REVIEW AND ANALYSIS OF THE BLUEFIN TUNA, *THUNNUS THYNNUS*, FISHERY IN THE EASTERN NORTH PACIFIC OCEAN

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ABSTRACT

Northern bluefin tuna migrate from waters near Japan to the eastern North Pacific where they are fished primarily by purse seine. While annual catches fluctuate greatly, two major periods are identified. The average annual catch in the second period (1950-present) is nearly double that for the first period (1921-50) and is attributed to increased fishing effort by the "high-seas" tuna fleet operating off Baja California. The declining catch per unit effort in the second period and declining catches after 1963 are assumed to indicate declining abundance of bluefin tuna in the eastern North Pacific.

Length-frequency analysis reveals 1) significantly smaller bluefin tuna in U.S. waters than in waters off Baja California and 2) significant variation in mean lengths among years.

Analysis of tag-recapture data confirms seasonal northward migration and vulnerability to the fishery for as many as three fishing seasons. A catchability coefficient of 1.66×10^{-4}/boat-day and an annual instantaneous total mortality rate of 2.07, both estimated from the tag-recapture data, are used with summaries of fishing effort to calculate an average annual exploitation rate of 30% for bluefin tuna in the eastern North Pacific.

Purse seining for northern bluefin tuna, *Thunnus thynnus* Linnaeus, in the eastern North Pacific Ocean began about 1914, with the first large commercial landings in 1918 (Whitehead 1931). Prior to the development of this purse seine fishery, a sport fishery existed off southern California at Santa Catalina Island; and since bluefin tuna are difficult to catch by hook and line, elaborate fishing methods evolved such as using a kite to make the bait (flying fish) skip across the water (Clemens and Craig 1965). The Tuna Club of Avalon at Santa Catalina Island even awarded "blue buttons" to its members for catching the large and wary prize. Because of this difficulty in hooking bluefin, the commercial "high-seas" fleet did not fish for bluefin until the late 1950's, when most of the fleet had converted from pole-and-line gear to purse seines (Bell[2]).

Currently the bluefin fishery consists of a "wetfish" fleet, principally out of San Pedro, Calif.; a high-seas fleet mostly out of San Diego, Calif.; and since 1975, an expanding Mexican fleet mostly out of Ensenada, Baja California. The bluefin fishery extends along the coast of North America from Cabo San Lucas, Baja California, to Point Conception, Calif., and occasionally farther north (Table 1). The bluefin catch is composed mainly of 1-, 2-, and 3-yr-old fish, which appear to migrate to the eastern North Pacific from the western Pacific near Japan (Schultze and Collins 1977); however, older and much larger bluefin are reported and occasionally caught in the eastern North Pacific.

This paper reviews and analyzes the bluefin tuna fishery in the eastern North Pacific, using data collected by the California Department of Fish and Game (CFG) in cooperation with the Inter-American Tropical Tuna Commission (IATTC), and the National Marine Fisheries Service (NMFS) of the U.S. Department of Commerce.

CATCH AND EFFORT ANALYSIS

Although annual bluefin catches have fluctuated considerably in the eastern North Pacific (Table 2), two major periods are identified in the catch by a plot of a 10-yr running average (Fig. 1). During the first period, about 1921-50, total landings averaged 5,066 t (metric tons)/yr and were declining toward the end of the period. During this time, bluefin were landed almost ex-

[1]California Department of Fish and Game, c/o Southwest Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038.

[2]Bell, Robert R. 1970. Bluefin tuna *Thunnus thynnus orientalis* in the northeastern Pacific Ocean. Unpubl. manuscr. Calif. Dep. Fish Game, 350 Golden Shore, Long Beach, CA 90802.

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TABLE 1.—Total number of months in which bluefin tuna catch exceeded 50 t within a 1° area of latitude and longitude for the years 1957-69 and 1974. Each latitude and longitude indicates the southeast corner of the 1° area of consideration. Asterisks indicate the coastline.

Latitude	Longitude 125	120	119	118	117	116	115	114	113	112	111	110
40	1*											
34		1	*									
33		1	3	7	2*							
32			7	12	14*							
31				3	11	5*						
30					8	11	*					
29					3	6	2	*				
28			7			3	7	*				
27						1	8	4*				
26							2	10	7	*		
25								1	12	6*		
24									6	8	1*	
23										4	3	1*

TABLE 2.—Total landings of bluefin tuna by commercial (in metric tons (t)) and sport fisheries (no. fish) in the eastern North Pacific Ocean, 1918-81. Asterisks indicate no data available.

Year	Landings Commercial (t)	Landings Sport (no. fish)	Year	Landings Commercial (t)	Landings Sport (no. fish)
1918	2,722		1950	1,242	27
1919	6,800		1951	1,752	7,142
1920	4,776		1952	2,076	145
1921	894		1953	4,433	4,276
1922	1,275		1954	9,537	966
1923	1,460		1955	6,173	8,179
1924	1,470		1956	5,727	34,187
1925	1,725		1957	9,215	6,428
1926	2,960		1958	13,934	884
1927	2,222		1959	6,914	1,330
1928	6,215		1960	5,422	97
1929	3,414		1961	9,603	2,268
1930	9,943		1962	14,651	2,453
1931	1,603		1963	14,189	737
1932	486		1964	10,642	693
1933	254		1965	7,556	92
1934	8,327		1966	16,846	1,998
1935	11,418		1967	6,601	3,166
1936	8,584	2,920	1968	6,063	1,231
1937	5,758	4,020	1969	7,172	1,470
1938	8,041	11,927	1970	4,024	1,833
1939	5,369	9,909	1971	8,415	749
1940	9,058	6,878	1972	13,390	1,470
1941	4,318	*	1973	10,576	5,347
1942	5,826	*	1974	5,748	5,765
1943	4,617	*	1975	9,578	3,348
1944	9,228	*	1976	10,561	2,040
1945	9,341	*	1977	5,151	1,838
1946	9,993	528	1978	5,903	479
1947	9,452	2,194	1979	6,743	1,087
1948	2,961	104	1980	3,128	729
1949	1,991	1,841	1981	1,016	

clusively by the San Pedro wetfish fleet, which seasonally targets fishing effort on sardines, anchovies, mackerel, bonito, bluefin tuna, and other fishes, depending on fish availability, market price, and market demand (cannery orders).

During the second period, about 1950-present, annual landings increased to 16,846 t in 1966, then declined to 1,016 t in 1981, averaging 9,076 t for the period. At the beginning of this period, many of the high-seas boats that had converted to purse seining began catching large numbers of bluefin off Baja California, although they targeted their fishing on yellowfin tuna, *Thunnus albacares*, and skipjack tuna, *Katsuwonus pelamis*.

Two sources of data were used in summarizing total catch by area. The first, landings reported by CFG, separates pounds landed in California for 1918-79 into those caught in California waters and those caught south of California waters. These data reveal an overall decreasing trend in bluefin catch north of the international border; and, until about 1963, there was an overall increasing trend in total catches south of the international border (Fig. 2).

The second source of catch data also includes effort information and was compiled into a data base for summary and analysis. These data, representing about 87% of the catch during the periods 1954-69 and 1971-74, came from summaries of skippers' logs, from interviews with skippers and engineers, from CFG landing receipts, and from IATTC summaries of the high-seas fleet. Catch and effort in the data base are recorded by 1° areas of latitude and longitude. For this study, one boat-day or part of a boat-day of effort is assigned to a seiner for each day or partial day of purse seining or searching for tuna in the bluefin fishing range (north of lat. 22°N) during months in which bluefin were caught. Catch data, summarized by areas north and south of lat. 32°N (the parallel nearest the international border), show trends similar to the reported California landings for the same years (Fig. 3).

For comparison with the CFG reported California landings and for future consideration of the effects of Mexican regulations concerning

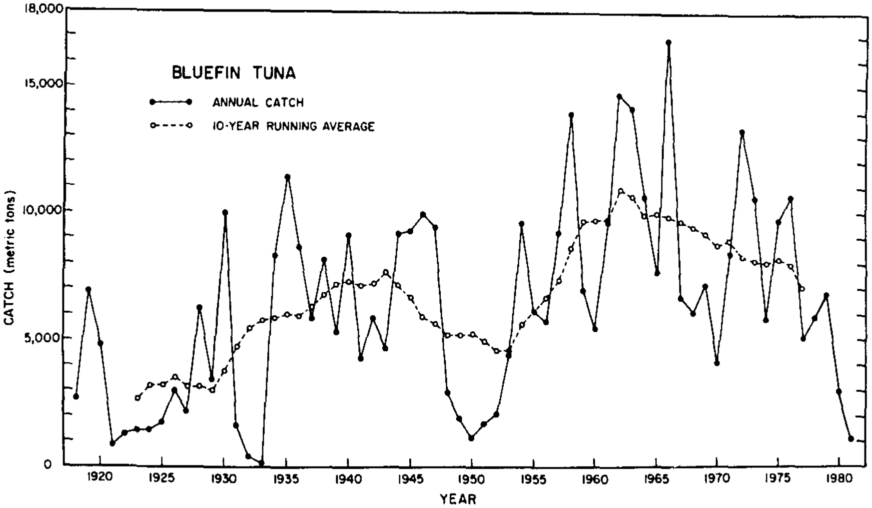

FIGURE 1.—Annual catches of northern bluefin tuna in the eastern North Pacific Ocean for the years 1918-81.

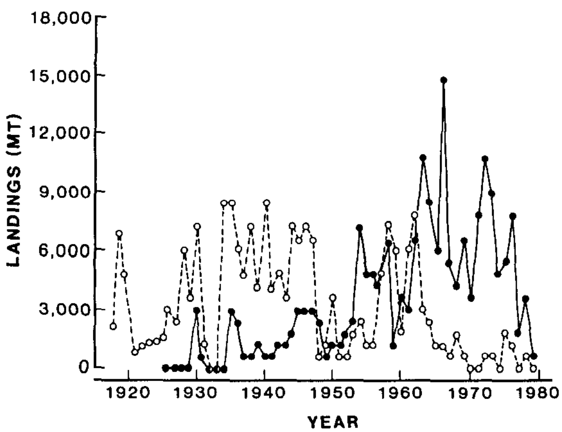

FIGURE 2.—Annual California landings (metric tons) of northern bluefin tuna caught north and south of the United States-Mexico international border, 1918-79. South is represented by solid circles and lines, north by open circles and broken lines.

the 200-mi exclusive economic zone, much of the data in this paper are separated into areas north and south of lat. 32°N. A better division from a biological standpoint would be north and south of lat. 29°N (Fig. 4).

The increase in California landings of bluefin caught south of the border during the 1957-66 period can be attributed to increased fishing effort, but the decline in catch north of the border cannot be explained by declining effort, since effort remained comparatively level throughout the period (Fig. 5). Because bluefin are valuable ($1,180/short ton in 1981) and because fishing effort north of the 32d parallel remained fairly constant, the decline in northern catches is attributed to a decrease in abundance in that area. During this period, increased catches south of the border appear to have offset the decline in catches to the north and to indicate the fish were intercepted before migrating northward. If this is true, the recent catch decline south of the border indicates declining bluefin abundance in the eastern North Pacific.

Catch and effort data summarized by latitude show a bimodal distribution centering just north of the 25th and 32d parallels (Table 3). The catches are concentrated in the period June-September, with the largest catches shifting northward during the fishing season (Fig. 4). Early in the

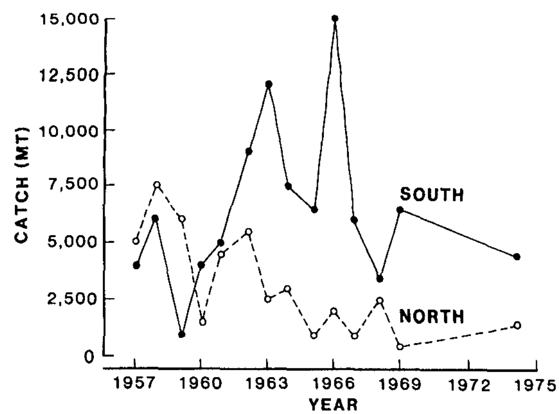

FIGURE 3.—Logged annual catches (metric tons) of bluefin tuna north and south of lat. 32°N for 1957-69 and 1974.

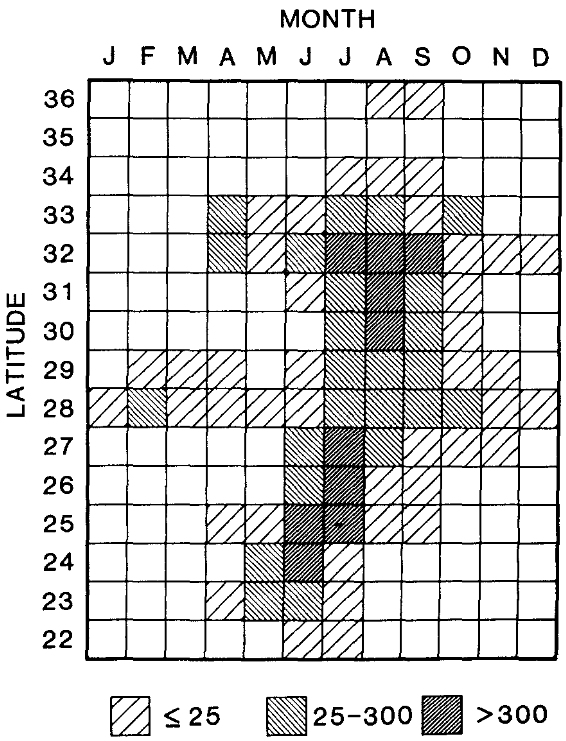

FIGURE 4.—Mean monthly catches of bluefin tuna ($\frac{\Sigma c}{13}$) for the period 1957-69 in metric tons per latitude. Totals are for areas between a given parallel and the next higher parallel.

TABLE 3.—Mean catch of bluefin tuna (metric tons (t)) and mean effort (boat-days) per latitude for the years 1957-69 and 1974.

Latitude	Mean catch (t)	Mean effort (boat-days)
36	3.29	1.16
35	0.00	0.29
34	23.06	6.67
33	452.60	75.27
32	2,160.34	460.39
31	1,048.67	214.39
30	622.63	155.11
29	544.82	135.96
28	561.82	170.37
27	615.46	253.89
26	734.33	359.86
25	981.61	629.56
24	543.07	348.16
23	234.57	353.10
22	0.44	122.02

season there are catches both in northern and southern parts of the bluefin range, whereas there are relatively few catches late in the season in the southern part of the range, thus indicating northward movement. This shift is also apparent in the number of occurrences of recorded bluefin

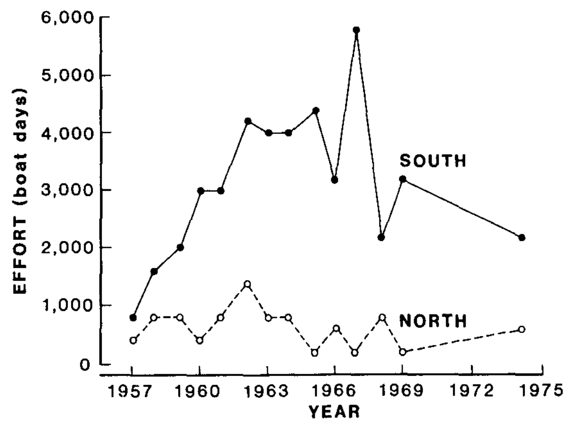

FIGURE 5.—Logged annual effort (boat-days/year) for bluefin tuna north and south of lat. 32°N for 1957-69 and 1974.

catch per month and latitude during the 1957-69 period (Table 4). The northward shift in location of the largest catches does not reflect a shift in fishing effort, since effort remains high in the south throughout the season (Fig. 6). Apparently, bluefin move northward or there is a shift in bluefin vulnerability towards the north during the fishing season.

Catch and effort data for 1957-69 summarized by vessel size indicate that seiners of 101-300 ton capacities accounted for more than 70% of bluefin landings and that smaller vessels tended to be phased out of the fishery and replaced by larger ones (Table 5).

CATCH-PER-UNIT-EFFORT ANALYSIS

Catch per unit effort (CPUE) is calculated for each year as total catch divided by total effort (Table 6). The relationship between the CFG data and the IATTC data (Bayliff and Calkins 1979) is expressed as a ratio which includes the origin. The ratio estimator $\Sigma y/\Sigma x$, obtained from years for which both CFG and IATTC measures of CPUE are available (1966-74), yielded a value of 1.01, by which the CFG values (1954-65) were multiplied to obtain IATTC equivalents. These equivalent CPUE values were then plotted, and a regression line fit to them reveals a decline in CPUE with time (Fig. 7). This observed decline is probably conservative because fishing effort, which was not standardized, has most likely become more effective with time (Pella and Psaropulos 1975).

CPUE values were highest in the northern

TABLE 4.—Total occurrences of recorded bluefin tuna catch per latitude and month during 1957-69 and 1974. Totals are for the areas between a given parallel and the next higher parallel.

Latitude	Month												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
36								1	1				2
35													0
34							2	2	1				5
33				2	1	5	9	9	4	2			32
32	1			3	2	6	11	13	12	4	2	1	55
31						2	9	11	8	1			31
30							8	10	6	2			26
29		3	1	1		3	9	6	1	2			26
28	7	5	4	5	7	9	11	7	4	1	3	2	65
27						3	9	7	2	1	1		23
26						9	10	1	1				21
25				1	3	11	11	3	1				30
24					3	10	7						20
23				1	3	6	4						14
22						1	1						2
Total	8	8	5	13	19	65	101	70	41	13	6	3	

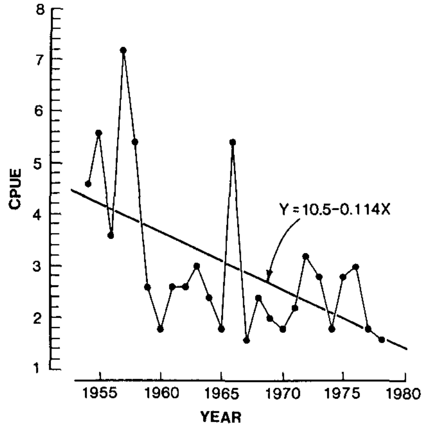

FIGURE 7.—Annual catch per unit effort (metric tons/boat-day) of bluefin tuna plotted by year (1954-78) with a regression line fitted to the curve.

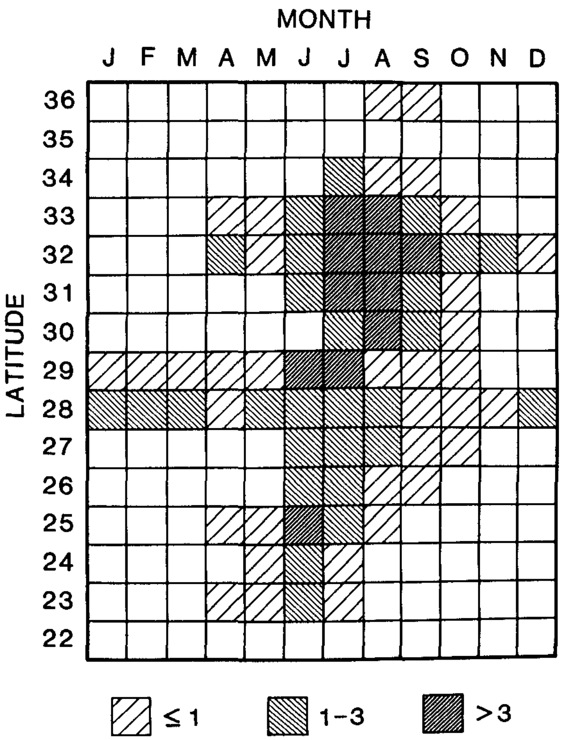

FIGURE 6.—Mean monthly effort for bluefin tuna ($\frac{\Sigma f}{13}$) for the period 1957-69 in boat-days per latitude. Totals are for areas between a given parallel and the next higher parallel.

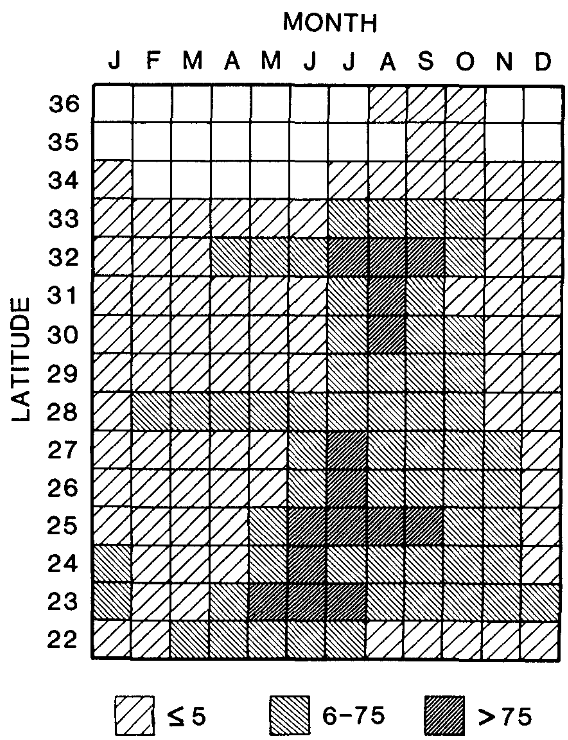

FIGURE 8.—Mean monthly catch per unit effort of bluefin tuna $\frac{(\Sigma \frac{c}{f})}{13}$ per latitude (metric tons/boat-day) for the period 1957-69. Totals are for areas between a given parallel and the next higher parallel.

part of the bluefin range (Figs. 8-10), and is attributed to differences in searching and fishing methods between the wetfish and the high-seas fleets.

Because effort data are not available for the 1979-81 period, the rapid decline in total catches during those years cannot be explained by direct

TABLE 5.—Yearly catch (metric tons) of bluefin tuna and effort (in parentheses) by vessel size class for 1957-69 and 1974, from logbook data. Hold capacity in short tons: 0-50 = Class 1; 51-100 = Class 2; 101-200 = Class 3; 201-300 = Class 4; 301-400 = Class 5; over 400 = Class 6.

	Vessel class						
Year	1	2	3	4	5	6	Total
1957	205	2,537	4,614	35	—	—	7,391
	(20)	(328)	(679)	(24)	(—)	(—)	(1,051)
1958	276	1,840	6,767	646	—	—	9,529
	(37)	(433)	(1,266)	(42)	(—)	(—)	(1,778)
1959	164	1,912	2,468	522	330	—	5,396
	(29)	(408)	(1,352)	(267)	(117)	(—)	(2,173)
1960	5	287	2,318	1,067	1,081	69	4,827
	(33)	(194)	(1,495)	(730)	(341)	(39)	(2,832)
1961	21	526	5,325	2,331	1,015	4	9,222
	(4)	(171)	(2,222)	(925)	(352)	(12)	(3,686)
1962	14	959	7,061	2,840	1,498	—	12,372
	(8)	(185)	(2,447)	(1,515)	(603)	(32)	(4,790)
1963	—	544	5,483	4,228	3,055	87	13,397
	(—)	(85)	(1,667)	(1,729)	(1,051)	(56)	(4,588)
1964	18	523	3,641	2,937	1,565	—	8,684
	(4)	(77)	(1,367)	(1,577)	(749)	(19)	(3,793)
1965	60	294	2,538	2,242	1,312	36	6,482
	(12)	(51)	(1,641)	(1,338)	(753)	(13)	(3,808)
1966	21	429	5,576	5,400	3,107	561	15,094
	(16)	(112)	(1,479)	(1,299)	(580)	(38)	(3,524)
1967	60	289	1,318	2,530	1,804	51	6,052
	(10)	(33)	(1,103)	(1,936)	(1,435)	(270)	(4,787)
1968	—	399	2,038	1,481	1,300	293	5,511
	(—)	(69)	(1,162)	(895)	(493)	(71)	(2,690)
1969	32	175	3,370	2,338	605	448	6,968
	(7)	(40)	(1,200)	(1,280)	(479)	(232)	(3,238)
1974	60	257	1,712	905	719	677	4,330
	(3)	(81)	(672)	(450)	(500)	(251)	(1,957)
Total	936	10,971	54,229	29,502	17,391	2,226	115,255
	(183)	(2,267)	(19,752)	(14,007)	(7,453)	(1,033)	(44,695)
Total	1%	10%	47%	26%	15%	2%	100%
	(0.4%)	(5%)	(44%)	(31%)	(17%)	(2%)	(100%)

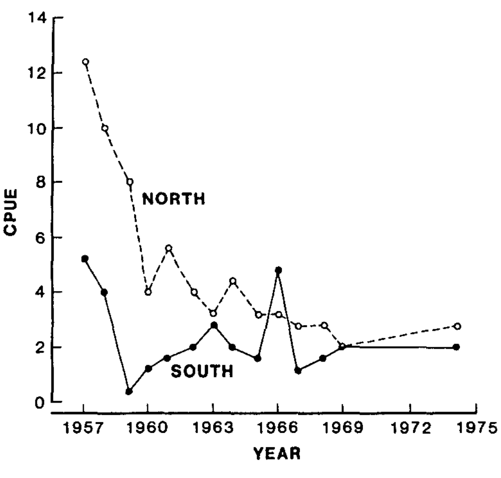

FIGURE 9.—Annual catch per unit effort of bluefin tuna (metric tons/boat-day) for 1957-69 and 1974 north and south of lat. 32°N.

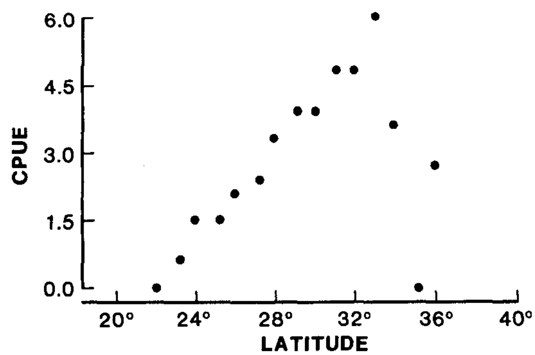

FIGURE 10.—Bluefin tuna catch per unit effort (metric tons/boat-day) by latitude for 1957-69 and 1974. Latitude area is that lying between a given latitude and the next higher latitude.

CPUE evidence. However, if it is assumed that effort remained at about the same levels, CPUE would have declined by an even greater rate than that predicted by the trend in Figure 7. This indicates that bluefin abundance in the eastern North Pacific has declined severely.

TABLE 6.—Bluefin tuna CPUE values from this study (CFG) for the years 1954-74 and from IATTC (Bayliff and Calkins 1979) for the years 1954-78. CFG values converted to IATTC equivalent values are in parentheses.

	CPUE values			CPUE values	
Year	CFG	IATTC	Year	CFG	IATTC
1954	4.49	(4.55)	1967	1.26	1.63
1955	5.44	(5.52)	1968	2.05	2.35
1956	3.59	(3.64)	1969	2.15	1.96
1957	7.03	(7.13)	1970	—	1.71
1958	5.36	(5.44)	1971	2.31	2.11
1959	2.48	(2.52)	1972	3.61	3.23
1960	1.70	(1.72)	1973	3.15	2.89
1961	2.50	(2.54)	1974	2.21	1.75
1962	2.58	(2.62)	1975		2.73
1963	2.92	(2.96)	1976		2.98
1964	2.29	(2.32)	1977		1.86
1965	1.71	(1.73)	1978		1.62
1966	4.28	5.40			

LENGTH-FREQUENCY ANALYSIS

Length-frequency data summaries (Figs. 11-14) were obtained from two CFG data sets of fork-length samples taken as frozen bluefin were unloaded at Terminal Island, Calif., canneries. Set 1 (1952-65) represents random samples of 50 fish/seiner; set 2 (1963-71 and 1974) represents random samples of 20 fish for every 200 short tons landed from each 1° area of latitude and longitude. Set 2 samples were taken for an age determination study. Although a smaller number of bluefin were sampled, they appear to represent the same population as the first data set,

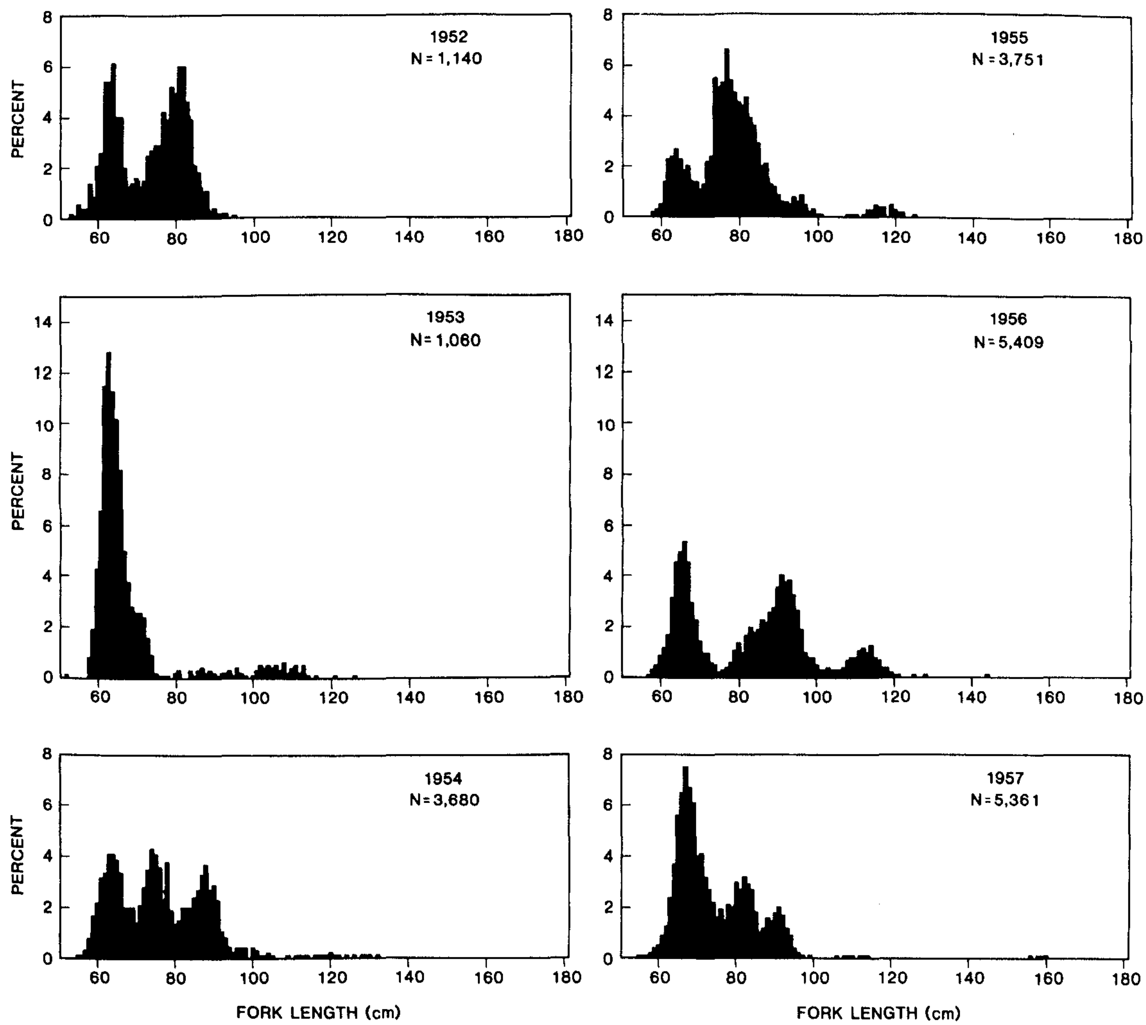

FIGURE 11.—Bluefin tuna percent length frequencies, 1952-57.

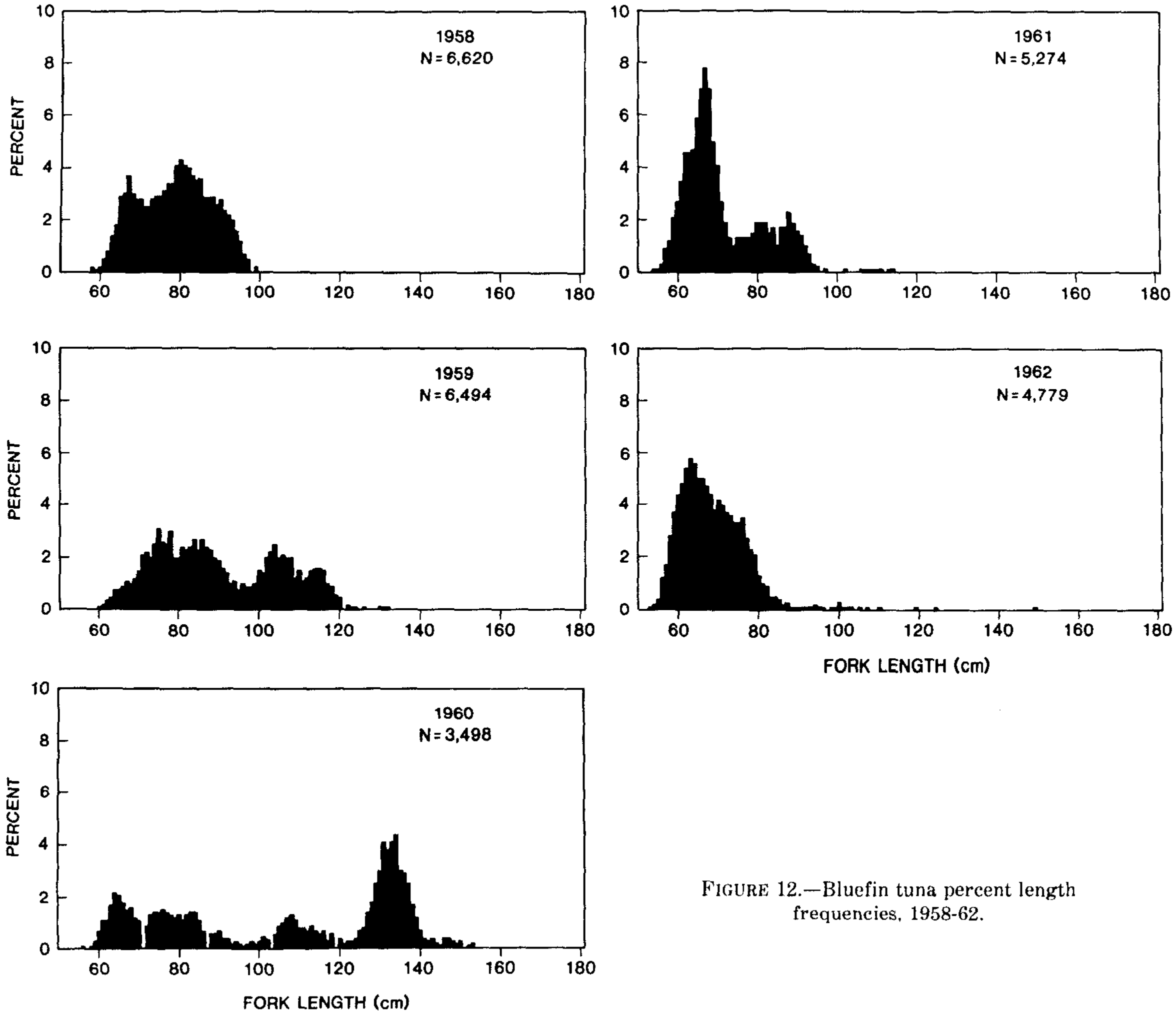

FIGURE 12.—Bluefin tuna percent length frequencies, 1958-62.

TABLE 7.—Mean length frequencies of bluefin tuna, north and south of lat. 32°N, 1952-65.

	Mean length		
Year	South	North	Combined
1952	73.7	70.2	73.2
1953	67.1	63.8	68.1
1954	79.7	66.3	76.3
1955	83.1	72.3	78.8
1956	90.4	65.8	83.1
1957	83.7	71.5	73.0
1958	81.3	77.7	78.6
1959	85.8	90.6	90.3
1960	112.1	96.8	105.6
1961	72.3	71.2	71.7
1962	73.5	64.0	68.8
1963	80.3	68.9	76.4
1964	70.4	62.8	67.9
1965	79.8	65.8	76.0

when overlapping years (1963-65) and composite samples for both data sets are compared (Fig. 15).

Analysis of fish lengths from the first data set shows a decrease in mean length with increasing latitude. These data (1952-65) were also summarized by year for areas north and south of the 32d parallel (Table 7) for a two-way analysis of variance. The analysis shows significant differences ($P<0.01$) among years and between areas. These results show that bluefin caught in the north are smaller than those to the south (Fig. 16) and that mean lengths vary considerably, as much as 39.8 cm/yr.

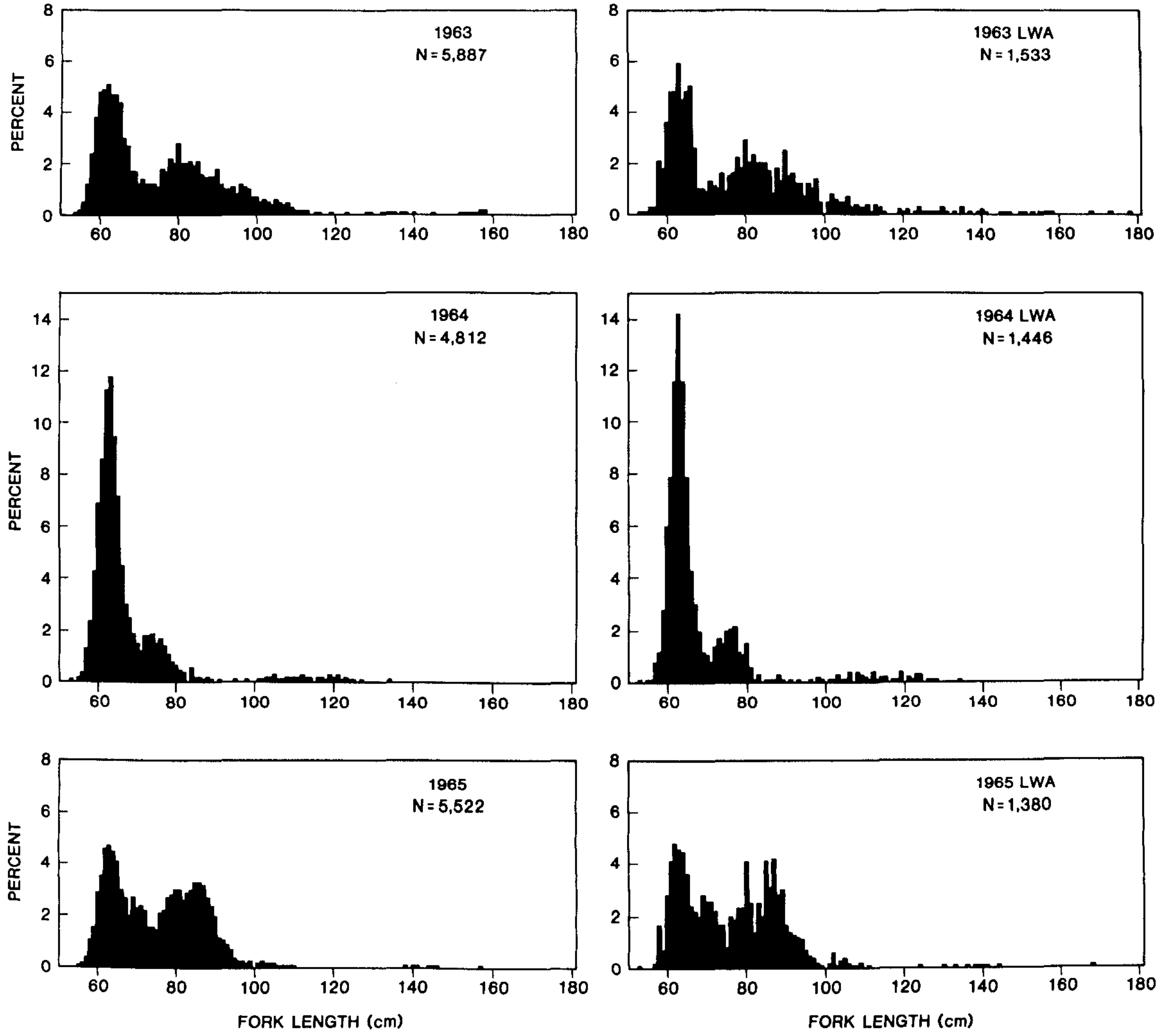

FIGURE 13.—Bluefin tuna percent length frequencies, 1963-65. Graphs to the left are based on length-frequency samples only, whereas those to the right are based on length-weight-age frequency samples.

TAGGING DATA ANALYSIS

From 1953 to 1958, 186 bluefin were tagged and released by CFG and IATTC in the eastern North Pacific incidental to tagging other species. From 1962 to 1968 a tagging cooperative of CFG, U.S. Bureau of Commercial Fisheries (NMFS), and the Mission Bay Research Foundation of San Diego tagged and released 2,836 bluefin. Of these, 565 (20%) were recaptured in the eastern North Pacific, including 7 by sport fishing and 9 in the western Pacific (Clemens and Flittner 1969). Bluefin for tagging were caught by purse seine and tagged with spaghetti-loop tags prior to 1960 and with spaghetti-dart tags since then.

Bluefin are caught within about 200 mi of the coast, thus spatial analysis of tag returns is expressed only by latitude. Of the 565 tagged bluefin caught in the eastern North Pacific, recovery latitude information is available for 540 returns. Data from tagged fish recovered during the season in which they were released (62%) show a general movement northward (Table 8); however, many were caught near the release point and to the south (Table 9). Tagged fish recaptured during the second and third fishing seasons after tagging were well dispersed throughout the fish-

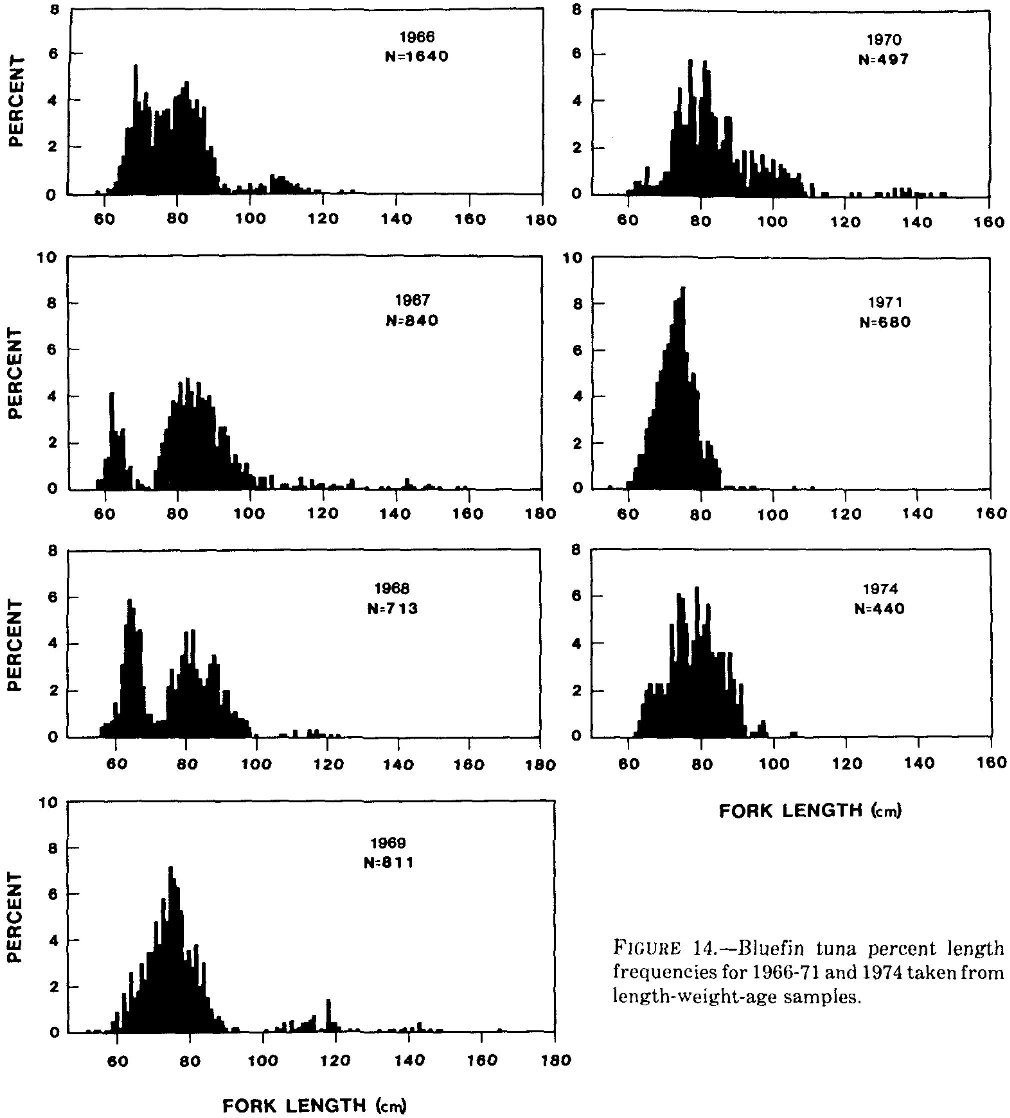

FIGURE 14.—Bluefin tuna percent length frequencies for 1966-71 and 1974 taken from length-weight-age samples.

TABLE 8.—Bluefin tuna tags returned during tagging season (1958-68) summarized by latitude of release and of return. Totals are for areas between a given parallel and the next higher parallel.

Release latitude	Return latitude										Total
	33	32	31	30	29	28	27	26	25	24	
33	13	28									41
32		85	28	1		1					115
31		20	16	2		2					40
30		16	19	7	4	2					48
29		1		2	1	3					7
28		2	1		1	5	1				10
27		2	8	5		1	1				17
26											
25											
24				1	1	2	7	23	2	22	58
Total	13	154	72	18	7	16	9	23	2	22	336

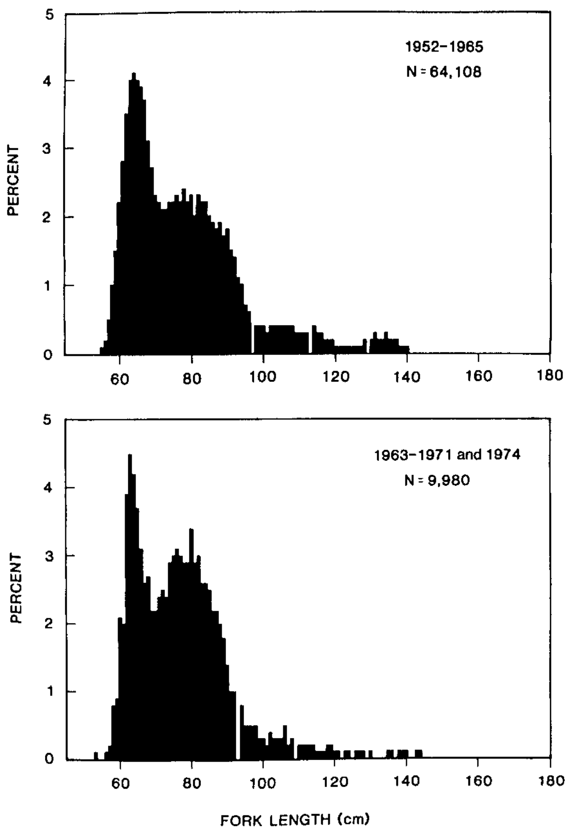

FIGURE 15.—Composite bluefin tuna percent length frequencies. Upper graph summarizes length-frequency samples for 1952-65, and lower graph summarizes length-weight-age samples for 1963-71 and 1974.

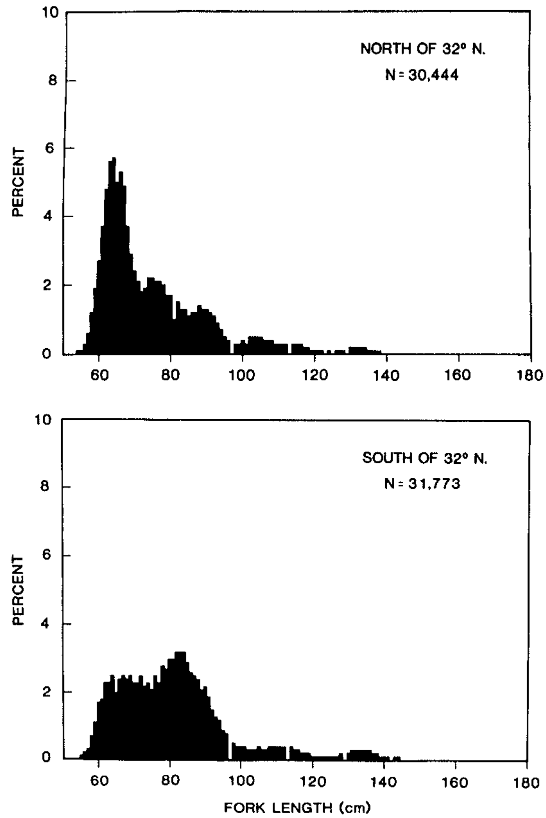

FIGURE 16.—Bluefin tuna percent length-frequency composites for 1952-65, north (top) and south (bottom) of lat. 32°N.

ing grounds and fishing season, indicating good mixing with the untagged population.

Gulland (1963) described a method of estimating fishing mortality from tagging experiments; this method was modified and applied to the bluefin data. It was assumed that the number of tags returned per unit of effort is proportional to the CPUE, and no provision was made for immigration or emigration. For any period following tagging, an estimate of catchability (q) would be the number of tags returned per unit of effort divided by the initial number released. When these

TABLE 9.—Total number of returned bluefin tags summarized by latitude of release and of return. Totals are for areas between a given parallel and the next higher parallel.

Release latitude	Return latitude											Total
	33	32	31	30	29	28	27	26	25	24	23	
33	13	28	1	4	3	4	3		9	3		68
32		87	30	5	9	5	7	6	20	7	1	177
31		21	17	3	2	4	1	2	8	1	1	60
30		17	27	14	10	3	2	6	8	3		90
29		3	2	9	2	8			4			28
28		5	2		7	7	8		5	2		36
27		2	8	5		4	1		1			21
26												
25												
24				1	1	2	7	25	2	22		60
Total	13	163	87	41	34	37	29	39	57	38	2	540

estimates are plotted against time, the intercept at time zero is an estimate of q for bluefin in the eastern North Pacific.

As tagged bluefin were not fully dispersed during the season of tagging, monthly estimates of q were calculated as the monthly mean, per 1° area of latitude and longitude, for 1° areas from which tagged fish were caught. For the second and third seasons, when tagged fish appeared to be fully dispersed, monthly estimates were calculated for the entire bluefin range; then, the natural logarithms of these values and those for the first season were plotted (Fig. 17). Effort and therefore $\hat{q}$ are expressed in boat-days. The regression line fitting these points ($Y = -8.7363 - 0.1725\ X$, $R^2 \approx 68\%$) was weighted by the number of tagged fish released each year, since the number of tagged fish varied between 35 and 960/yr.

The best estimate of q from the tag-recapture data is the antilogarithm of the regression line intercept, 1.66×10^{-4}/boat-day with a 95% confidence interval of 0.99×10^{-4} to 2.63×10^{-4}/boat-day corrected for geometric mean bias (Beauchamp and Olson 1973). The slope of the regression (-0.17, $S^2 = 0.02$) is an estimate of the monthly instantaneous mortality coefficient (Z), and was expanded to estimate the yearly instantaneous mortality ($Z = 2.07$, $S^2 = 0.24$) including immigration and emigration. This estimate compares favorably with Bayliff and Calkins' (1979) and Bayliff's (1980) estimates ($\overline{Z} = 2.08$, $S^2 = 0.8$) for 1962-66. They call these estimates "rates of attrition," since immigration and emigration are included.

The ratio of fishing mortality to instantaneous total mortality is an estimate of the exploitation ratio (Ricker 1975) and was calculated as a mean for the period 1962-70 because $\hat{q}$ was also calculated for that period. The mean annual fishing effort in that period was 4,215 boat days which, multiplied by $\hat{q}$, estimates a fishing mortality of 0.7/yr. Dividing this value by estimated Z (2.07/yr) yields an exploitation ratio of 0.34, and then multiplying by the annual mortality or "attrition" (0.87) yields a 30% exploitation rate.

DISCUSSION

The review and analysis of data concerning the bluefin tuna fishery in the eastern North Pacific show large fluctuations in the catch to be a major part of two important phases. The decline in catch near the end of the first phase (1921-50) is offset by the development of a "high seas" purse seine fleet and the resultant increased catch of bluefin off Baja California. The current decline (1963-present) is probably due to a decline in the abundance of bluefin as indicated by CPUE evidence. The effect on the resource of Mexico's 200-mi regulations was not assessed at this time; however, the apparent decline in catch and CPUE cannot be attributed to such regulation since it has been enforced only recently.

The declines in catch and CPUE in the eastern North Pacific are significant and are reflected by an even greater decline in catch and nominal CPUE in the western Pacific (Figs. 18, 19).

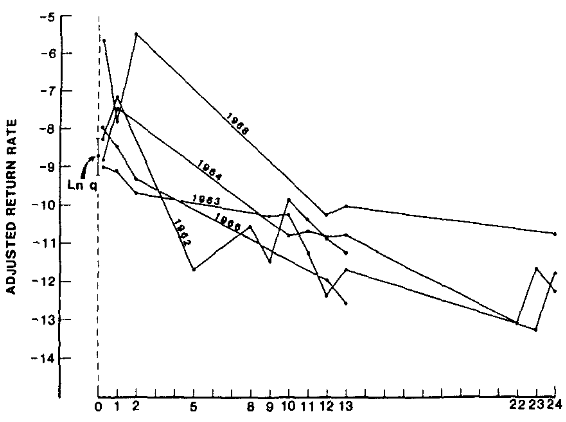

FIGURE 17.—Natural logarithms of adjusted return rates for tagged bluefin tuna plotted against number of months between tagging and recapture, for the years 1962-64, 1966, and 1968. The predicted catchability coefficient ($\hat{q}$) from straight-line regression and the 95% confidence interval around ($\hat{q}$) are shown at the zero-month intercept.

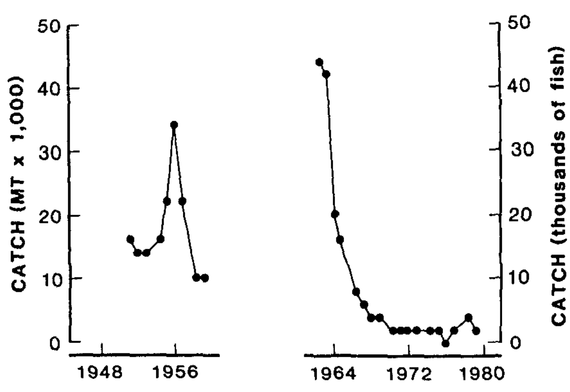

FIGURE 18.—Annual Japanese landings of northern Pacific bluefin tuna for the years 1951-59 (metric tons × 1,000) and 1962-79 (thousands of fish).

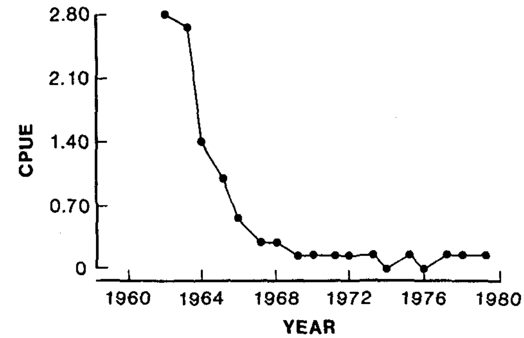

FIGURE 19.—Annual Japanese catch per unit effort (metric tons/boat-day) from longline catches of northern bluefin tuna for the years 1962-79.

Although those data (Anonymous 1981; Yamanaka and Staff 1963) represent only a portion oı the fishing effort in the western Pacific, they indicate a need for more extensive and explicit data from that area. With improved data, mathematical models for estimating sustainable yields can be used to describe the status of the bluefin resource throughout the North Pacific Ocean.

Based on strong evidence of declining stock abundance, the bluefin tuna fisheries in the Pacific Ocean should receive an extensive analytical review, and nations fishing bluefin, especially Japan, Mexico, and the United States, should consider needed actions. If management to conserve this valuable resource is to be taken, it should be soon, so that the resource can return to an optimal level of abundance.

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