SCRS/1974/037 Col.Vol.Sci.Pap. ICCAT, 4: 145-160 (1975)

BIOLOGICAL INFORMATION ON ATLANTIC BLUEFIN TUNA CAUGHT BY LONGLINE FISHERY AND SOME VIEWS ON THE MANAGEMENT OF THE RESOURCES

by

C. Shingu, K. Hisada, S. Kume, M. Honma

SUMMARY

1) Japanese longline fishery made good catch of bluefin tuna in Area 19, 1962-1965 and in Area 17, 1964-1966. Since 1971, relatively good catch has been recurring in Area 15 and 16. Japanese bluefin catch data until 1970 were revised by dividing into bluefin and southern bluefin tuna, respectively (Addendum).

2) Longline bluefin occur almost entire Atlantic but mainly in the northern hemisphere with clear seasonal change in abundance.

3) Longline bluefin are composed mainly of large-sized fish with less medium and much less small-sized fish. Small-sized fish distributing more northern and coastal waters are separated in eastern and western sides of the ocean and spread towards high sea area with growth, seemingly increasing the opportunity to intermingle each other.

4) Hook rate of bluefin tuna has decreased clearly as concerns large-sized fish. Longline bluefin fishery seems to have experienced the peak years followed to those of other types of bluefin fisheries in the adjacent waters. Considering the longline bluefin being mainly composed of oldest age groups, there has not been substantial recruitment to the longline stock since 1966.

5) Regarding the stock assessment, annual change in the longline catch was examined, and two possibilities were made focused, (1) variation in year class strength and (2) effect of the catch of small and medium-sized fish on the amount of recruitment of the longline stock. Various calculations indicated that biomass maximum from a year class occurs at about 9-10 age, that Y/R becomes larger when only large-sized fish are exploited, and that increase in the catch of 1,000 tons of small-sized fish will result in the decrease by several times of amount of the large-sized fish. It is concluded that in the bluefin stock management much consideration should be given on the extent of the exploitation of small-sized fish.

RESUME

(1) La pêcherie palangrière japonaise a effectué de bonnes prises de thon rouge dans la zone 19 en 1962-1965, et dans la zone 17 en 1964-1966. Depuis 1971, des prises relativement bonnes se sont répétées dans les zones 15 et 16. Les données japonaises de capture de thon rouge jusqu'à 1970 ont été révisées en séparant thon rouge et thon rouge du sud (Addendum).

(2) Le thon rouge pris à la palangre se présente dans presque tout l'Atlantique, mais surtout dans l'hémisphère nord, avec des changements saisonniers nets dans l'abondance.

(3) Le thon rouge pris à la palangre se compose principalement de poissons de grande taille, avec une moindre quantité de poissons de taille moyenne et beaucoup moins de petits poissons. Les poissons de petite taille répartis dans les eaux plus au nord et plus près des côtes sont séparés de chaque côté de l'océan et s'étendent vers la zone de haute mer au fur et à mesure de leur croissance, ce qui fait que leurs occasions de se mélanger augmentent en conséquence.

(4) Le taux par hameçon du thon rouge a baissé de façon nette dans les secteurs où sont pêchés les grands poissons. La pècherie palangrière du thon rouge semble avoir connu ses meilleures années à la suite de celles d'autres types de pêche portant sur la même espèce dans les eaux adjacentes. Etant donné que le thon rouge pêché à la palangre se compose surtout des groupes d'âge les plus âgés, il n'y a pas eu de recrutement substantiel dans la pêcherie depuis 1966.

(5) En ce qui concerne l'évaluation des stocks, les modifications annuelles de la prise palangrière ont fait l'objet d'un examen, faisant apparaître deux facteurs: (1) variation de l'importance des classes annuelles, et (2) répercussions de la capture de poissons de petite taille et de taille moyenne sur le volume du recrutement du stock palangrier. Divers calculs ont indiqué que la biomasse maximale d'une classe annuelle donnée se situe à environ 9-10 ans, que la production par recrue augmente lorsque seuls les poissons de grande taille sont exploités, et qu'une augmentation de 1.000 tonnes de la prise de poisson de petite taille entraînerait une diminution plusieurs fois plus importante du volume des poissons de grande taille. En conclusion, la gestion des stocks de thon rouge exige qu'une attention très poussée soit accordée à l'importance de l'exploitation du poisson de petite taille.

*

RESUMEN

1) La pesquería japonesa con palangre obtuvo capturas sustanciales de atún en la zona 19, durante el periodo 1962-1965 y en la zona 17, durante el periodo 1964-1966. Desde 1971 se han estado obteniendo capturas bastante buenas periódicamente en las zonas 15 y 16. Los datos de capturas japonesas sobre el atún fueron examinados hasta 1970, dividiéndose en atún y atún del sur, respectivamente (Addendum).

2) El atún capturable con palangre aparece en casi todo el Atlántico, pero principalmente en el hemisferio norte, con unos cambios claros estacionales en la abundancia.

3) El atún de palangre se compone principalmente de peces de gran tamaño, en menor cantidad de peces de talla mediana y aún menos frecuentemente de peces de talla pequeña. Los peces pequeños que se distribuyen en aguas más al norte y en aguas costeras están separados a ambos lados del oceano - oriental y occidental - y se extienden al crecer hacia la zona de alta mar, aumentando al parecer la posibilidad de mezclarse entre sí.

4) El índice de capturas por anzuelo de atún ha disminuído claramente en las zonas de peces de gran tamaño. La pesquería de atún con palangre parece haber experimentado los más altos niveles más tarde que otros tipos de pesquerías de atún en aguas adyacentes. Considerando que el atún de palangre está compuesto principalmente por los grupos de edad mayores, no se ha producido un reclutamiento importante en el stock de palangre desde 1966.

5) En cuanto a la evaluación de los stocks, se examinó la variación anual en la captura con palangre y se han considerado dos posibilidades: (1) variación en la importancia de la clase anual, y (2) efecto de la captura de peces pequeños y medianos sobre el volumen de reclutamiento del stock de palangre. Los diversos cálculos efectuados indicaron que la biomasa máxima de una clase anual se produce alrededor de los 9-10 años de edad, que el rendimiento-por-recluta resulta mayor cuando solo son explotados los peces de gran tamaño y que el aumento en la captura de 1.000 tons de peces pequeños producirá un descenso múltiple en el volumen de peces grandes. La conclusión a la que se llega es que en la ordenación del stock del atún debe prestarse mucha atención a la importancia de la explotación de peces pequeños.

*

* Figures 5, 6 and 7 reproduced in Data Record Vol. 5.

Figures 5, 6 et 7 reproduites dans la Vol. 5 du Recueil de Données.

Las Figuras 5, 6 y 7 reproducidos en el Vol. 5 de la Colección de Datos Estadísticos.

The amount of catch of bluefin tuna in the Atlantic including the Mediterranean Sea has decreased to a lower level in recent years. This has surfaced rapidly the problem on the status of the stock not only by ICCAT but also by ICES. The traditional study on this species has been developed with the information obtained from the coastal fisheries, while the more information has become recently available and accumulated with the wide expansion of the longline fishery. in the offshore waters. At the same time, the concern relating to the resource management on this species has become more active, and the needs of the comprehensive examination of the status of the stock is originated in the whole Atlantic Ocean.

1. Bluefin tuna fishery in the Atlantic.

Bluefin tuna fisheries have been continuously conducted in both coastal waters of eastern and western Atlantic of the northern hemisphere as well as in the Mediterranean Sea since long before. On the other hand, relatively new fishery of longline gear that captures bluefin tuna more or less has encountered the occurrence of the species in considerably wide area ranging from coastal waters to high seas throughout the entire Atlantic (Fig. 1).

There exist various types of fisheries in coastal waters, which in general are classified into two groups according to the size of the fish in the catch: the fishery for small-sized fish (under 32 kg in gill-and-gutted weight) and that for large-sized fish (over 100 kg) (Fig. 2). The main fisheries are purse seine fishery in the western Atlantic, and pole-and-line and trolling fisheries in the eastern Atlantic, for the former, and purse seine fishery and trap fishery in the eastern Atlantic for the latter. In recent years, the fishery aiming for medium-sized fish (32-100 kg) is very limited.

Only bluefin tuna fishery in the offshore area is the longline fishery, taking mainly large-sized fish with less medium- and small-sized fish.

The annual catch for 1970-1972 amounted about 20,000 tons in the Atlantic and 5,000-7,000 tons in the Mediterranean Sea, respectively (ICCAT 1974). Of these amount of catch, the share of the longline fishery is estimated to be from 300 to 4,600 tons for the same period (refer to Addendum on the longline bluefin catch).

2. Bluefin tuna catch by longline fishery.

Japanese longline fishery started its activity in the Atlantic in 1956, and harvested rarely bluefin tuna in earlier years. Since 1962, the catch of the species had become increased taken with yellowfin and bigeye tunas mainly in the equatorial area off Brazil. Later on, when the longline fleet switched their main object to albacore and bigeye tuna in the middle latitudes, the fair amount of bluefin tuna was also harvested seasonally. In recent years, longline bluefin fishing ground is observed in the area around the latitudinal line of 40°N in the western Atlantic, and in the Mediterranean Sea and around the Strait of Gibraltar.

With the historical change in the main longline fishing ground, the successful bluefin ground and period in the past are distinguished in two parts (Fig. 3): the one is in the equatorial area (Area 19 -refer to Fig. 4-), during four years, 1962-1965 with peak catch of 60,000 fish in number in 1963 and the lowest 15,000 fish in 1965, and the other is in the offshore area off Florida through New York (Area 17), during the years 1964-1966 with the catch fluctuation in number between 20,000 and 40,000. From 1967 to 1970, the blufin catch by longline fishery in both areas decreased remarkably. Since 1971, the amount of catch by the longline fishery has begun to increase: in 1971 about 7,000 in number of fish of catch in Area 13 and, after 1972 the longline aiming for bluefin tuna being on the increase in the area off Atlantic sides of Spain and Portugal as well as in the Mediterranean Sea.

3. Geographical distribution of bluefin tuna observed through the longline activity.

The major study on the seasonal distribution and migration of bluefin tuna has been progressed mainly based on the information of coastal fisheries. Therefore the ecological information in the offshore area and high seas are not accumulated sufficiently. In this connection, the longline data obtained through the wide-ranged operation is useful to delineate more fully the overall distribution in the entire Atlantic.

The bluefin distribution through the longline data is plainly understood when the Atlantic is grouped into three areas: north of 20°N, 15°N-10°S and south of 20°S. In each area, the occurrence of the fish is continuous in east-west direction, together with the seasonal fluctuation (Fig. 5).

(1) North of 20°N: Two main distributions are observed in the western and eastern sides of the area. The western area of high density appears in the northern part of Gulf of Mexico as far as off Florida, and in the area north of 30°N in May and June. This occurrence seems to make a northward shift along the North America until July-September. During the months of December and January, the higher occurrence is again observed around the latitudinal line of 40°N, and then with progress of time moves southward to the south of 30°N in spring. In the eastern area, the higher density appears in the Atlantic side of the Strait of Gibraltar in May, and in the Mediterranean Sea in June and July. The dense occurrence in the high sea area is observed only in particular 2 or 3 months. In the overall area of the middle latitudes in the northern hemisphere, the area of high density shifts from around 30°N to 40°N during spring and summer, and the reverse southward movement is observed from winter to spring.

(2) 15°N-10°S: The hook rate in the equatorial area begins to rise in February, reaching its peak in March and declines in the southern portion gradually in April and then rapidly in the whole area in May, disappearing in June. A slight rise in hook rate is again observed in the period from September through November.

(3) South of 20°S: The catch itself of the species in this area is extremely seldom. Only one or two individuals are caught throughout one longline cruise, if any. The occurrence seems to be higher in the areas relatively close to both continents. Relatively high hook rate appearing in the coastal area off southern Africa are due to the inclusion of southern bluefin tuna.

4. The size composition in weight of the longline catch.

The size of bluefin tuna caught by the longline fishery ranges widely from small to large. However, the main component of the catch is predominated by large-sized fish with less medium-sized fish. The catch of small-sized fish is limited in particular area. Since the data are rather fragmental, it is not possible to examine the year-to-year change in the size composition. The size composition of the catch is different by area and described as follows (Fig. 6):

(1) Equatorial area (15°N-10°S): Major catch is of large-sized fish mixed with few medium-sized fish. No small-sized fish was sampled.

(2) North Atlantic, west of 40°W: In the area south of 40°N, large-sized fish are predominated, while in the area north of 40°N the predominance is replaced by medium-sized fish. Until 1972, small-sized fish were sampled few, but in the northern area of the Gulf of Mexico in June and July of 1973 and in the area of 40°-45°N and 60°-70°W, the latter of which is originally bigeye tuna fishing ground, from December 1973 to February 1974, it is noted that small-sized fish are observed in appreciable proportion.

(3) North Atlantic, 20-40°W: The catch in this high sea area being small, the fish are mainly large-sized.

(4) North Atlantic, east of 20°W: The data of April to June, 1970 in the area of 20°-30°N and 10°-20°W, show the main constituent of medium-sized fish, with fair amount of large-sized fish. Another data, in the area of 40°-45°N and 0°-10°W in July-September, 1972, indicate the predominance of medium-sized fish mixed with small- and large-sized fish.

(5) In the area around the Strait of Gibraltar and in the Mediterranean Sea: Large-sized fish are predominant in May-August 1972 with far less small- and medium-sized fish. Though the exact weight data are not available, the information on the size of the fish caught in this area in May and June 1974, disclosed that 97 % of catch in number were of large-sized in the Atlantic side and 80 % in the Mediterranean side.

(6) South Atlantic, south of 20°S: The rare catch of bluefin tuna are mostly of large-sized fish.

5. Intermingling of the fish based on the longline data.

The occurrence of bluefin tuna by size in the whole Atlantic, as obtained by the above section, is schematically summarized as follows: (1) the occurrence of small-sized fish is limited in the eastern and western coastal areas north of middle latitudes of the northern hemisphere, (2) the medium-sized fish also appear in the coastal areas of both eastern and western sides, whereas the range of distribution is more seaward extended than that of small-sized fish, and (3) the large-sized fish overspread widely from equatorial area to the higher latitudes of both hemispheres.

From the above, the distribution by size is suggestive that in the early stage of the life span bluefin tuna are separated in the eastern and western areas, and, with growth, expand its distribution range from coastal waters to offshore and high sea areas. While the apparent separation of the occurrence of fish on early life stage seems to correspond with the two main existing spawning grounds, in the western area around off Florida and in the Mediterranean Sea, respectively, it appears that an opportunity of intermingling between two eastern and western groups would increase as the fish grow.

6. Stock assessment.

6 - 1. Annual change in the longline catch in bluefin tuna.

As already described in section 2, bluefin catch by the Japanese Atlantic longline fishery has experienced three peak seasons: 1962-1965, 1964-1966 and after 1971. The catches of the former two seasons were mostly large-sized fish, while that of the latest season includes some medium sized fish besides. The fishing ground in each peak season was completely different each other. After the bluefin ground off Florida during 1964-1966 disappeared, the bluefin catch by Japanese longliners had been remarkably small for the time being. During this period, Japanese longline fleet had been focussing their effort gradually for such <u>sashimi</u> species as southern bluefin and bigeye tuna, aparting from albacore and yellowfin tuna that had been their major objects. As a result, the effort exerted in the tropical waters was shifted to temperate waters in rather higher latitudes, having indicated also the diminishing interest of the longline fleet for the bluefin spawning groups in the area off Florida and Brazil.

Annual change in hook rate of bluefin tuna by areas until recently (Fig.7) indicates that:

(1) In the longline area operated during recent decade or more than this period, there seems to be a difference in trend of hook rate fluctuation between Areas 17-22 and Areas 13-14. The Areas 17-22 are fishing grounds for large-sized fish, where the hook rate has been on the contineous decrease. On the contrary, in Areas 13-14 in the higher latitudes with larger share of medium-sized fish, the hook rate has not necessarily been on the declining trend since 1964.

(2) Any trend in annual change of the hook rate in recent major fishing grounds, in the coastal area off Iberian Peninsula and in the Mediterranean Sea, can not be traced with only two years' data.

(3) Regarding the recent increase in bluefin catch in the Areas 13-14 since 1971, there remain some point that is not fully understood. It is obvious that the increase in effort in the Mediterranean Sea was directed for bluefin tuna. However, the increase in the catch in Areas 13-14 has not influenced the past effort distribution aiming for bigeye tuna. Therefore, it may not be appropriate at least to relinguish the possibility that the increase in bluefin catch in these areas was attributed to the increased recruitment to the longline fishery.

(4) It is important to make a comparison of the annual change in the catch by longline fishery with that by other type of fishery. The general trend is that in the high seas as well as in the Mediterranean Sea, the peak season of longline fishery appears in the last stage of the peak season of the other fishery of the adjancent waters (Fig.8). In the past, the objectives of the longline fishery were the oldest ages groups, thus being considered that the fish recruited to the longline fishery had been the remainder of the age groups undergone other fisheries. In this regard, the longline fishery in the off-shore areas might have not encountered new recruitment since 1966. It is important to examine whether this is due to the lack of the occurrence of dominant year class or to decreased escapement from preceding catch.

6 - 2. Examination of the annual change in longline bluefin catch.

(1) Possibility of the variation in year class strength.

In the North Pacific Ocean, there has been observed a remarkable yearly fluctuation in year class strength of bluefin tuna, which has made the catch of this species notably unstable. At the same time, once dominant year class appears in the fishing ground in certain year, then this year class supports the good bluefin catch for successive several years (Fig. 9). To examine the above possibility in the Atlantic bluefin tuna, Figs. 10a and b are prepared besides Fig. 6. As are indicated in these Figures, a few series of modal groups suggesting the appearance of the dominant year class are observed. However, in other available data, such phenomena are not clearly detectable.

(2) Possibility of the decline in amount of recruitment due to the preceding catch of small-and medium-sized fish.

As a preliminary approach to this problem, the change in total catch or yield of large-sized fish per recruitment was examined due to the change in the type of exploitation of bluefin stock.

A: Age at maximum biomass attained from a year class.

Under the assumption $M = 0.2$, and employing the growth equations by Rodoriquez-Roda (1971) and Mather and Jones (1972), biomass maximum occurs at about 9-10 age (Fig. 11). Therefore, it may be more effective to employ a fishing gear that captures mainly the fish around these ages.

B: Y/R calculated for various exploitation with the change of age interval.

Two types of Y/R's were calculated employing the growth equation by Mather and Jones (op. cit.): (1) when t_c is changed from 1.0 to 10.0 age by 1 age interval, $t_r = 1.0$ age and $t_d = 16.0$ age (Figs. 12a and b), and (2) when small-sized fish (1-5 age), medium sized fish (5-9 age) and large-sized fish (9 age and over) are exploited independently (Figs. 13a and b). In both cases, it is obvious that Y/R's calculated for the exploitation of only large-sized fish are conspicuously large. Even in the range of small F, Y/R's for large-sized fish and those inclusive of medium-sized fish attain at least more than 30 times as much of the Y/R's for small-sized fish (Fig. 14). Hence, it is most likely that the increase in catch of small-sized fish would result in the remarkable decrease in the catch of large-sized fish.

C: Reduction of the catch of large-sized fish originated by the increment of the catch of small-sized fish.

The results of the trial calculation are shown in Figs. 15a and b, to evaluate in quantity, assuming the amount of recruitment at age 1 is a million of fish, the effect of small-sized fish catch on the catch of large-sized fish.
Two examples are taken to make explanation simpler:

Case-1: Initial F is common, 0.2, and irrespective of the size of the fish. Then only F on small-sized fish changes (Fig. 15a).

F	Amount of catch		
	small-sized fish	medium-sized fish	large-sized fish
0.2	536	3,234	4,633
0.4	575	1,453 (0.45)	2,868 (0.62)
0.6	469	652 (0.20)	1,289 (0.28)
0.0	0	4,989 (1.54)	14,207 (3.07)

A figure in the parenthsis indicates the ratio of the initial catch of large-sized fish or medium-sized fish to that after F's on small-sized fish are changed.

Case-2: Initial F is common, 0.4, and irrespective of the size of the fish. Then only F on small-sized fish changes (Fig. 15b).

F	amount of catch		
	small-sized fish	medium-sized fish	large-sized fish
0.4	575	1,907	1,410
0.6	469	856 (0.45)	634 (0.45)

A figure in the parenthesis indicates the ratio of the initial catch amount of large-sized fish or medium-sized fish to that after F's on small-sized fish are changed.

When the fishing intensity on small-sized fish is increased, the catch of small-sized fish does not change much, in the range of 0.2< F <0.6, whereas those of medium-sized fish and large-sized fish are influenced remarkably. Recent F, e.g. estimated by Sakagawa and Coan (1974), appears to be around 0.3-0.4. In this case, if the amount of fishing on small-sized fish is changed 50 % less or 50 % more, then the catch of large-sized fish would result in two times as much or one half, respectively. The problem to be considered now is that even if F is increased the catch of small-sized fish is almost unchanged. Accordingly, it is difficult to verify whether the variation in catch is attributable to the fluctuation of the amount of recruitment or to the variation of F. Thus, if management measures on bluefin tuna is enforced by the regulation on amount of catch, it is necessary to obtain the evidence through some method that F or Z (total mortality coefficient) is under control.

Through the above examinations, it seems that the possibility that reduction in the catch of large-sised fish is caused by the increase in exploitation of small-sized fish is undeniable, as already pointed out by several scientists. In recent years, the fishery directing to the younger bluefin tuna than 5 age is expanding in the Ocean, and resultant catch is also increasing. As is suggested by the calculation in Case-1, the increase in the catch of 1,000 tons of small-sized fish corresponds to the catch of several thousand tons of large-sized fish.

6 - 3. Suggestion on the stock management.

In the preceding sections, the catch variation of Atlantic bluefin tuna was analysed. The results, regarding on the cause of the variation, may be summarized into following two cases:

(1) The occurrence of the remarkable fluctuation of year class strength.

(2) Recent increase in catch of small-sized fish that reduced the catch of large-sized fish.

Of these, the possibility of (1) is not entirely ascribable, but there is not much positive relevant evidence. On the otherhand, since more than 1,000 tons of increase in the catch of small-sized fish has been actually observed in the Ocean since 1962, the case (2) above holds more actuality as the possible cause of the catch variation of the large-sized fish. Therefore, it appears to be of importance for the point of the future fisheries management to bring the mode of utilization of the resources to more rational one. Even in the case when the effect of the year class strength fluctuation is not negligible, as indicated in (1) above, it is advisable to restrain from the increment of the catch of small-sized fish, to sustain the potential reproduction fecundity of the stock (Fig. 16).

In conclusion, it is an effective and fundamental strategy in bluefin tuna fishery management to give much consideration on the exploitation of small-sized fish as small as possible.

References

ICCAT 1974a. Statistical Bulletin. 4

_______ 1974b. Report for bienial period, 1972-1973. Part II. English version. 203 p.

Mather, F.J.,III, and A.C. Jones. 1972. A preliminary review of the stock structure of bluefin tuna in the Atlantic Ocean. Unpublished ms., Woods Hole Oceano. Inst., 18 p. (Cited from Sakagawa and Coan, 1974)

Mather, F.J.,III, J.M. Mason, Jr. and A.C. Jones. 1974. Distribution, fisheries and life history data relevant to identification of Atlantic bluefin tuna stocks. ICCAT Coll. Vol. Sci. Papers, (II), (SCRS -1973), 234-258 and Data Record, (III), 103-145

Sakagawa, G.T. and A.L. Coan. 1974. A review of some aspects of the bluefin tuna(Thunnus thynnus thynnus) fisheries of the Atlantic Ocean. ICCAT Coll. Vol. Sci. Papers, (II) (SCRS -1973), 259-313

Rodriguez -Roda, J. 1971. Investigations of tuna(Thunnus thynnus) in Spain. ICCAT Rept. Bien. Per., 1970 -1971, Part II, English version, 110-113

Yamanaka H.. Unpublished ms.. A study on the bluefin tuna stock in the Pacific Ocean. Far Seas Fish. Res. Lab., Shimizu

Addendum

(1) Bluefin catch of Japanese longline fleet in the Atlantic Ocean included the catch of southern bluefin tuna until the year of 1971. Recent catch statistics made it possible to revise these data into species level. The result on Japanese annual catch in tons is as follows:

Year	S.B.F. & B.F. combined	S.B.F.	B.F.
1957	63	0	63
1958	34	0	34
1959	256	0	256
1960	820	0	820
1961	577	0	577
1962	3,703	0	3,703
1963	7,809	0	7,809
1964	12,629	0	12,629
1965	9,612	61	9,551
1966	2,860	339	2,521
1967	858	64	794
1968	363	78	285
1969	822	704	118
1970	4,374	4,287	87

(2) Korean bluefin catch of 3.0 thousand tons in 1971 is attributable to the highest catch of 4,600 tons during 1970-1972.

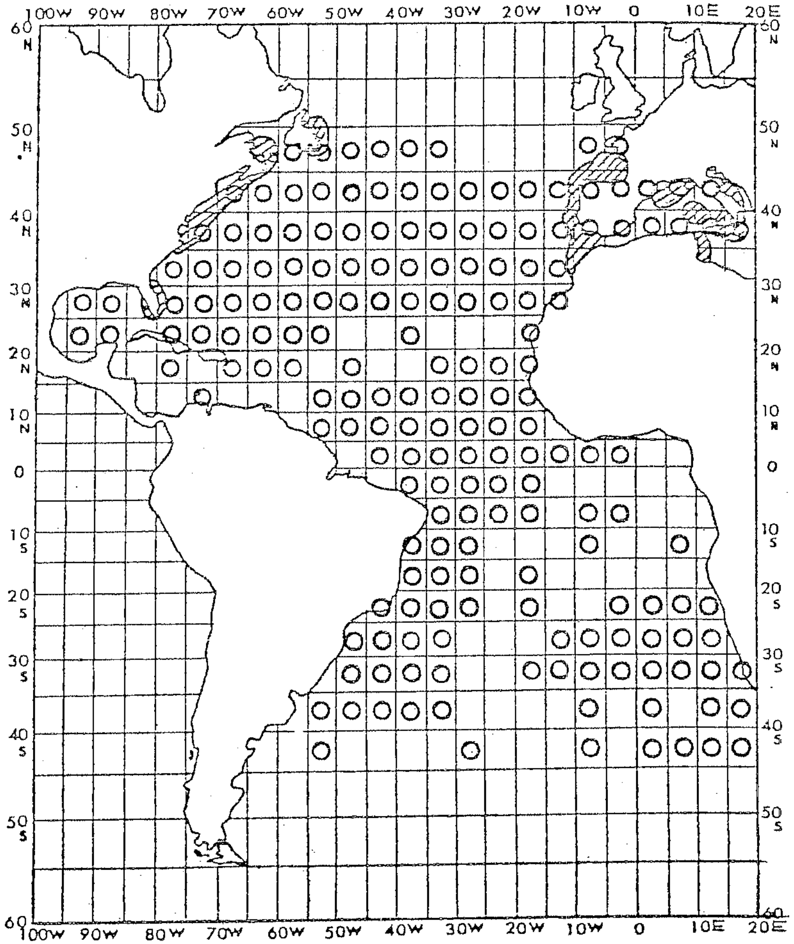

Fig. 1. The occurrence of bluefin tuna caught by Japanese longline fishery by 5° areas. Striated parts indicate the major coastal fisheries for bluefin tuna.

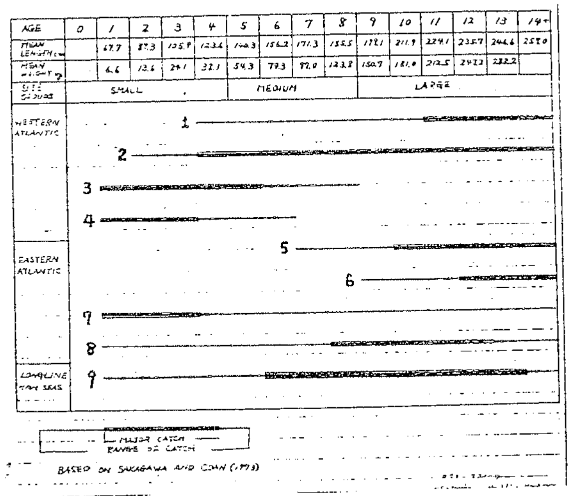

Fig. 2. Size ranges of bluefin tuna caught by various types of fisheries.

Remarks:

1 ..... Canada: sportfishing
2 ..... U.S. and Canada: Handline, harpooning and trap
3 ..... U.S. and Canada: purse seine
4 ..... U.S.: sportfishing
5 ..... Norway: purse seine
6 ..... Germany and Holland: Handline
7 ..... France, Portugal and Spain: trolling and pole-and-line
8 ..... Morocco, Portugal and Spain: Trap
9 ..... Japan: longline

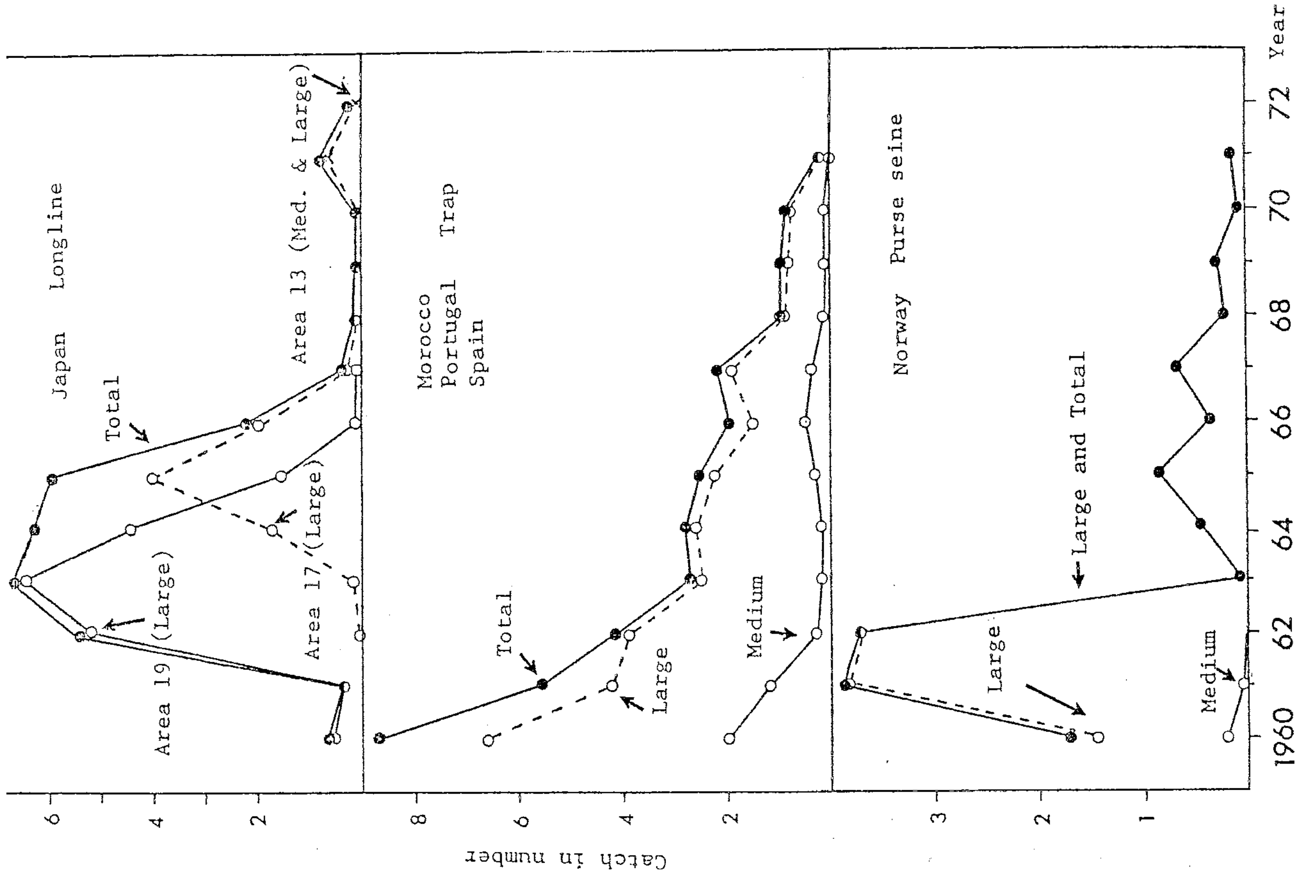

Fig. 3. Annual change in the catch of the fisheries aiming for large-sized fish by fishing gears, 1960-1972 (ICCAT 1974 b)

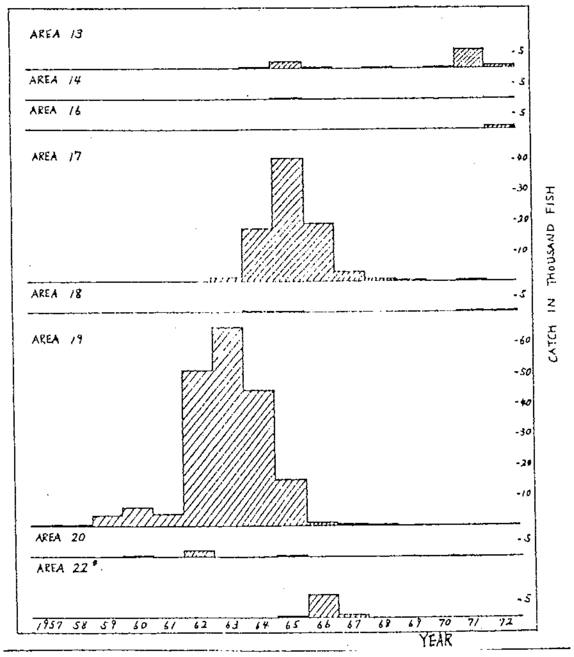

Fig. 3. Annual catch of longline caught bluefin tuna by areas denoted in Fig. 4.
Catch data less than 250 fish in one area were excluded.
* Catches in Area 22 are mostly southern bluefin tuna.

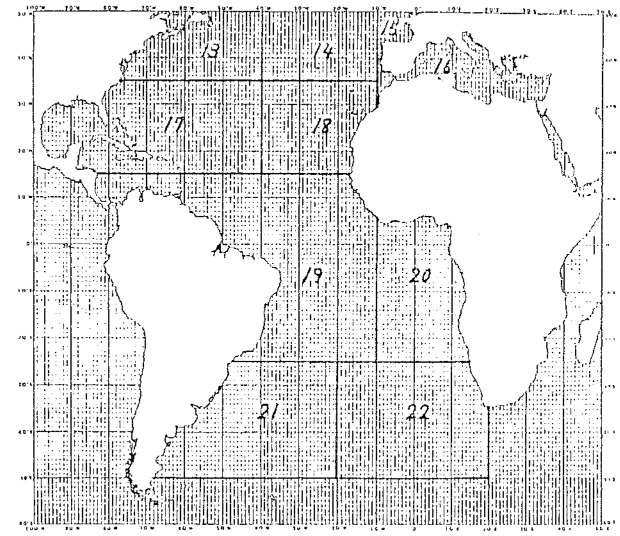

Fig. 4. Division of area.

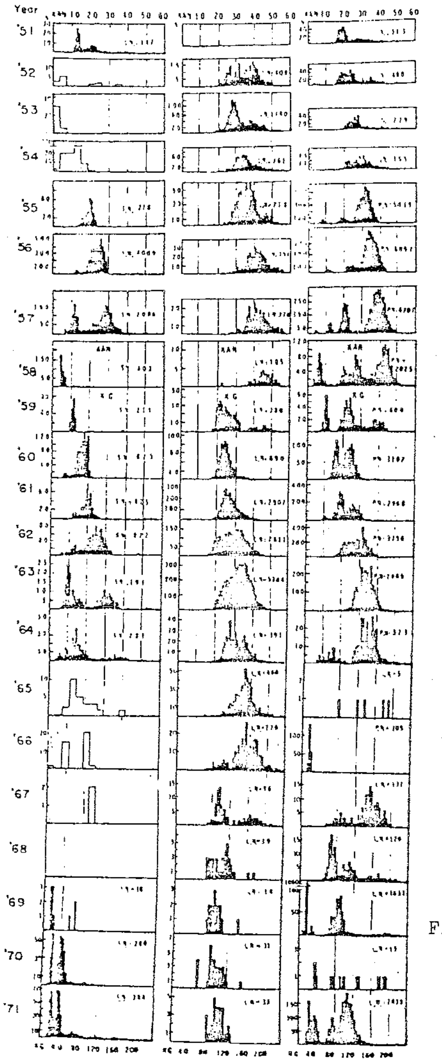

Fig. 9. Annual fluctuation in size composition of the Pacific bluefin tuna in the northwestern Pacific area (after Yamanaka unpublished).

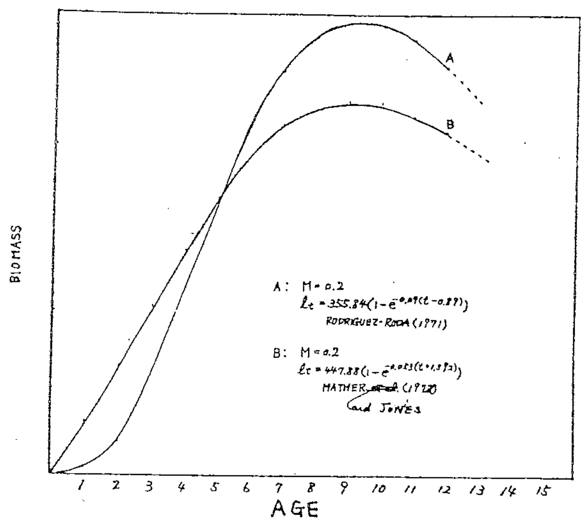

Fig. 11. Age dependant change in biomass of bluefin tuna stock, assuming natural mortality coefficient as 0.2.

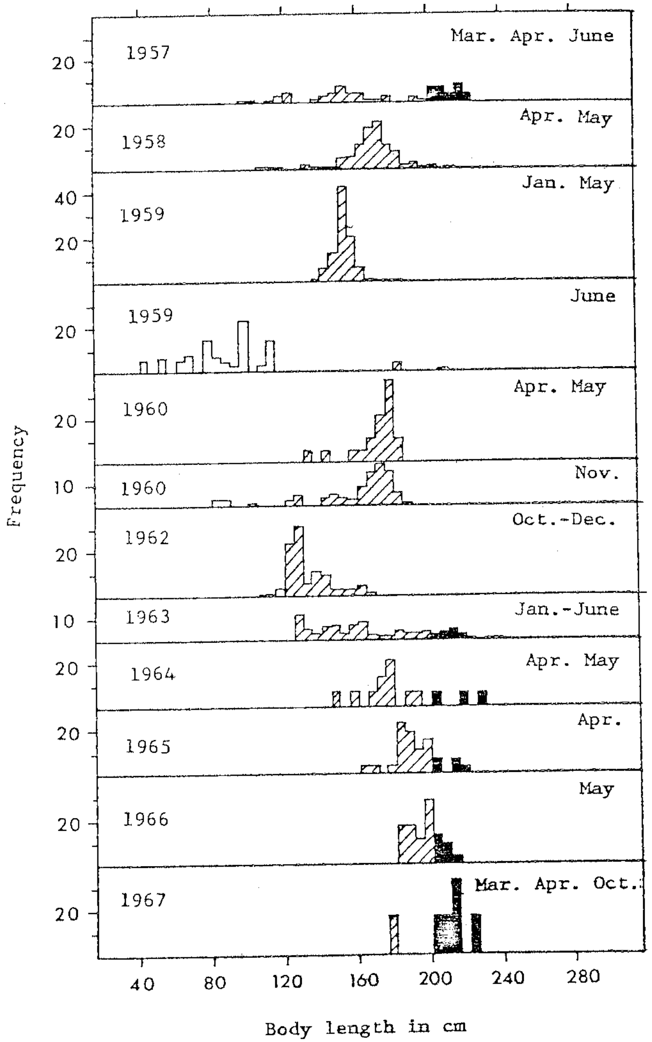

Fig. 10a. Size composition of bluefin tuna caught by the US experimental longline fishery in the northwestern Atlantic, 1957-1967. (ICCAT 1974 b)

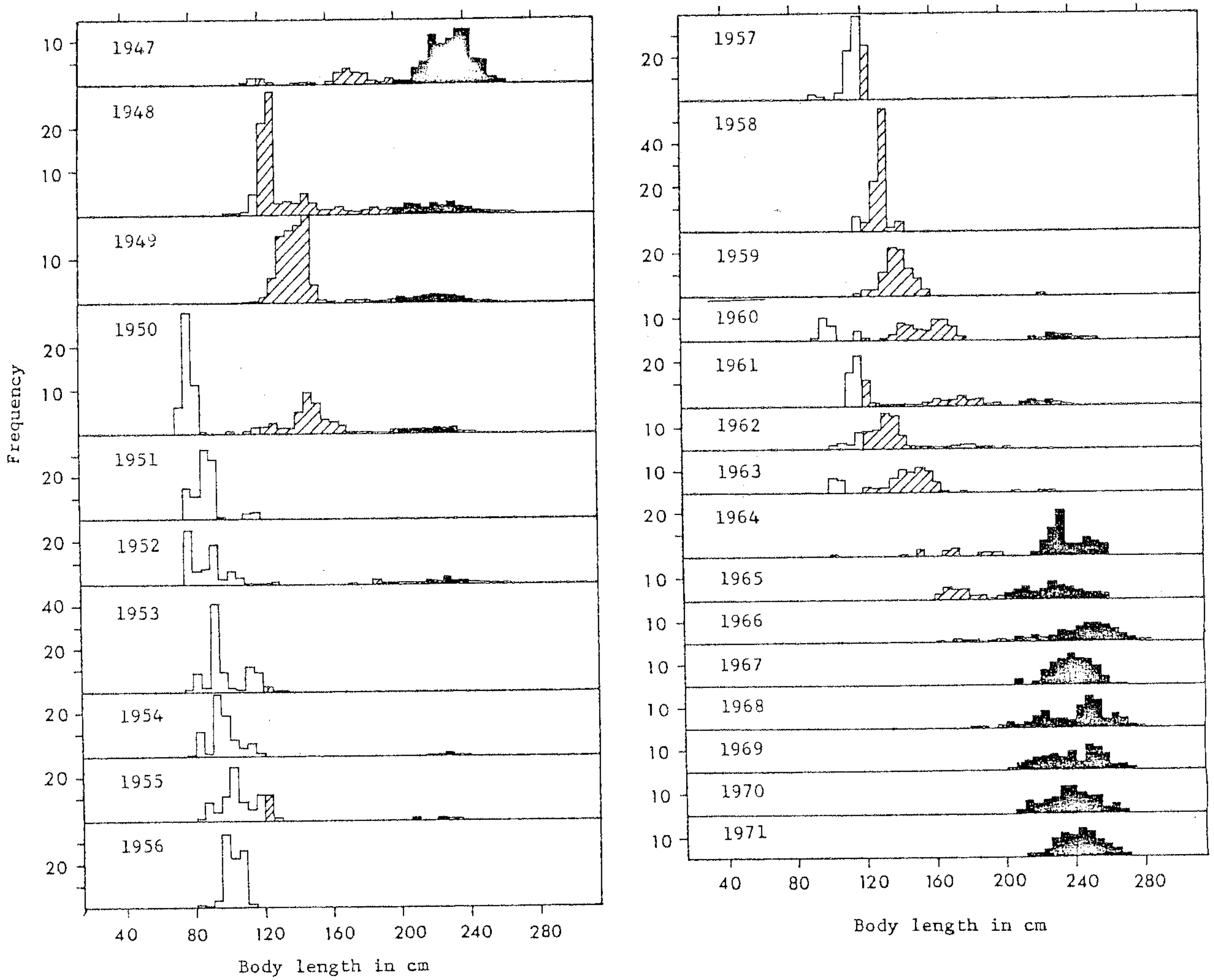

Fig. 10b. [illegible] change in the length composition of bluefin tuna [illegible] the coastal [illegible] of the northwestern [illegible], [illegible]

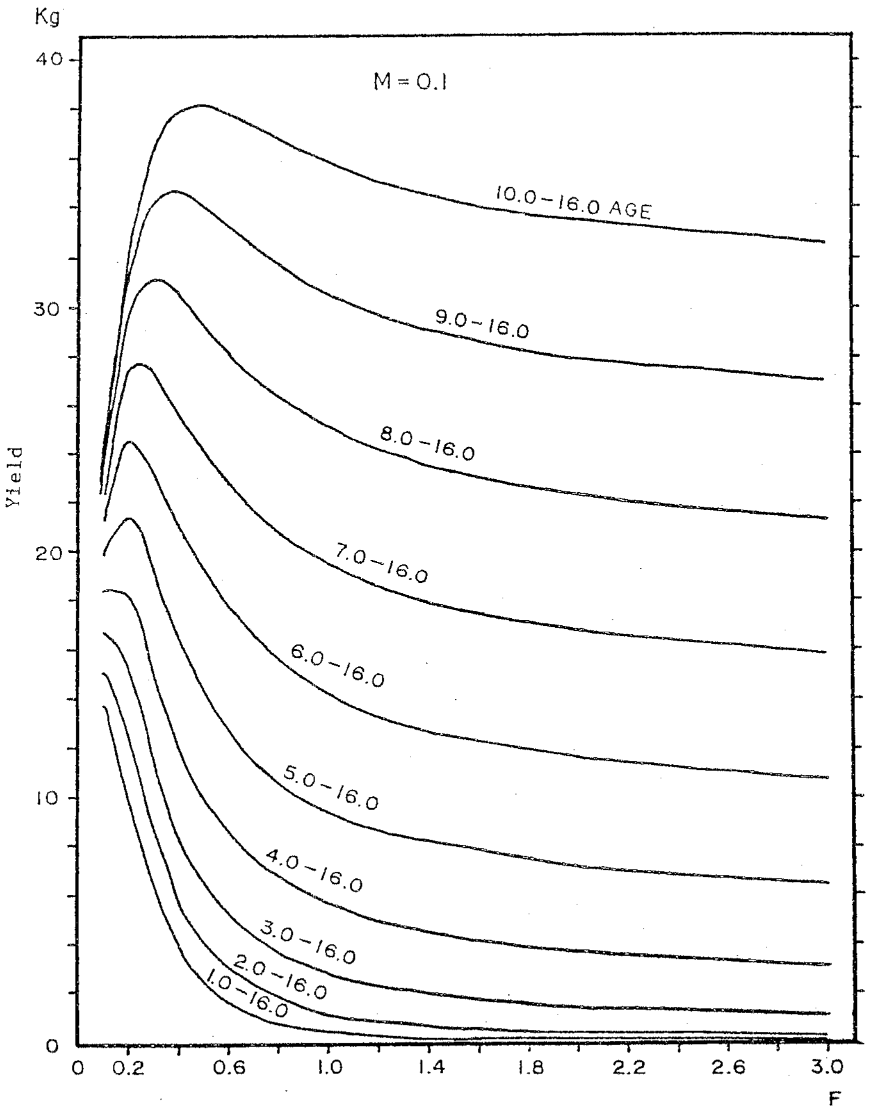

Fig. 12a. Comparison of Y/R of bluefin tuna when t_c changes from 1 to 10 age and M = 0.1.

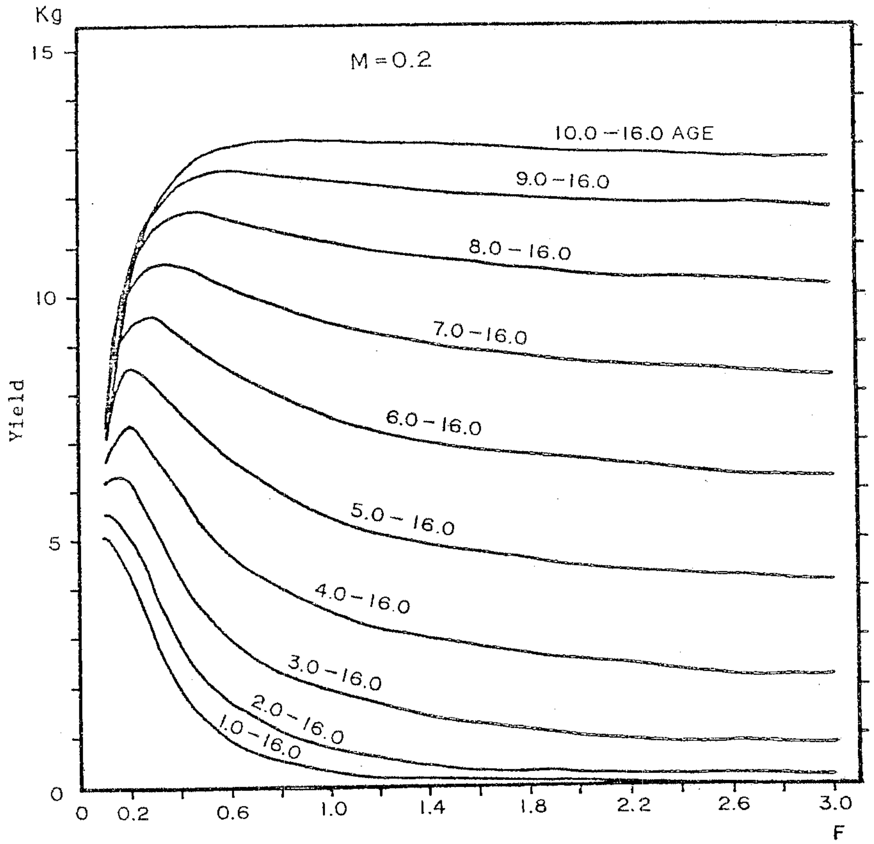

Fig. 12b. Comparison of Y/R of bluefin tuna when t_c changes from 1 to 10 age and M = 0.2.

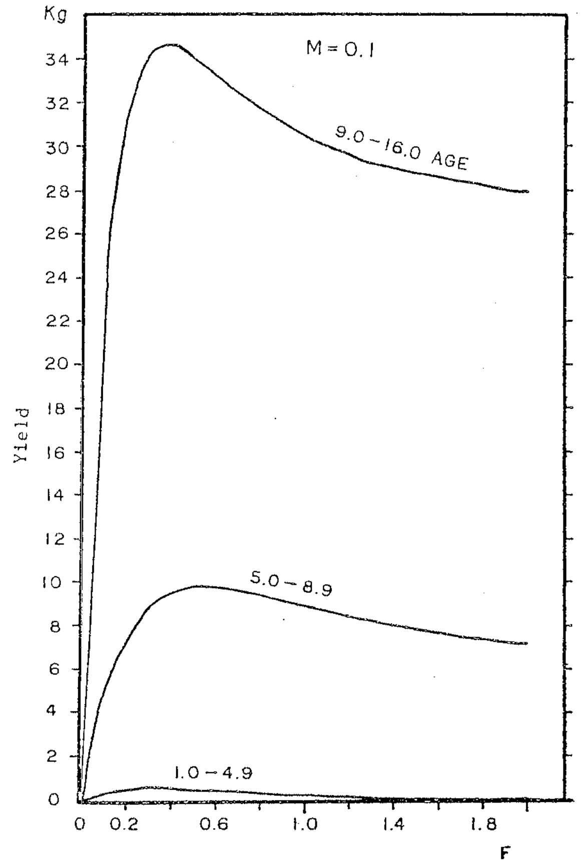

Fig. 13a. Comparison of Y/R of bluefin tuna by three types of fisheries aiming at 1.0-4.9 age, 5.0-8.9 age and 9.0-16.0 age, respectively, when M = 0.1.

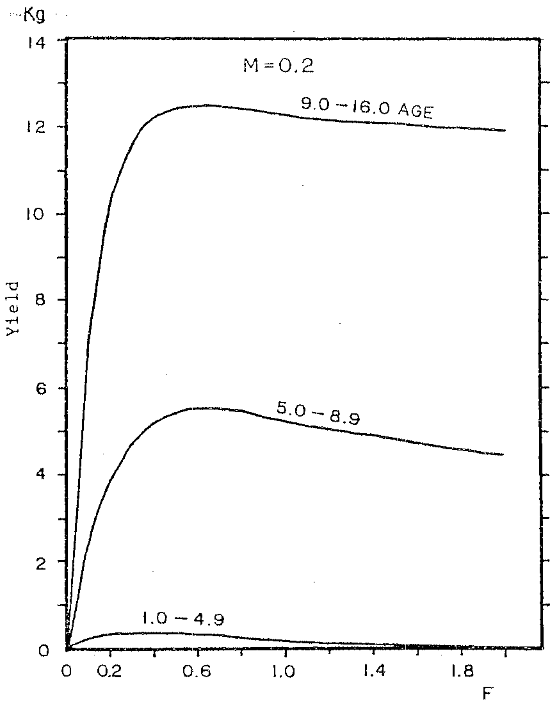

Fig. 13b. Comparison of Y/R of bluefin tuna by three types of fisheries aiming at 1.0-4.9 age, 5.0-8.9 age and 9.0-16.0 age, respectively, when M = 0.2.

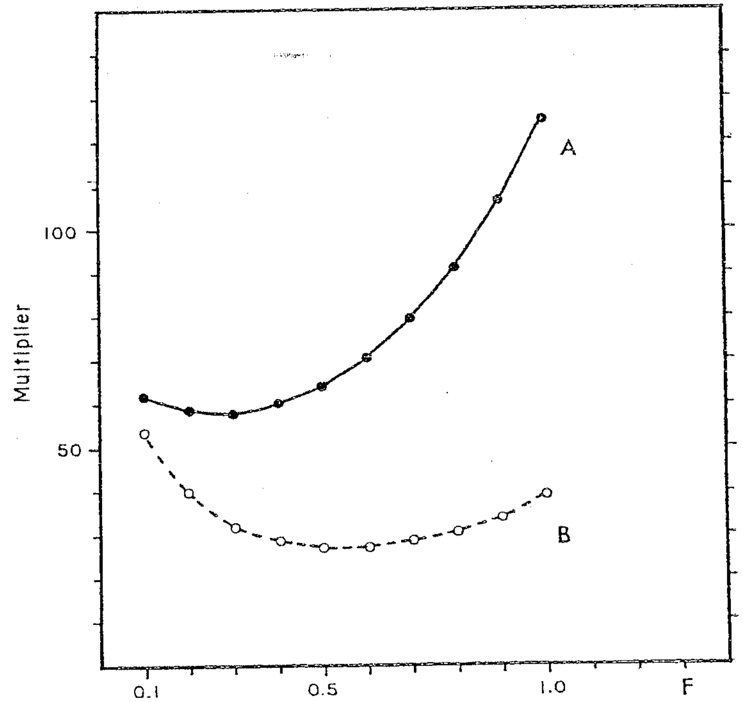

Fig. 14. Ratio of Y/R of small-sized fish to Y/R's of other size groups.

A : $\frac{\text{Catch of large-sized fish}}{\text{Catch of small-sized fish}}$

B : $\frac{\text{Catch of large- and medium-sized fish}}{\text{Catch of small-sized fish}}$

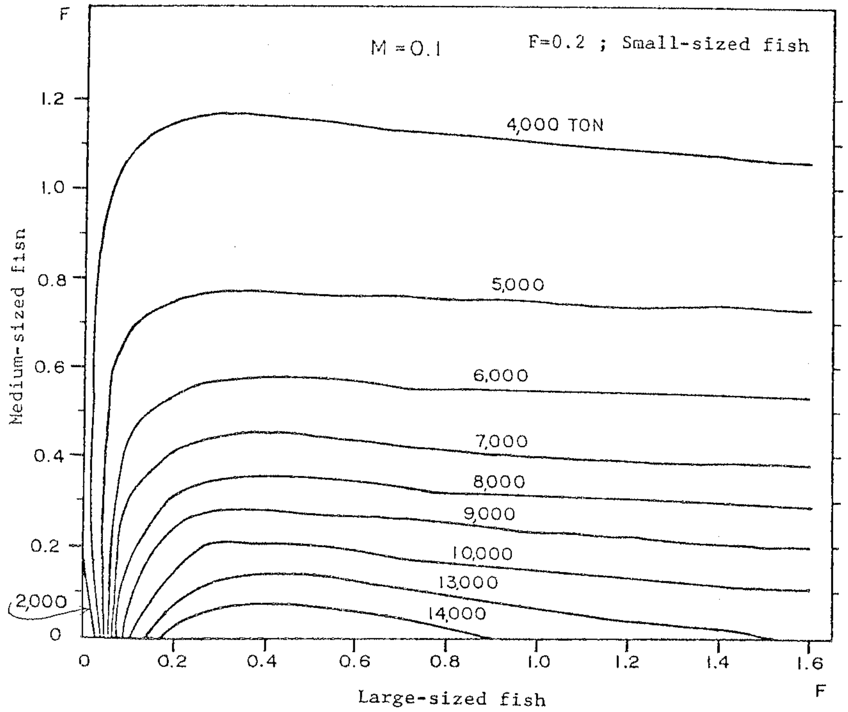

Fig. 15a. Isopleth diagram of Y/R (R is a million fish at 1 age and M = 0.1) when small-sized fish is precedingly exploited at F = 0.2.

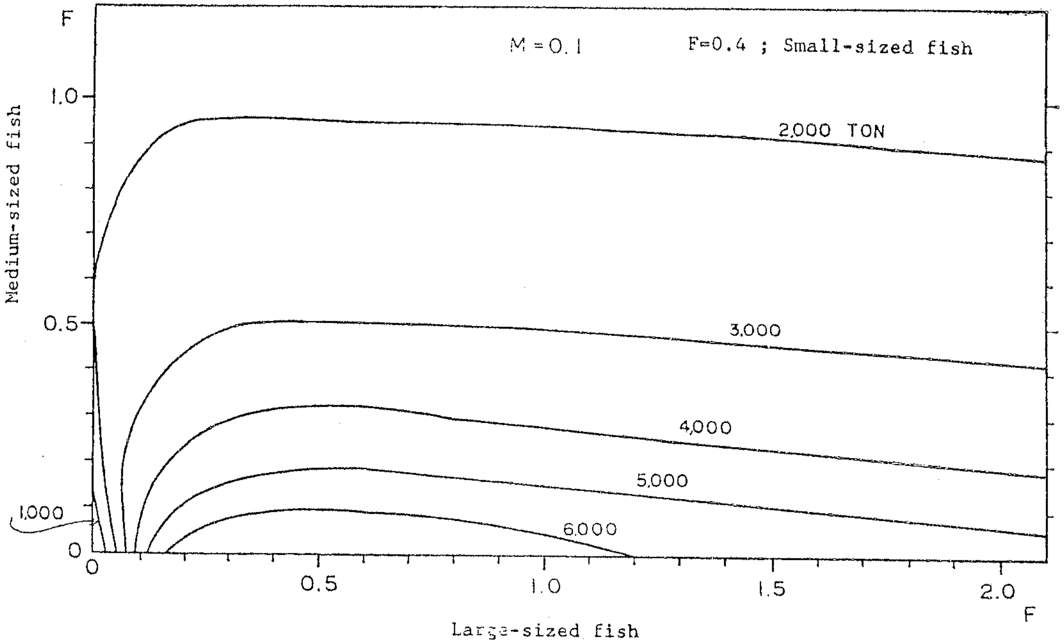

Fig. 15b. Isopleth diagram of Y/R ([illegible] million fish at 1 age and M = 0.1) when small-sized fish is [illegible] exploited at F = 0.4.

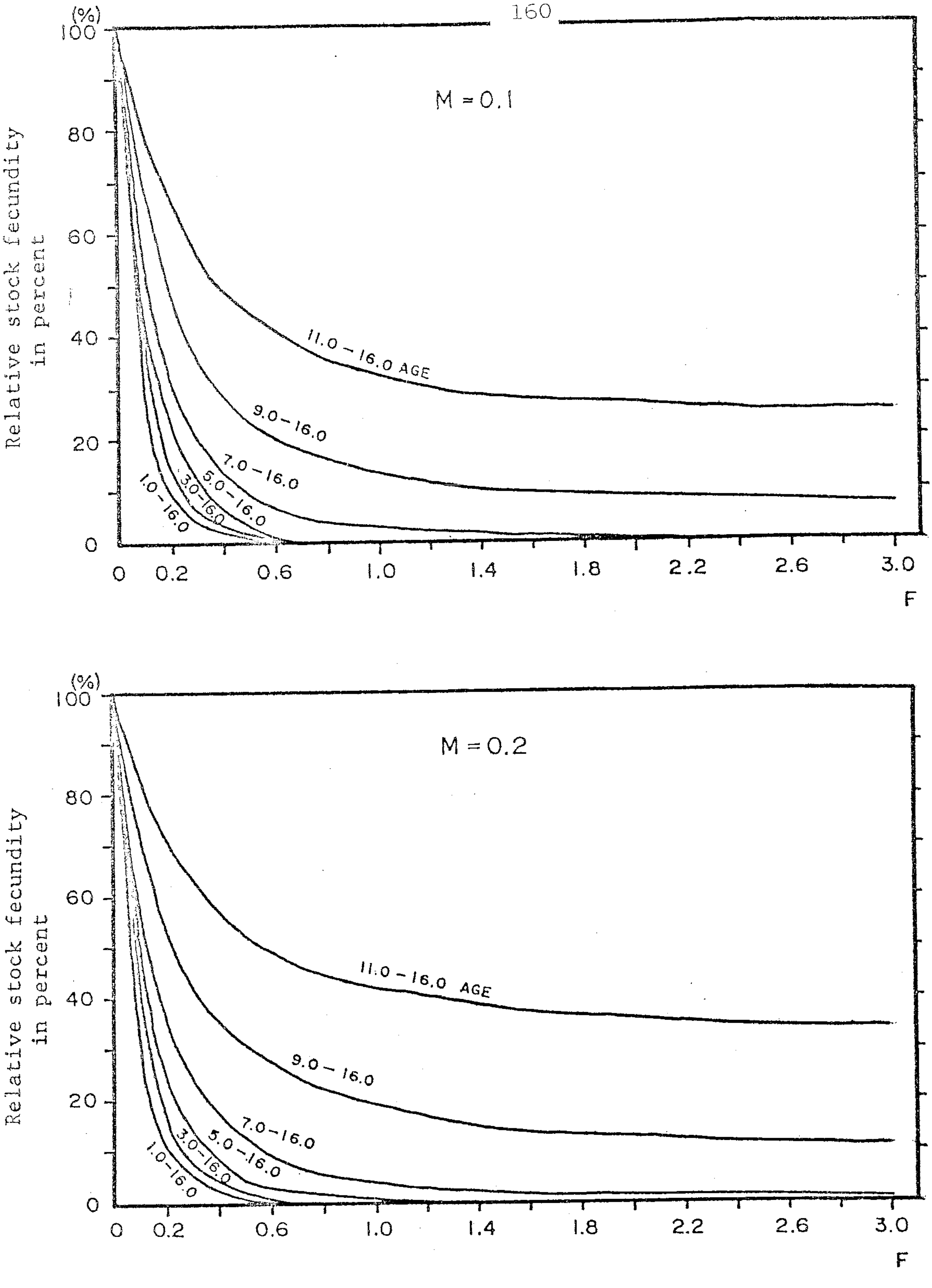

Fig. 16. Relative stock fecundity in percent of bluefin tuna against fishing intensity in various cases of exploitation aiming at different range of age groups, when M = 0.1 in upper panel and M = 0.2 in lower panel.