern and western North Pacific, causing an exchange of fish between the U.S. fishery north of about 40°N, the Japanese livebait and gill net fisheries, and the foreign longline fisheries west of 180°. The proposed southern group of fish has a different migration scheme from that of the northern group, and appears to enter the U.S. fishery south of about 40°N, and the longline fisheries east of 180°. Only a very small proportion of the southern group of fish appears to migrate between the eastern and western Pacific and enter the Japanese pole-and-line or gill net fisheries. Also, during a given fishing season there is virtually no exchange of fish in the U.S. fishery between the northern and southern groups, although there is a small amount of interannual exchange.

Laurs and Wetherall (1981) found that the growth rate of North Pacific albacore recaptured either off the coast of North America north of 40°N or in the western North Pacific off Japan was significantly lower than that for tagged fish recovered off North America south of 40°N during 1972-78. The differences in growth rate are consistent with differences in length frequencies of albacore caught off North America north and south of 38°N during the period when most recoveries were made (Laurs and Lynn 1977) and during earlier years (Brock 1943). Thus a variety of types of information including tag and recapture data, growth-rate analyses, and differences in size composition of fish caught in the U.S. fishery support the hypothesis that the North Pacific albacore is not a homogeneous population, but rather that there are at least two substocks.

DETERMINATION OF ABSOLUTE AGE

A major void in our understanding of albacore biology is an understanding of true size and age structure. The daily ring increment method for aging fishes (Pannella 1971) offers great promise for determining absolute age and growth rates for albacore. Results from an experiment with tetracycline injection at time of tagging and release have verified that daily rings are laid down on the otolith of the albacore (Laurs and Nishimoto 1981). The method is being applied to albacore otoliths, and valid data on absolute age and size structure will be available in the near future. Preliminary results indicate that the length at first birthday is about 35 to 40 cm FL.

INFLUENCE OF OCEANOGRAPHIC CONDITIONS ON ALBACORE

There is ample evidence that the migration routes and small-scale movements of albacore are markedly influenced by oceanographic conditions. For example, albacore fishing grounds in the western Pacific have been linked to oceanic fronts (Uda 1973). Also, the

TABLE 3
CPUE[1] Statistics for Major North Pacific Albacore Fisheres, 1961-80

Year	Japan Pole-and-line Fishing days	Japan Pole-and-line Poles	United States jig	Japan longline "Young" area[2]	Japan longline "Main spawning" area[3]	Japan longline Entire area[4]
1961	4.40		69.17	0.55	0.14	0.25
1962	7.22		124.59	0.67	0.14	0.30
1963	6.29		132.09	0.68	0.19	0.32
1964	6.86		97.61	0.90	0.19	0.40
1965	6.26		89.07	0.70	0.25	0.33
1966	5.94		90.45	1.20	0.27	0.54
1967	6.09	259	126.83	0.88	0.29	0.40
1968	5.34	227	135.23	0.84	0.29	0.38
1969	4.95	211	112.57	0.60	0.31	0.28
1970	6.13	261	127.39	0.66	0.27	0.31
1971	6.94	295	96.68	0.43	0.22	0.21
1972	6.25	266	61.08	0.63	0.30	0.30
1973	5.49	242	82.89	0.85	0.30	0.38
1974	7.81	325	105.17	0.64	0.30	0.34
1975	5.98	255	99.81	0.46	0.21	0.23
1976	6.13	306	69.22	0.66	0.21	0.30
1977	3.01	157	59.90	0.60	0.14	0.26
1978	3.58	186	86.80	0.52	0.17	0.23
1979	3.50	187	45.41	0.53	0.21	0.24
1980	4.44	268	36.78	0.72	0.26	0.33
1981	3.05	—	80.11	—	—	—

[1]Unit: MT/vessel-day and kg/pole-day for Japan pole-and-line; fish/vessel-day for United States jig; fish/100 hooks for Japan longline
[2]"Young" area is 25°-45°N from October to March and 30°-45°N from April to September.
[3]"Main spawning" area: 10°-25°N
[4]Entire area: 0°-45°N

seasonal migration of albacore into North American coastal waters has been found to be associated with the Transition zone and its frontal boundaries (Laurs and Lynn 1977). In addition, oceanographic conditions play an important role in the local concentrations and movements of albacore in U.S. coastal waters. Using concurrent ultrasonic tracking of free-swimming fish and oceanographic sampling, Laurs et al. (1977) found that albacore tend to aggregate in the vicinity of coastal upwelling fronts, presumably to feed, and to move away from the area when upwelling ceases and the front is no longer present.

TABLE 4
Summary of Where Tagged Albacore Were Recovered Relative to Area of Release

Area of Recovery	Area of release: Inshore south 40°N	Inshore north 40°N	Offshore 130°W
Inshore south 40°N	78%	7% (0.8)*	31%
Inshore north 40°N	5% (0.4)*	32%	30%
Japanese livebait	4.5%	48%	21%
Japanese longline			
East of 180°	2%	0%	0.5%
West of 180°	0%	2.5%	1.5%
Unknown			
U.S. fishery	11.5%	9.5%	16%
Japanese fishery	0%	1%	0%

*Percentage recovered same year of release.

Very little has been published concerning relationships between oceanographic conditions and the vertical distribution of albacore. However, Clemens (1961) hypothesized that the thermocline acts as a barrier to albacore and that variations in albacore availability in waters off the U.S. are related to variations in the topography of the 14°C (58°F) isotherm.

Laurs et al. (1980) examined the vertical distribution of free-swimming albacore, measured by acoustic telemetry, in relation to ocean vertical thermal structure, measured concurrently with expendable bathythermographs (XBTs). We found that tracked fish spend little time in the upper layer, where it has been generally believed immature albacore (< about 6 years old) are distributed. The fish spent much of their time in the thermocline and were often well below the thermocline. Fish were found in waters 2° to 5°C (4° to 10°F) below what has been thought to be the optimal temperature range for albacore (Clemens 1961). Also, in some instances the tracked fish underwent changes in depth distribution resulting in temperature changes of as much as 5°C (10°F) within 10- to 30-minute periods.

Recently Laurs and Austin (unpublished results) investigated the small-scale migration patterns of albacore in relation to oceanic frontal boundaries using ocean color and infrared satellite data collected contemporaneously with observations made from ships at sea. NIMBUS-7 Coastal Zone Color Scanner (CZCS) and NOAA 6 satellite AVHRR infrared data were collected in conjunction with field experiments where acoustic telemetering methods were used to track the horizontal and vertical movements of free-swimming albacore, and XBT observations were made to determine subsurface ocean thermal structure. Three albacore were tracked for approximately 24 hours and one for about 15 hours. The results showed that (1) total distances tracked ranged from about 40 to 60 km, with all fish remaining in the same parcel of warm water that was separated from waters to the north, south, and inshore by about a 2°C (4°F) temperature gradient as shown by infrared thermal imagery; (2) tracked fish spent most of the time in waters within and below the thermocline, and only small amounts of time in the upper mixed layer; (3) the fish exhibited marked vertical excursions in depth, with the range being larger during the day than at night; (4) the fish spent most time in waters with temperatures considerably lower than what has been generally believed to be the preferred temperature range for albacore; and (5) when changing depth, the fish, frequently within a 20-minute period, passed through a vertical gradient of temperature amounting to 6° to 7°C (12° to 15°F), or about 3+ times greater than the horizontal temperature gradient at the surface indicated by ship measurements and the infrared thermal imagery.

These findings indicate that the reasons that tunas aggregate on the warm side of surface temperature fronts—an economically significant phenomenon that has been observed on scientific cruises and is well known by fishermen—may not be related to thermal-physiological mechanisms (Neill 1976). Instead, Laurs and Austin speculate that one or more behavioral mechanisms related to feeding may be responsible. Ocean color measurements made by the CZCS in conjunction with the tracking study and with catches made by commercial fishing vessels[3] provide data that support this hypothesis.

The diffuse attenuation coefficient (k), a measure of water clarity measured by the CZCS, showed a gradient nearly coincident with the sea-surface temperature gradient pattern, with lower values of k in the warm waters and higher values in the cooler waters. The distribution of color boundaries indicated by the ratio of blue:green color bands measured by the CZCS was also similar to the gradient pattern observed in the diffuse attenuation coefficient (k).

The results show that the albacore remained in water that had higher clarity than adjacent waters. This suggests that water clarity's effect on the tuna's ability to see its prey may play a key role in the mechanisms underlying the aggregation of tunas on the warm, clear side of ocean surface thermal fronts.

[3]Fiedler, P. C., R. M. Laurs, and D. R. Montgomery. (MS) Albacore catch distribution relative to environmental features observed from satellite.

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