Col.Vol.Sci.Pap. ICCAT, 18 (2): 474-483 (1983)

CPUE TRENDS OF ATLANTIC BLUEFIN TUNA BASED ON AGE SPECIFIC EFFECTIVE FISHING EFFORT ESTIMATED FROM JAPANESE LONGLINE FISHERY, 1971-1980

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SUMMARY

Applying the Honma method (1974) by age based on Japanese longline catch and effort data, age-specific effective effort was calculated under three stock assumptions, i.e., western, eastern and total Atlantic cases. The result showed no increasing or decreasing trends in CPUE throughout the period studied. Occurrences of strong year classes originated during the 1970-1973 period are indicated for the western stock.

RESUME

L'effort effectif spécifique de l'âge a été calculé selon trois hypothèses de stock, c'est-à-dire Atlantique ouest, est ou entier, en utilisant la méthode de Honma (1974) pour l'âge à partir des données palangrières japonaises de prise et effort. Les résultats n'ont montré aucune tendance à la hausse ou à la baisse au cours de la période étudiée en ce qui concerne la CPUE. La présence de fortes classes ayant leur origine en 1970-1973 est indiquée pour le stock ouest.

RESUMEN

Por medio del método Honma (1974) por edad, y en base a los datos de captura y esfuerzo del palangre japonés, se calculó el esfuerzo efectivo específico de la edad, bajo tres supuestos: Atlántico Este, Atlántico Oeste y todo el Atlántico. Los resultados no mostraban tendencias ascendentes o descendentes de la CPUE a lo largo del periodo en estudio. En el caso del stock Oeste se señala la presencia de fuertes clases anuales procedentes del periodo 1970-73.

Introduction

The stock assessment of bluefin tuna in the Atlantic has been mainly performed by cohort analysis (hereinafter abbreviated as CA) but the data bases and analysis methods have many problems so that the mutual check with the result of actual condition analyses of main bluefin tuna fisheries is required. The catch and effort statistics of Japanese longline fishery, being one of the best in exactitude of the statistics, continuity of historical data, extent of fishing grounds and wide range of size of the fish caught compared to that of other fisheries, has been used for various analyses including the CA.

The evaluation of effective fishing effort of Japanese longline fishery should be performed by age specific method because the age range is wide and the ages of the fish caught are different in accordance with fishing grounds and fishing seasons, in addition to its general characteristic of large variation by time and space of the longline operations. Two methods were previously employed: the first is the method in which the nominal number of hooks is considered as the effective hooks in performance of the analyses by dividing fishing grounds and fishing seasons into as small stratum as possible (method (1), for example, Hisada and Suzuki, 1982) and the second is the method in which the cpue when the bluefin tuna caught per unit operation is more than 45% of the total catch in number of all species is considered as the average density and thus the effective fishing effort is evaluated (method (2), Parrack 1982).
The problem that the effective hooks has no age specific evaluation is common to both methods. However, in addition, the method (1) is difficult to grasp clearly whether the nominal number of hooks is effectivized enough and, on the other hand the method (2) has the problems that the criterion of 45% has no objectivity, that the bluefin tuna caught in accordance with this criterion in most cases account for less than 10 % of the total catch in number of bluefin tuna and that the fishing effrot is not corrected according to the difference in density.

In this study we calculated the effective fishing effort by using Honma method (Honma 1974) in age specific approach basing on the Japanese longline data and evaluated the changes of the stock condition from the trends of cpue based on the calculated age specific effective effort.

Materials and Method

We, first, calculate the density index per unit time and space in average years in accordance with Honma (1974) but this time by age:

1. Calculation of d_{ija}.... average density index of a-age fish in j-month and i-5x5° squares during the average years.

$$d_{ija} = \frac{1}{m} \sum_{k=1}^{m} (d_{ijk} \times P_{qJka}) \quad \cdots (1)$$

$$dijk = \frac{C_{ijk}}{G_{ijk}} \quad \cdots (2)$$

where C_{ijk}: number of bluefin caught in k-year, j-month and i-5x5°sq.
G_{ijk}: nominal number of hooks in k-year, j-month and i-5x5°sq.
P_{qJka}: ratio of a-age fish to the total bluefin carch in k-year, J-quarter, q-subarea.
m: number of years where the data were available.

2. Calculation of E_{ija}....effectiveness index of a-age fish in the ij stratum.

$$E_{ija} = r_{ija} \times a_{ja} \quad \cdots (3)$$

where r_{ija}: relative density index of a-age fish in the ij stratum.
a_{ja}: relative availability of a-age fish in j-month

$$r_{ija} = d_{ija}/(N_{ja}/A_{ja}) \quad \cdots (4)$$

$$N_{ja} = \sum_{n=1}^{n} A_{ij} \times d_{ija} \quad \cdots (5)$$

$$A_{ja} = \sum_{n=1}^{n} A_{ija} \quad \cdots (6)$$

$$a_{ja} = N_{ja}/[(1/R)\sum_{j=1}^{R} N_{ja}] \quad \cdots (7)$$

where N_{ja}: stock size index of a-age fish in j-month
A_{ja}: sum of squres operated in j-month
n: number of squares operated
R: number of months

3. Calculation of X_{ijka}.... effective fishing effort of a-age fish in the ijk stratum.

$$X_{ijka} = E_{ija} \times G_{ijk} \quad \cdots (8)$$

4. Calculation of X_{qjka} and f_{qjka}.....effective effort and fishing intensity in the qjk stratum.

$$X_{qjka} = \sum_{i=1}^{n(q)} X_{ijka} \quad \cdots\cdots\cdots(9)$$

$$f_{qjka} = X_{qjka}/A_{qja} \quad \cdots\cdots\cdots(10)$$

where n(q): number of i squares in q-subarea

A_{qja}: sum of extent of i squares in q-subarea.

The values obtained by the series of calculation are summed by stock by year. Fig. 1 shows the areal extent of the supposed stocks and of subarea q. The area south of 15°N is included into the area of West stock because it is thought reasonable that this region is included into the area of West stock rather than separated into eastern and western part in consideration of the geographic distribution of the catch of bluefin tuna in the offshore region of North-eastern Brasil by Japanese longliners in the first half of the 1960s.

5. Conversion factors of body weight to body length data and length data to age employed are those estimated by Parrack (1981) and Parrack and Phares (1979), respectively (Table 1). A factor of 1.15 is used for the transformation from gilled-and-gutted weight to whole weight and age is calculated, after calculating the absolute age at the time of the measurement and backcalculating the orign, as the difference between the generation year calculated back and the measurement year.
6. The measurement of body lengths and body weights of bluefin tuna caught by Japanese longliners is quite insufficient before 1970 so that the calculation is conducted over the period of 1971-1980 and 1971-1980 is used as average years. Matching of measured data of body length and catch data in number is performed by subareas q, by year and quarter of the year, but length measurement data are lacking in many cases for a period of 1971-1975. The surrounding length data are used in substitution taking into the characteristics in length composition in time and space consideration.

Results and discussion

1. Comparison to the directed effort evaluated in the past

Table 2 shows the fishing intensity and the catch in number by age by stock and by year. When comparing this fishing intensity with the directed effort of Parrack (1982), the trend of these two nearly correspond to each other only in the case of large-sized fish in the West stock and in all other cases, the trend by Parrack (1982) is considerably different from that evaluated this time (Fig. 2). The similarity of the variation tendency of fishing efforts evaluated by the two methods for large-sized fish in the West stock shows that the simple stratification of time and space enables to evaluate the nearly exact directed effort as parent fish of practically similar age composition are caught in the Gulf of Mexico during the comparatively limited period and other types of tunas are scarecely caught simultaneaously. As, for example, with regard to the small-sized fish of the West stock, the age composition of the fish caught varies largely year by year (Fig. 3), the method of Parrack (1982) has the limit of effectivizing of fishing effort. The fishing intensity evaluated in this study also does not necessarily reflect the variation of age composition to a very sensitive extent, but the estimates do behave age-specifically.

2. Trend of cpue

Fig. 4 shows the trend of cpue by age by stock, divided value of catch in number by fishing intensity is an index of apparent stock size. Concerning the West stock, the cpue of 1-3 years old fish reduces in the latter half of the 1970s in comparison to its first half, that of 4-7 years old fish, on the contrary, increases in the latter half of the 1970s, that of 8-9 years old fish reduces in the middle of the 1970s, that of 10-13 years old fish reduces in the latter half of 1970s and that of 14-20 years old fish is leveling off or increases in the latter half of the 1970s. The cpue of 1970-1973 year classes is larger than that of other year classes, except the cpue in 1975 when the catch was very low for every age, so that it can be traced as the dominant year class. However, 7-10 years old fish of these year classes seem to be lowered to almost the same level as the year classes of the beginning of the 1960s. We, however, can say that 1970-1973 year classes are similar to or stronger than the year classes of the beginning of the 1960s. The analysis of the catch by major bluefin fisheries, especially Japanese longline fishery which is the only one fishery to catch the middle-sized fish, will become important in the future to confirm whether or not these year classes are really strong ones.

Concerning East stock, the cpue of 2-6 years old fish seems to increase in the latter half of the 1970s compared to the first half, the cpue of 7-10 years old fish reduces in 1973-1976 and has the tendency of increase after 1977. The cpue of 11-15 years old fish increases in 1980 in some cases, but as a whole it reduces during 1971-1980 period. On the other hand, the cpue of 16-20 years old fish is leveling off till 1978 and at the low level in 1979 and 1980. The 1973 and 1974 year classes are stronger than the other year classes in the East stock and the succession by the year classes can be traced. But it requires to wait for the future accumulation of the data for judging whether these year classes are the dominant year classes. When we look at the whole Atlantic stock, the variation is larger and the cpue of 1-10 years old has no tendency of one-sided increase or decrease. The cpue of 11-16 years old fish has tendency of reduction and that of 17-20 years old fish has the tendency of increase or leveling-off.

The succession of the cpue for 1970-1973 year classes and 1974 year class seen in the West and East stocks can be supposed.

3. Comparison with trend of the cpue based on the nominal effort in stratified time and space.

As the trend calculated by aforementioned Hisada and Suzuki (1982) is not calculated by age, the strict comparison is not possible. However, we will roughly compare their trends with the example of the West stock. The main fishing grounds of Japanese longliners are w-1, w-2, w-3 and w-5 (Fig. 5) and the main fish catch of w-1 are middle-sized fish (7-10 years old) and those of w-2 and w-3 are small-sized fish (3-6 years old) and those of w-5 are large-sized fish (14-18 years old). When we look at the trend of cpue equivalent to these ages shown in Fig. 2-1, we can find the coincident pattern that the cpue of 1975-1977 is lower than that of before and after years in the region of w-1, the cpue of 1974-1978 is high in the regions of w-2 and w-3 and the cpue increases till 1975 and subsequently is leveling off or slightly increases in w-5.

4. Comparison with the CA's

The result that, concerning the West stock, 1970-1973 year classes are probably dominant and these year classes are recently entering the catergory of large-sized fish through the period of middle-sized correspond that of Suzuki and Hisada (1982 MS) and is largely different from that of Parrack (1982). With regard to the East stock, both Parrack (1982) and Farrugio (1981) indicated the increase of recruitment of 1 year old fish from the first half of the 1970s and the trend of the cpue in this study also shows this tendency. This analysis also recognizes that 1974 year class in the East stock considered as the dominant year class as Farrugio (1981) estimated, but it is not recognized in the CA by Parrack (1982). In addition, it is interesting that 1973 year class which is the dominant year class in the West stock can be considered as the large year class also in the East stock in this study, indicating the intermingling of west and east stock hitherto demonstrated by various evidences, from the viewpoint of stock structure of the Atlantic bluefin tuna. However, according to the CA's of both Parrack (1982) and Farrugio (1981), the 1973 year class is not the dominant year class in the East stock. Therefore, it is required to pay more attention to the catch of this cohort in the future.

With regard to the whole Atlantic, 1970-1974 year classes can be regarded to be larger than other year classes from the result of the present study, but the evaluation by Parrack (1982) shows only 1973 year class is dominant. According to the above comparisons, we can conclude that the CA's and the analysis of this study coincide nearly with each other concerning the East stock, but the result concerning the West and the whole Atlantic stocks does not correspond with Parrack (1982).

5. Degree of concentration of fishing effort in the fishing grounds of the middle-sized fish in the West Atlantic.

Main fishing grounds of Japanese longliners of bluefin tuna in the West Atlantic are along the coast of the USA and Canada in the north-western Atlantic, the contiguous offshore regions and the Gulf of Mexico. As shwon in Talble 2-1, 8-10 years old fish which could not be the main fish catch previously became to be caught in large quantity after 1978 and the cpue of those fish group is very high. This increase of the cpue may be considered due to concentration of effort into the region of high density due to the accumulation of information concerning the operation conditions, especially of the fishing grounds. We calculated the concentration index of fishing effort (X/G) concerning the subareas w-1, w-2 and w-3 for the purpose of examining this possibility.

According to the result shown in Table 3, the concentration index for 8-10 years old fish can not be regarded to be significantly high in two years of 1979 and 1980 than in other years in most cases. Therefore, the possibility is low that the recent large increase of the catch and cpue of the middle-sized fihs is brought about by the concentration into the areas of high density with 8-10 years old fish.

Conclusion

As shown in the above, the fishing intensity used in this study may have problem that the effectivization for age is not sufficiently done. However, this method has much objectiveness relative to that of Parrack (1982) for obtaining the effective hooks of lonlgine fishery whose shift of target species and that of time and space of the fishing grounds are great.

The result of this analysis shows that the stock condition of bluefin tuna during the period of 1971-1980 is not deteriorated in any stocks supposed here. In addition, the possibility that the 1970-1973 year classes in the West stock and 1973-1974 year classes in the East stock are the dominant year classes was pointed out.

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Table 1. Conversion factors used in the analysis

Whole weight (Kg) to Fork length (cm)	
West Atlantic stock	
First and second quarters (fat fish)	$L=35.5794(1.15W)^{0.3414}$
Third and fourth quarters (lean fish)	$L=37.3509(1.15W)^{0.3333}$
East Atlantic stock	
First and second quarters (fat fish)	$L=36.5912(1.15W)^{0.3319}$
Third and fourth quarters (lean fish)	$L=50.7143(1.15W)^{0.2825}$
Fork length (cm) to Age	
Common to West and East Atlantic stock	$L=313(1-0.9169e^{-0.0903A})$

Data Sources: Parack and Phares (1979) and Parrack (1981)

Table 2-1. Fishing intensity (effective hooks/5x5° sq.) by Japanese longline fishery on Atlantic bluefin by assumed stocks, age and by year.

West stock

year	age 1	2	3	4	5	6	7	8	9	10
71	8223	3664	3615	1815	363	3927	2965	4792	5557	7463
72	5108		484	35	186	810	295	1005	1377	1850
73	5472	4926	7773	1061	946	1654	1179	2800	3798	3826
74	994	5522	4947	4480	3608	3401	1607	4253	3390	4740
75	1490	46	65	4397	1441	1481	271	1553	2141	4107
76	4167	13154	12453	10312	7402	7677	5805	2599	2611	5355
77	2602	12080	15157	13484	8575	8001	7072	4950	5251	7348
78	5369	11712	14489	12011	5416	6204	5089	2978	3335	4920
79	1900	14195	13507	14143	10407	11212	10243	8865	9373	11088
80	6530	9383	19081	18359	14016	7438	12196	11433	11079	11063

year	age 11	12	13	14	15	16	17	18	19	20
71	6772	7393	6267	2416	1847	3619	1675	283	477	1513
72	897	978	1681	935	817	665	183	15	188	
73	2607	2191	2644	1078	720	521	328	130	597	
74	5422	3960	3951	2715	2388	1732	1261	987	1160	939
75	6418	5868	6434	8430	8449	6558	6309	6268	5440	6009
76	8255	10820	11171	16655	15947	12903	13594	13708	12973	14877
77	10181	9546	11792	16355	16255	13162	14303	14222	14092	17119
78	5703	6431	8046	10629	10748	8740	9831	9619	9731	11881
79	11244	12131	11860	13629	13597	13131	11516	11062	11710	14721
80	7681	6344	7037	6108	8790	11673	15855	18304	16901	17536

East stock

Year	age 1	2	3	4	5	6	7	8	9	10
71	12720		15			435	619	116	697	
72	5423		204	125		214	1040	441	3949	803
73	7139				91		160	361	560	614
74	5504	7505	13685	13832	13849	11332	13845	8811	12410	9562
75	7257	6799	9544	12121	11729	10363	12804	16837	13001	12552
76	15911	546	822	667	891	2540	5094	9579	8228	8415
77	9271	589	576	886	513	1438	2980	7319	5390	5280
78	11212	761	350	534	639	1205	1979	799	541	1484
79	8637	950	545	675	475	930	2284	4731	4155	3064
80	15597		159	400	234	680	1396	3074	2906	2947

year	age 11	12	13	14	15	16	17	18	19	20
71	397	482	340	481	1170	1 29	836	379	142	61
72	736	559	514	526	104	360	547	378	1	542
73	939	440	800	706	648	522	482	458	954	477
74	10773	7720	7813	10754	10226	10099	10038	7050	7448	7557
75	12215	14926	14269	16624	16870	15380	20955	14096	15423	14481
76	8066	8334	7492	8320	8545	7928	9785	6290	7341	7233
77	4414	5713	4619	5225	5443	5456	7629	4788	5219	3708
78	1444	1836	1271	1926	1977	2196	4070	2925	2479	2287
79	1609	2119	1628	295	62	84	2	165		
80	2416	2599	2294	2374	2231	1842	2621	1599	2124	1524

Total stock

Year	age 1	2	3	4	5	6	7	8	9	10
71	12720	2792	2663	1479	269	2393	1839	3094	3018	3107
72	5423		410	52	105	577	627	776	879	1158
73	7139	3754	5716	865	725	1060	725	1808	2180	1705
74	5504	6471	7259	6209	6248	6498	7044	6108	7763	7922
75	7257	2085	2574	5847	4092	4949	5849	7773	7407	10324
76	15911	10189	9375	8529	5724	5671	5489	5440	5337	7374
77	9271	9383	11298	11154	6498	5439	5250	5914	5406	5982
78	11212	9154	10755	6093	4185	4252	3704	3290	1977	2652
79	8637	11103	10076	11652	7848	7198	6700	7182	6839	5792
80	15597	7150	14073	15038	10453	4470	7388	8031	7211	5709

year	age 11	12	13	14	15	16	17	18	19	20
71	2006	2103	1534	976	1414	1382	1244	182	310	827
72	777	641	621	635	362	478	373	155	61	291
73	1245	984	1173	806	674	496	410	300	1015	229
74	9459	6842	7041	8657	7433	6952	5799	4106	4376	4083
75	10791	12805	12754	14492	12869	12069	13876	10232	10759	10031
76	8014	8572	8235	10492	11189	9801	11628	9665	10099	11254
77	5635	6512	6063	8118	9300	8354	10345	9356	9550	10737
78	2493	2916	2635	4197	5134	4656	6856	6189	6026	7246
79	3980	4486	3691	3768	6092	4986	5559	5480	5713	7740
80	3717	3478	3239	3340	4574	5530	8845	9745	9223	9941

Table 2-2. Catches of the Atlantic bluefin by Japanese longline fishery by assumed stocks, age and by year.

West stock

year	age 1	2	3	4	5	6	7	8	9	10
71	24	198	57	120	42	296	721	1535	1141	776
72	177		145	7	38	153	25	124	227	105
73	47	373	230	710	582	475	207	824	1212	383
74	45	1368	3777	1382	541	350	249	738	273	691
75	1	7	35	45	78	202	6	99	307	482
76	56	449	3561	4239	2641	1602	279	98	244	895
77	16	308	3303	9086	3801	1649	2104	694	210	207
78	57	77	747	2587	2748	2672	1356	405	333	213
79	23	104	828	1768	580	1117	2388	2094	870	334
80	90	276	980	2652	1913	946	2037	3358	4359	1380

year	age 11	12	13	14	15	16	17	18	19	20
71	610	562	410	233	110	218	59	4	11	9
72	37	54	82	39	23	66	26		14	
73	188	247	391	134	65	67	66	15	79	
74	381	413	378	283	343	152	78	67	53	24
75	1147	776	794	807	982	809	403	403	283	139
76	261	547	888	1764	2047	1446	1245	684	555	380
77	222	256	329	601	1517	1394	1333	1301	880	606
78	167	267	303	489	980	829	1250	1130	1014	785
79	304	352	444	813	1282	967	1279	782	611	475
80	688	412	546	441	873	1268	1611	1427	1091	601

East stock

year	age 1	2	3	4	5	6	7	8	9	10
71			3				121	107	17	83
72			9	26		80	32	72	57	238
73					10		14	11	92	69
74		267	2023	1527	2044	2645	2455	532	1255	1234
75		161	167	658	880	672	514	548	846	926
76		38	171	41	112	364	321	192	329	534
77		18	31	31	32	132	374	930	1126	1515
78		14	31	54	94	222	50	47	44	9
79		16	38	62	59	160	1024	1886	1891	976
80			45	58	11	120	240	366	451	681

year	age 11	12	13	14	15	16	17	18	19	20
71	106	137	77	32	41	13	26	7	24	5
72	300	199	151	129	8	61	67	34	1	32
73	218	81	280	191	160	116	42	35	134	13
74	2970	2141	3014	3391	2773	2183	890	510	446	333
75	2551	3299	4502	4613	3923	2744	1694	918	796	552
76	1067	1975	1919	1805	2185	1626	964	622	506	560
77	1468	1610	1150	1065	826	979	641	313	210	46
78	33	71	73	117	225	551	1081	520	383	70
79	200	95	49	30	10	12		11		
80	538	732	605	237	199	63	47	12	15	9

Total stock

year	age 1	2	3	4	5	6	7	8	9	10
71	24	198	59	121	42	296	841	1643	1159	857
72	177		154	33	38	233	57	196	284	343
73	47	373	230	710	592	475	218	835	1304	451
74	45	1634	5800	2909	2585	2995	2703	1270	1528	1925
75	1	168	202	703	957	874	520	648	1152	1408
76	56	487	3732	4280	2752	1966	600	290	573	1429
77	17	326	3334	9117	3833	1781	2478	1584	1335	1722
78	57	90	778	2641	2841	2894	1406	452	377	222
79	23	120	866	1832	639	1477	3412	3980	2761	1309
80	90	276	1025	2710	1924	1066	2277	3725	4810	2060

year	age 11	12	13	14	15	16	17	18	19	20
71	715	699	487	264	151	231	84	11	35	14
72	337	254	233	168	30	127	93	34	15	32
73	405	328	671	325	225	183	108	49	212	13
74	3350	2554	3391	3674	3116	2335	967	577	499	357
75	3698	4075	5296	5420	4905	3553	2007	1320	1078	691
76	1329	2522	2807	3570	4232	3071	2209	1306	1061	941
77	1690	1865	1478	1666	2343	2373	1973	1615	1090	651
78	200	339	375	606	1205	1380	2330	1650	1397	855
79	505	447	494	843	1292	979	1279	793	611	475
80	1227	1143	1150	679	1072	1332	1658	1439	1106	611

Table 3. Trends of concentration index for ages 8-10 years old bluefin caught by the Japanese longline boats in the North-western Atlantic

	Age 8			Age 9			Age 10		
	W1	W2	W3	W1	W2	W3	W1	W2	W3
1971	0.99	0.45	0.01	1.15	0.19	0.06	1.59	0.24	0.07
1972	0.78	0	0	1.07	0	0	1.51	0	0
1973	1.43	0.17	0	1.88	0	0	1.95	0.17	0.04
1974	1.25	1.66	0.11	1.40	0.15	0	2.00	0.18	0
1975	0.63	0	0	0.67	0	0	1.02	0	0
1976	0.88	0	0	0.62	0	0	0.83	0	0
1977	0.72	2.32	1.38	0.71	2.17	1.27	1.25	0.73	0.50
1978	0.64	0.46	0.44	0.65	0.48	0.36	1.03	0.04	0.28
1979	0.93	0.79	1.07	1.04	0.61	1.19	1.74	0.20	0.42
1980	1.01	0.99	0.56	1.03	0.76	0.58	1.56	0.34	0.26

Areal divisions (W1-W3) are shown in Fig. 1.

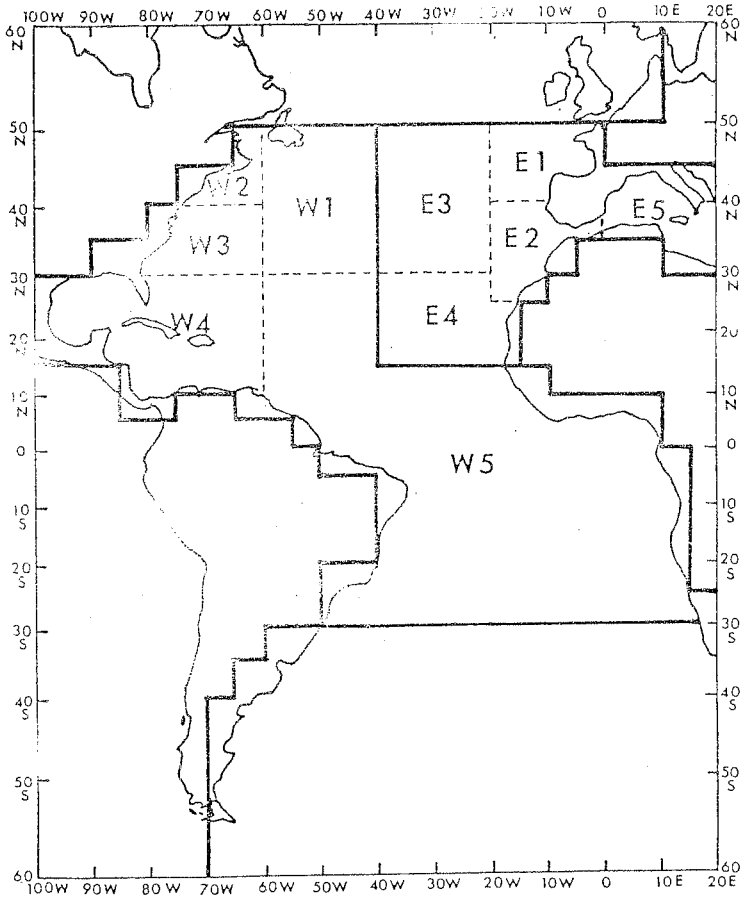


Fig. 1. Areal extent of the West (areas W1-W5) and East (E1-E5) stocks. Areas W1-W5 and E1-E5 denote subareas q's in the text.

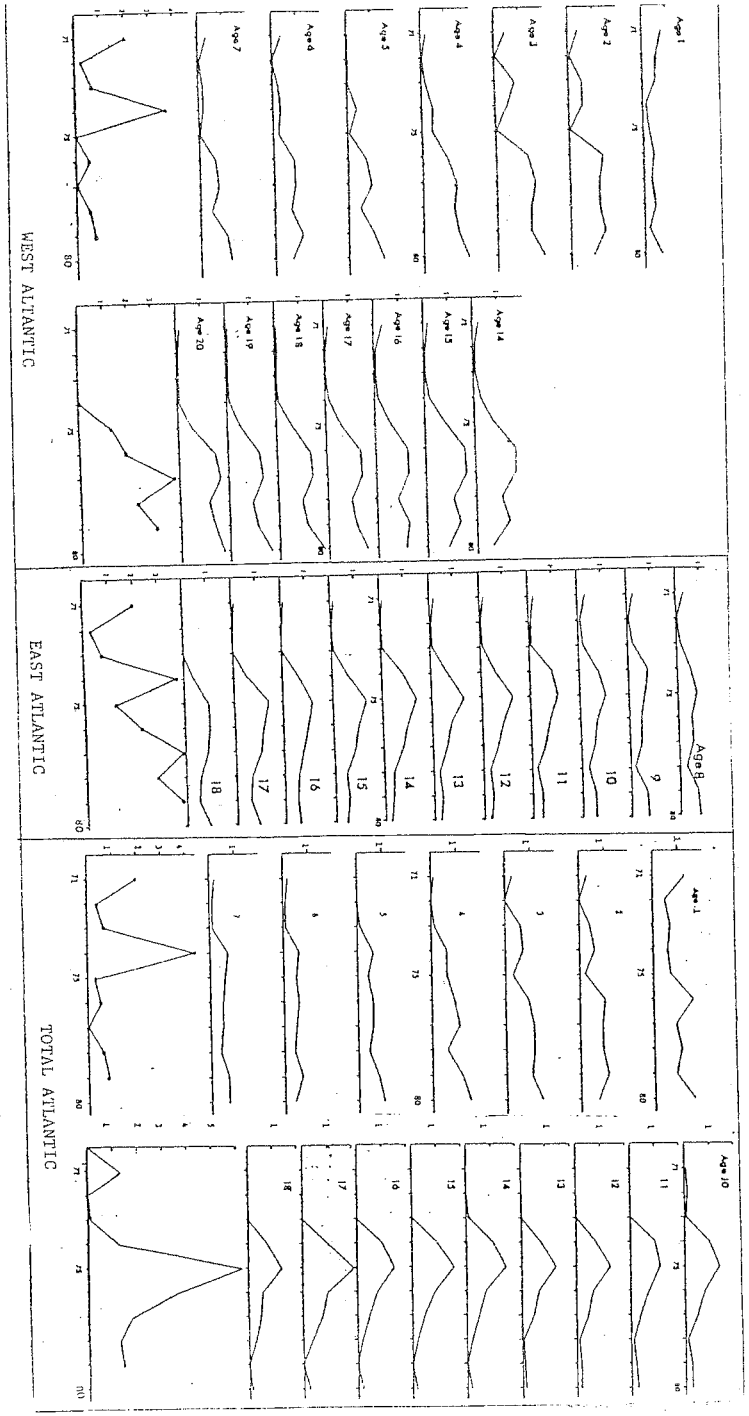


Fig. 2. Comparison of age specific fishing intensity (10^4 effective hooks/5x5° sq.) and directed effort (10^6 nominal hooks) by Parrack (1982) during 1971-1980.
Parrack's estimates are shown in the bottom rows with dots.

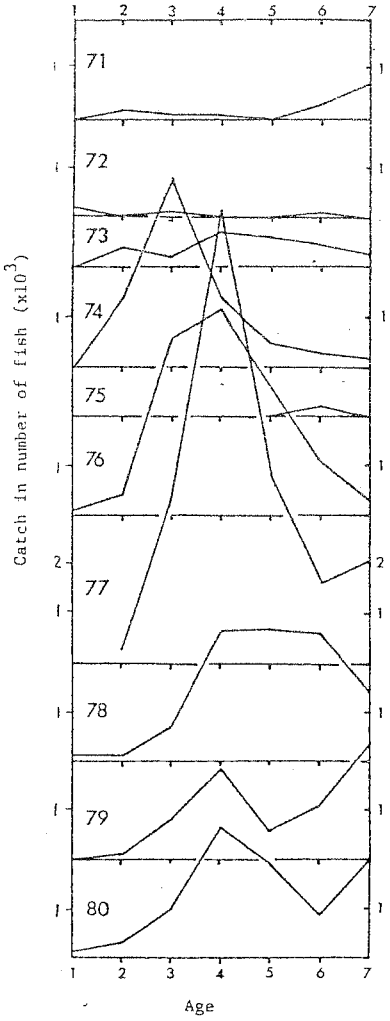


Fig. 3. Age composition of the West Atlantic stock caught by the Japanese longline boats for ages 1-7 during 1971-1980.

Fig. 4. Trend of cpue (catch in number of fish/ fishing intensity) by stock by age

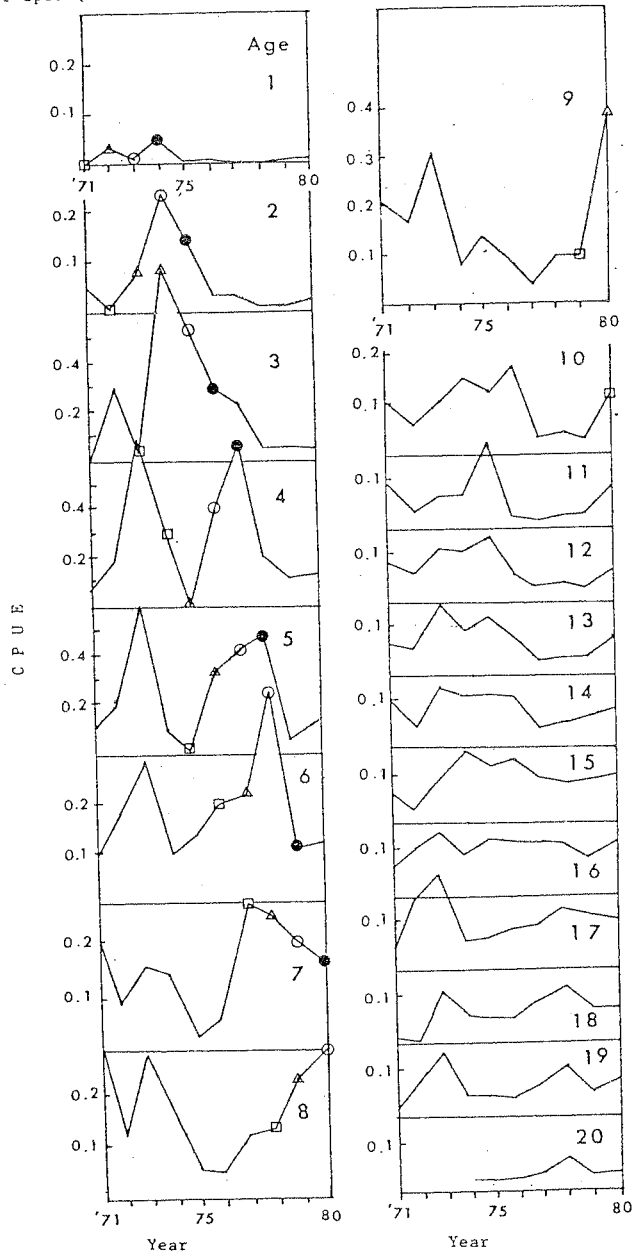
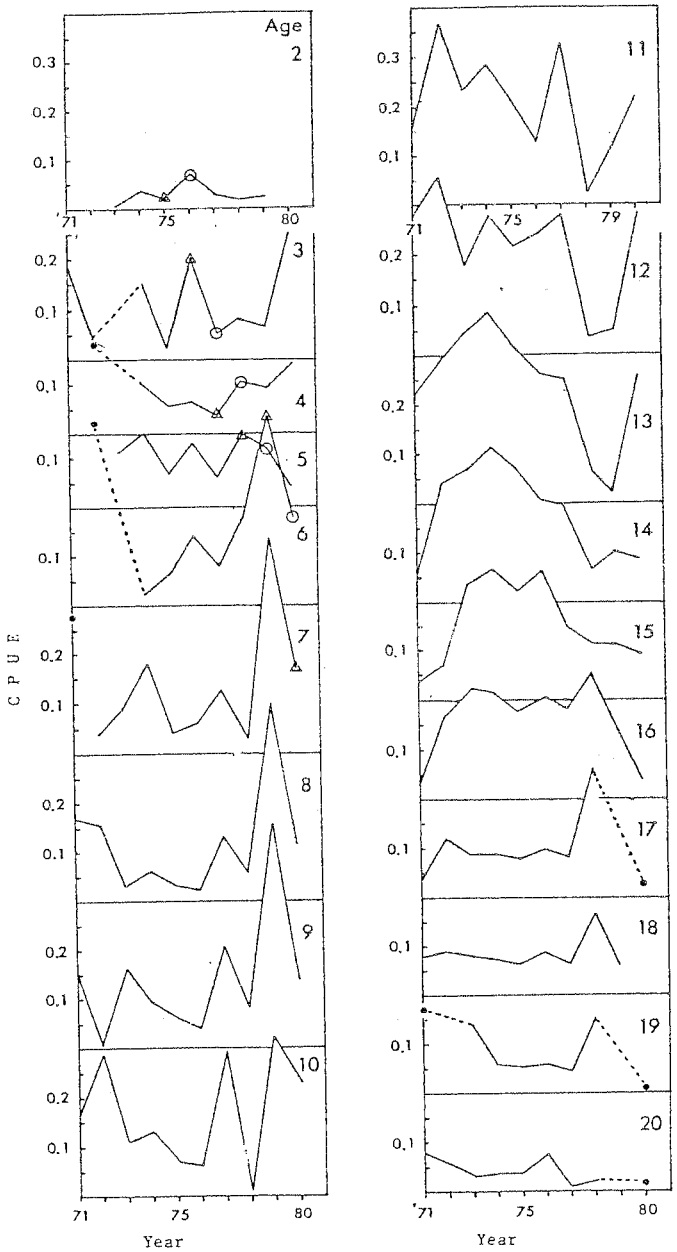


Fig. 4-1. West stock

1970 year class ... □
1971 year class ... △
1972 year class ... ○
1973 year class ... ⊛



Note scale reduction for ages 3-5 fish.

Fig. 4-2. East stock

1973 year class... △
1974 year class... ○

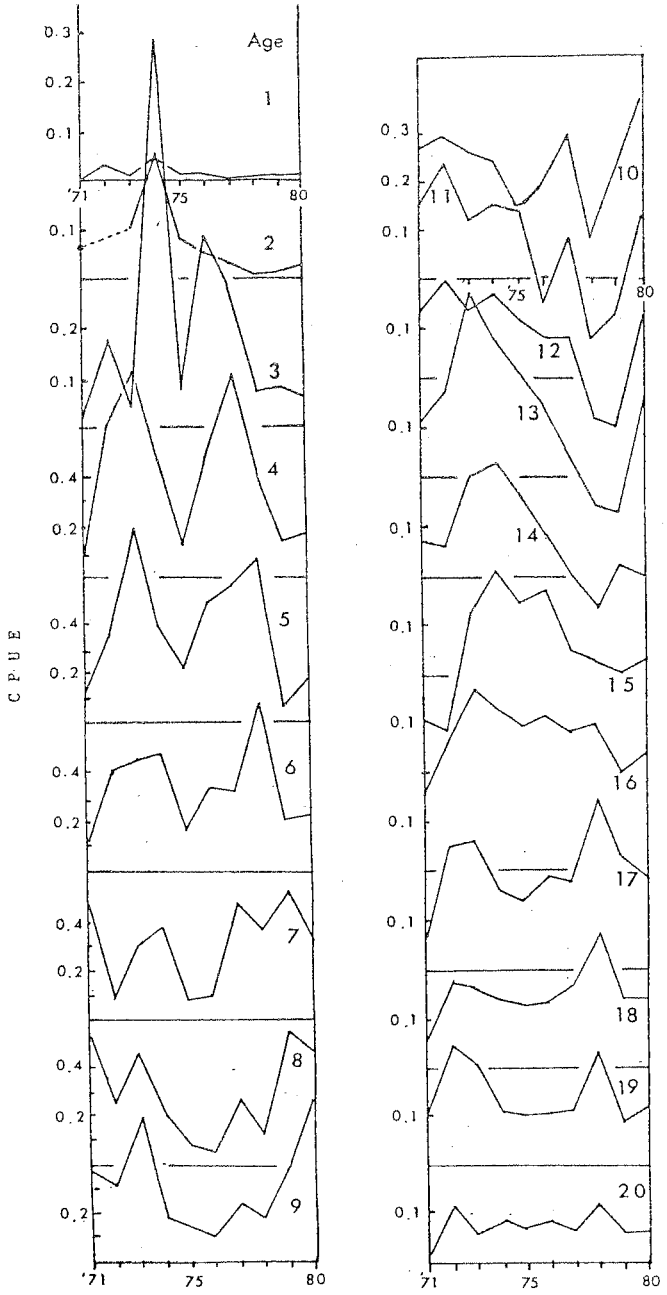


Fig. 4-3. Total stock

Note scale reduction for ages 4-9 fish.

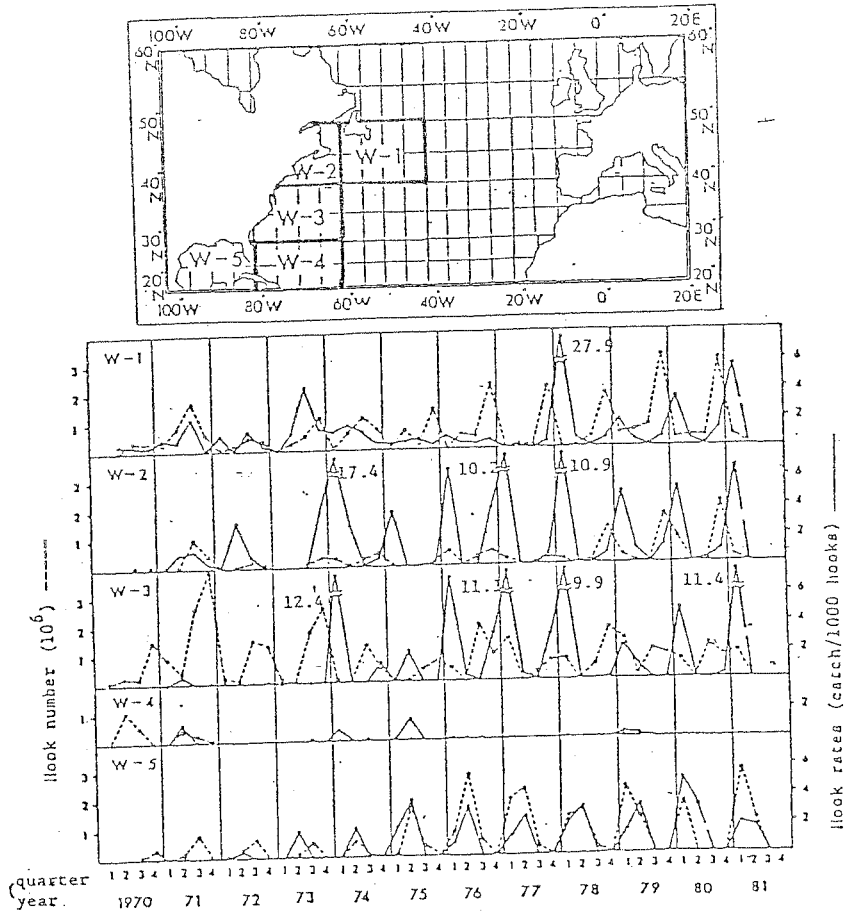


Fig. 5. Major fishing grounds of bluefin tuna in the West Atlantic (W1-W5) by the Japanese longline fishery and their trends of cpue in terms of catch in number of fish by nominal number of hooks (after Hisada and Suzuki 1982)