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AN EXAMINATION OF THE YIELD PER RECRUIT BASIS FOR A MINIMUM SIZE REGULATION FOR ATLANTIC YELLOWFIN TUNA

by

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and B. J. Rothschild

SUMMARY

Some of the conceptual foundations of yield-per-recruit analysis as a management tool and as applied to the Atlantic yellowfin tuna fishery were critically explored. Problems examined include: (1) estimating the current state of the fishery in terms of a knife-edged recruitment approximation, (2) implementing advice from the yield-per-recruit, (3) the difficulty in achieving a maximum yield-per-recruit when there exists several gear types exploiting different size ranges, (4) the difficulty in obtaining projected increases in yield per recruit when the killing and discarding (dumping) of fish smaller than the optimum size occurs, and (5) the possible interaction between a size limit and the projection of the maximum sustainable yield.

In employing yield-per-recruit analysis to the Atlantic yellowfin tuna fishery, two approaches were taken -- one approach makes use of a wide range of parameter estimates and a number of simplifying assumptions, but little data, and the other approach makes use of considerably more data, but is more confined in the parameter estimates and uses fewer of the simplifying assumptions. The general results of both approaches, assuming no dumping occurs, indicate that only minor increases in yield-per-recruit would occur if the size at recruitment is increased from our estimate of the present size at recruitment and fishing effort remains constant; an increase in fishing effort without changing other aspects of the fishery would not appreciably increase yield-per-recruit, and an increase in size at recruitment and in fishing effort would result in modest gains in yield-per-recruit. Specifically meeting the request of the International Commission for the Conservation of Atlantic Tunas, we recommended that a minimum size limit regulation in the vicinity of 55 cm (3.2 kg) be enacted.

EXAMEN DU RENDEMENT PAR RECRUE COMME BASE D'UNE REGLEMENTATION DE LA TAILLE MINIMUM DE L'ALBACORE DE L'ATLANTIQUE

par

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RESUME

Certains des fondements conceptuels de l'analyse du rendement par recrue, en tant que moyen de contrôle de la pêche des thonidés dans l'Atlantique, ont fait l'objet d'un examen critique. Les problèmes étudiés comprenaient: (1) une étude de l'état actuel de la pêcherie en termes d'une approximation extrêmement précise du recrutement, (2) application des résultats fournis

par le rendement par recrue, (3) les difficultés d'atteindre un rendement maximal par recrue lorsque plusieurs sortes d'engins pêchent des tailles variées de poissons, (4)les difficultés d obtenir une augmentation future du rendement par recrue lorsque des poissons de dimensions inférieures à la taille optimum sont tués et rejetés, et (5) l'interaction éventuelle entre une limitation de la taille et la projection du rendement maximal soutenu.

L'analyse du rendement par recrue a été appliquée à la pêcherie de l'albacore dans l'Atlantique de deux façons -- l'une d'entre elles aborde le problème au moyen d'un large éventail de paramètres estimés et d'un certain nombre d'hypothèses simplificatrices, mais peu de données -- l'autre met en oeuvre des données plus abondantes, avec un nombre plus limité de paramètres et moins d'hypothèses simplificatrices. Dans les deux cas, le résultat général montre, en admettant qu'il n'y ait pas de rejets, que seules des augmentations minimes du rendement par recrue se produiraient si la taille au recrutement était plus grande que notre estimation de celle qui existe à l'heure actuelle et si l'effort de pêche ne varie pas. Une augmentation de l'effort de pêche, sans modification d'autres aspects de la pêcherie, n'augmenterait pas sensiblement le rendement par recrue, et une augmentation de la taille au recrutement et de l'effort de pêche n'augmenterait que faiblement le rendement par recrue.

En réponse à la demande exprimée par la Commission Internationale pour la Conservation des Thonidés de l'Atlantique, nous recommandons qu'un règlement fixant la taille minimum aux environs de 55 cm (3,2 kgs) soit établi.

EXAMEN DE LAS BASES DE LA PRODUCCION-POR-RECLUTAMIENTO PARA EL ESTABLECIMIENTO DE UNA REGULACION DE TALLA MINIMA DEL RABIL EN EL OCEANO ATLANTICO

por

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RESUMEN

Se hizo un examen crítico de algunas de las bases conceptuales del análisis de la producción-por-reclutamiento como instrumento de ordenación aplicable a la pesquería de rabil Atlántico. Los problemas examinados fueron los siguientes: (1) estimación de la situación actual de la pesquería, basándose en una aproximación tajante del reclutamiento, (2) cumplimiento de la recomendación sugerida por la producción-por-reclutamiento, (3) dificultad en conseguir una producción-por-reclutamiento máxima cuando existen varios tipos de artes que explotan distintas tallas, (4) dificultad en obtener los proyectados aumentos de producción-por-reclutamiento cuando se desecha, con la consiguiente pérdida, los peces de una talla inferior a la talla óptima, y (5) posible interacción entre un límite de talla y la proyección de la producción máxima continuada.

Se abordó el análisis de la producción-por-reclutamiento del rabil Atlántico de dos formas diferentes: una, teniendo en cuenta una amplia gama de estimaciones de parámetros y un número de supuestos simplificadores, pero pocos datos, y la otra utilizando muchos más datos, pero un número más reducido de estimaciones de parámetros y menos supuestos simplificadores. El resultado general de ambos enfoques, suponiendo que no haya desechos, indica que sólo se producirían aumentos ligeros de la producción-por-reclutamiento si la talla actual de reclutamiento fuera mayor que la que hemos estimado nosotros, permaneciendo el esfuerzo pesquero constante; un aumento del esfuerzo pesquero sin alterar otros aspectos de la pesquería no aumentaría apreciablemente la producción-por-reclutamiento y un aumento en la talla del reclutamiento y en el esfuerzo pesquero no produciría sino pequeñas mejoras en la producción-por-reclutamiento. Concretamente, en respuesta a lo solicitado por la Comisión Internacional para la Conservación del Atún Atlántico, recomendamos que se ponga en vigor una regulación de talla mínima de unos 55 cm (3,2 Kg)

AN EXAMINATION OF THE YIELD PER RECRUIT BASIS FOR A MINIMUM SIZE REGULATION FOR ATLANTIC YELLOWFIN TUNA

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BACKGROUND

The second regular meeting (Madrid, December 2-7, 1971) of the commission of ICCAT authorized the "Council to recommend to the Contracting Parties that they prohibit landing of yellowfin weighing less than a minimum weight somewhere between 3.2 and 10 kg." This recommendation was based on studies by members of the Sub-Committee on Stock Assessment that showed that theoretically the size at first capture which maximizes the yield per recruit of yellowfin is between 10 and 25 kg (Appendix I).

A special working group on stock assessment of yellowfin tuna met in Abidjan (June 12-16, 1972) to consider further scientific aspects of size regulation and other matters pertaining to the Atlantic yellowfin fishery. Studies on yield per recruit were presented by Hayasi, Honma, and Suzuki (1972); Joseph and Tomlinson (1972); and Lenarz and Sakagawa (1972). The report of the meeting (Appendix II) may be considered as a summary of these papers which indicated that increases in size at recruitment would probably increase yield per recruit but by not more than about 10%.

The special working group also examined available evidence on the practicability of minimum size regulations. Scientists of the group were concerned that since the gears that fish for yellowfin in the Atlantic supposedly kill most fish that are captured, a minimum size regulation would reduce the number of small yellowfin that are landed but would not have the desired effect of reducing mortality rates of small yellowfin. This of course assumes that schools of yellowfin containing yellowfin less than any minimum size would actually be set upon. In this connection the group noted the conditions which must be met before minimum size regulations can be effective. The conditions are: (1) the fishermen must be able to estimate the average size of yellowfin in a school, and (2) there must be little or no mixing of small yellowfin with large yellowfin within schools. Very little evidence is available from the Atlantic on these subjects. Dr. LeGuen presented 10 samples that indicated considerable mixing of small yellowfin (<5 kg) with large yellowfin (> 5 kg) within schools. The working group also took note of a study on the subject that was done by Calkins (1965) when size regulations were being considered by the IATTC for the yellowfin fishery in the eastern tropical Pacific. Calkins, working with only one hypothetical minimum size out of a range of 12.7 to 25.0 kg, concluded that a 12.7 kg size regulation would be seriously complicated by size variation within sets. He also noted that a considerable amount of small yellowfin are often captured in sets that include skipjack. Thus it appears that it would not be possible to fish for skipjack without killing some small yellowfin. Evidence based on LeGuen's scanty samples from the Atlantic indicated that sets would include yellowfin tuna larger and smaller than 5 kg, thus even if a minimum size regulation were set at this value it would be difficult to prevent the capture of fish smaller than 5 kg. The working group recommended that more data should be collected on the subject from the Atlantic. The working group also noted that a reduction in the size at first recruitment should be prevented and that minimum size regulations of 3.2 kg that have been passed by several African nations should help prevent a reduction in size at recruitment.

INTRODUCTION

The population dynamics of Atlantic yellowfin tuna are complex because the fishery is prosecuted by several types of gear; bait boats, small purse seiners, large purse seiners, and longliners. These gears tend to capture different sizes of fish and thus affect the population in different ways. FAO (1968) noted that longline gear tends to capture large yellowfin while the other gears capture small yellowfin. Lenarz (1970) showed that this observation may not be correct; American[1/] purse seine gear tends to capture relatively more large yellowfin -- in significant quantities -- than was indicated by FAO (1968). Joseph and Tomlinson (1972) presented data that indicated that small purse seiners of France-Ivory Coast-Senegal (FIS) tend to capture relatively more small yellowfin than the large FIS and American purse seiners. The differences among size selectivity of the four gears necessitates consideration of the physical makeup of the fleet when examining size regulations. Therefore, considerable attention was paid to this aspect of the problem during the study.

The above paragraph might be taken to imply that adequate data are available respecting the relative quantities and size distributions of fish caught by the various gears. It is our feeling that the adequacy of the data needs to be demonstrated. What this means is that we cannot place much faith in the details of the relative size distributions per unit effort among the various fishing units, but that

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1/ Refers to vessels registered in Canada, Panama, and the U.S.A.

we do feel that the general orders of magnitude are essentially correct. We should also point out that with the improvement in data over the last several years that the interpretations which accrue from the data and our appreciation of the considerable complexity of the fishery are more evident.

This paper examines several of the concepts involved in yield per recruit analyses. The reason for it, of course, is that the minimum size question is interpreted through yield-per-recruit analyses. Both the classical approach in which fishing mortality is constant with knife-edge recruitment and the more complex approach in which fishing mortality is size specific are explored. Joseph and Tomlinson (1972) used the more complex approach in a recent study on minimum size regulations for the Atlantic yellowfin fishery. We have updated their analysis by using data made available at the Abidjan meeting and have also examined the sensitivity of the methodology to various sources of errors in the data.

Because this paper discusses minimum size, it is necessary to define the term explicitly to avoid ambiguity and to prevent possible misapplications of the results of this study. "Minimum size" may be viewed from two aspects: absolute minimum size and effective minimum size. Absolute minimum size is defined as the smallest fish in the catch and is related to the concept of knife-edge recruitment in defining the size at entry to the fishery. Since most recruitment is size specific, hence sequential, the term effective minimum size is also needed. Effective minimum size is that size whose corresponding age is used as the lower bound for integration of the yield equation, and giving the same yield per recruit if recruitment were knife-edged as for the sequential recruitment case.[2/] If recruitment is knife-edged, then the effective and absolute minimum sizes are synonymous. If it is possible to precisely avoid capturing fish below a certain size, then the minimum size regulation would pertain to an absolute minimum size. On the other hand, if the selectivity of the fishery were to be altered but without the absolute avoidance of fish smaller than the regulated minimum size, then the minimum size regulation would pertain to an effective minimum size. In nearly all fisheries it is impossible to avoid killing some fish smaller than the minimum size regulation, therefore, in practice the minimum size regulation should refer to an effective minimum size.

[2/] Up until this study the term "average minimum size" has been used to denote this idea. But because of the precise mathematical nature of the concept, the term "effective minimum size" has been adopted.

MATERIALS AND METHODS

Catch- and length-frequency data for each type of gear for the 1967-71 period were obtained from the report of the meeting of the special working group (Tables 10, 11 and 12 of the report) with the exception of length-frequency data of the 1967-68 FIS fishery and 1971 Japanese longline fishery. Length frequencies for the 1967-68 FIS fishery were compiled from various ORSTOM publications (Sakagawa and Lenarz, 1972). Length frequencies for the 1971 Japanese longline fishery are assumed to be the same as the 1970 Japanese longline fishery.

Length-frequency data were available only from the Japanese longline fishery, FIS surface fisheries, and American large purse seine fishery. Thus it was necessary to make several assumptions before estimating the length frequencies of the total catch of yellowfin in the Atlantic. Length frequencies for longline fisheries other than Japan are assumed to be the same as Japan's. Length frequencies for the bait boat and small purse seine fisheries other than FIS were assumed to be the same as the FIS fishery. Length frequencies for the large purse seine fisheries other than FIS and American were assumed to be the same as those two fisheries.

The growth equation $\left[L = 194.8 \times (1-e^{-0.42(t-0.62)})\right]$ presented in LeGuen and Sakagawa (in press) and length-weight relationship $(W = 0.0000214L^{2.9736})$ given by Lenarz (1971a) were used.

The instantaneous coefficient of natural mortality (M) is a difficult parameter to estimate and due to a lack of data only preliminary estimates have been made for the parameter in the Atlantic. Estimates of M = 2.61 and 1.50 for the Atlantic were made by Pianet and LeHir (1971) based on data from bait boats and seiners respectively. These estimates seem unreasonably high perhaps because their data were only from the Point Noire region which is a small area compared to the total region in the Atlantic that contains yellowfin. Henemuth (1961) estimated that M is 0.8 in the Pacific while Davidoff (1969) used a value of 1.0. We assumed for the purposes of our calculations here that M is constant for all fishable ages and is 0.8 as is conventional (based on Henemuth's work in the Pacific); we also used values of 0.6 and 1.0 to encompass what we believe is the range of reasonable values.

Pianet and LeHir (1971) also estimated an average _F_, instantaneous coefficient of fishing mortality, of 0.88 for the segment of the Atlantic yellowfin tuna population that is exploited in the Point Noire region. As we have indicated, their estimate is not representative for the population as a whole.

Our range of estimates of _Z_, instantaneous coefficient of total mortality, for 1967-71 is 0.91-1.82 (Lenarz and Sakagawa, 1972). If we assumed that _M_ = 0.8 for the Atlantic population, then _F_ is 0.11-1.02. Our feeling is that _F_ is about 0.6 for recent years. However, we used a range of _F_ values in the remainder of the paper.

Several computer programs were used during the study. Length-frequency data were compiled by 5 cm intervals, starting at 35 cm [3/] (32.5 cm ≤ fork length < 37.5 cm) and ending at 180 cm with computer programs written by Lenarz. A general simulation model, GXPOPS by Fox, was used to examine estimates of knife-edged approximations of age at entry and to examine the interactions between minimum size and catch quota regulations. The program FRG708, Paulik and Bayliff (1967), was used to calculate yield-per-recruit isopleths when knife-edged recruitment was assumed. Size specific instantaneous rates of fishing mortality were estimated with the method of Gulland (1965) and Murphy (1965) as suggested by Lenarz (1971b). We followed the modification of Joseph and Tomlinson (1972) by using the inverse of the growth equation to convert size distributions to age distributions and we used a computer program, COHORT, by Fox to perform the calculations. A program, MGEAR, by Lenarz was employed to calculate, using the yield equation of Ricker (1958), yield-per-recruit isopleths with size specific F. The program computes yield per recruit by gear; yield per recruit by gear when fish under the size limit are caught, and discarded dead; catch-per-recruit-per-effort isopleths by gears, and average weight isopleths by gear. Another program, OPSIZE, written by Lenarz was used to estimate optimum size at recruitment under different levels of effort by two gears.

[3/] The value, 32.5 cm, represents our selection for an approximate absolute minimum size for the Atlantic yellowfin tuna fishery, which also agrees with that chosen by Joseph and Tomlinson (1972)

KNIFE-EDGED RECRUITMENT APPROACH

The classical way of examining yield per recruit assumes that recruitment is knife-edged (or instantaneous) at some age, t_r', or corresponding length, l_r'. In most cases, this is an approximation to the true pattern of recruitment which usually is size specific and occurs as a function of time or age rather than instantaneously. If recruitment is knife-edged then l_r' represents the absolute minimum size taken in the catch. On the other hand, if recruitment occurs over several sizes (or ages), then l_r' represents an <u>effective minimum size</u> and the corresponding t_r' represents an effective age at entry for the lower bound in computing the integral of yield per recruit. What this means is that the advice from the isopleth gives us either a knife-edge absolute minimum size or an effective minimum size. Since the fishery under consideration and other fisheries as well is not knife-edged, then we are talking about an effective minimum size. Now, on the other hand, if we assume that the absolute minimum size, the regulated size, and the effective minimum size, are all the same, then we will have an inappropriate estimate of the yield per recruit. Somehow we need to determine the effective minimum size from the regulated size; in some instances they can roughly be the same; but this equality will usually not obtain if the regulated size is the absolute minimum size. Also it should be clear at this point that if we take the optimal size from the yield-per-recruit isopleth and set it at the absolute minimum size, then optimality will not be achieved (unless, of course, recruitment is knife-edged).

Employing the classical approach involves: (1) the estimation of t_r' or l_r' which represents an approximation of the current state of the fishery in terms of knife-edged recruitment; (2) finding $t_r^{*\prime}$ or $l_r^{*\prime}$ which maximizes the yield per recruit at a given level of fishing mortality; (3) imposing some regulation on the fishery to achieve as its minimum size, the value for $l_r^{*\prime}$.

The two commonly used models for computing yield per recruit and finding $l_r^{*\prime}$ are those of Beverton and Holt (1957) and Ricker (1958). The Beverton and Holt model uses the von Bertalanffy growth equation and constant rates of mortality to obtain an expression of yield per recruit (Y/R) in a neat closed form. The Ricker model, on the other hand, makes no assumptions about the form of growth or mortality and is computed as a sum over small time intervals.

The determination of t_r' (or l_r') is more complex than generally recognized by practitioners of population dynamics for a fishery like that for Atlantic yellowfin tuna, which does not have knife-edged recruitment. It is important to stress that the material in the simplified Beverton and Holt model involves fewer assumptions than the material in subsequent sections. This is important because as our approach becomes more complex the data requirements become more rigorous. It can be argued that we have sufficient data for this simplified approach. In the more complex approaches this assertion becomes more tenuous; because we use more assumptions in the more complex approaches we do not necessarily obtain more information, even though it may appear that way.

We employed two analyses dependent on knife-edged approximation -- the simplified Beverton and Holt model, making use of a wide range of parameter estimates or extrapolations from fisheries for similar species, and the Ricker model making use of the best parameter estimates and giving a more detailed analysis of yield per recruit. These analyses are followed by sections discussing the problems of determining the proper parameters which represent the current position of the fishery.

Simplified Beverton and Holt Model

The Beverton and Holt yield-per-recruit model may be simplified such that relative yield per recruit, Y', is a function of three ratios:

$$C = l_r'/L_\infty$$

$$Q = M/K$$

$$E = F/(F + M)$$

$$Y' = Y/(RW_\infty)$$

and where W_∞, L_∞ and K are parameters of the von Bertalanffy growth equation. Y' is tabulated extensively by Beverton and Holt (1966). Beverton and Holt (1959) have concluded that, within reason, there exists a common ratio between M and K within related species groups. Therefore, a range of estimates for the various parameters are utilized along with other information obtained by examining parameter estimates for M and K for yellowfin tuna from areas other than the Atlantic.

The range of values for the various parameters are as follows: $K = 0.28\text{-}0.53$ and $L_\infty = 175.2\text{-}223.0$ cm from Le Guen and Sakagawa (in press), $Z = 0.91\text{-}1.82$ from Lenarz and Sakagawa (1972), and $M = 0.6\text{-}1.0$. From these parameter ranges a maximum range for E is 0.0-0.67 and for Q is 1.13-3.57. Using our most reasonable parameter estimates of $K = 0.42$, $M = 0.8$, and $Z = 1.4$, however, a reasonable range for E and Q was established by allowing either the numerator or denominator of the ratio to be one of our most reasonable estimates -- the reasonable ranges are $E = 0.12\text{-}0.56$ and $Q = 1.42\text{-}2.86$. With $K = 0.42$, $M = 0.8$, and $Z = 1.4$ our most reasonable estimates of E and Q are 0.43 and 1.9 respectively.

Table 1 contains optimal values of size (cm) at recruitment, $l_r^{*}{}'$, for the maximum range of estimates of E and Q (deleting the impossible $E = 0.0$ and the unreasonably high $Q = 3.57$) for the range and most reasonable estimates of L_∞. The dashed lines enclose the reasonable range of estimates (deleting the unreasonably low $E = 0.12$) and the underlined value in the center of Table 1 is our most reasonable estimate. One can see that the values in Table 1 are all greater than the approximate absolute minimum size of 32.5 cm for the Atlantic yellowfin tuna fishery regardless of the estimate of L_∞.

For the moment let us assume that recruitment is knife-edged at 32.5 cm (0.67 kg) and that the fishery can be regulated such to obtain a knife-edged recruitment at any desired size. Therefore, the maximum possible increases in yield per

Table 1.--Optimal values of size at recruitment (cm) for three estimates of L_∞ as a function of E and Q

Q	E 0.1	0.2	0.3	0.4	0.5	0.6	0.7
	L_∞ = 175.2 cm						
1.0	57.8	73.6	85.8	95.5	103	110	117
1.5	49.9	64.8	75.3	84.1	92.0	98.1	103
2.0	44.7	57.8	67.5	75.3	82.3	88.5	93.7
2.5	40.3	52.6	61.3	68.3	74.5	80.6	85.0
3.0	36.8	48.2	56.1	63.1	68.3	73.6	78.8
	L_∞ = 194.8 cm						
1.0	64.3	81.8	95.5	106	115	123	130
1.5	55.5	72.1	83.8	93.5	102	109	115
2.0	49.7	64.3	75.0	83.8	91.6	98.4	104
2.5	44.8	58.4	68.2	76.0	82.8	89.6	94.5
3.0	40.9	53.6	62.3	70.1	76.0	81.8	87.7
	L_∞ = 223.0 cm						
1.0	73.6	93.7	109	122	132	140	148
1.5	63.6	82.5	95.9	107	117	125	132
2.0	56.9	73.6	85.9	95.9	105	113	119
2.5	51.3	66.9	78.0	87.0	94.8	103	108
3.0	46.8	61.3	71.4	80.3	87.0	93.7	100

recruit may be computed with Tables I and IIb of Beverton and Holt (1966). Our smallest reasonable values for optimal size at recruitment are 48.2 cm (2.2 kg), 53.6 cm (3.0 kg), or 61.3 cm (4.4 kg) depending on L_∞. The respective predicted values of yield per recruit are 2.2%, 3.3% and 4.6% higher than when size at recruitment is 32.5 cm. Our largest reasonable estimates of optimal size at recruitment are 98.1 cm (17.9 kg), 109 cm (24.5 kg), or 125 cm (36.9 kg). The respective predicted increases in yield per recruit are 67.0%, 74.6%, and 83.6%. The predicted increase in yield per recruit using all of our most reasonable parameter estimates, i.e., raising 32.5 cm to 83.8 cm (11.2 kg), is 23.4%. The bounds on an increase in yield per recruit, 2.2%, to 83.6%, with the most likely value of 23.4%, are estimated under the assumptions of knife-edged recruitment and that size at recruitment represents an absolute minimum size. The Atlantic yellowfin tuna fishery, however, does not have knife-edged recruitment.

The most reasonable estimate of the 1967-71 average effective minimum size for the Atlantic yellowfin tuna fishery is about 57 cm or 3.6 kg (Lenarz and Sakagawa, 1972). Nearly all the values within the dashed lines in Table 1, however, are greater than 57. The only smallest reasonable estimate of optimal effective minimum size greater than 57 cm is 61.3 cm with L_∞ = 223.0 cm. An increase from 57 to 61.3 cm would give an increase in yield per recruit $< 0.1\%$.

The largest reasonable estimates of optimal effective minimum size predict increases in yield per recruit of 25.0%, 32.6%, or 43.0% with increases from 57 cm, depending on L_∞. The increase in yield per recruit by increasing the effective minimum size from 57 to 83.8 cm, our most reasonable estimate, is only 6.7%.

From the above analysis using a wide range of parameter estimates, we can conclude with reasonable assurance that virtually any increase in the effective minimum size will cause an increase in yield per recruit. Our most likely estimate of this increase in yield per recruit is only 6.7% which is bounded, with reasonable parameter estimates, by 0.0% and 43.0%.

Ricker Model with Constant Z

Yield per recruit isopleths were calculated using values of M of 0.6, 0.8, and 1.0 (Figures 1, 2, and 3). As will be mentioned in the next section it is difficult to estimate the location of the fishery on the graphs. That is when fishing mortality is size specific it is not a trivial matter to make reasonable estimates of age at recruitment and Z. Our most reasonable estimates, taken from Lenarz and Sakagawa (1972), of these parameters are: age at recruitment is 1.45 years and Z is 1.4.

The results (Figures 1, 2 and 3) show that when M = 0.6 and Z remains constant, an increase in age at recruitment from 1.45 to 1.85 years (or 77.5 cm) raises the yield per recruit by 18%, when M = 0.8 the same change raises the yield per recruit by 8%, and when M = 1.0 the same change does not change yield per recruit. If age at recruitment is held constant and fishing mortality is doubled, when M = 0.6 yield per recruit decreases by 19%, when M = 0.8 yield per recruit increases by 4%, and when M = 1.0 yield per recruit increases by 28%. If effort is doubled and age at recruitment is raised to 77.5 cm, when M = 0.6 yield per recruit increases by 18%, when M = 0.8 yield per recruit increases by 21%, and when M = 1.0 yield per recruit increases by 36%.

Determination of t_r' and $l_{r'}$

In employing a knife-edged approximation to size specific recruitment that is protracted over some time period, the first problem is determining the proper t_r' such that the integration reflects the same yield per recruit as the size specific recruitment case. There are two problems in doing so. First, there are two values for t_r' that will give the same yield-per-recruit as the size specific recruitment case, unless optimality obtains. Often, however, this may be of little consequence, since one of the two values for t_r' should be obviously incorrect. Second, $t_{r'}$ will depend on the fishing mortality.

Two estimators of t_r' are provided, at least implicitly, by Beverton and Holt (1957): (1) the age corresponding to the mean selection length, and (2) the resultant of a formula depending on Z and the average age in the catch, $\bar{t}$. The mean selection length is the 50% selection length if the selection curve is symmetrical, but it is not dependent on the magnitude of F. The estimator of t_r' is

$$t_r' = \bar{t} - 1/Z. \qquad (1)$$

Several computations of yield per recruit with the program GXPØPS were made utilizing $F = 0.1$ and $F = 2.0$, $M = 0.8$, the von Bertalanffy equation for Atlantic yellowfin tuna, and an arbitrary age specific selection curve (Figure 4) in order to demonstrate the two problems and to evaluate the two estimators of t_r'. At

$F = 0.1$ the values of $t_{r'}$ giving the same Y/R's as the selection curve are <8 months (t_o of the von Bertalanffy growth curve is 7.48 months) or 24 months, and 19 or 45 months for $F = 2.0$. Since the state of the simulated fishery is not optimal for either value of F, there are two knife-edged approximation locations. The effect of the magnitude of F on the true $t_{r'}$ is obvious, with the lower value increasing from <8 to 19 months and the upper value increasing from 24 to 45 months as F is changed from 0.1 to 2.0. The reasonable values for $t_{r'}$ to approximate the selection curve, however, are 24 months for $F = 0.1$ and 19 months for $F = 2.0$, a change of 5 months.

Estimator 1, the mean selection age, is 21 months and is shown along with the reasonable values in Figure 4. Using 21 months for $t_{r'}$ would result in Y/R's that are 4% and 15% too high for $F = 0.1$ and $F = 2.0$ respectively. Estimator 1 does not change with F, of course, but in this case it lies intermediate between the true $t_{r'}$ values. Estimator 2 gives 19 months for $F = 0.1$ and 18 months for $F = 2.0$. We emphasize that this estimator does depend on the magnitude of F.

Neither estimator is exact in this example where the catches and their ages are known without error. This places doubt on their estimates from the usual catch at age data where considerable random error would be involved. Encouraging though, is that both estimators indicate the proper direction that the fishery's selectivity should proceed to approach the optimal Y/R--about 15 months for $F = 0.1$ and 30 months for $F = 2.0$. Since estimator 1 requires size selective data not frequently available and does not respond to changes in F, estimator 2 appears to be the most attractive for knife-edged approximations. The Atlantic yellowfin tuna fishery, however, has a much more complex recruitment pattern and size specific F than this simple example owing to the diverse gear types. The mix of relative F among the various gear types makes the determination of the appropriate current t_r' somewhat tenuous.

Determination of Z

The yield-per-recruit isopleths shown in Figures 1, 2, and 3 were calculated under the assumption that fishing mortality and Z is constant after the fish are recruited. The value of Z was also estimated under the same assumption. The section on size specific fishing mortality will indicate that F is not a constant, but is related to size. Thus our estimate of a constant Z may not be realistic but perhaps is a reasonable assumption given the quality of the data. It is the average of values of Z estimated for the FIS bait boat and purse seine fisheries, Lenarz and Sakagawa (1972). The size specific F section indicates that F decreases with size for bait boats and increases with size for purse seiners. Beverton and Holt (1956) gave examples that indicated that when F decreases with age, Z will be overestimated and when F increases with age Z will be underestimated. Hopefully we have obtained a reasonable estimate by taking the average of Z's for the two gears.

SIZE SPECIFIC F APPROACH

Estimates of Length Frequencies

Length frequencies (numbers of yellowfin caught by 5-cm intervals) were estimated for each gear and the total fishery for two overlapping periods 1967-71, and 1969-71 (Figure 5). The first period was used with the hope that the effect caused by unequal strength of year classes would be minimized by averaging. The second period was used because it was felt that the data are more accurate. Length frequencies of the two periods are quite similar and produce similar estimates of size specific fishing mortality and estimates of yield per recruit. Thus, to avoid redundancy, only the data for the 1967-71 period are used. Figure 6 and Table 2 show the length frequencies for each gear. The curves are as described in the Introduction.

Estimates of Size Specific Fishing Mortality

The reverse iterative procedure with computer program COHORT and M = 0.8 was used to estimate size specific values of fishing mortality (F) starting at the 180 cm interval. Four initial values of F were tried: 0.2, 0.4, 0.6, and 0.8 (Figure 7). Estimates of F tend to converge as size of the yellowfin tuna decreases with the range of initial values tried as is characteristic of the methodology (Tomlinson, 1970). Calculations of yield per recruit that were calculated using initial values of F of 0.2 and 0.8 are shown in Figures 8 and 9 as functions of initial values of F, effort, and size at recruitment. The values of yield per recruit do not vary significantly (<10%) with changes in the initial values of F, and the relative values are quite similar. Values of size specific F are shown for each gear in Figure 10 when initial values of F are 0.2 and 0.8. When the initial value of F is 0.8, values of F for small purse seiners increase sharply with size from 170 to 180 cm. This does not occur when the initial value of F is 0.2. Intuitively we do not expect an increase in F with size past 170 cm and thus choose to use the results when the initial value of F is 0.2 in the remainder of the paper.

Table 2. Basic data used in study

Size interval (cm)	Weight (kg) at beginning of interval	Age (years) at beginning of interval	1967-71 average number of yellowfin landed				
			Bait boats	Small Purse Seiners	Large purse seiners	Longliners	Total
35	.67	1.0579	1,886	372	100		2,358
40	1.03	1.1325	14,551	5,445	9,057		29,053
45	1.49	1.2093	72,972	21,782	28,372		123,126
50	2.08	1.2888	246,924	89,614	36,684	7	373,229
55	2.79	1.3710	245,206	146,883	83,153	22	475,264
60	3.66	1.4562	251,017	110,755	59,648	451	421,871
65	4.69	1.5445	165,328	42,427	35,891	647	244,293
70	5.90	1.6363	197,855	49,929	26,992	2,151	276,927
75	7.30	1.7317	143,885	36,942	23,263	5,435	209,525
80	8.90	1.8310	128,810	37,082	15,528	5,694	187,114
85	10.72	1.9348	89,637	31,143	13,338	12,025	146,143
90	12.77	2.0432	64,128	31,135	9,818	13,049	118,130
95	15.06	2.1568	70,422	22,248	10,062	11,665	114,397
100	17.61	2.2761	63,619	36,483	13,323	15,074	128,499
105	20.43	2.4017	45,582	48,274	11,647	34,071	139,574
110	23.54	2.5343	36,414	42,283	24,296	40,209	143,202
115	26.95	2.6748	29,227	21,268	21,466	44,034	115,995
120	30.67	2.8240	18,877	18,311	15,144	42,859	95,191
125	34.72	2.9832	22,228	23,711	15,618	57,358	118,915
130	39.10	3.1538	15,152	20,612	16,238	58,544	110,546
135	43.84	3.3376	7,142	18,304	18,504	44,690	88,640
140	48.95	3.5368	4,137	15,790	13,569	52,070	85,566
145	54.43	3.7542	3,393	17,301	17,886	55,582	94,162
150	60.31	3.9935	3,459	20,222	16,711	45,648	86,040
155	66.60	4.2595	1,511	12,057	14,926	39,108	67,602
160	73.30	4.5590	793	8,754	10,678	24,489	44,714
165	80.44	4.9017	634	7,803	6,633	13,659	28,729
170	88.03	5.3021	327	2,470	2,918	6,265	11,980
175	96.07	5.7838	209	2,132	1,383	241	3,965
180	104.59	6.3883	49	1,429	361	55	1,894
	113.60	7.2004					
Total			1,945,374	942,961	573,207	625,102	4,086,645

Validity of the estimates of F depends on the validity of the assumption that recruitment has been fairly constant for the cohorts included in the analysis. The special working group noted that the cohort which entered the surface fisheries in 1969 appears to be weaker than the following two cohorts. Although inclusion of 5 years of data in the analysis may minimize the source of error, future studies should examine the sensitivity of the results to errors of this type.

Estimates of Yield Per Recruit

Results of the yield-per-recruit calculations with M = 0.8 are shown by gear in Table 3. Yield per recruit isopleths and the line of eumetric fishing (size at recruitment, $l^*_{r'}$, which maximizes yield per recruit at a given effort) for the entire fishery are shown in Figure 11. Table 3 and Figures 8, 9, and 11 indicate that if size at recruitment remains constant at 32.5 cm, very little increase in yield-per-recruit (~ 5%) can be expected if effort is increased, and if effort remains constant very little (~ 10%) increase in yield per recruit can be expected by increasing size at recruitment. However, if fishing effort is doubled (i.e., multiplier = 2.0) and size at recruitment increased to 55 cm (3.2 kg) the yield per recruit would increase 15% or to 77.5 cm (~10 kg) yield per recruit would increase about 30% (Table 3). Since the line of eumetric fishing shows that optimum size at recruitment changes with fishing effort, any "minimum size" regulation must be geared to fishing effort. Again it should be recalled that "minimum size" is absolute only if a knife-edged size at recruitment is obtained. Otherwise the "minimum size" refers to an effective minimum size.

TABLE 3. ESTIMATES OF YIELD PER RECRUIT (KG) WHEN M=0.8, INITIAL F=0.2, AND GROWTH CURVE OF LE GUEN AND SAKAGAWA (IN PRESS) IS USED

BAIT BOATS

MINIMUM SIZE CM	KG.	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.08	0.15	0.21	0.31	0.39	0.46	0.49	0.56	0.62	0.68
117.5	30.6	0.09	0.17	0.24	0.36	0.46	0.54	0.58	0.66	0.73	0.80
112.5	26.9	0.11	0.21	0.29	0.43	0.55	0.65	0.69	0.80	0.89	0.96
107.5	23.5	0.13	0.24	0.33	0.50	0.64	0.75	0.80	0.92	1.02	1.11
102.5	20.4	0.15	0.27	0.38	0.57	0.73	0.86	0.92	1.06	1.17	1.27
97.5	17.6	0.17	0.31	0.44	0.66	0.85	1.01	1.08	1.24	1.38	1.50
92.5	15.0	0.19	0.35	0.50	0.75	0.96	1.15	1.23	1.41	1.58	1.72
87.5	12.7	0.20	0.38	0.54	0.81	1.04	1.24	1.32	1.52	1.69	1.84
82.5	10.7	0.22	0.41	0.58	0.88	1.12	1.34	1.43	1.64	1.82	1.98
77.5	8.9	0.24	0.45	0.63	0.95	1.22	1.45	1.55	1.78	1.97	2.13
72.5	7.3	0.26	0.48	0.68	1.02	1.30	1.54	1.64	1.87	2.07	2.23
67.5	5.9	0.27	0.51	0.72	1.08	1.38	1.62	1.73	1.96	2.14	2.30
62.5	4.7	0.29	0.53	0.75	1.12	1.41	1.65	1.76	1.98	2.16	2.30
57.5	3.7	0.30	0.56	0.78	1.15	1.43	1.66	1.76	1.96	2.11	2.22
52.5	2.8	0.31	0.57	0.79	1.15	1.42	1.63	1.72	1.83	2.00	2.08
47.5	2.1	0.31	0.58	0.80	1.15	1.42	1.61	1.69	1.84	1.94	2.00
42.5	1.5	0.31	0.58	0.80	1.15	1.41	1.60	1.68	1.82	1.91	1.97
37.5	1.0	0.31	0.58	0.80	1.15	1.41	1.60	1.67	1.81	1.90	1.96
32.5	0.7	0.31	0.58	0.80	1.15	1.41	1.60	1.67	1.81	1.90	1.95

SMALL PURSE SEINERS

MINIMUM SIZE CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.34	0.58	0.75	0.97	1.09	1.16	1.19	1.24	1.28	1.31
117.5	30.6	0.35	0.60	0.77	0.99	1.11	1.18	1.21	1.27	1.30	1.33
112.5	26.9	0.36	0.61	0.79	1.01	1.13	1.20	1.23	1.28	1.31	1.34
107.5	23.5	0.38	0.64	0.83	1.06	1.20	1.28	1.32	1.38	1.43	1.47
102.5	20.4	0.40	0.67	0.87	1.12	1.27	1.37	1.41	1.49	1.55	1.60
97.5	17.6	0.41	0.69	0.89	1.14	1.30	1.40	1.44	1.52	1.59	1.64
92.5	15.0	0.41	0.70	0.90	1.15	1.30	1.39	1.43	1.50	1.56	1.61
87.5	12.7	0.42	0.71	0.91	1.16	1.31	1.40	1.44	1.51	1.56	1.60
82.5	10.7	0.42	0.71	0.91	1.16	1.30	1.39	1.43	1.49	1.53	1.57
77.5	8.9	0.43	0.71	0.91	1.15	1.29	1.37	1.40	1.45	1.49	1.51
72.5	7.3	0.43	0.71	0.91	1.14	1.27	1.34	1.36	1.41	1.43	1.44
67.5	5.9	0.43	0.72	0.91	1.13	1.24	1.30	1.32	1.35	1.36	1.35
62.5	4.7	0.43	0.71	0.90	1.11	1.22	1.27	1.28	1.30	1.29	1.28
57.5	3.7	0.43	0.71	0.90	1.10	1.19	1.23	1.24	1.24	1.23	1.21
52.5	2.8	0.44	0.72	0.89	1.08	1.16	1.19	1.20	1.19	1.17	1.14
47.5	2.1	0.44	0.71	0.89	1.06	1.13	1.15	1.15	1.14	1.11	1.07
42.5	1.5	0.44	0.71	0.88	1.06	1.12	1.14	1.14	1.11	1.08	1.05
37.5	1.0	0.44	0.71	0.88	1.06	1.12	1.13	1.13	1.11	1.08	1.04
32.5	0.7	0.44	0.71	0.88	1.06	1.12	1.13	1.13	1.11	1.08	1.04

LARGE PURSE SEINERS

MINIMUM SIZE CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.31	0.54	0.69	0.89	0.99	1.05	1.07	1.10	1.12	1.12
117.5	30.6	0.32	0.55	0.71	0.90	1.01	1.06	1.08	1.11	1.12	1.13
112.5	26.9	0.33	0.56	0.73	0.92	1.03	1.09	1.11	1.14	1.16	1.17
107.5	23.5	0.34	0.58	0.74	0.94	1.04	1.10	1.12	1.15	1.17	1.18
102.5	20.4	0.34	0.58	0.74	0.93	1.02	1.06	1.08	1.10	1.10	1.10
97.5	17.6	0.35	0.58	0.74	0.92	1.00	1.04	1.05	1.06	1.06	1.06
92.5	15.0	0.35	0.58	0.73	0.91	0.99	1.02	1.03	1.03	1.03	1.02
87.5	12.7	0.35	0.58	0.73	0.90	0.97	1.00	1.00	1.00	0.99	0.97
82.5	10.7	0.35	0.58	0.73	0.89	0.96	0.98	0.98	0.97	0.95	0.93
77.5	8.9	0.35	0.58	0.72	0.88	0.93	0.95	0.95	0.93	0.91	0.88
72.5	7.3	0.35	0.57	0.72	0.86	0.92	0.92	0.92	0.90	0.87	0.84
67.5	5.9	0.35	0.57	0.71	0.85	0.89	0.89	0.88	0.86	0.82	0.79
62.5	4.7	0.35	0.57	0.71	0.84	0.87	0.87	0.86	0.83	0.80	0.76
57.5	3.7	0.35	0.57	0.70	0.82	0.85	0.84	0.82	0.79	0.75	0.71
52.5	2.8	0.35	0.57	0.69	0.80	0.82	0.80	0.79	0.75	0.71	0.67
47.5	2.1	0.35	0.56	0.68	0.78	0.79	0.77	0.75	0.71	0.66	0.62
42.5	1.5	0.35	0.56	0.68	0.78	0.79	0.76	0.75	0.70	0.65	0.61
37.5	1.0	0.35	0.56	0.68	0.78	0.79	0.76	0.75	0.70	0.65	0.61
32.5	0.7	0.35	0.56	0.68	0.78	0.79	0.76	0.74	0.70	0.65	0.61

TABLE 3.--CONTINUED

LONG LINERS

MINIMUM SIZE CM	KG	MULTIPLIER OF EFFORT 0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.80	1.40	1.86	2.49	2.87	3.12	3.21	3.38	3.49	3.57
117.5	30.6	0.82	1.44	1.90	2.53	2.90	3.14	3.23	3.38	3.47	3.54
112.5	26.9	0.84	1.46	1.93	2.54	2.90	3.12	3.19	3.32	3.39	3.43
107.5	23.5	0.85	1.48	1.93	2.52	2.84	3.02	3.08	3.17	3.20	3.21
102.5	20.4	0.86	1.48	1.93	2.49	2.78	2.93	2.97	3.03	3.03	3.01
97.5	17.6	0.86	1.47	1.90	2.43	2.69	2.81	2.83	2.85	2.82	2.76
92.5	15.0	0.86	1.46	1.89	2.38	2.62	2.71	2.72	2.71	2.66	2.58
87.5	12.7	0.86	1.46	1.87	2.34	2.55	2.62	2.63	2.59	2.52	2.43
82.5	10.7	0.86	1.45	1.85	2.29	2.48	2.52	2.52	2.46	2.36	2.25
77.5	8.9	0.85	1.43	1.82	2.23	2.38	2.40	2.38	2.29	2.17	2.04
72.5	7.3	0.85	1.41	1.79	2.17	2.29	2.28	2.24	2.13	1.99	1.85
67.5	5.9	0.84	1.39	1.75	2.09	2.18	2.13	2.09	1.95	1.79	1.63
62.5	4.7	0.84	1.38	1.72	2.03	2.09	2.03	1.98	1.82	1.64	1.48
57.5	3.7	0.83	1.35	1.67	1.95	1.97	1.88	1.81	1.63	1.44	1.27
52.5	2.8	0.82	1.33	1.63	1.86	1.85	1.73	1.66	1.46	1.26	1.09
47.5	2.1	0.82	1.31	1.60	1.81	1.77	1.64	1.56	1.35	1.15	0.98
42.5	1.5	0.82	1.31	1.59	1.79	1.75	1.61	1.53	1.32	1.12	0.94
37.5	1.0	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94
32.5	0.7	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94

ENTIRE FISHERY

MINIMUM SIZE CM	KG	MULTIPLIER OF EFFORT 0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	1.54	2.67	3.52	4.65	5.34	5.79	5.96	6.28	6.51	6.68
117.5	30.6	1.59	2.76	3.62	4.78	5.47	5.93	6.10	6.41	6.64	6.80
112.5	26.9	1.65	2.85	3.73	4.90	5.60	6.05	6.22	6.53	6.74	6.90
107.5	23.5	1.71	2.94	3.84	5.02	5.72	6.16	6.32	6.62	6.82	6.97
102.5	20.4	1.75	3.00	3.92	5.10	5.79	6.23	6.38	6.67	6.85	6.99
97.5	17.6	1.78	3.06	3.97	5.16	5.84	6.26	6.41	6.68	6.85	6.96
92.5	15.0	1.81	3.09	4.01	5.19	5.86	6.27	6.41	6.66	6.82	6.92
87.5	12.7	1.83	3.12	4.04	5.21	5.87	6.26	6.39	6.63	6.77	6.85
82.5	10.7	1.85	3.14	4.07	5.22	5.86	6.23	6.35	6.56	6.67	6.73
77.5	8.9	1.87	3.17	4.08	5.22	5.82	6.16	6.27	6.45	6.53	6.56
72.5	7.3	1.88	3.18	4.09	5.19	5.77	6.08	6.17	6.31	6.36	6.36
67.5	5.9	1.90	3.19	4.09	5.15	5.68	5.94	6.02	6.11	6.11	6.08
62.5	4.7	1.91	3.20	4.08	5.10	5.59	5.82	5.88	5.92	5.89	5.83
57.5	3.7	1.92	3.19	4.05	5.01	5.44	5.60	5.63	5.61	5.53	5.41
52.5	2.8	1.92	3.18	4.01	4.90	5.26	5.36	5.36	5.28	5.14	4.99
47.5	2.1	1.92	3.16	3.97	4.81	5.11	5.17	5.15	5.03	4.86	4.67
42.5	1.5	1.92	3.16	3.95	4.78	5.07	5.11	5.08	4.95	4.76	4.57
37.5	1.0	1.92	3.16	3.95	4.77	5.06	5.10	5.07	4.93	4.74	4.54
32.5	0.7	1.92	3.16	3.95	4.77	5.05	5.09	5.07	4.93	4.74	4.54

If fishermen are unable to distinguish the size of yellowfin before capturing them and a minimum size regulation prevents their landing, then the discarding of dead yellowfin will occur. Table 4 presents landings per recruit by gear and Figure 12 the landings per recruit for the total fishery when killing and discarding ("dumping") of all yellowfin smaller than the size limit occurs. If the minimum size were 55 cm and effort were constant then a 2.7% decrease in landings per recruit would occur and a 13% decrease in landings per recruit would occur if the minimum size is set at 77.5 cm. If effort were doubled and the minimum size were 55 cm then a 1% increase in landings per recruit would occur and a 17% decline in landings per recruit would occur if the minimum size is 77.5 cm. Therefore, if effort is constant then the predicted gain is greater than the possible loss if the minimum size is 55 cm, but the predicted gain is less than the possible loss if the minimum size is 77.5 cm. Both size limits predict a greater gain than possible loss if effort is doubled.

Assuming constant recruitment, the yield per recruit per unit effort is a measure of fishing success. Table 5 presents the estimated yield per recruit per effort by gear assuming no dumping. Increasing the size at recruitment to 77.5 cm at the current level of effort would cause a 17% decrease for bait boats, a 9% increase for small purse seiners, a 12% increase for large purse seiners, and a 25% increase for longliners. Yield per recruit per effort would drop by about 35% for each of the gears if effort doubled and size at recruitment increased to 77.5 cm. If effort doubled and size at recruitment remained at 32.5 cm, yield per recruit per effort would decrease by 30% for bait boats, 50% for purse seiners, and 60% for longliners.

TABLE 4. LANDINGS PER RECRUIT (KG) WHEN M=0.8, INITIAL F=0.2, CURVE OF LE GUEN AND SAKAGAWA IS USED, AND YELLOWFIN LESS THAN THE MINIMUM SIZE ARE CAUGHT AND DISCARDED DEAD

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.07	0.12	0.15	0.18	0.18	0.17	0.16	0.14	0.12	0.10
117.5	30.6	0.08	0.14	0.18	0.22	0.22	0.22	0.21	0.19	0.16	0.14
112.5	26.9	0.10	0.17	0.22	0.27	0.29	0.28	0.28	0.25	0.22	0.19
107.5	23.5	0.12	0.20	0.26	0.33	0.36	0.36	0.36	0.33	0.30	0.27
102.5	20.4	0.14	0.24	0.31	0.40	0.44	0.45	0.44	0.42	0.39	0.35
97.5	17.6	0.16	0.27	0.36	0.48	0.53	0.56	0.56	0.54	0.51	0.47
92.5	15.0	0.18	0.31	0.41	0.55	0.63	0.66	0.67	0.66	0.63	0.59
87.5	12.7	0.19	0.34	0.45	0.61	0.70	0.74	0.75	0.75	0.73	0.69
82.5	10.7	0.21	0.37	0.50	0.68	0.79	0.84	0.86	0.87	0.85	0.81
77.5	8.9	0.23	0.41	0.55	0.76	0.89	0.97	0.99	1.01	1.00	0.97
72.5	7.3	0.25	0.44	0.60	0.84	0.99	1.08	1.11	1.15	1.15	1.12
67.5	5.9	0.27	0.48	0.66	0.92	1.10	1.22	1.25	1.31	1.33	1.32
62.5	4.7	0.28	0.51	0.70	0.98	1.18	1.31	1.35	1.43	1.46	1.46
57.5	3.7	0.29	0.54	0.74	1.05	1.27	1.42	1.48	1.57	1.62	1.64
52.5	2.8	0.30	0.56	0.77	1.10	1.34	1.51	1.57	1.69	1.76	1.79
47.5	2.1	0.31	0.57	0.79	1.14	1.39	1.58	1.65	1.79	1.87	1.92
42.5	1.5	0.31	0.58	0.80	1.15	1.41	1.59	1.67	1.81	1.90	1.95
37.5	1.0	0.31	0.58	0.80	1.15	1.41	1.60	1.67	1.81	1.90	1.95
32.5	0.7	0.31	0.58	0.80	1.15	1.41	1.60	1.67	1.81	1.90	1.95

SMALL PURSE SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.31	0.47	0.54	0.56	0.50	0.43	0.40	0.31	0.25	0.19
117.5	30.6	0.32	0.49	0.57	0.60	0.55	0.48	0.44	0.36	0.29	0.23
112.5	26.9	0.33	0.51	0.60	0.64	0.59	0.53	0.49	0.41	0.33	0.27
107.5	23.5	0.35	0.55	0.65	0.71	0.68	0.62	0.58	0.50	0.42	0.35
102.5	20.4	0.37	0.58	0.70	0.78	0.76	0.71	0.68	0.60	0.52	0.45
97.5	17.6	0.38	0.61	0.73	0.82	0.81	0.77	0.74	0.66	0.59	0.51
92.5	15.0	0.39	0.62	0.75	0.84	0.84	0.80	0.78	0.70	0.62	0.55
87.5	12.7	0.40	0.63	0.76	0.87	0.88	0.84	0.82	0.75	0.67	0.60
82.5	10.7	0.40	0.64	0.78	0.90	0.91	0.88	0.85	0.79	0.71	0.64
77.5	8.9	0.41	0.65	0.80	0.92	0.94	0.91	0.89	0.83	0.76	0.69
72.5	7.3	0.41	0.66	0.81	0.94	0.96	0.94	0.92	0.86	0.79	0.73
67.5	5.9	0.42	0.67	0.82	0.96	0.99	0.98	0.96	0.90	0.84	0.77
62.5	4.7	0.42	0.68	0.83	0.98	1.01	1.00	0.98	0.93	0.87	0.81
57.5	3.7	0.43	0.69	0.85	1.01	1.05	1.05	1.04	1.00	0.95	0.89
52.5	2.8	0.43	0.70	0.87	1.04	1.10	1.10	1.10	1.07	1.03	0.98
47.5	2.1	0.44	0.71	0.88	1.05	1.11	1.13	1.13	1.10	1.07	1.03
42.5	1.5	0.44	0.71	0.88	1.05	1.12	1.13	1.13	1.11	1.08	1.04
37.5	1.0	0.44	0.71	0.88	1.06	1.12	1.13	1.13	1.11	1.08	1.04
32.5	0.7	0.44	0.71	0.88	1.06	1.12	1.13	1.13	1.11	1.08	1.04

LARGE PURSE SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.28	0.43	0.50	0.51	0.46	0.39	0.36	0.28	0.21	0.16
117.5	30.6	0.29	0.45	0.52	0.54	0.50	0.43	0.39	0.31	0.25	0.19
112.5	26.9	0.30	0.47	0.55	0.59	0.54	0.48	0.44	0.36	0.29	0.24
107.5	23.5	0.31	0.49	0.58	0.63	0.59	0.53	0.50	0.42	0.35	0.28
102.5	20.4	0.32	0.50	0.59	0.64	0.61	0.55	0.52	0.44	0.37	0.31
97.5	17.6	0.32	0.51	0.60	0.66	0.63	0.57	0.54	0.46	0.39	0.33
92.5	15.0	0.33	0.51	0.61	0.67	0.64	0.59	0.56	0.48	0.41	0.35
87.5	12.7	0.33	0.52	0.62	0.68	0.65	0.60	0.57	0.50	0.42	0.36
82.5	10.7	0.33	0.52	0.62	0.69	0.67	0.62	0.59	0.51	0.44	0.38
77.5	8.9	0.33	0.53	0.63	0.70	0.68	0.63	0.60	0.53	0.46	0.40
72.5	7.3	0.34	0.53	0.64	0.71	0.70	0.65	0.62	0.55	0.49	0.43
67.5	5.9	0.34	0.54	0.65	0.72	0.71	0.67	0.64	0.57	0.51	0.45
62.5	4.7	0.34	0.54	0.65	0.74	0.73	0.69	0.66	0.60	0.54	0.48
57.5	3.7	0.35	0.55	0.66	0.75	0.75	0.71	0.69	0.63	0.58	0.53
52.5	2.8	0.35	0.56	0.68	0.77	0.77	0.74	0.73	0.67	0.62	0.58
47.5	2.1	0.35	0.56	0.69	0.77	0.78	0.75	0.74	0.69	0.64	0.60
42.5	1.5	0.35	0.56	0.68	0.78	0.79	0.76	0.74	0.70	0.65	0.61
37.5	1.0	0.35	0.56	0.69	0.78	0.79	0.76	0.74	0.70	0.65	0.61
32.5	0.7	0.35	0.56	0.68	0.78	0.79	0.76	0.74	0.70	0.65	0.61

TABLE 4. CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.72	1.13	1.34	1.43	1.33	1.16	1.07	0.85	0.67	0.52
117.5	30.6	0.74	1.18	1.41	1.53	1.43	1.27	1.18	0.96	0.76	0.60
112.5	26.9	0.77	1.22	1.47	1.61	1.53	1.37	1.28	1.06	0.86	0.69
107.5	23.5	0.79	1.25	1.51	1.68	1.61	1.45	1.37	1.15	0.94	0.77
102.5	20.4	0.80	1.28	1.55	1.72	1.67	1.52	1.43	1.21	1.01	0.84
97.5	17.6	0.81	1.29	1.56	1.74	1.69	1.54	1.46	1.24	1.04	0.86
92.5	15.0	0.81	1.29	1.57	1.76	1.70	1.56	1.48	1.26	1.06	0.88
87.5	12.7	0.81	1.30	1.58	1.77	1.72	1.58	1.49	1.28	1.08	0.90
82.5	10.7	0.81	1.30	1.58	1.78	1.73	1.59	1.51	1.30	1.10	0.92
77.5	8.9	0.82	1.31	1.59	1.78	1.74	1.60	1.51	1.30	1.10	0.93
72.5	7.3	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.93
67.5	5.9	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94
62.5	4.7	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94
57.5	3.7	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94
52.5	2.8	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94
47.5	2.1	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94
42.5	1.5	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94
37.5	1.0	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94
32.5	0.7	0.82	1.31	1.59	1.78	1.74	1.60	1.52	1.31	1.11	0.94

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	1.38	2.14	2.53	2.68	2.47	2.15	1.98	1.59	1.25	0.97
117.5	30.6	1.44	2.26	2.68	2.88	2.70	2.39	2.22	1.82	1.46	1.16
112.5	26.9	1.51	2.37	2.84	3.10	2.95	2.66	2.49	2.08	1.71	1.39
107.5	23.5	1.57	2.50	3.01	3.34	3.23	2.96	2.80	2.39	2.01	1.68
102.5	20.4	1.63	2.60	3.15	3.54	3.47	3.22	3.07	2.67	2.29	1.94
97.5	17.6	1.67	2.67	3.26	3.70	3.67	3.44	3.30	2.91	2.53	2.18
92.5	15.0	1.70	2.73	3.34	3.82	3.82	3.61	3.48	3.10	2.72	2.37
87.5	12.7	1.73	2.79	3.41	3.93	3.95	3.77	3.64	3.27	2.90	2.55
82.5	10.7	1.76	2.84	3.49	4.04	4.09	3.93	3.81	3.46	3.10	2.75
77.5	8.9	1.79	2.89	3.57	4.16	4.25	4.11	4.00	3.67	3.32	2.98
72.5	7.3	1.81	2.94	3.64	4.27	4.39	4.27	4.17	3.87	3.54	3.21
67.5	5.9	1.84	3.00	3.72	4.39	4.54	4.46	4.38	4.10	3.79	3.48
62.5	4.7	1.86	3.03	3.77	4.48	4.66	4.60	4.52	4.27	3.98	3.68
57.5	3.7	1.88	3.08	3.84	4.59	4.81	4.79	4.73	4.51	4.26	3.99
52.5	2.8	1.90	3.13	3.90	4.69	4.95	4.96	4.92	4.74	4.52	4.29
47.5	2.1	1.92	3.15	3.94	4.75	5.03	5.06	5.03	4.88	4.69	4.48
42.5	1.5	1.92	3.16	3.95	4.77	5.05	5.09	5.06	4.92	4.73	4.53
37.5	1.0	1.92	3.16	3.95	4.77	5.05	5.09	5.07	4.93	4.74	4.54
32.5	0.7	1.92	3.16	3.95	4.77	5.05	5.09	5.07	4.93	4.74	4.54

TABLE 5. ESTIMATES OF YIELD PER RECRUIT PER EFFORT (KG) WHEN M=0.8, INITIAL F=0.2, AND GROWTH CURVE OF LE GUEN AND SAKAGAWA (IN PRESS) IS USED

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.40	0.37	0.35	0.31	0.28	0.25	0.24	0.22	0.21	0.19
117.5	30.6	0.47	0.43	0.40	0.36	0.33	0.30	0.29	0.26	0.24	0.23
112.5	26.9	0.55	0.51	0.48	0.43	0.39	0.36	0.35	0.32	0.30	0.28
107.5	23.5	0.64	0.60	0.56	0.50	0.45	0.42	0.40	0.37	0.34	0.32
102.5	20.4	0.73	0.68	0.64	0.57	0.52	0.48	0.46	0.42	0.39	0.36
97.5	17.6	0.84	0.78	0.74	0.66	0.61	0.56	0.54	0.50	0.46	0.43
92.5	15.0	0.94	0.88	0.83	0.75	0.69	0.64	0.61	0.57	0.53	0.49
87.5	12.7	1.01	0.95	0.90	0.81	0.74	0.69	0.66	0.61	0.56	0.53
82.5	10.7	1.09	1.03	0.97	0.88	0.80	0.74	0.72	0.66	0.61	0.57
77.5	8.9	1.19	1.12	1.06	0.95	0.87	0.81	0.78	0.71	0.66	0.61
72.5	7.3	1.28	1.20	1.13	1.02	0.93	0.85	0.82	0.75	0.69	0.64
67.5	5.9	1.37	1.28	1.21	1.08	0.98	0.90	0.86	0.78	0.71	0.65
62.5	4.7	1.43	1.34	1.25	1.12	1.01	0.92	0.88	0.79	0.72	0.66
57.5	3.7	1.49	1.39	1.30	1.15	1.02	0.92	0.88	0.78	0.70	0.64
52.5	2.8	1.54	1.42	1.32	1.15	1.02	0.91	0.86	0.75	0.67	0.60
47.5	2.1	1.57	1.44	1.33	1.15	1.01	0.90	0.84	0.74	0.65	0.57
42.5	1.5	1.57	1.44	1.33	1.15	1.01	0.89	0.84	0.73	0.64	0.56
37.5	1.0	1.57	1.44	1.33	1.15	1.01	0.89	0.84	0.72	0.63	0.56
32.5	0.7	1.57	1.44	1.33	1.15	1.01	0.89	0.84	0.72	0.63	0.56

SMALL PURSE SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	1.72	1.46	1.26	0.97	0.78	0.65	0.60	0.50	0.43	0.38
117.5	30.6	1.77	1.50	1.29	0.99	0.79	0.66	0.61	0.51	0.43	0.38
112.5	26.9	1.82	1.54	1.31	1.01	0.80	0.67	0.61	0.51	0.44	0.38
107.5	23.5	1.91	1.61	1.38	1.06	0.85	0.71	0.66	0.55	0.48	0.42
102.5	20.4	1.99	1.69	1.45	1.12	0.90	0.76	0.70	0.59	0.52	0.46
97.5	17.6	2.05	1.73	1.48	1.14	0.93	0.78	0.72	0.61	0.53	0.47
92.5	15.0	2.07	1.74	1.49	1.15	0.93	0.77	0.72	0.60	0.52	0.46
87.5	12.7	2.10	1.76	1.51	1.16	0.93	0.78	0.72	0.60	0.52	0.46
82.5	10.7	2.12	1.78	1.52	1.16	0.93	0.77	0.71	0.60	0.51	0.45
77.5	8.9	2.13	1.78	1.52	1.15	0.92	0.76	0.70	0.58	0.50	0.43
72.5	7.3	2.14	1.79	1.52	1.14	0.91	0.74	0.68	0.56	0.48	0.41
67.5	5.9	2.15	1.79	1.51	1.13	0.89	0.72	0.66	0.54	0.45	0.39
62.5	4.7	2.16	1.78	1.50	1.11	0.87	0.70	0.64	0.52	0.43	0.37
57.5	3.7	2.17	1.79	1.50	1.10	0.85	0.68	0.62	0.50	0.41	0.35
52.5	2.8	2.19	1.79	1.49	1.08	0.83	0.66	0.60	0.48	0.39	0.33
47.5	2.1	2.19	1.78	1.48	1.06	0.81	0.64	0.58	0.45	0.37	0.31
42.5	1.5	2.19	1.78	1.47	1.06	0.80	0.63	0.57	0.45	0.36	0.30
37.5	1.0	2.19	1.78	1.47	1.06	0.80	0.63	0.57	0.44	0.36	0.30
32.5	0.7	2.19	1.78	1.47	1.06	0.80	0.63	0.57	0.44	0.36	0.30

LARGE PURSE SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	1.57	1.34	1.16	0.89	0.71	0.58	0.53	0.44	0.37	0.32
117.5	30.6	1.61	1.37	1.18	0.90	0.72	0.59	0.54	0.44	0.37	0.32
112.5	26.9	1.66	1.41	1.21	0.92	0.74	0.60	0.55	0.46	0.39	0.33
107.5	23.5	1.71	1.44	1.24	0.94	0.75	0.61	0.56	0.46	0.39	0.34
102.5	20.4	1.72	1.44	1.23	0.93	0.73	0.59	0.54	0.44	0.37	0.32
97.5	17.6	1.73	1.45	1.23	0.92	0.72	0.58	0.53	0.43	0.35	0.30
92.5	15.0	1.74	1.45	1.22	0.91	0.71	0.57	0.51	0.41	0.34	0.29
87.5	12.7	1.74	1.45	1.22	0.90	0.69	0.56	0.50	0.40	0.33	0.28
82.5	10.7	1.74	1.44	1.21	0.89	0.68	0.54	0.49	0.39	0.32	0.27
77.5	8.9	1.75	1.44	1.20	0.88	0.67	0.53	0.47	0.37	0.30	0.25
72.5	7.3	1.75	1.44	1.20	0.86	0.65	0.51	0.46	0.36	0.29	0.24
67.5	5.9	1.75	1.43	1.19	0.85	0.64	0.49	0.44	0.34	0.27	0.23
62.5	4.7	1.76	1.43	1.18	0.84	0.62	0.48	0.43	0.33	0.27	0.22
57.5	3.7	1.76	1.42	1.17	0.82	0.60	0.46	0.41	0.32	0.25	0.20
52.5	2.8	1.76	1.42	1.15	0.80	0.59	0.45	0.40	0.30	0.24	0.19
47.5	2.1	1.76	1.40	1.14	0.78	0.57	0.43	0.38	0.28	0.22	0.18
42.5	1.5	1.76	1.40	1.14	0.78	0.56	0.42	0.37	0.28	0.22	0.18
37.5	1.0	1.76	1.40	1.14	0.78	0.56	0.42	0.37	0.28	0.22	0.17
32.5	0.7	1.76	1.40	1.14	0.78	0.56	0.42	0.37	0.28	0.22	0.17

TABLE 5. CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	4.00	3.51	3.10	2.49	2.05	1.74	1.61	1.35	1.16	1.02
117.5	30.6	4.12	3.60	3.17	2.53	2.07	1.75	1.61	1.35	1.16	1.01
112.5	26.9	4.21	3.66	3.21	2.54	2.07	1.73	1.60	1.33	1.13	0.98
107.5	23.5	4.27	3.69	3.22	2.52	2.03	1.68	1.54	1.27	1.07	0.92
102.5	20.4	4.31	3.70	3.21	2.49	1.99	1.63	1.49	1.21	1.01	0.86
97.5	17.6	4.31	3.68	3.17	2.43	1.92	1.56	1.42	1.14	0.94	0.79
92.5	15.0	4.30	3.66	3.14	2.38	1.87	1.50	1.36	1.08	0.89	0.74
87.5	12.7	4.30	3.64	3.11	2.34	1.82	1.46	1.31	1.04	0.84	0.69
82.5	10.7	4.29	3.61	3.08	2.29	1.77	1.40	1.26	0.98	0.79	0.64
77.5	8.9	4.27	3.57	3.03	2.23	1.70	1.33	1.19	0.92	0.72	0.58
72.5	7.3	4.24	3.53	2.98	2.17	1.63	1.26	1.12	0.85	0.66	0.53
67.5	5.9	4.21	3.49	2.91	2.09	1.55	1.19	1.05	0.78	0.60	0.47
62.5	4.7	4.19	3.45	2.86	2.03	1.49	1.13	0.99	0.73	0.55	0.42
57.5	3.7	4.15	3.39	2.79	1.95	1.40	1.04	0.91	0.65	0.48	0.36
52.5	2.8	4.12	3.33	2.72	1.86	1.32	0.96	0.83	0.58	0.42	0.31
47.5	2.1	4.09	3.29	2.67	1.81	1.26	0.91	0.78	0.54	0.38	0.28
42.5	1.5	4.08	3.27	2.65	1.79	1.25	0.89	0.76	0.53	0.37	0.27
37.5	1.0	4.08	3.27	2.65	1.78	1.24	0.89	0.76	0.52	0.37	0.27
32.5	0.7	4.08	3.27	2.65	1.78	1.24	0.89	0.76	0.52	0.37	0.27

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	7.70	6.68	5.86	4.65	3.82	3.22	2.98	2.51	2.17	1.91
117.5	30.6	7.97	6.90	6.04	4.78	3.91	3.29	3.05	2.57	2.21	1.94
112.5	26.9	8.25	7.12	6.22	4.90	4.00	3.36	3.11	2.61	2.25	1.97
107.5	23.5	8.53	7.34	6.40	5.02	4.08	3.42	3.16	2.65	2.27	1.99
102.5	20.4	8.75	7.51	6.53	5.10	4.14	3.46	3.19	2.67	2.28	2.00
97.5	17.6	8.92	7.64	6.62	5.16	4.17	3.48	3.20	2.67	2.28	1.99
92.5	15.0	9.04	7.73	6.69	5.19	4.19	3.48	3.21	2.67	2.27	1.95
87.5	12.7	9.14	7.80	6.74	5.21	4.19	3.48	3.20	2.65	2.26	1.96
82.5	10.7	9.24	7.86	6.78	5.22	4.18	3.46	3.18	2.62	2.22	1.92
77.5	8.9	9.34	7.92	6.81	5.22	4.16	3.42	3.14	2.58	2.18	1.88
72.5	7.3	9.42	7.96	6.82	5.19	4.12	3.38	3.09	2.52	2.12	1.82
67.5	5.9	9.49	7.99	6.82	5.15	4.06	3.30	3.01	2.44	2.04	1.74
62.5	4.7	9.54	7.99	6.80	5.10	4.00	3.23	2.94	2.37	1.97	1.66
57.5	3.7	9.58	7.98	6.75	5.01	3.88	3.11	2.81	2.25	1.84	1.55
52.5	2.8	9.60	7.95	6.68	4.90	3.75	2.98	2.68	2.11	1.71	1.42
47.5	2.1	9.61	7.91	6.61	4.81	3.65	2.87	2.58	2.01	1.62	1.33
42.5	1.5	9.60	7.90	6.59	4.78	3.62	2.84	2.54	1.98	1.59	1.31
37.5	1.0	9.60	7.89	6.59	4.77	3.61	2.83	2.53	1.97	1.58	1.30
32.5	0.7	9.60	7.89	6.59	4.77	3.61	2.83	2.53	1.97	1.58	1.30

TABLE 6. ESTIMATES OF AVERAGE WEIGHT OF CATCH (KG) WHEN M=0.8, INITIAL F=0.2, AND GROWTH CURVE OF LE GUEN AND SAKAGAWA (IN PRESS) IS USED

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	48.87	47.71	46.73	45.18	44.03	43.14	42.78	42.01	41.41	40.91
117.5	30.6	45.55	44.47	43.56	42.12	41.06	40.24	39.90	39.19	38.61	38.14
112.5	26.9	41.63	40.64	39.80	38.47	37.49	36.72	36.40	35.71	35.15	34.68
107.5	23.5	38.03	37.10	36.32	35.08	34.15	33.42	33.10	32.43	31.87	31.40
102.5	20.4	34.67	33.80	33.07	31.91	31.02	30.31	30.01	29.35	28.79	28.31
97.5	17.6	31.19	30.39	29.71	28.63	27.80	27.12	26.83	26.19	25.65	25.19
92.5	15.0	28.34	27.59	26.96	25.95	25.16	24.53	24.25	23.64	23.12	22.67
87.5	12.7	26.21	25.51	24.91	23.95	23.19	22.58	22.31	21.72	21.21	20.77
82.5	10.7	23.80	23.13	22.57	21.65	20.93	20.34	20.08	19.50	19.00	18.57
77.5	8.9	21.12	20.51	19.98	19.12	18.44	17.87	17.62	17.06	16.58	16.16
72.5	7.3	18.89	18.31	17.82	17.00	16.35	15.81	15.57	15.03	14.56	14.16
67.5	5.9	16.57	16.04	15.58	14.81	14.20	13.68	13.45	12.93	12.48	12.09
62.5	4.7	15.08	14.57	14.13	13.39	12.80	12.29	12.07	11.57	11.13	10.75
57.5	3.7	13.31	12.82	12.40	11.70	11.13	10.64	10.42	9.93	9.50	9.13
52.5	2.8	11.97	11.50	11.10	10.41	9.85	9.37	9.16	8.67	8.25	7.88
47.5	2.1	10.87	10.42	10.02	9.35	8.80	8.33	8.11	7.63	7.21	6.85
42.5	1.5	10.57	10.13	9.73	9.07	8.51	8.04	7.83	7.35	6.93	6.56
37.5	1.0	10.51	10.07	9.67	9.01	8.46	7.98	7.77	7.29	6.87	6.50
32.5	0.7	10.51	10.06	9.67	9.00	8.45	7.98	7.76	7.28	6.86	6.50

SMALL PURSE SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	63.08	60.94	58.99	55.67	53.02	50.93	50.04	48.20	46.76	45.59
117.5	30.6	60.95	59.69	56.65	53.18	50.44	48.28	47.36	45.47	43.98	42.78
112.5	26.9	58.62	56.24	54.09	50.47	47.62	45.38	44.44	42.48	40.94	39.69
107.5	23.5	54.53	51.97	49.68	45.87	42.91	40.61	39.65	37.65	36.10	34.85
102.5	20.4	50.69	48.01	45.65	41.78	38.82	36.55	35.61	33.67	32.18	31.00
97.5	17.6	48.15	45.42	43.03	39.15	36.22	33.99	33.07	31.19	29.74	28.60
92.5	15.0	46.71	43.96	41.55	37.66	34.74	32.53	31.61	29.75	28.32	27.19
87.5	12.7	44.78	41.99	39.57	35.67	32.76	30.55	29.64	27.79	26.37	25.24
82.5	10.7	42.99	40.17	37.73	33.82	30.92	28.72	27.82	25.97	24.55	23.43
77.5	8.9	41.01	38.17	35.71	31.79	28.89	26.71	25.81	23.97	22.55	21.41
72.5	7.3	39.22	36.35	33.88	29.96	27.07	24.89	24.00	22.16	20.74	19.60
67.5	5.9	37.02	34.12	31.65	27.73	24.86	22.69	21.80	19.97	18.55	17.41
62.5	4.7	35.35	32.44	29.96	26.06	23.20	21.05	20.16	18.34	16.93	15.79
57.5	3.7	31.69	28.79	26.34	22.51	19.73	17.65	16.79	15.04	13.68	12.59
52.5	2.8	27.97	25.13	22.75	19.09	16.46	14.52	13.72	12.10	10.86	9.88
47.5	2.1	26.14	23.35	21.02	17.47	14.93	13.07	12.31	10.77	9.60	8.67
42.5	1.5	25.72	22.94	20.63	17.10	14.59	12.74	11.99	10.47	9.31	8.39
37.5	1.0	25.62	22.84	20.54	17.01	14.50	12.66	11.91	10.39	9.23	8.32
32.5	0.7	25.61	22.84	20.53	17.00	14.50	12.65	11.90	10.39	9.23	8.32

LARGE PURSE SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	63.26	61.49	59.84	56.92	54.48	52.45	51.57	49.68	48.15	46.90
117.5	30.6	61.30	59.40	57.62	54.47	51.88	49.72	48.78	46.77	45.16	43.83
112.5	26.9	58.69	56.61	54.69	51.30	48.50	46.19	45.19	43.07	41.37	39.9[illegible]
107.5	23.5	55.99	53.75	51.68	48.07	45.11	42.70	41.66	39.47	37.72	36.31
102.5	20.4	54.78	52.46	50.33	46.62	43.59	41.13	40.07	37.84	36.07	34.63
97.5	17.6	53.40	51.00	48.79	44.96	41.84	39.30	38.21	35.92	34.10	32.62
92.5	15.0	52.39	49.92	47.65	43.73	40.53	37.94	36.83	34.48	32.62	31.1[illegible]
87.5	12.7	51.41	48.87	46.54	42.52	39.24	36.59	35.45	33.05	31.13	29.57
82.5	10.7	50.10	47.48	45.07	40.91	37.54	34.80	33.63	31.15	29.16	27.5[illegible]
77.5	8.9	48.65	45.92	43.43	39.13	35.64	32.82	31.61	29.05	27.00	25.3[illegible]
72.5	7.3	46.62	43.77	41.16	36.69	33.07	30.15	28.90	26.27	24.16	22.4[illegible]
67.5	5.9	44.46	41.48	38.78	34.14	30.43	27.44	26.17	23.50	21.38	19.6[illegible]
62.5	4.7	41.92	38.81	36.01	31.24	27.46	24.46	23.18	20.53	18.44	16.7[illegible]
57.5	3.7	38.35	35.12	32.23	27.39	23.62	20.67	19.44	16.90	14.94	13.4[illegible]
52.5	2.8	34.39	31.08	28.17	23.32	19.74	16.96	15.82	13.50	11.75	10.41
47.5	2.1	32.91	29.60	26.69	21.96	18.39	15.68	14.58	12.35	10.69	9.4[illegible]
42.5	1.5	31.85	28.53	25.64	20.94	17.43	14.78	13.70	11.54	9.93	8.71
37.5	1.0	31.52	28.21	25.31	20.63	17.13	14.50	13.43	11.29	9.70	8.4[illegible]
32.5	0.7	31.52	28.20	25.31	20.62	17.13	14.50	13.43	11.29	9.70	8.4[illegible]

TABLE 6. CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	59.30	57.92	56.63	54.33	52.38	50.73	50.00	48.41	47.10	46.09
117.5	30.6	57.53	56.05	54.68	52.23	50.16	48.41	47.63	45.96	44.57	43.41
112.5	26.9	55.76	54.18	52.71	50.11	47.91	46.05	45.23	43.45	41.97	40.74
107.5	23.5	54.18	52.51	50.96	48.20	45.87	43.90	43.03	41.14	39.58	38.26
102.5	20.4	52.88	51.13	49.50	46.61	44.16	42.09	41.18	39.19	37.53	36.13
97.5	17.6	52.31	50.51	48.85	45.89	43.38	41.25	40.31	38.26	36.55	35.11
92.5	15.0	51.85	50.02	48.32	45.30	42.74	40.56	39.60	37.49	35.72	34.23
87.5	12.7	51.33	49.46	47.72	44.62	41.98	39.74	38.74	36.55	34.71	33.14
82.5	10.7	50.84	48.93	47.15	43.98	41.27	38.95	37.92	35.65	33.73	32.09
77.5	8.9	50.61	48.68	46.88	43.66	40.91	38.56	37.50	35.19	33.22	31.54
72.5	7.3	50.39	48.44	46.61	43.35	40.56	38.16	37.09	34.72	32.70	30.96
67.5	5.9	50.30	48.34	46.51	43.23	40.41	38.00	36.91	34.52	32.47	30.70
62.5	4.7	50.28	48.31	46.48	43.19	40.37	37.94	36.86	34.45	32.40	30.62
57.5	3.7	50.26	48.29	46.45	43.16	40.34	37.91	36.82	34.40	32.34	30.56
52.5	2.8	50.26	48.29	46.45	43.16	40.34	37.91	36.82	34.40	32.34	30.56
47.5	2.1	50.26	48.29	46.45	43.16	40.34	37.91	36.82	34.40	32.34	30.56
42.5	1.5	50.26	48.29	46.45	43.16	40.34	37.91	36.82	34.40	32.34	30.56
37.5	1.0	50.26	48.29	46.45	43.16	40.34	37.91	36.82	34.40	32.34	30.56
32.5	0.7	50.26	48.29	46.45	43.16	40.34	37.91	36.82	34.40	32.34	30.56

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	60.20	58.54	57.01	54.35	52.17	50.37	49.59	47.93	46.60	45.49
117.5	30.6	58.08	56.31	54.69	51.89	49.60	47.73	46.92	45.19	43.81	42.66
112.5	26.9	55.65	53.77	52.05	49.10	46.69	44.73	43.88	42.08	40.64	39.45
107.5	23.5	52.91	50.91	49.09	45.97	43.45	41.41	40.53	38.67	37.17	35.94
102.5	20.4	50.52	48.41	46.51	43.28	40.67	38.57	37.67	35.77	34.24	32.99
97.5	17.6	48.46	46.28	44.32	40.99	38.33	36.18	35.27	33.33	31.79	30.53
92.5	15.0	46.75	44.51	42.50	39.09	36.38	34.21	33.28	31.33	29.76	28.49
87.5	12.7	45.06	42.76	40.70	37.23	34.48	32.28	31.34	29.36	27.78	26.50
82.5	10.7	43.12	40.76	38.65	35.11	32.31	30.08	29.14	27.14	25.55	24.26
77.5	8.9	40.84	38.41	36.26	32.66	29.83	27.58	26.63	24.63	23.04	21.74
72.5	7.3	38.57	36.10	33.91	30.27	27.42	25.18	24.23	22.24	20.66	19.38
67.5	5.9	35.94	33.42	31.20	27.54	24.71	22.49	21.55	19.60	18.06	16.82
62.5	4.7	33.91	31.37	29.15	25.50	22.70	20.51	19.59	17.68	16.18	14.97
57.5	3.7	30.97	28.42	26.20	22.60	19.86	17.74	16.86	15.03	13.61	12.47
52.5	2.8	28.27	25.73	23.54	20.02	17.38	15.35	14.50	12.77	11.44	10.38
47.5	2.1	26.48	23.97	21.81	18.36	15.79	13.83	13.02	11.36	10.09	9.09
42.5	1.5	25.94	23.43	21.28	17.86	15.30	13.37	12.57	10.93	9.68	8.69
37.5	1.0	25.81	23.30	21.16	17.74	15.19	13.26	12.46	10.83	9.58	8.60
32.5	0.7	25.80	23.29	21.15	17.73	15.18	13.25	12.45	10.82	9.57	8.59

Changes in the average weight of landings should be considered because average weight affects the values of landings particularly in light of size specific changes in the value of yellowfin tuna. Table 6 presents estimates of the average weight of catches by gear. Figure 13 shows average weight isopleths for the entire fishery. If effort remained cons'ant and size at recruitment increased to 77.5 cm, the average weight of the catch of the total fishery would increase from 17.7 kg to 30.3 kg. If effort doubled and size at recruitment increased to 77.5 cm, the average weight would increase to 24.2 kg.

Sensitivity of Results to Errors in Ageing Large Yellowfin

The growth curve used in this study was based on the use of modal progressions to age yellowfin. Unfortunately while this method is probably reasonably accurate for ageing yellowfin less than about 130 cm, beyond this size it becomes increasingly difficult to separate modes and there is a reasonable probability that ages are increasingly underestimated with increases in size. In addition, because tuna apparently spawn over a large portion of the year, the exact meaning of age is not always clear. Because the usual hard parts are not easily interpreted for ageing purposes, it is extremely difficult to ascertain the age of large yellowfin tuna.

The marked increase in estimates of size specific F beyond 130 cm for the purse seine gears is a possible result of underestimating ages of older yellowfin. To examine this possibility, the growth curve of LeGuen and Sakagawa (in press) was modified. It was hypothetically assumed that the percentage of underestimation of the time interval within a size interval increased linearly from 0% at 135 cm to 100% at 180 cm. The resulting growth curve is compared to the original in Figure 14.

Values of size specific F were then estimated as before with initial values of 0.2 and 0.8. The resulting values converged at sizes below 130 cm. An initial value of 0.2 gave the most reasonable results for reasons similar to before. Values of size specific F for each gear are shown in Figure 15. The values of F at large fish are relatively smaller than those estimated using the original growth curve.

Results of the yield-per-recruit calculations are shown in Table 7. The results indicate that if effort is held constant and size at recruitment is increased to the optimum, less than a 3% increase in yield per recruit would occur. If size at recruitment is constant and effort is doubled, yield per recruit would increase by about 28% which is considerably more than when the original growth curve is used. If size at recruitment is increased to 77.5 cm and effort doubled, a 44% increase in yield per recruit would occur.

Sensitivity of Results to Errors in Estimates of Natural Mortality

Size specific values of F were estimated using values of M of 0.6 and 1.0 and an initial value of F = 0.2. The results are compared to size specific F when M = 0.8 in Figure 16. Although the absolute values differ considerably, the same general trends appear in each curve. The ratio of F/M varies about threefold.

Results of yield-per-recruit calculations are shown in Tables 8 and 9 and Figures 17 and 18. There is a steeper horizontal gradient when M = 1.0 and a steeper vertical gradient when M = 0.6 than when M = 0.8. That is, yield per recruit is more sensitive to changes in effort when M = 1.0 and more sensitive to changes in size at recruitment when M = 0.6 than when M = 0.8. When M = 1.0 and effort is

TABLE 7. ESTIMATES OF YIELD PER RECRUIT (KG) WHEN M = 0.8, INITIAL F = 0.2, AND HYPOTHETICAL GROWTH CURVE IS USED

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.05	0.09	0.13	0.20	0.26	0.31	0.34	0.40	0.45	0.50
117.5	30.6	0.05	0.10	0.15	0.23	0.31	0.37	0.40	0.48	0.54	0.60
112.5	26.9	0.07	0.13	0.18	0.28	0.37	0.46	0.49	0.58	0.66	0.73
107.5	23.5	0.08	0.15	0.22	0.34	0.44	0.54	0.58	0.68	0.77	0.85
102.5	20.4	0.09	0.17	0.25	0.39	0.51	0.63	0.68	0.79	0.90	0.99
97.5	17.6	0.11	0.20	0.29	0.46	0.61	0.74	0.80	0.94	1.06	1.17
92.5	15.0	0.12	0.23	0.33	0.52	0.69	0.84	0.91	1.07	1.21	1.35
87.5	12.7	0.13	0.25	0.36	0.57	0.75	0.91	0.99	1.16	1.32	1.46
82.5	10.7	0.14	0.27	0.40	0.62	0.82	0.99	1.08	1.26	1.43	1.58
77.5	8.9	0.16	0.30	0.44	0.68	0.90	1.09	1.18	1.38	1.56	1.71
72.5	7.3	0.17	0.33	0.47	0.73	0.96	1.16	1.26	1.47	1.65	1.82
67.5	5.9	0.18	0.35	0.51	0.79	1.03	1.24	1.34	1.56	1.74	1.90
62.5	4.7	0.19	0.37	0.53	0.82	1.07	1.28	1.38	1.59	1.78	1.93
57.5	3.7	0.20	0.39	0.55	0.85	1.10	1.31	1.40	1.61	1.77	1.91
52.5	2.8	0.21	0.40	0.57	0.86	1.10	1.30	1.39	1.58	1.73	1.84
47.5	2.1	0.21	0.41	0.58	0.87	1.11	1.30	1.39	1.56	1.70	1.80
42.5	1.5	0.21	0.41	0.58	0.87	1.11	1.30	1.38	1.55	1.68	1.78
37.5	1.0	0.21	0.41	0.58	0.87	1.11	1.30	1.38	1.55	1.67	1.77
32.5	0.7	0.21	0.41	0.58	0.87	1.11	1.30	1.38	1.55	1.67	1.77

SMALL PURSE-SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.17	0.32	0.44	0.62	0.76	0.86	0.90	0.99	1.06	1.11
117.5	30.6	0.18	0.33	0.46	0.65	0.79	0.89	0.93	1.02	1.09	1.14
112.5	26.9	0.19	0.34	0.47	0.67	0.81	0.92	0.96	1.05	1.11	1.17
107.5	23.5	0.20	0.37	0.51	0.72	0.87	0.99	1.04	1.14	1.21	1.28
102.5	20.4	0.22	0.39	0.54	0.77	0.93	1.06	1.11	1.23	1.31	1.39
97.5	17.6	0.22	0.41	0.56	0.79	0.96	1.10	1.15	1.26	1.35	1.43
92.5	15.0	0.23	0.41	0.56	0.80	0.97	1.10	1.15	1.26	1.35	1.42
87.5	12.7	0.23	0.42	0.57	0.81	0.99	1.12	1.17	1.28	1.36	1.43
82.5	10.7	0.23	0.43	0.58	0.82	0.99	1.12	1.17	1.27	1.35	1.41
77.5	8.9	0.24	0.43	0.59	0.82	0.99	1.11	1.16	1.26	1.33	1.38
72.5	7.3	0.24	0.43	0.59	0.82	0.99	1.10	1.15	1.23	1.30	1.34
67.5	5.9	0.24	0.44	0.59	0.82	0.98	1.08	1.13	1.20	1.25	1.28
62.5	4.7	0.24	0.44	0.59	0.82	0.97	1.07	1.10	1.17	1.21	1.24
57.5	3.7	0.25	0.44	0.60	0.81	0.96	1.05	1.08	1.14	1.17	1.19
52.5	2.8	0.25	0.45	0.60	0.81	0.95	1.03	1.06	1.11	1.13	1.14
47.5	2.1	0.25	0.45	0.60	0.80	0.93	1.01	1.03	1.07	1.09	1.09
42.5	1.5	0.25	0.45	0.60	0.80	0.93	1.00	1.02	1.06	1.07	1.07
37.5	1.0	0.25	0.45	0.59	0.80	0.92	1.00	1.02	1.06	1.07	1.06
32.5	0.7	0.25	0.45	0.59	0.80	0.92	1.00	1.02	1.06	1.07	1.06

LARGE PURSE-SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.16	0.29	0.40	0.57	0.69	0.78	0.82	0.89	0.94	0.98
117.5	30.6	0.17	0.30	0.42	0.59	0.71	0.81	0.84	0.91	0.96	1.00
112.5	26.9	0.17	0.32	0.43	0.61	0.74	0.84	0.87	0.95	1.00	1.04
107.5	23.5	0.18	0.33	0.45	0.63	0.77	0.86	0.90	0.97	1.02	1.06
102.5	20.4	0.18	0.33	0.45	0.63	0.76	0.85	0.88	0.95	0.99	1.02
97.5	17.6	0.18	0.33	0.46	0.64	0.76	0.84	0.87	0.93	0.97	0.99
92.5	15.0	0.19	0.34	0.46	0.63	0.75	0.83	0.86	0.92	0.95	0.97
87.5	12.7	0.19	0.34	0.46	0.63	0.75	0.82	0.85	0.90	0.93	0.94
82.5	10.7	0.19	0.34	0.46	0.63	0.74	0.81	0.84	0.88	0.90	0.91
77.5	8.9	0.19	0.34	0.46	0.63	0.73	0.80	0.82	0.86	0.87	0.88
72.5	7.3	0.19	0.34	0.46	0.62	0.72	0.79	0.81	0.84	0.85	0.85
67.5	5.9	0.19	0.34	0.46	0.62	0.71	0.77	0.79	0.81	0.82	0.81
62.5	4.7	0.19	0.34	0.46	0.61	0.71	0.76	0.77	0.80	0.80	0.79
57.5	3.7	0.19	0.34	0.46	0.61	0.69	0.74	0.75	0.77	0.76	0.75
52.5	2.8	0.20	0.34	0.46	0.60	0.68	0.72	0.73	0.74	0.73	0.71
47.5	2.1	0.20	0.34	0.45	0.59	0.67	0.70	0.71	0.71	0.69	0.67
42.5	1.5	0.20	0.34	0.45	0.59	0.66	0.70	0.70	0.70	0.69	0.67
37.5	1.0	0.20	0.34	0.45	0.59	0.66	0.69	0.70	0.70	0.69	0.66
32.5	0.7	0.20	0.34	0.45	0.59	0.66	0.69	0.70	0.70	0.68	0.66

TABLE 7. CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.42	0.78	1.09	1.60	1.98	2.28	2.41	2.67	2.87	3.02
117.5	30.6	0.44	0.81	1.13	1.65	2.04	2.34	2.47	2.72	2.91	3.05
112.5	26.9	0.45	0.84	1.16	1.69	2.07	2.37	2.49	2.73	2.90	3.03
107.5	23.5	0.46	0.85	1.18	1.70	2.07	2.35	2.46	2.67	2.82	2.92
102.5	20.4	0.47	0.86	1.19	1.70	2.06	2.32	2.42	2.61	2.73	2.81
97.5	17.6	0.47	0.86	1.18	1.68	2.02	2.26	2.35	2.51	2.60	2.65
92.5	15.0	0.47	0.86	1.18	1.66	1.99	2.21	2.29	2.43	2.50	2.53
87.5	12.7	0.47	0.86	1.17	1.64	1.96	2.16	2.23	2.35	2.41	2.43
82.5	10.7	0.47	0.86	1.17	1.62	1.92	2.10	2.17	2.27	2.30	2.30
77.5	8.9	0.47	0.85	1.15	1.59	1.87	2.03	2.08	2.16	2.17	2.15
72.5	7.3	0.47	0.84	1.14	1.56	1.81	1.96	2.00	2.05	2.04	2.00
67.5	5.9	0.47	0.83	1.12	1.52	1.75	1.87	1.90	1.92	1.89	1.83
62.5	4.7	0.47	0.83	1.11	1.49	1.70	1.80	1.82	1.83	1.78	1.70
57.5	3.7	0.46	0.82	1.09	1.44	1.62	1.70	1.71	1.69	1.61	1.52
52.5	2.8	0.46	0.81	1.07	1.40	1.55	1.60	1.60	1.55	1.46	1.36
47.5	2.1	0.46	0.80	1.05	1.36	1.50	1.54	1.53	1.46	1.36	1.25
42.5	1.5	0.46	0.80	1.05	1.35	1.49	1.52	1.51	1.44	1.33	1.22
37.5	1.0	0.46	0.80	1.05	1.35	1.48	1.51	1.50	1.43	1.33	1.21
32.5	0.7	0.46	0.80	1.05	1.35	1.48	1.51	1.50	1.43	1.33	1.21

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.80	1.48	2.06	2.99	3.70	4.24	4.47	4.95	5.32	5.61
117.5	30.6	0.84	1.55	2.15	3.12	3.85	4.41	4.65	5.13	5.50	5.79
112.5	26.9	0.88	1.62	2.25	3.25	4.00	4.58	4.82	5.30	5.67	5.97
107.5	23.5	0.92	1.70	2.35	3.39	4.15	4.74	4.98	5.46	5.83	6.11
102.5	20.4	0.96	1.76	2.43	3.49	4.27	4.85	5.09	5.57	5.93	6.21
97.5	17.6	0.98	1.80	2.49	3.56	4.35	4.93	5.17	5.64	5.99	6.25
92.5	15.0	1.00	1.84	2.53	3.67	4.40	4.98	5.21	5.68	6.01	6.26
87.5	12.7	1.02	1.87	2.57	3.66	4.44	5.01	5.24	5.69	6.01	6.25
82.5	10.7	1.04	1.89	2.60	3.69	4.47	5.03	5.25	5.69	5.99	6.21
77.5	8.9	1.05	1.92	2.63	3.72	4.48	5.03	5.24	5.65	5.93	6.12
72.5	7.3	1.07	1.94	2.66	3.74	4.48	5.01	5.21	5.59	5.84	6.01
67.5	5.9	1.08	1.96	2.68	3.74	4.47	4.96	5.15	5.49	5.70	5.83
62.5	4.7	1.09	1.98	2.69	3.74	4.44	4.91	5.08	5.39	5.57	5.66
57.5	3.7	1.11	1.99	2.69	3.71	4.37	4.80	4.95	5.20	5.32	5.37
52.5	2.8	1.11	1.99	2.69	3.67	4.28	4.66	4.79	4.98	5.05	5.05
47.5	2.1	1.12	1.99	2.68	3.63	4.21	4.55	4.66	4.81	4.84	4.81
42.5	1.5	1.12	1.99	2.67	3.62	4.18	4.51	4.61	4.75	4.77	4.73
37.5	1.0	1.12	1.99	2.67	3.61	4.18	4.50	4.60	4.73	4.75	4.71
32.5	0.7	1.12	1.99	2.67	3.61	4.17	4.50	4.60	4.73	4.75	4.70

TABLE 8. ESTIMATES OF YIELD PER RECRUIT (KG) WHEN M=0.6, INITIAL F=0.2, AND GROWTH CURVE OF LE GUEN AND SAKAGAWA (IN PRESS) IS USED

BAIT BOATS

MINIMUM SIZE CM	KG	MULTIPLIER OF EFFORT 0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.17	0.31	0.42	0.60	0.74	0.85	0.90	1.02	1.12	1.21
117.5	30.6	0.20	0.35	0.48	0.69	0.85	0.99	1.05	1.18	1.29	1.39
112.5	26.9	0.23	0.41	0.57	0.81	1.01	1.17	1.24	1.40	1.53	1.64
107.5	23.5	0.26	0.47	0.64	0.93	1.15	1.33	1.41	1.58	1.72	1.83
102.5	20.4	0.29	0.53	0.73	1.05	1.30	1.50	1.59	1.78	1.93	2.06
97.5	17.6	0.33	0.60	0.83	1.20	1.49	1.73	1.83	2.06	2.25	2.41
92.5	15.0	0.37	0.67	0.92	1.34	1.67	1.94	2.06	2.32	2.54	2.72
87.5	12.7	0.39	0.71	0.98	1.43	1.78	2.07	2.19	2.46	2.69	2.87
82.5	10.7	0.42	0.76	1.05	1.53	1.90	2.20	2.33	2.61	2.84	3.03
77.5	8.9	0.45	0.82	1.13	[illegible]	2.03	2.35	2.48	2.77	3.00	3.18
72.5	7.3	0.48	0.87	1.20	1.72	2.13	2.44	2.58	2.85	3.07	3.24
67.5	5.9	0.51	0.92	1.26	1.80	2.21	2.51	2.64	2.90	3.09	3.23
62.5	4.7	0.53	0.95	1.30	1.83	2.23	2.52	2.64	2.87	3.03	3.14
57.5	3.7	0.54	0.97	1.32	1.84	2.20	2.45	2.55	2.72	2.83	2.89
52.5	2.8	0.55	0.98	1.32	1.81	2.12	2.33	2.40	2.52	2.57	2.57
47.5	2.1	0.56	0.99	1.32	1.79	2.08	2.25	2.31	2.39	2.41	2.39
42.5	1.5	0.56	0.99	1.32	1.78	2.06	2.22	2.27	2.34	2.35	2.32
37.5	1.0	0.56	0.99	1.32	1.77	2.05	2.21	2.26	2.33	2.33	2.30
32.5	0.7	0.56	0.99	1.32	1.77	2.05	2.21	2.26	2.32	2.33	2.30

SMALL PURSE SEINERS

MINIMUM SIZE CM	KG	MULTIPLIER OF EFFORT 0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.81	1.29	1.59	1.89	2.01	2.08	2.10	2.13	2.16	2.17
117.5	30.6	0.82	1.31	1.60	1.90	2.02	2.08	2.09	2.12	2.14	2.16
112.5	26.9	0.84	1.33	1.62	1.90	2.01	2.06	2.07	2.09	2.10	2.11
107.5	23.5	0.87	1.37	1.67	1.97	2.09	2.16	2.18	2.23	2.26	2.29
102.5	20.4	0.89	1.41	1.72	2.04	2.18	2.27	2.30	2.36	2.42	2.46
97.5	17.6	0.91	1.43	1.74	2.06	2.20	2.29	2.32	2.38	2.43	2.47
92.5	15.0	0.91	1.43	1.74	2.04	2.17	2.24	2.26	2.31	2.34	2.36
87.5	12.7	0.92	1.44	1.75	2.04	2.16	2.22	2.24	2.28	2.30	2.31
82.5	10.7	0.92	1.44	1.74	2.02	2.12	2.17	2.18	2.20	2.21	2.20
77.5	8.9	0.93	1.44	1.72	1.98	2.07	2.09	2.10	2.09	2.08	2.06
72.5	7.3	0.93	1.43	1.70	1.93	2.00	2.00	2.00	1.97	1.93	1.89
67.5	5.9	0.92	1.42	1.67	1.88	1.91	1.90	1.88	1.83	1.77	1.71
62.5	4.7	0.92	1.40	1.65	1.83	1.84	1.81	1.78	1.71	1.64	1.56
57.5	3.7	0.92	1.39	1.62	1.76	1.75	1.70	1.67	1.58	1.49	1.42
52.5	2.8	0.92	1.37	1.59	1.70	1.67	1.60	1.56	1.46	1.37	1.29
47.5	2.1	0.92	1.36	1.56	1.65	1.60	1.51	1.47	1.36	1.26	1.17
42.5	1.5	0.91	1.35	1.55	1.63	1.57	1.48	1.43	1.32	1.22	1.13
37.5	1.0	0.91	1.35	1.54	1.63	1.57	1.47	1.43	1.31	1.21	1.12
32.5	0.7	0.91	1.35	1.54	1.62	1.57	1.47	1.42	1.31	1.21	1.12

LARGE PURSE SEINERS

MINIMUM SIZE CM	KG	MULTIPLIER OF EFFORT 0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.73	1.18	1.46	1.74	1.83	1.86	1.87	1.86	1.84	1.83
117.5	30.6	0.74	1.20	1.47	1.73	1.82	1.85	1.85	1.84	1.82	1.81
112.5	26.9	0.76	1.22	1.49	1.75	1.83	1.86	1.86	1.85	1.84	1.83
107.5	23.5	0.77	1.23	1.50	1.74	1.82	1.84	1.84	1.83	1.81	1.80
102.5	20.4	0.77	1.22	1.47	1.69	1.74	1.73	1.72	1.69	1.65	1.62
97.5	17.6	0.77	1.21	1.46	1.65	1.69	1.67	1.65	1.60	1.55	1.51
92.5	15.0	0.77	1.20	1.44	1.62	1.64	1.61	1.58	1.52	1.47	1.41
87.5	12.7	0.77	1.20	1.42	1.59	1.59	1.55	1.52	1.45	1.38	1.32
82.5	10.7	0.77	1.19	1.40	1.55	1.54	1.48	1.45	1.37	1.30	1.23
77.5	8.9	0.77	1.18	1.38	1.50	1.48	1.41	1.37	1.28	1.20	1.13
72.5	7.3	0.77	1.17	1.36	1.46	1.42	1.34	1.30	1.21	1.12	1.05
67.5	5.9	0.76	1.15	1.33	1.41	1.35	1.26	1.22	1.11	1.02	0.94
62.5	4.7	0.76	1.14	1.31	1.37	1.31	1.21	1.16	1.06	0.97	0.89
57.5	3.7	0.76	1.12	1.28	1.32	1.23	1.13	1.08	0.96	0.87	0.80
52.5	2.8	0.75	1.11	1.25	1.26	1.16	1.05	1.00	0.89	0.80	0.73
47.5	2.1	0.75	1.09	1.22	1.21	1.10	0.98	0.93	0.81	0.72	0.65
42.5	1.5	0.75	1.08	1.21	1.20	1.09	0.97	0.91	0.80	0.71	0.64
37.5	1.0	0.75	1.08	1.21	1.20	1.09	0.97	0.91	0.79	0.70	0.64
32.5	0.7	0.75	1.08	1.21	1.20	1.09	0.96	0.91	0.79	0.70	0.63

TABLE 8. CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	1.81	3.04	3.87	4.86	5.35	5.60	5.68	5.80	5.86	5.89
117.5	30.6	1.85	3.08	3.91	4.86	5.31	5.52	5.58	5.67	5.69	5.69
112.5	26.9	1.88	3.10	3.91	4.80	5.19	5.35	5.39	5.41	5.39	5.34
107.5	23.5	1.89	3.10	3.87	4.67	4.97	5.05	5.06	5.00	4.90	4.80
102.5	20.4	1.89	3.08	3.81	4.54	4.76	4.78	4.75	4.64	4.49	4.34
97.5	17.6	1.89	3.04	3.74	4.37	4.53	4.48	4.42	4.24	4.04	3.84
92.5	15.0	1.88	3.01	3.67	4.25	4.34	4.24	4.17	3.94	3.70	3.47
87.5	12.7	1.87	2.98	3.61	4.13	4.17	4.04	3.94	3.68	3.42	3.17
82.5	10.7	1.86	2.94	3.54	4.00	3.98	3.81	3.69	3.39	3.11	2.84
77.5	8.9	1.85	2.89	3.46	3.83	3.75	3.53	3.39	3.06	2.74	2.46
72.5	7.3	1.83	2.84	3.37	3.67	3.54	3.27	3.12	2.75	2.42	2.12
67.5	5.9	1.81	2.78	3.26	3.48	3.28	2.97	2.80	2.41	2.05	1.77
62.5	4.7	1.80	2.74	3.18	3.34	3.10	2.75	2.58	2.17	1.82	1.53
57.5	3.7	1.77	2.67	3.06	3.13	2.83	2.45	2.26	1.84	1.50	1.22
52.5	2.8	1.75	2.60	2.94	2.93	2.58	2.18	1.99	1.57	1.23	0.97
47.5	2.1	1.73	2.55	2.86	2.80	2.42	2.00	1.81	1.40	1.07	0.82
42.5	1.5	1.73	2.54	2.84	2.76	2.37	1.95	1.76	1.35	1.03	0.78
37.5	1.0	1.73	2.53	2.83	2.75	2.36	1.94	1.75	1.34	1.02	0.78
32.5	0.7	1.73	2.53	2.83	2.75	2.36	1.94	1.75	1.34	1.02	0.77

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	3.52	5.82	7.34	9.07	9.93	10.39	10.55	10.81	10.98	11.10
117.5	30.6	3.61	5.94	7.47	9.18	10.00	10.43	10.58	10.81	10.95	11.04
112.5	26.9	3.70	6.06	7.58	9.26	10.04	10.44	10.56	10.76	10.86	10.92
107.5	23.5	3.79	6.16	7.68	9.30	10.03	10.39	10.48	10.63	10.70	10.72
102.5	20.4	3.85	6.24	7.74	9.31	9.98	10.28	10.36	10.47	10.49	10.48
97.5	17.6	3.90	6.28	7.77	9.28	9.91	10.16	10.22	10.28	10.27	10.22
92.5	15.0	3.93	6.31	7.77	9.24	9.82	10.03	10.07	10.09	10.04	9.97
87.5	12.7	3.95	6.33	7.77	9.18	9.70	9.87	9.90	9.87	9.79	9.68
82.5	10.7	3.97	6.33	7.74	9.09	9.55	9.66	9.66	9.58	9.45	9.31
77.5	8.9	3.99	6.33	7.70	8.95	9.33	9.38	9.35	9.20	9.01	8.82
72.5	7.3	4.00	6.31	7.63	8.79	9.08	9.06	8.99	8.78	8.54	8.30
67.5	5.9	4.01	6.27	7.53	8.57	8.75	8.64	8.54	8.25	7.94	7.65
62.5	4.7	4.01	6.23	7.44	8.37	8.47	8.29	8.16	7.80	7.45	7.13
57.5	3.7	4.00	6.15	7.28	8.05	8.01	7.73	7.55	7.11	6.70	6.33
52.5	2.8	3.98	6.06	7.10	7.70	7.54	7.16	6.95	6.43	5.97	5.56
47.5	2.1	3.96	5.99	6.96	7.45	7.20	6.75	6.52	5.95	5.46	5.04
42.5	1.5	3.95	5.96	6.92	7.37	7.09	6.62	6.38	5.80	5.30	4.87
37.5	1.0	3.95	5.96	6.90	7.35	7.06	6.59	6.35	5.77	5.26	4.83
32.5	0.7	3.95	5.96	6.90	7.34	7.06	6.59	6.34	5.76	5.26	4.83

TABLE 9. ESTIMATES OF YIELD PER RECRUIT (KG) WHEN M = 1.0, INITIAL F=0.2, AND GROWTH CURVE OF LE GUEN AND SAKAGAWA (IN PRESS) IS USED

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.04	0.07	0.10	0.15	0.19	0.23	0.25	0.29	0.33	0.36
117.5	30.6	0.04	0.08	0.12	0.18	0.23	0.28	0.30	0.35	0.39	0.43
112.5	26.9	0.05	0.10	0.14	0.21	0.28	0.34	0.36	0.43	0.48	0.53
107.5	23.5	0.06	0.11	0.16	0.25	0.33	0.40	0.43	0.50	0.57	0.63
102.5	20.4	0.07	0.13	0.19	0.29	0.39	0.47	0.50	0.59	0.66	0.73
97.5	17.6	0.08	0.15	0.22	0.35	0.45	0.55	0.60	0.70	0.79	0.87
92.5	15.0	0.09	0.18	0.25	0.39	0.52	0.63	0.68	0.80	0.91	1.01
87.5	12.7	0.10	0.19	0.28	0.43	0.56	0.69	0.74	0.87	0.99	1.09
82.5	10.7	0.11	0.21	0.30	0.47	0.62	0.75	0.81	0.95	1.08	1.19
77.5	8.9	0.12	0.23	0.33	0.52	0.68	0.82	0.89	1.05	1.18	1.31
72.5	7.3	0.13	0.25	0.36	0.56	0.73	0.89	0.96	1.12	1.27	1.40
67.5	5.9	0.14	0.27	0.39	0.60	0.79	0.95	1.03	1.20	1.35	1.48
62.5	4.7	0.15	0.28	0.41	0.63	0.82	0.99	1.06	1.24	1.39	1.52
57.5	3.7	0.15	0.30	0.42	0.65	0.85	1.02	1.09	1.26	1.40	1.52
52.5	2.8	0.16	0.30	0.44	0.67	0.86	1.02	1.10	1.25	1.38	1.49
47.5	2.1	0.16	0.31	0.45	0.68	0.87	1.03	1.10	1.25	1.38	1.47
42.5	1.5	0.17	0.31	0.45	0.68	0.87	1.03	1.10	1.25	1.37	1.46
37.5	1.0	0.17	0.31	0.45	0.68	0.87	1.03	1.10	1.25	1.36	1.46
32.5	0.7	0.17	0.31	0.45	0.68	0.87	1.03	1.10	1.25	1.36	1.46

SMALL PURSE SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.14	0.26	0.34	0.47	0.56	0.62	0.64	0.69	0.73	0.76
117.5	30.6	0.15	0.27	0.36	0.49	0.58	0.64	0.66	0.71	0.75	0.78
112.5	26.9	0.16	0.27	0.37	0.50	0.59	0.66	0.68	0.73	0.77	0.80
107.5	23.5	0.16	0.29	0.39	0.54	0.64	0.71	0.74	0.80	0.85	0.89
102.5	20.4	0.17	0.31	0.42	0.58	0.69	0.77	0.80	0.88	0.93	0.98
97.5	17.6	0.18	0.32	0.43	0.60	0.71	0.80	0.83	0.91	0.97	1.02
92.5	15.0	0.18	0.33	0.44	0.60	0.72	0.80	0.84	0.91	0.97	1.02
87.5	12.7	0.19	0.33	0.45	0.61	0.73	0.82	0.85	0.93	0.99	1.03
82.5	10.7	0.19	0.34	0.45	0.62	0.74	0.82	0.86	0.93	0.99	1.03
77.5	8.9	0.19	0.34	0.46	0.62	0.74	0.82	0.86	0.93	0.98	1.02
72.5	7.3	0.19	0.34	0.46	0.63	0.74	0.82	0.85	0.92	0.96	1.00
67.5	5.9	0.20	0.35	0.46	0.63	0.74	0.81	0.84	0.90	0.94	0.97
62.5	4.7	0.20	0.35	0.46	0.62	0.73	0.80	0.83	0.88	0.92	0.94
57.5	3.7	0.20	0.35	0.47	0.63	0.73	0.80	0.82	0.87	0.90	0.92
52.5	2.8	0.20	0.35	0.47	0.63	0.73	0.79	0.82	0.86	0.89	0.90
47.5	2.1	0.20	0.35	0.47	0.63	0.72	0.78	0.80	0.84	0.86	0.87
42.5	1.5	0.20	0.35	0.47	0.62	0.72	0.78	0.80	0.83	0.85	0.86
37.5	1.0	0.20	0.35	0.47	0.62	0.72	0.78	0.80	0.83	0.85	0.86
32.5	0.7	0.20	0.35	0.47	0.62	0.72	0.78	0.80	0.83	0.85	0.86

LARGE PURSE SEINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.13	0.24	0.32	0.43	0.51	0.56	0.58	0.62	0.64	0.66
117.5	30.6	0.14	0.24	0.33	0.45	0.52	0.58	0.60	0.63	0.66	0.68
112.5	26.9	0.14	0.25	0.34	0.46	0.54	0.60	0.62	0.66	0.69	0.71
107.5	23.5	0.15	0.26	0.35	0.48	0.56	0.62	0.64	0.68	0.71	0.73
102.5	20.4	0.15	0.26	0.35	0.48	0.56	0.61	0.63	0.67	0.69	0.71
97.5	17.6	0.15	0.27	0.36	0.48	0.56	0.61	0.63	0.66	0.68	0.69
92.5	15.0	0.15	0.27	0.36	0.48	0.55	0.60	0.62	0.65	0.67	0.68
87.5	12.7	0.15	0.27	0.36	0.48	0.55	0.60	0.61	0.64	0.66	0.67
82.5	10.7	0.15	0.27	0.36	0.48	0.55	0.59	0.61	0.63	0.65	0.65
77.5	8.9	0.15	0.27	0.36	0.47	0.54	0.58	0.60	0.62	0.63	0.63
72.5	7.3	0.16	0.27	0.36	0.47	0.54	0.58	0.59	0.61	0.62	0.62
67.5	5.9	0.16	0.27	0.36	0.47	0.53	0.57	0.58	0.60	0.60	0.60
62.5	4.7	0.16	0.27	0.36	0.47	0.53	0.57	0.58	0.59	0.59	0.59
57.5	3.7	0.16	0.27	0.36	0.47	0.53	0.56	0.57	0.58	0.58	0.57
52.5	2.8	0.16	0.28	0.36	0.47	0.52	0.55	0.56	0.56	0.56	0.56
47.5	2.1	0.16	0.27	0.36	0.46	0.51	0.54	0.54	0.55	0.54	0.53
42.5	1.5	0.16	0.28	0.36	0.46	0.51	0.53	0.54	0.54	0.54	0.53
37.5	1.0	0.16	0.28	0.36	0.46	0.51	0.53	0.54	0.54	0.54	0.53
32.5	0.7	0.16	0.28	0.36	0.46	0.51	0.53	0.54	0.54	0.54	0.53

TABLE 9. CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.34	0.63	0.86	1.21	1.46	1.65	1.72	1.87	1.99	2.06
117.5	30.6	0.36	0.65	0.89	1.25	1.50	1.69	1.76	1.90	2.01	2.09
112.5	26.9	0.37	0.67	0.91	1.27	1.53	1.71	1.78	1.91	2.01	2.05
107.5	23.5	0.38	0.68	0.92	1.28	1.52	1.69	1.76	1.88	1.96	2.02
102.5	20.4	0.38	0.68	0.93	1.28	1.52	1.67	1.73	1.84	1.91	1.95
97.5	17.6	0.38	0.68	0.92	1.27	1.49	1.63	1.68	1.77	1.82	1.85
92.5	15.0	0.38	0.68	0.92	1.25	1.47	1.60	1.65	1.72	1.76	1.77
87.5	12.7	0.38	0.68	0.92	1.24	1.45	1.57	1.61	1.68	1.70	1.71
82.5	10.7	0.38	0.68	0.91	1.23	1.42	1.53	1.57	1.62	1.64	1.63
77.5	8.9	0.38	0.68	0.90	1.21	1.39	1.49	1.52	1.55	1.55	1.53
72.5	7.3	0.38	0.67	0.89	1.19	1.35	1.44	1.46	1.49	1.47	1.44
67.5	5.9	0.38	0.66	0.88	1.16	1.31	1.38	1.40	1.41	1.38	1.33
62.5	4.7	0.38	0.66	0.87	1.14	1.28	1.34	1.35	1.35	1.31	1.25
57.5	3.7	0.38	0.65	0.86	1.11	1.23	1.28	1.28	1.26	1.21	1.14
52.5	2.8	0.37	0.65	0.84	1.08	1.19	1.22	1.21	1.18	1.11	1.04
47.5	2.1	0.37	0.64	0.83	1.06	1.15	1.17	1.17	1.12	1.05	0.97
42.5	1.5	0.37	0.64	0.83	1.05	1.15	1.16	1.15	1.10	1.03	0.95
37.5	1.0	0.37	0.64	0.83	1.05	1.14	1.16	1.15	1.10	1.03	0.95
32.5	0.7	0.37	0.64	0.83	1.05	1.14	1.16	1.15	1.10	1.03	0.95

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
122.5	34.6	0.66	1.18	1.62	2.26	2.72	3.06	3.19	3.47	3.67	3.84
117.5	30.6	0.69	1.24	1.68	2.36	2.83	3.18	3.32	3.60	3.81	3.98
112.5	26.9	0.72	1.29	1.76	2.45	2.94	3.30	3.45	3.74	3.96	4.13
107.5	23.5	0.75	1.35	1.83	2.55	3.06	3.42	3.57	3.87	4.09	4.27
102.5	20.4	0.77	1.39	1.89	2.63	3.15	3.52	3.67	3.97	4.20	4.37
97.5	17.6	0.79	1.43	1.93	2.69	3.21	3.59	3.74	4.04	4.27	4.44
92.5	15.0	0.81	1.45	1.97	2.73	3.26	3.64	3.79	4.09	4.31	4.46
87.5	12.7	0.82	1.47	1.99	2.76	3.29	3.67	3.82	4.12	4.34	4.50
82.5	10.7	0.83	1.49	2.02	2.79	3.32	3.70	3.85	4.14	4.35	4.51
77.5	8.9	0.85	1.51	2.05	2.82	3.35	3.72	3.86	4.14	4.34	4.49
72.5	7.3	0.86	1.53	2.07	2.84	3.36	3.72	3.86	4.13	4.32	4.45
67.5	5.9	0.87	1.55	2.09	2.86	3.37	3.72	3.85	4.10	4.27	4.38
62.5	4.7	0.88	1.56	2.10	2.86	3.36	3.70	3.82	4.06	4.21	4.31
57.5	3.7	0.89	1.57	2.11	2.86	3.34	3.65	3.76	3.97	4.09	4.16
52.5	2.8	0.90	1.58	2.11	2.84	3.30	3.58	3.68	3.85	3.94	3.99
47.5	2.1	0.90	1.58	2.11	2.82	3.26	3.52	3.61	3.76	3.83	3.85
42.5	1.5	0.90	1.58	2.10	2.81	3.24	3.50	3.59	3.73	3.79	3.80
37.5	1.0	0.90	1.58	2.10	2.81	3.24	3.50	3.58	3.72	3.78	3.79
32.5	0.7	0.90	1.58	2.10	2.81	3.24	3.50	3.58	3.72	3.78	3.79

constant an increase in size at recruitment to 77.5 cm does not change yield per recruit. However, when M = 0.6 the same change in size at recruitment causes a 22% increase in yield per recruit. When M = 1.0 and size at recruitment is held constant, a doubling of effort causes a 29% increase in yield per recruit. When M=0.6 the same change causes a 14% decrease in yield per recruit. When M = 1.0 and size at recruitment is increased to 77.5 cm a doubling of effort causes a 39% increase in yield per recruit. When M = 0.6 the same changes cause a 27% increase in yield per recruit.

Relation Between Composition of Fleet and Optimum Size at Recruitment

The preceding text has assumed that the composition of the fleet remains constant. The history of the fishery reveals that the composition has been a very dynamic process and there is no reason to believe that it will not continue to be. Since each fishing gear has a different curve of size specific F, changes in the fleet composition will cause changes in size specific F for the entire fleet. These changes will cause changes in the yield-per-recruit isopleths.

To examine the influence of changes in fleet composition on management strategy the optimum size at recruitment was estimated for 441 combinations of bait boat and longline effort. Effort by purse seiners is not included for simplicity. Multipliers of effort for each gear ranged from 0 to 2.0 with increments of 0.1.

The results (Table 10) show a considerable range in the estimates of optimum size at recruitment and that minimum size regulations must be adjusted to changes in the composition of the fleet to maintain optimality. As an example, with a 1.0 level of effort by both gears, the minimum size should be about 72.5 cm. If this were instituted as a minimum size regulation, the bait boat effort might decline to say 0.2 because of the extreme loss of catch. The minimum size, therefore, should be lowered to 67.5 cm. Now the longline effort might increase, say 80%, due to the decrease in competition from bait boat-caught fish--the minimum size should be increased to 77.5 cm. Finally, suppose an innovation occurs in bait fishing such that non-nominal effort again increases to say 0.7--the minimum size should be raised further to about 82.5 cm. These changes could occur slowly allowing for a smooth transition of the minimum size regulations, however, when economics are involved, the changes might be precipitous causing the confusion in the above example. If the possible changes in composition of both small and large purse seiners are included, the attempts to achieve some reason in the minimum size regulation based on maximal yield per recruit can become quite unwieldly.

DISCUSSION

Although there is some uncertainties in our knowledge of the parameters that enter into calculations of yield-per-recruit of yellowfin in the Atlantic, it is possible to come to some conclusions from our results.

Table 10. Optimum size at recruitment for 441 combinations of multipliers of effort by baitboats and longliners

Longline multiplier	Bait boat multiplier																				
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
0	32.5	32.5	32.5	32.5	32.5	32.5	37.5	37.5	42.5	42.5	42.5	42.5	47.5	47.5	47.5	47.5	52.5	52.5	52.5	52.5	52.5
0.1	32.5	32.5	32.5	37.5	37.5	42.5	42.5	42.5	47.5	47.5	47.5	47.5	52.5	52.5	52.5	52.5	52.5	52.5	57.5	57.5	57.5
0.2	32.5	37.5	42.5	42.5	42.5	47.5	47.5	47.5	47.5	52.5	52.5	52.5	52.5	52.5	57.5	57.5	57.5	57.5	57.5	57.5	57.5
0.3	32.5	42.5	47.5	47.5	47.5	47.5	52.5	52.5	52.5	52.5	52.5	57.5	57.5	57.5	57.5	57.5	57.5	57.5	62.5	62.5	62.5
0.4	32.5	47.5	52.5	52.5	52.5	52.5	52.5	57.5	57.5	57.5	57.5	57.5	57.5	57.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
0.5	32.5	52.5	52.5	52.5	57.5	57.5	57.5	57.5	57.5	57.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	67.5	67.5	67.5
0.6	32.5	57.5	57.5	57.5	57.5	57.5	57.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5
0.7	32.5	57.5	57.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5
0.8	62.5	62.5	62.5	62.5	62.5	62.5	62.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	72.5	72.5	72.5	72.5
0.9	62.5	62.5	62.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5
1.0	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5
1.1	67.5	67.5	67.5	67.5	67.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	77.5	77.5	77.5
1.2	67.5	67.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5
1.3	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5
1.4	72.5	72.5	72.5	72.5	72.5	72.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5
1.5	72.5	72.5	72.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	82.5	82.5
1.6	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	82.5	82.5	82.5	82.5	82.5	82.5
1.7	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
1.8	77.5	77.5	77.5	77.5	77.5	77.5	77.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
1.9	77.5	77.5	77.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
2.0	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5

The method that involves the least amount of data and assumptions is the simplified Beverton and Holt method. Results from this method (Table 1) show that, in all but a few extreme cases of a wide range of values of growth and mortality parameters, an increase in the effective minimum size would result in an increase in yield per recruit. However, our most reasonable estimates of the parameters indicated that at the current level of fishing, an increase in minimum size could only result in about a 7% increase in yield per recruit. We conclude that even if the quality of our data is poor an increase, probably minor, in yield per recruit of Atlantic yellowfin would occur, if the effective minimum size is increased and assuming that no dumping of small yellowfin tuna would occur.

We next assumed that our most reasonable estimate of growth, constant Z, and effective minimum size are correct and constructed yield-per-recruit isopleths for the values of natural mortality with the Ricker method. The results indicated that yield per recruit would increase from 0-18% if effective minimum size is increased and effort remains constant. Our most reasonable estimate of the increase is 8%, which is nearly identical to the simplified method. The results also indicate that little if any increase in yield per recruit would occur if fishing effort is doubled and effective minimum size is unchanged. However if the effective minimum size is increased and effort is doubled, a modest (18-36%) increase in yield per recruit could occur. All these results again assume that no dumping of small yellowfin tuna would occur.

We finally assumed that the available data is accurate enough to also make reasonably accurate estimates of size specific F. When using our most reasonable parameter estimates and holding effort constant, an increase in size at recruitment to

55 cm (3.2 kg) would obtain a 3.9% increase in yield per recruit and to 77.5 cm (~10 kg) would cause less than a 10% increase in yield per recruit. Increasing the size at recruitment to 55 cm with M = 0.6 would cause a 7% increase in yield per recruit, but with M = 1.0 only a 1% increase would occur. Increasing the size at recruitment to 77.5 cm with M = 0.6 would increase yield per recruit by 22%, but with M = 1.0 no increase would occur. When size at recruitment is held constant and fishing effort is doubled, our best estimate of the change in yield per recruit is a 6% increase. Our estimates ranged from a 14% decrease to a 29% increase. It seems safe to agree with the report of the Abidjan meeting that if conditions remain constant, there is little to be gained on a yield-per-recruit basis from increases in fishing effort. With a doubling of fishing effort and an increase in size of recruitment to 55 cm our most reasonable estimate is a 15% increase in yield per recruit, with a range of a 1% decrease to a 35% increase. When size at recruitment is increased to 77.5 cm and fishing effort is doubled our most reasonable estimate of the change in yield per recruit is a 30% gain; however, the estimates range from 27 to 44%. Thus it appears that if it is possible to increase the size at recruitment, a doubling of effort would produce a modest increase in yield per recruit. These results, it must be noted, assume that no dumping of small yellowfin tuna occurs.

It is interesting to note that the same general conclusions would be made using either the knife-edged recruitment or size specific F approaches. The size specific F approach, in addition, allows us to examine the effects on each gear.

The conclusions from both aspects of this study also agree fairly well with those of Joseph and Tomlinson (1972). It is not surprising, however, that results from the size specific F approach agree with theirs because they used similar methodology and data. Both estimates suggest that under present conditions the fishery is near to the point of maximum yield per recruit.

The conclusions of our study are based on three further assumptions. It is assumed that the composition of the fleet will not change; that either the gear is currently dispersed such that all qualitative characteristics of the population are available to capture by each gear, or that the dispersal of gear as it now stands will not change; and that recruitment is constant.

As mentioned previously the composition of the fleet is a dynamic process. If size or effort regulations are considered, the results should be recalculated using predictions of the new composition of the fleet.

The second assumption can be very important. For example in the eastern Pacific yellowfin tuna fishery effort has expanded further offshore. Evidence suggests that larger fish were further offshore and were not previously fully available to the fishery. A possible consequence of this phenomenon is a change in yield per recruit.

If recruitment is not constant, then the interaction between minimum size and catch quota regulations should be examined. Catch quotas are frequently based on assessments of the maximum sustainable yield (MSY), usually through a production model type analysis. The shape of the total yield curve, however, may be strongly dependent, on the age-at-first-capture $t_{r'}$. Therefore, the interaction between the two types of regulation should be examined before a singular action is taken. This example should not be considered as an exhaustive study of the problem for Atlantic yellowfin, but as an illustration of possible implications of singular action.

Consider a population consisting of six age groups with the growth curve and natural mortality coefficient (M = 0.8) similar to that of the Atlantic yellowfin tuna fishery, and let us also assume that recruitment is knife-edged at 19 months. Figure 19 (lower curve) shows the total annual yield as a function of fishing mortality with an assumed arbitrary stock-recruitment function. Let us further assume that the fishery is operating at an F = 1.0. The Y/R at F = 1.0 and $t_{r'}$ = 19 months is 5.391, but the maximum Y/R is 6.108 at $t_{r'}$ = 27 months. If singular action were taken to increase $t_{r'}$ to 27 months, the upper total yield curve in Figure 19 would result. Not only did the Y/R increase, but so did the total yield at F = 1.0. In addition, the MSY increased, but occurs at a much higher value for F. A phenomenon such as this may have occurred inadvertantly in the eastern tropical Pacific with the introduction of purse seiners which gave a better Y/R than the existing bait boats (Joseph, 1970).

The above result of singular action on the minimum size regulation resulted in a fortuitous increase in total yield and MSY. This result may not always occur, however. Consider that if the fishery were operating with $t_{r'}$ at 27 and F = 0.2, then the Y/R would be 2.773. The optimal Y/R is 3.022 at a $t_{r'}$ of 19 months. If singular action were taken to lower the $t_{r'}$ to 19 months a slight loss of total yield would occur even with the improved yield per recruit. Even more disconcerting would be the loss in potential MSY of 28%. The fishery would be sub-optimized in a sense. Since the MSY is usually estimated from a time series of catch and effort data, the actual potential which could have been realized had $t_{r'}$ remained at 27 months would likely be underestimated. It is likely that Y/R studies would continue as the fishery developed effort beyond F = 0.2, such that eventually the upper curve would probably be attained. However, the low initial forecasts of MSY could hamper development of the fishery.

An even worse consequence of singular action on yield per recruit is illustrated in Figure 20. Assume the fishery is operating at about 0.6 units of effort with an age at recruitment such to obtain curve A, but the Y/R is adjusted to maximal for the age at recruitment giving curve B. The actual MSY of curve A likely would never be realized since the maximum equilibrium yield in curve B is also at 0.6 units of fishing effort. This case represents true sub-optimization.

The results of this paper were obtained using reasonable assumptions and all available data on Atlantic yellowfin tuna. As we increased the number of assumptions we increased the number of conclusions. We think that it is unlikely that use of techniques not used in this paper would result in conclusions that are significantly different than ours. That is, an increase in effective minimum size would result in a minor increase in yield per recruit, an increase in effort without increasing effective minimum size would not appreciably increase yield per recruit, and an increase in effective minimum size and effort would result in modest gains in yield per recruit. We wish to emphasize that these conclusions are based on a number of assumptions. We consider the assumptions reasonable, but because they are assumptions any management decisions, including the decision of taking no action, should be followed with careful evaluation of the results. Obviously evaluation of the results requires adequate and timely data. Some of the data used in this report are 2 years out of date and some of the fisheries are inadequately sampled.

Specifically addressing the recommendations outlined in the background section of this paper of considering a minimum size between 3.2 and 10 kg, we offer the following results based on our most reasonable parameter estimates:

1) Minimum size limit 55 cm (3.2 kg)

   a) Current levels of fishing mortality

      i) No dumping → 4% increase in landed yield per recruit

      ii) 100% dumping → 3% decrease in landed yield per recruit

   b) Doubling fishing mortality

      i) No dumping → 15% increase in landed yield per recruit

      ii) 100% dumping → 1% increase in landed yield per recruit

2) Minimum size limit 77.5 cm (8.9 kg)

   a) Current levels of fishing mortality

      i) No dumping → 9% increase in landed yield per recruit

      ii) 100% dumping → 13% decrease in landed yield per recruit

   b) Doubling fishing mortality

      i) No dumping → 31% increase in landed yield per recruit

      ii) 100% dumping → 16% decrease in landed yield per recruit

The 55 cm (3.2 kg) minimum size limit would likely be of more benefit to the tuna fishery than the larger minimum size limit of 77.5 cm (8.9 kg) since less dumping would occur and because there would likely be, on the average, an increase in landed yield per recruit at the current or greater levels of fishing mortality; whereas, if a larger size limit were adopted there would likely be, on the average, a decrease in landed yield per recruit at current levels of fishing mortality and less of an increase (perhaps even a decrease) in landed yield per recruit than with the 55 cm (3.2 kg) minimum size and an increase in fishing mortality.

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FIGURES

Figure 9.--Yield per recruit (kg) of Atlantic yellowfin tuna, with the current level of fishing effort, as a function of the size (fork length in cm) at recruitment.

Figure 10.--Estimates of size specific instantaneous fishing mortality coefficients (F) by gear type when initial values of F are (A) F = 0.2, (B) F = 0.8.

Figure 11.--Yield-per-recruit (kg) isopleths for the whole Atlantic yellowfin tuna fishery. Dotted curve is the line of eumetric fishing.

Figure 12.--Landings-per-recruit (kg) isopleths for Atlantic yellowfin tuna when discarding of dead fish less than some minimum size occurs.

Figure 13.--Average weight (kg) isopleths for the whole Atlantic yellowfin tuna fishery.

Figure 14.--Growth curves of Atlantic yellowfin tuna used in this study. Upper curve is from Le Guen and Sakagawa (in press). Lower curve is a modification of the upper curve (see text).

Figure 15.--Estimates of size specific F when its initial value is 0.2 and using the modified growth curve.

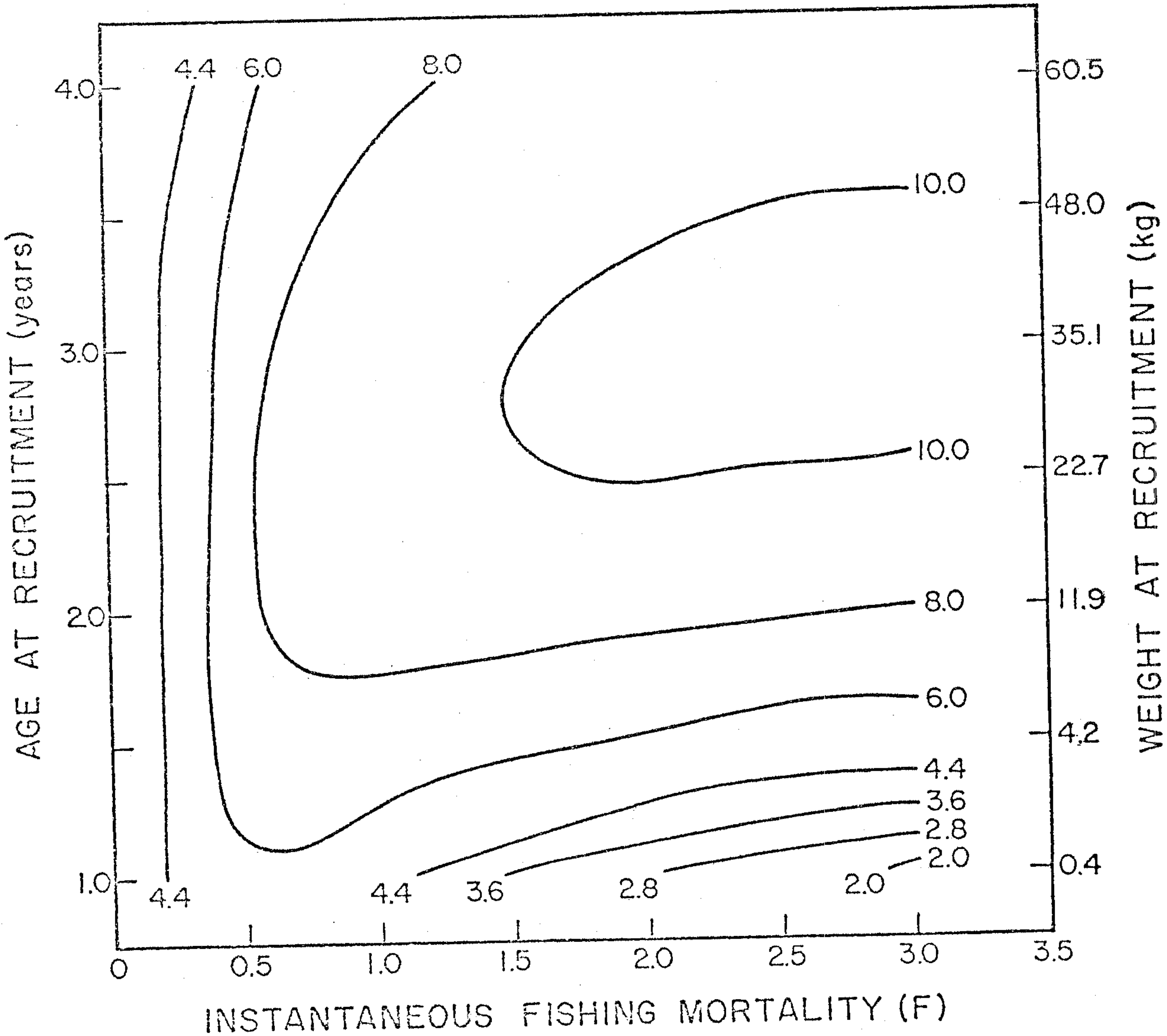
Figure 16.--Estimates of size specific F when its initial value is 0.2 and using values for M of 0.6, 0.8, and 1.0

Figure 17.--Yield-per-recruit isopleths for the whole Atlantic yellowfin tuna fishery with M = 1.0.

Figure 18.--Yield-per-recruit isopleths for the whole Atlantic yellowfin tuna fishery with M = 0.6.

Figure 19.--Annual equilibrium yield as a function of fishing effort at two different ages at recruitment, $t_{r'}$.

Figure 20.--Annual equilibrium yield as a function of fishing effort at two different ages at recruitment.



4.4
6.0
8.0
10.0
10.0
8.0
6.0
4.4
3.6
2.8
2.0
4.4
4.4
3.6
2.8
2.0
4.0
3.0
2.0
1.0
AGE AT RECRUITMENT (years)
60.5
48.0
35.1
22.7
11.9
4.2
0.4
WEIGHT AT RECRUITMENT (kg)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
INSTANTANEOUS FISHING MORTALITY (F)

Figure 1

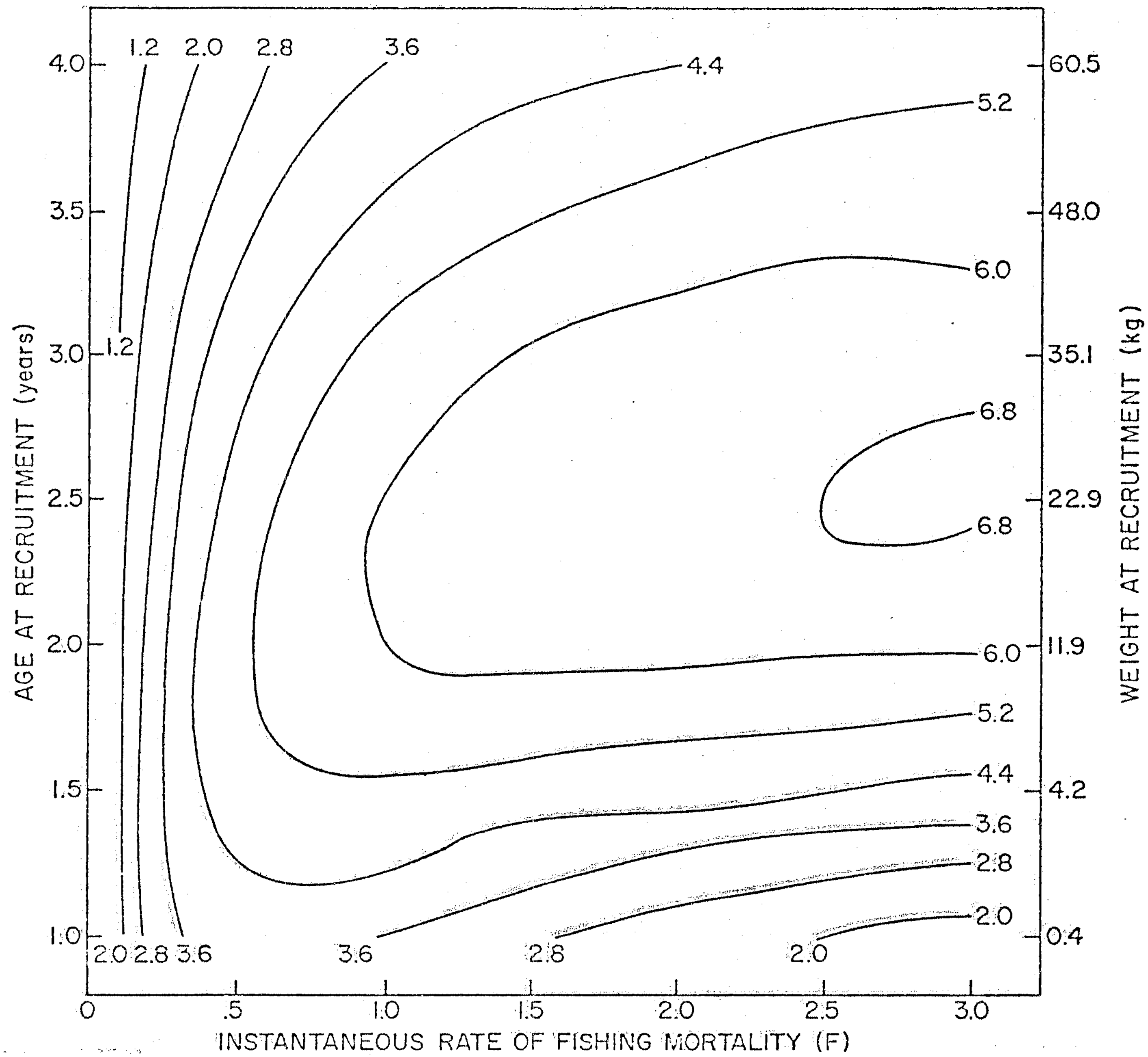
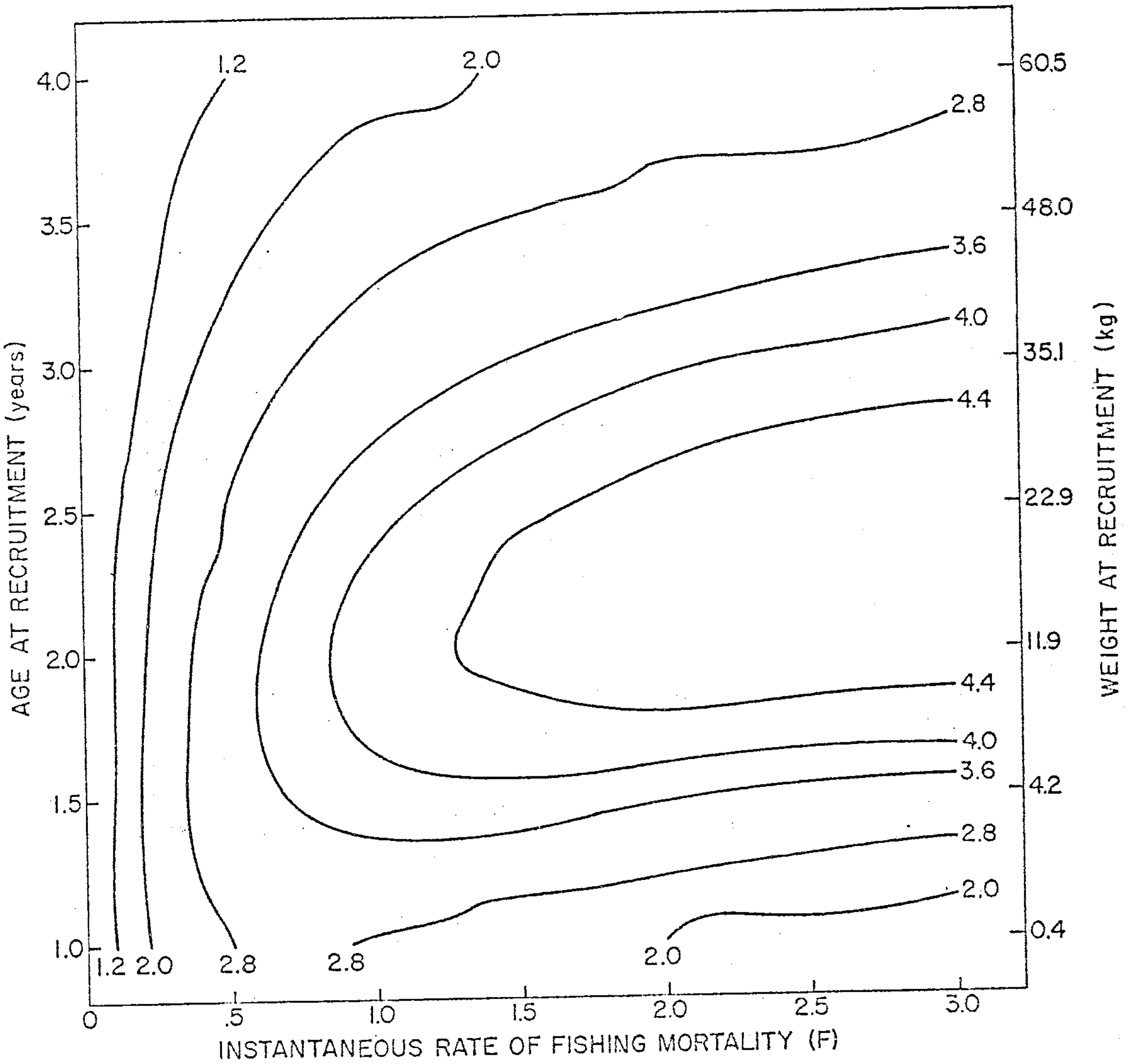

AGE AT RECRUITMENT (years)
WEIGHT AT RECRUITMENT (kg)
INSTANTANEOUS RATE OF FISHING MORTALITY (F)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
60.5
48.0
35.1
22.9
11.9
4.2
0.4
0
.5
1.0
1.5
2.0
2.5
3.0
1.2
2.0
2.8
3.6
4.4
5.2
6.0
6.8

Figure 2



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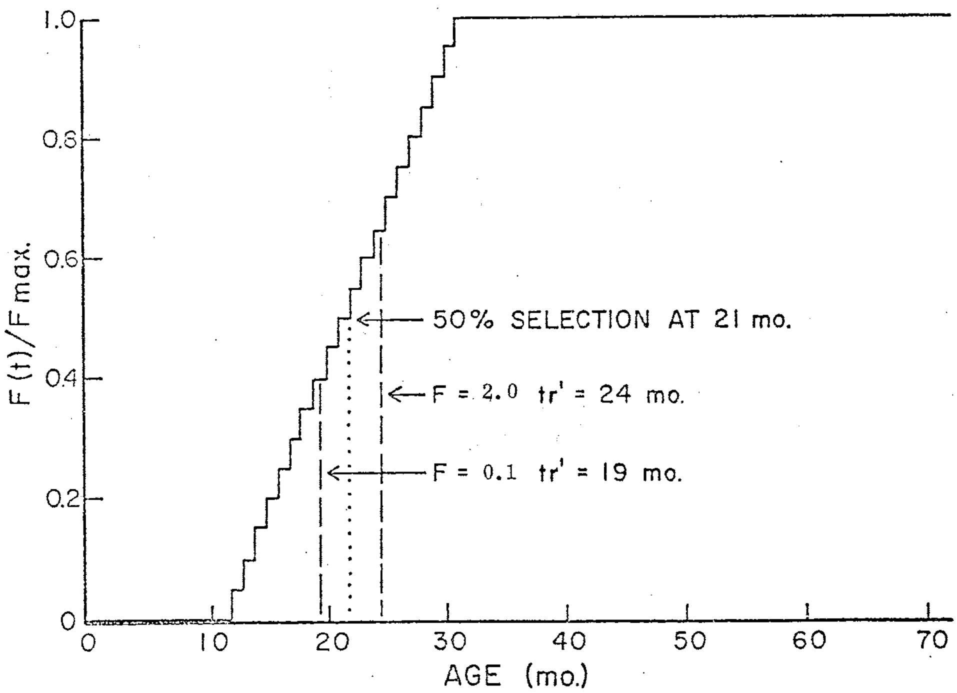

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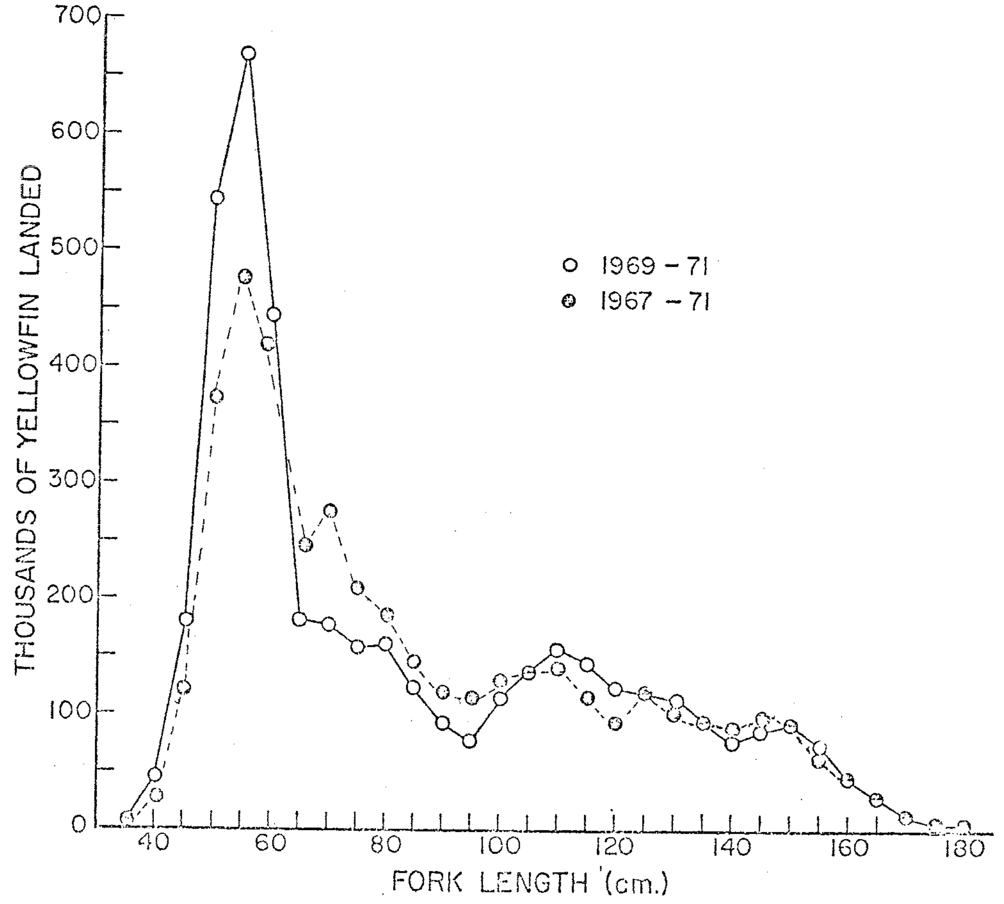

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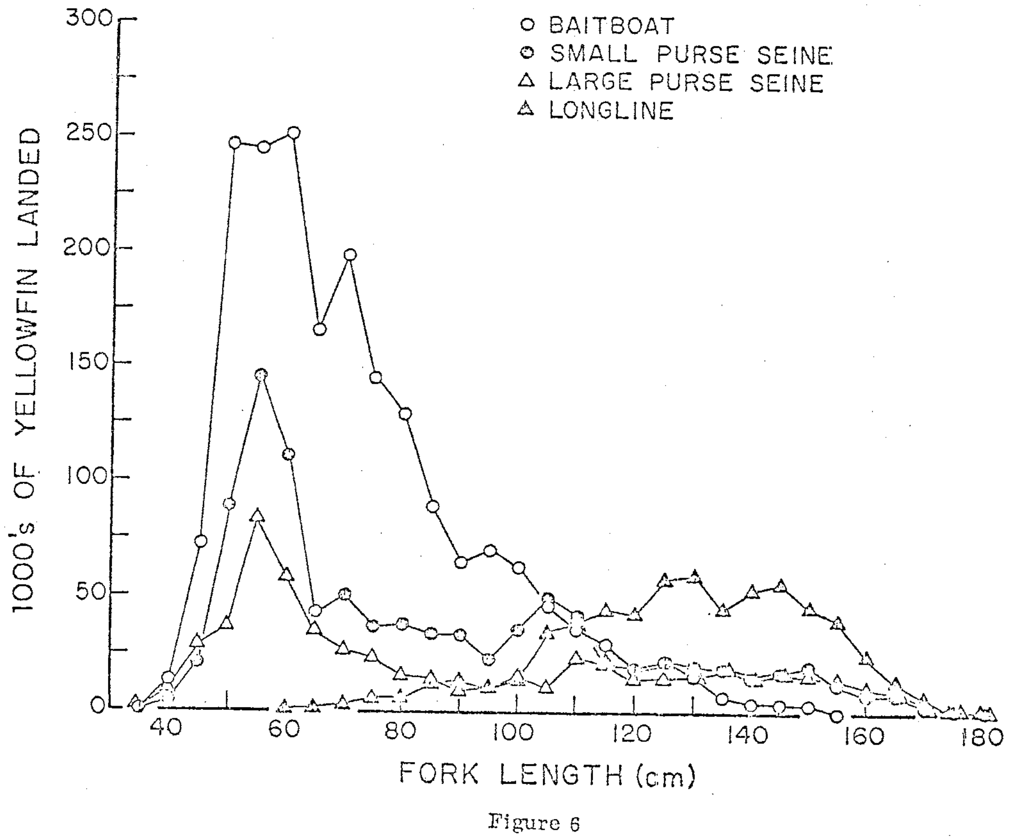


Figure 6

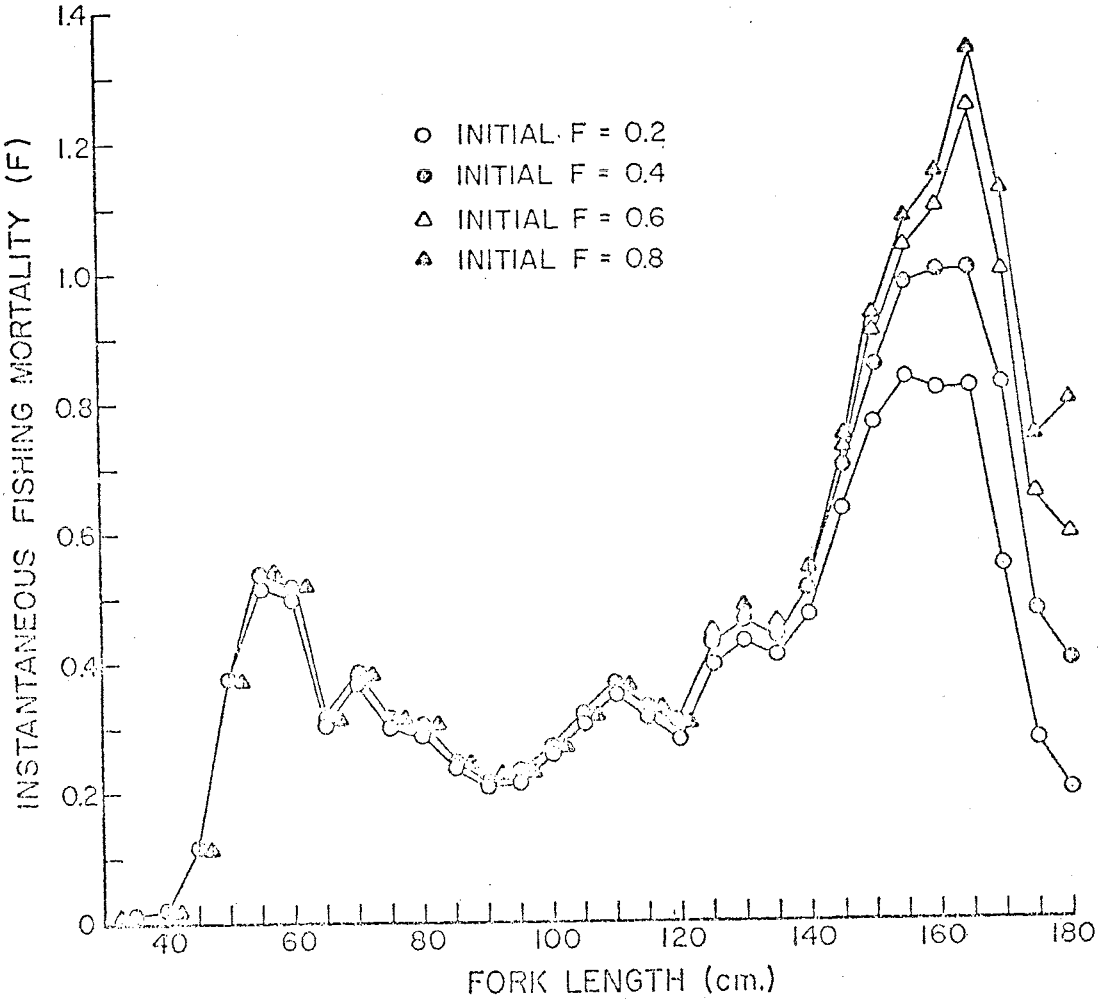


Figure 7

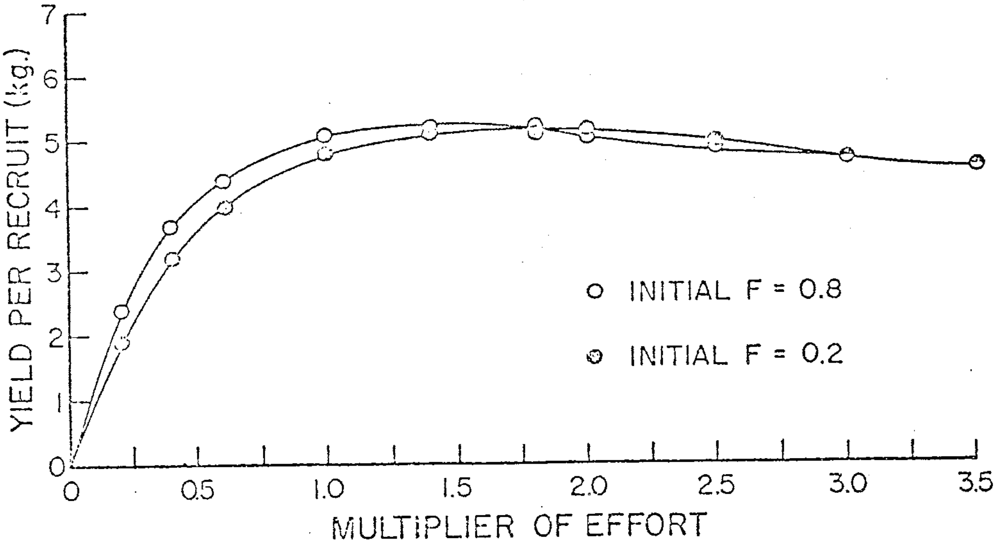


Figure 8

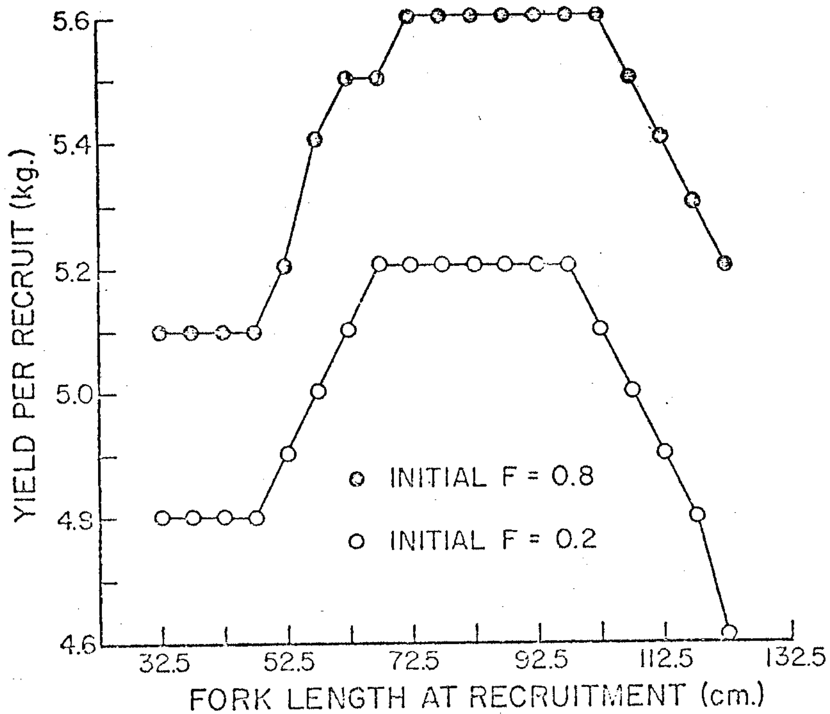


Figure 9

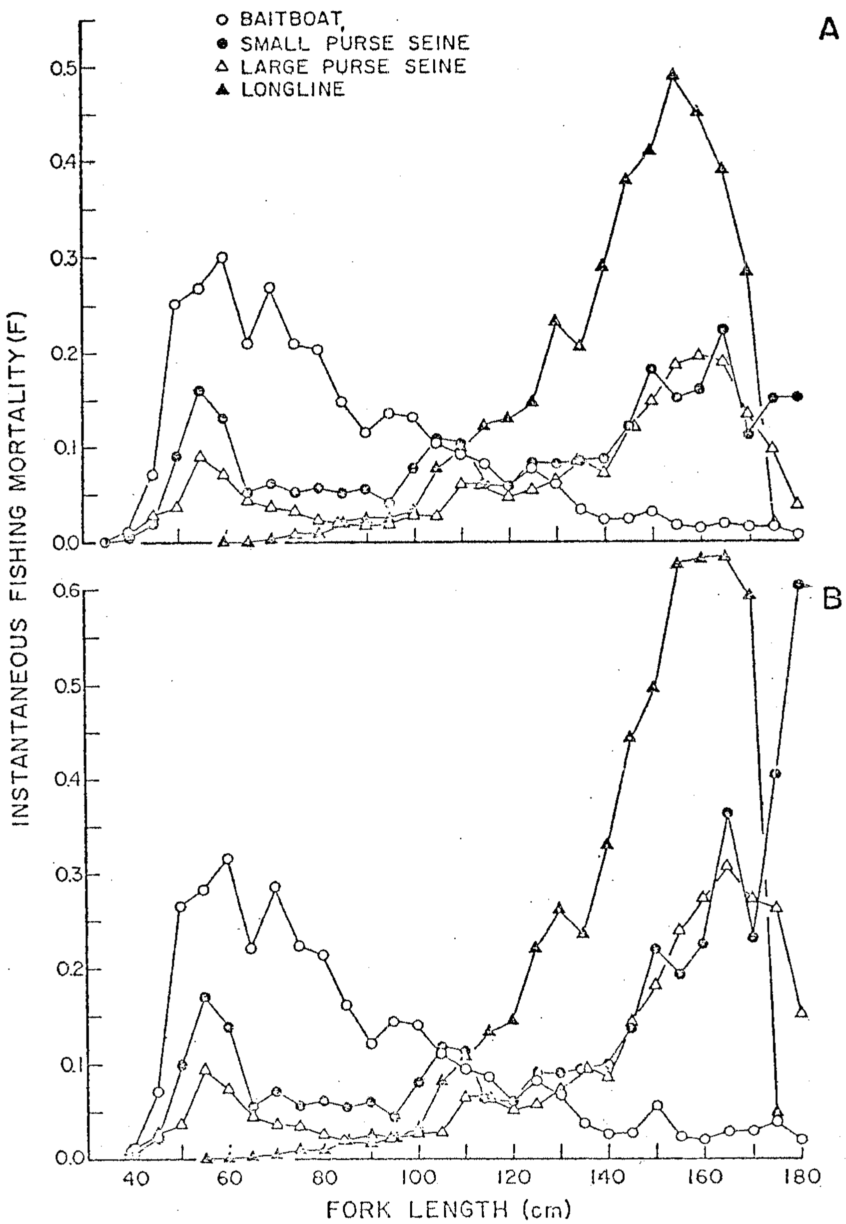
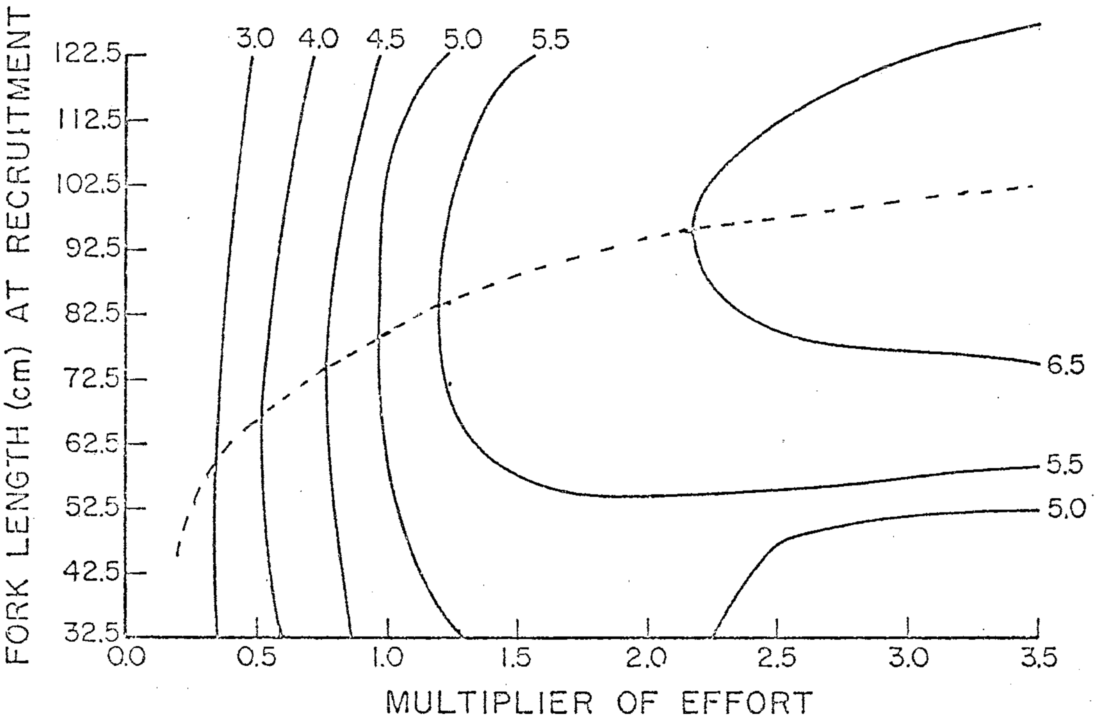


Figure 10



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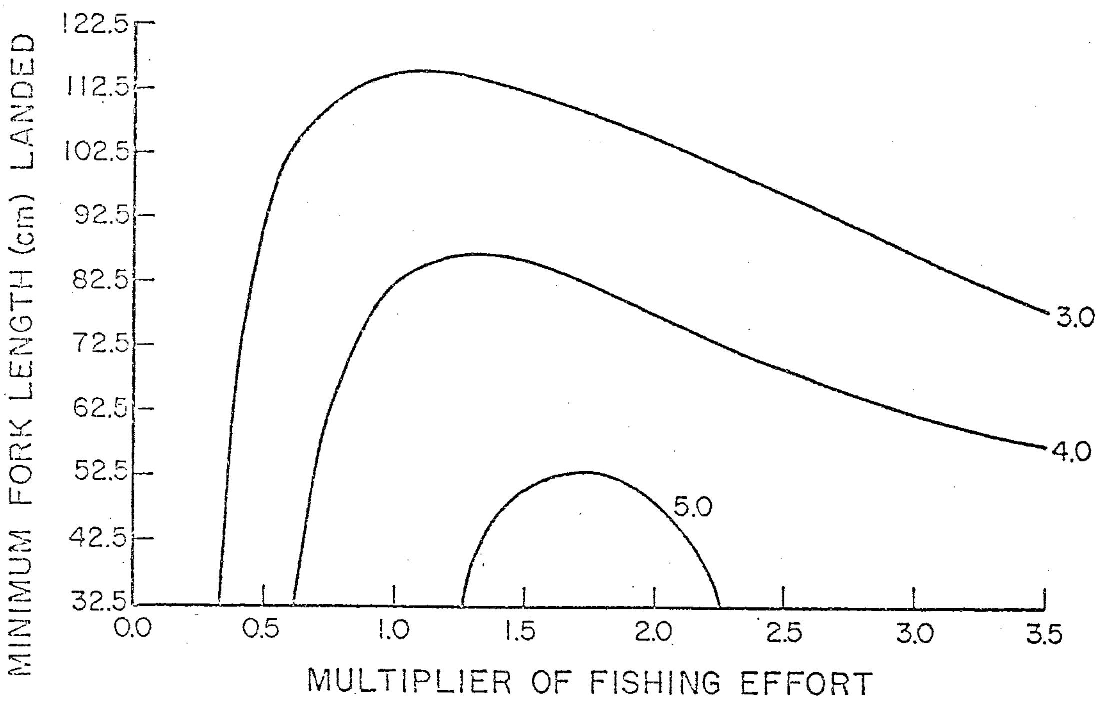

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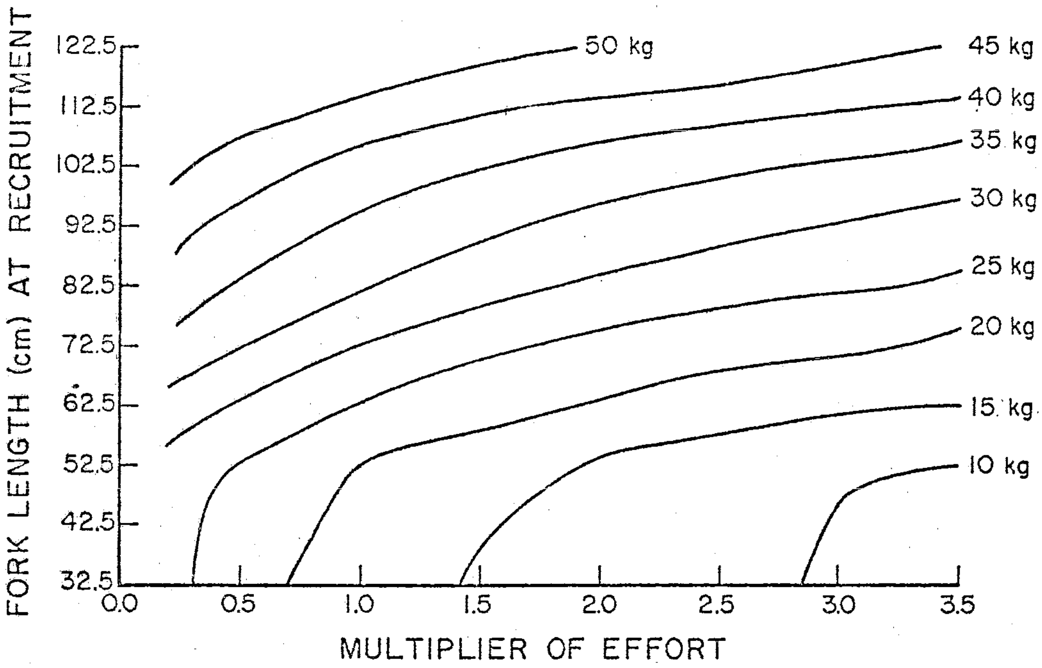


Figure 13

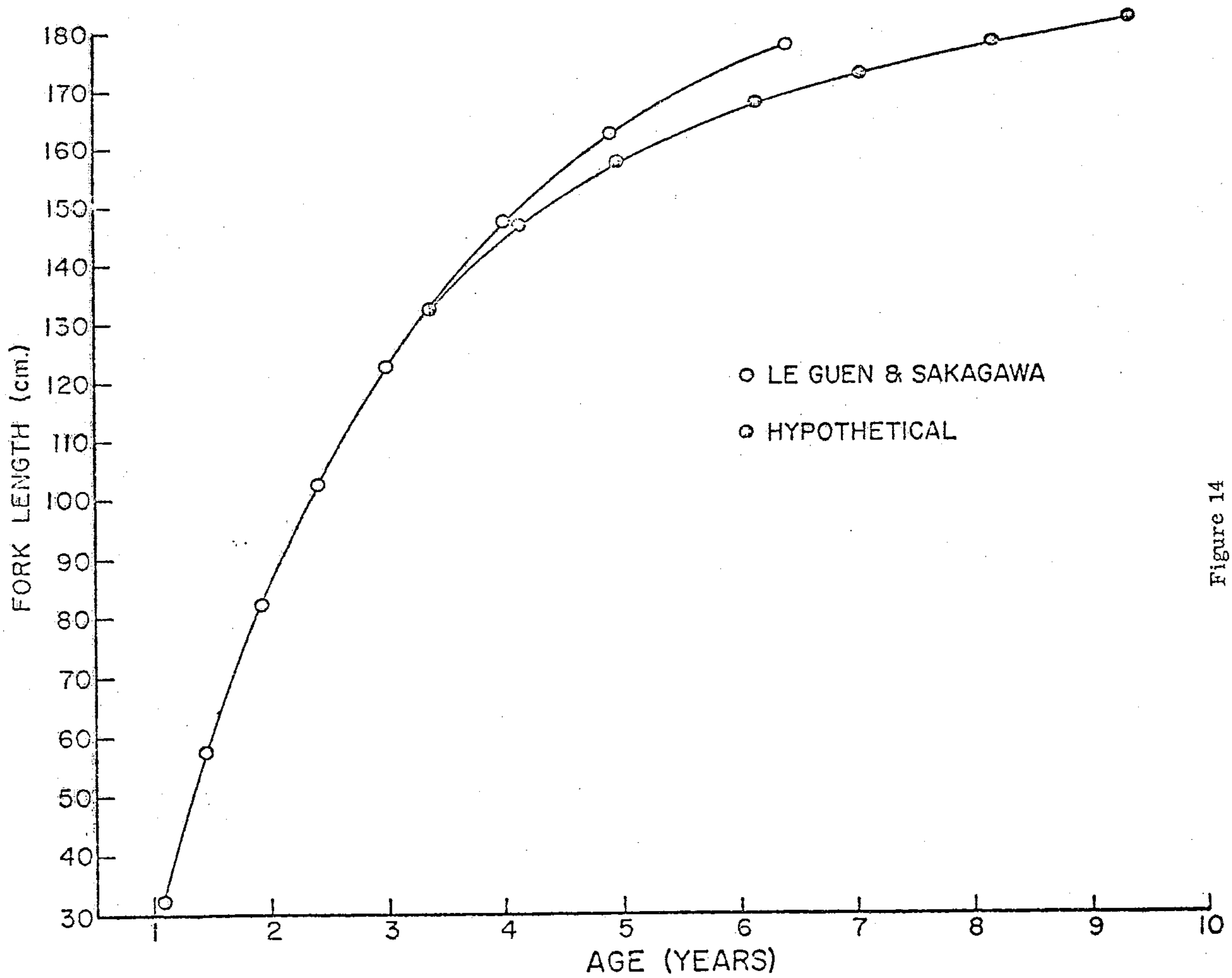


Figure 14

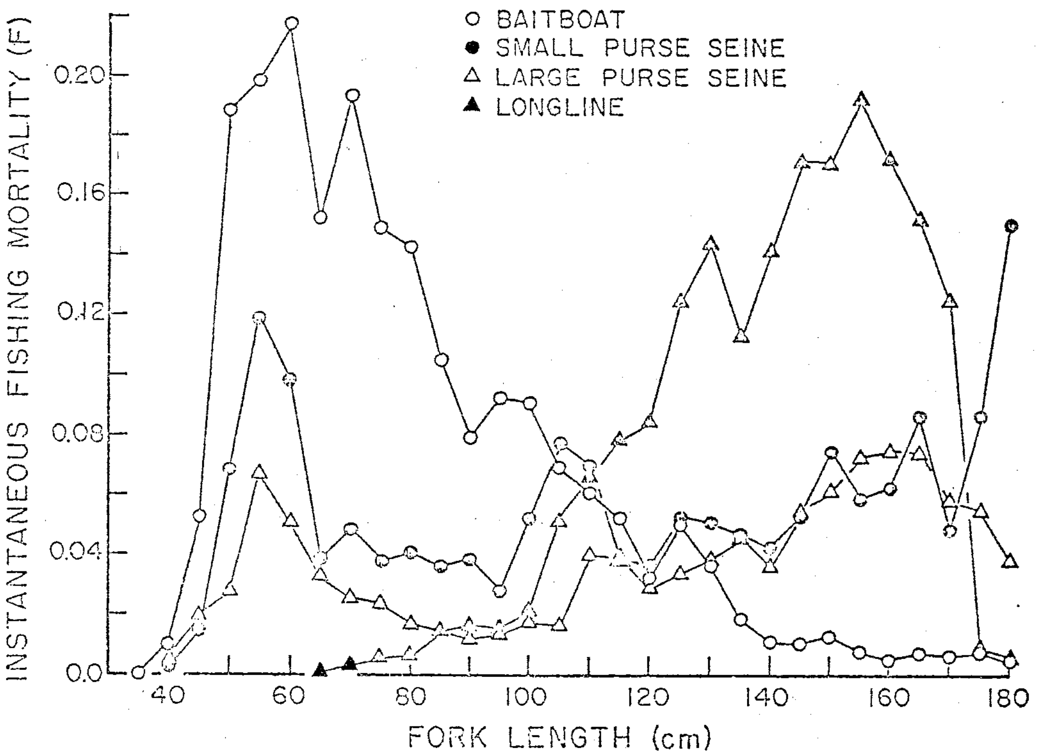


Figure 15

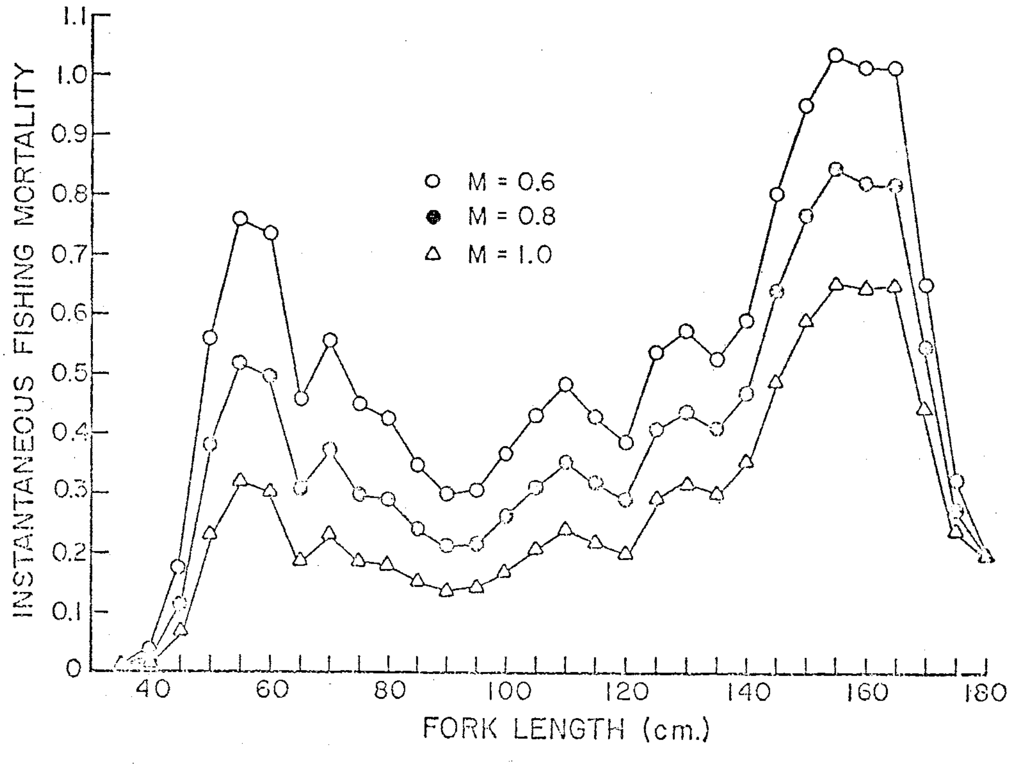


Figure 16

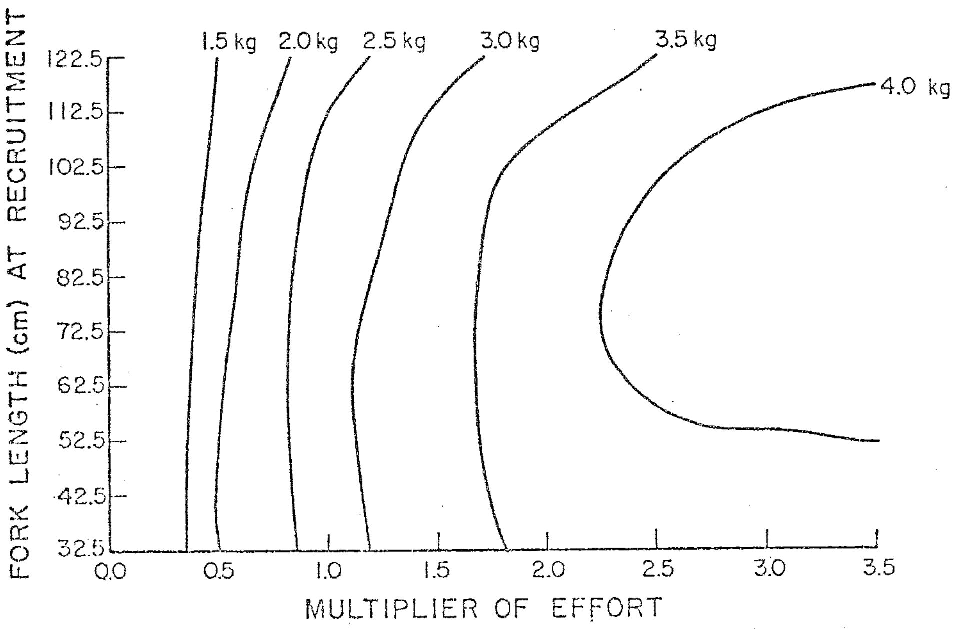


Figure 17

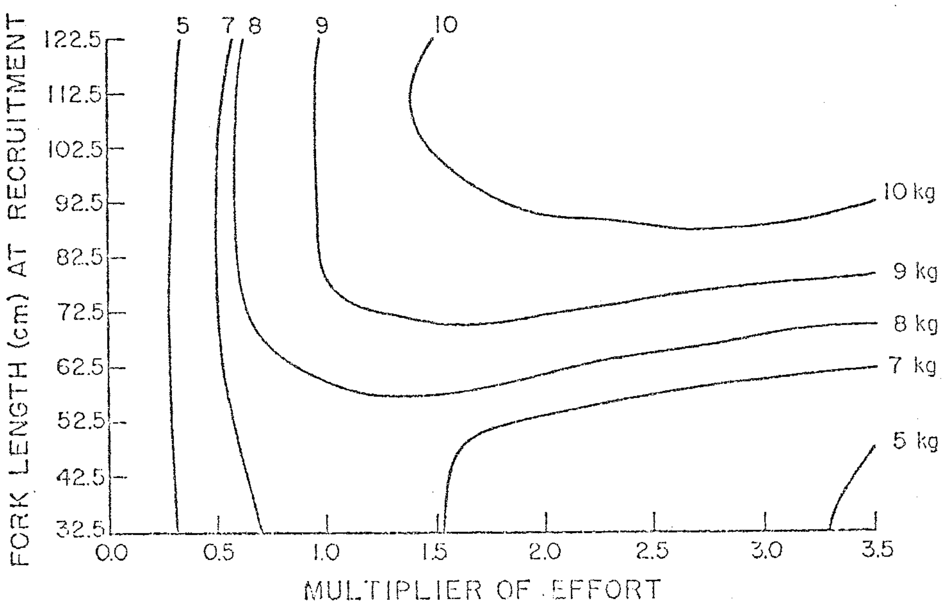


Figure 18

Figure 19

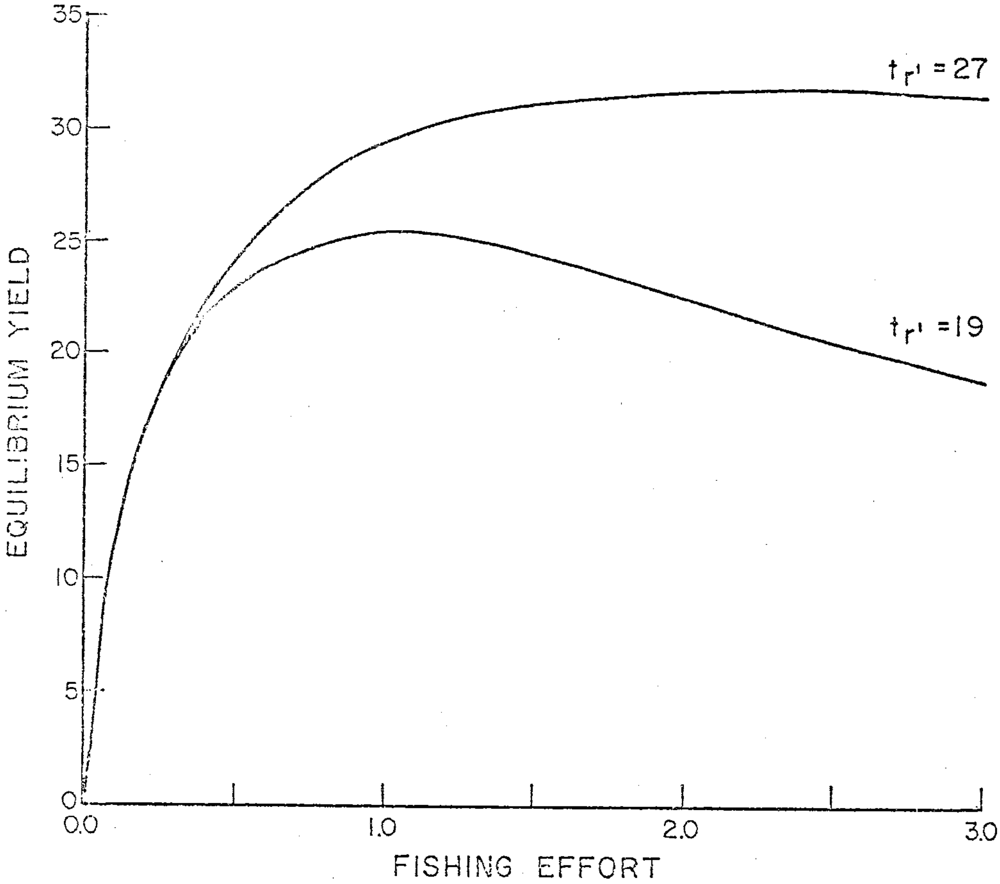
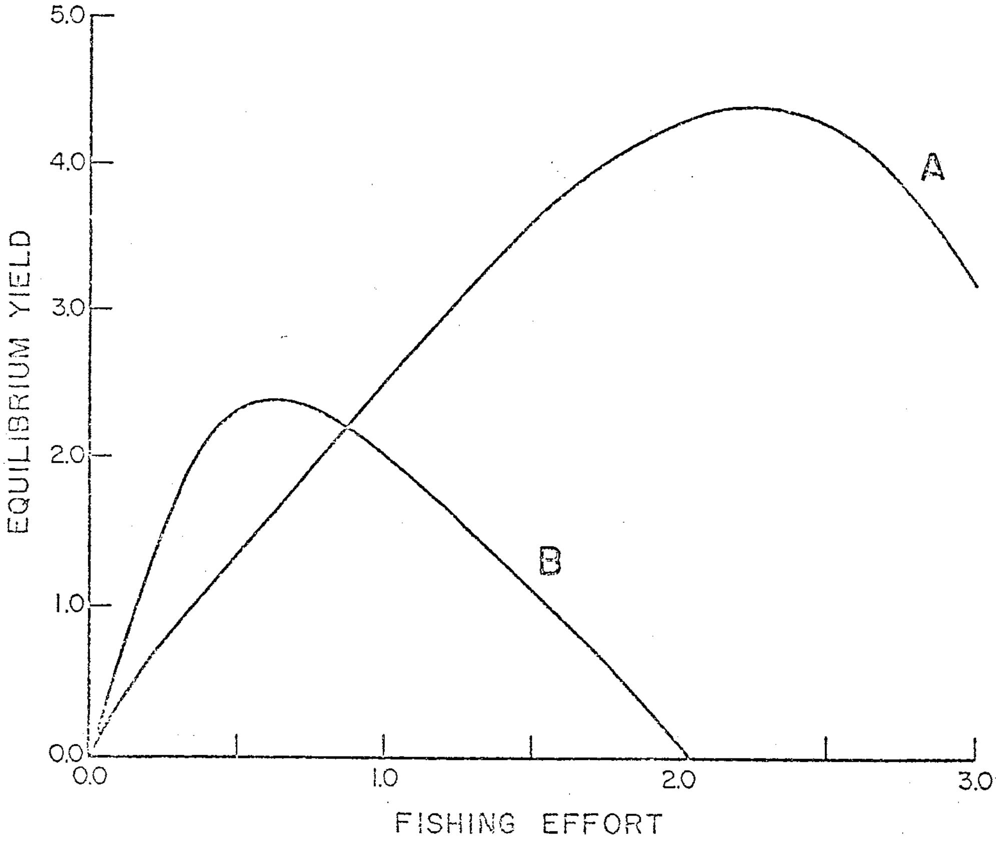


Figure 20



APPENDIX I. ICCAT proposal on minimum size regulations. ICCAT, 1971. Proceedings of the Second Regular Meeting of the Commission. Dec. 2-7, 1971, Madrid.

Item 29.- Other Matters.

15.- A proposal was made by the Spanish delegate to establish a system whereby information on the maximum tolerance level of heavy metal contamination in tuna might be exchanged among member countries concerned. Following lengthy discussion it was agreed that the Secretariat should maintain contact with the World Health Organization and FAO Codex Alimentarius to obtain information for the benefit of the authorities of member countries on whatever progress is made in research on the subject.

Proceedings of Fourth Plenary Session. December 6, 1971 (afternoon).

Item 23.- Relations with other organizations (continued).

16.- Since the International Commission for Southeastern Atlantic Fisheries (ICSEAF) only recently came into being, certain arrangements with said Commission may be required in future with regard to Articles III and XI of its Convention in order to avoid duplication of effort.

Item 21.- Reports of Panels.

17.- Report of Panels 1, 2, 3 and 4 were submitted by their Chairmen or Rapporteurs and all were approved. The reports are attached hereto as Annex 3.

Item 15.- Measures for Rendering Effective the Provisions of the Convention (Joint Enforcement).

18.- The report of the Working Group on this subject was submitted by its Chairman, M. Lagarde. The report, attached as Annex 4, was reviewed and approved.

Item 13.- Provisions for Conservation of Stocks.

19.- A proposal for conservation of yellowfin tuna was made jointly by Brazil, France, Korea, Morocco, Portugal, South Africa and Spain.

20.- Some doubt was expressed by the delegates of Canada, the U.S.A. and Japan as to the procedure whereby the proposed conservation measures were presented directly to the Commission, even though there are Panels whose purpose it is to present such proposals. Upon reexamination of Article 8 of the

Commission Convention, the proposal was accepted. It was hoped, however, that this was a special case, particularly since the Report of the Standing Committee on Research and Statistics had not been available for sufficient time to permit detailed study prior to the Panel meetings. It is hoped that in future such proposed conservation measures may be presented through Panels.

21.- The U.S. delegate proposed that the minimum size limit for bluefin tuna should also be considered at the time of the next Council meeting.

22.- The Japanese delegate proposed that at the same time the Council should discuss other conservation measures in co-ordination with minimum size limit of fish. After lengthy discussion the joint proposal as amended was approved.

23.- A delegation pointed out that a procedure for authorizing the Council to decide on the matter of conservation measures is acceptable only because almost all member countries are in the Council at the present time and that it would not establish a precedent.

24.- The proposal thus modified and agreed upon is as follows:

The Commission:

"Noting with concern the conclusions reached by the Sub-Committee on Stock Assessment, and endorsed by the Standing Committee on Research and Statistics with regard to the effects of the present level of fishing on the stocks of yellowfin in the Atlantic,

"Noting further that there is still an upward trend in the fishing effort on this species,

"Realizing that scientific investigations based on the data so far available have indicated that at the present level of fishing mortality the optimum size at first capture of yellowfin can be calculated to be between 10 and 25 Kg.,

"Taking into account that in some countries in West Africa a size unit of 3.2 Kg. for yellowfin has been in force for several years in order to protect the smallest age-class, "Considering the urgency for taking measures to protect small yellowfin on an interim basis,

"Authorizes the Council to recommend to the Contracting Parties that they prohibit landing of yellowfin weighing less than a minimum weight somewhere between 3.2 and 10 Kg.

Item 20.- Report of Standing Committee on Finance and Administration (STACFAD).

25.- The Report (Annex 5) was presented by the Chairman of the Committee, Dr. Sprules. It was reviewed in respect to Agenda Items 5 through 12, 14, 16, 27 and 28 of the Plenary Session and the Commission adopted the report.

Item 5.- Review of Panel Members (continued).

26.- The STACFAD report was reviewed. The Commission was satisfied that all changes in membership as proposed during the previous Plenary Session had been taken into consideration by STACFAD.

Item 6.- Administrative Report.

27.- The Administrative Report (COMM/71/10) was reviewed and approved by the Commission as recommended by STACFAD.

Item 7.- Secretariat Staff Rules.

28.- The amended Staff Rules proposed by STACFAD (Appendix 4 to Annex 5, report of said Committee) were reviewed and approved.

Item 8.- Auditors Report (1970).

29.- The Auditors Report (COMM/71/12) and recommendations made by STACFAD were reviewed and approved. The Commission instructed the Secretariat to express its special appreciation to the Auditor for his excellent work.

Item 9.- Financial Statement (1970-1971).

30.- The Financial Report (COMM/71/13) and Inventory (Suppl. 1) were reviewed with the Report of STACFAD and the Commission approved the Financial Report together with the recommendations made by STACFAD.

II REGULAR MEETING OF THE COMMISSION

Proceedings of the Fourth Plenary Session, December 6, 1971.

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Item 13.- Provisions for Conservation of Stocks.

Paragraph 24 (corrected)

The proposal thus modified and agreed upon is as follows:

The Commission:

"Noting with concern the conclusions reached by the Sub-Committee on Stock Assessment, and endorsed by the Standing Committee on Research and Statistics with regard to the effects of the present level of fishing on the stocks of yellowfin in the Atlantic.

"Noting further that there is still an upward trend in the fishing effort on this species,

"Realizing that scientific investigations based on the data so far available have indicated that at the present level of fishing mortality the optimum size at first capture of yellowfin can be calculated to be between 10 and 25 Kg.,

"Taking into account that in some countries in West Africa a size limit of 3.2 Kg. for yellowfin has been in force for several years in order to protect the smallest age-class,

"Considering the urgency for taking measures to protect small yellowfin on an interim basis,

"Authorizes the Council to recommend to the Contracting Parties that they prohibit landing of yellowfin weighing less than a minimum weight somewhere between 3.2 and 10 Kg.

"Authorizes the Council, if necessary, to take any other conservation measures with regard to all species concerned, including the decision as to a minimum size limit of bluefin, somewhere between 3.2 and 10 Kg."

However, in order to take into consideration the mixture of age-classes in stocks exploited, a certain tolerance will be acceptable upon initiative of the Contracting Parties, each of which will respectively stipulate, within reasonable limits, the catch percentage to be exempted from said prohibition, it being understood that such percentages shall be reported to the Commission.

art of APPENDIX I

INTERNATIONAL COMMISSION FOR THE CONSERVATION OF ATLANTIC TUNAS

COMMISSION INTERNATIONALE POUR LA CONSERVATION DES THONIDES DE L'ATLANTIQUE

COMISION INTERNACIONAL PARA LA CONSERVACION DEL ATUN ATLANTICO

General Mola, 17 - MADRID-1
Spain - Espagne - España

Telephone - Téléphone - Teléfono 275 85 24

Ref.

January 25, 1972
CIRCULAR Nº 1972/6

TO: All Concerned

FROM: Executive Secretary

SUBJECT: Proceedings of Second Regular Meeting of the Commission

With a view to official publication of the Proceedings of the Second Regular Meeting of the Commission, the provisional version of which was distributed on January 11, 1971, the Secretariat has already received some comment and is currently revising same.

Two points of importance being involved, we wish to call these to your attention:

A) Paragraph C, Section 8 of Report of Standing Committee on Research and Statistics (p. 13, Annex 6)

The last item in this paragraph has been amended to read as follows:

"The Committee was informed that the Ivory Coast had enforced a 3.2 Kg. size limit, but that the Government of said country, concerned by the fact that ICCAT member countries fish very small yellowfin (1 Kg.), inquires whether these practices have any scientific basis. The Committee considers that catching such small fish is detrimental and that the Governments of the Congo, Ivory Coast and Senegal (the first two are not members of ICCAT) have taken a first step forward in adopting regulations which it is desirable be enforced by everyone."

B) Paragraph 24, Proceedings of Fourth Plenary Session, December 6, 1971 (pp. 5 and 6).

This item will read as shown in the attached page. The last two paragraphs were omitted from the English version only.

We will appreciate your keeping in mind the above amendments when writing to comment on publication of the Proceedings.

APPENDIX II. Discussion of results of yield-per-recruit analyses. ICCAT, 1972. Draft Report of the ICCAT Special Working Group on Stock Assessment of Yellowfin Tuna, June 12-16, '972, Abidjan.

V. YIELD-PER-RECRUIT

The Working Group discussed papers prepared by Lenarz and Sakagawa, and Joseph and Tomlinson on yield-per-recruit in the Atlantic yellowfin fishery. It was agreed that such analyses are complicated by the presence of gear types which harvest different and varying proportions of the total catch for each length or age of yellowfin. The surface fishing gear, baitboats and small and large purse seiners, catch about twice the tonnage taken by the longline gear, with half of this being from the range of sizes harvested by the longline fleet (Fig. 11). Thus, surface gears for the years shown take one-third of the total yellowfin catch before the fish are recruited to the longline fishery and then compete directly with these vessels for the remainder of the catch (Fig. 11).

Yield-per-recruit analysis is limited by the quality of information on sizes of yellowfin harvested by the fishery, on growth rates, and on natural and fishing mortality.

Lenarz and Sakagawa evaluated the effect on yield-per-recruit of changes in recruitment size and in instantaneous rate of fishing mortality. Joseph and Tomlinson utilized a similar technique to examine yield-per-recruit, but in addition partitioned fishing mortality by size increments, by type of gear, over the range of sizes of yellowfin taken by the fishery in recent years. This permitted examination of the effects of changes in recruitment size and fishing effort on the yields by each gear type.

The studies indicated that at low levels of fishing effort (for example, F =.2) the yield-per-recruit would not be increased measurably by any increase in the size of first capture. However, if fishing mortality is higher (for example, 1.0 and above), an increase in the size of recruitment to the optimum level indicated in Table 6 would result in about a 10% increase in yield-per-recruit. In addition, this increase in the entering size would shift the share of total catch among the gears. Baitboats, which take a high percentage of smaller sizes, would suffer a loss of share, while the small purse seiners, large purse seiners, and the longline vessels divide the gains. It was noted that size regulations could cause unanticipated changes in fishing strategy that might change size specificity of fishing mortality. Thus, yield may be affected in an unpredictable fashion by size regulations. If fishermen cannot distinguish sizes of tuna in the water and/or there is a wide variety of sizes within schools, it is likely that many fish below the minimum size will be captured and discarded. Fishing on mixed schools of skipjack and small yellowfin will result in additional wastage of undersized yellowfin. The losses from these effects following the establishment of minimum size regulations may exceed the gains that may be expected from yield-per-recruit calculations.

No data are available on the relationship between small yellowfin and skipjack and limited information is available on the distribution of yellowfin by size within single schools fished by the surface gear in the Atlantic fishery (Table 7). The latter indicates substantial mixing (5 of 12 schools sampled) of yellowfin below 5 Kg. with larger yellowfin. The Working Group <u>strongly recommends</u> that more effort be devoted to this problem in the Atlantic.

Extensive data on single school relationships are available for the eastern Pacific surface fishery (Calkins, 1965) and indicate that the tendency to aggregate by size is stronger than the tendency to aggregate by species. In addition (Calkins, 1965), there was sufficient size variation among pure schools of yellowfin to greatly complicate any management program aimed at maximizing the yield-per-recruit through an increase in size at first capture.

However, the isopleth diagrams presented to the group indicate that a reduction of the size at first capture below the present value would substantially reduce the yield-per-recruit. Therefore, any future shift in fishing effort to very small sizes should be prevented. The regulation of minimum landing size of 3.2 Kg. edicted in Senegal, the Ivory Coast and the Congo should help prevent a decrease in the size of first capture.

VI. ESTIMATION OF MORTALITY RATES

It should be mentioned at the outset that in most instances catch-per-unit statistics are utilized for estimating mortality rates. As indicated in Section III, these statistics are subject to various sources of error. Therefore, we emphasize that there may be errors in the mortality rates that are related to errors in CPUE.

We next consider the estimation of Z and F. These are treated simultaneously in the next section because the value of M for yellowfin tuna in the Atlantic is assumed to be similar to the value of M estimated for yellowfin tuna in the Pacific Ocean (M = 0.8). Under this assumption an estimate of Z automatically produces an estimate of F, and an

APPENDIX III. LENGTH, WEIGHT, AND AGE OF YELLOWFIN TUNA FROM THE ATLANTIC OCEAN

LENGTH		WEIGHT		AGE	
CM	IN	KG	LB	MO	YR
30.0	11.8	0.53	1.17	12.2	1.02
31.0	12.2	0.58	1.29	12.4	1.03
32.0	12.6	0.64	1.41	12.6	1.05
33.0	13.0	0.70	1.55	12.7	1.06
34.0	13.4	0.77	1.69	12.9	1.08
35.0	13.8	0.84	1.85	13.1	1.09
36.0	14.2	0.91	2.01	13.3	1.11
37.0	14.6	0.99	2.18	13.5	1.12
38.0	15.0	1.07	2.36	13.6	1.14
39.0	15.4	1.15	2.55	13.8	1.15
40.0	15.7	1.24	2.74	14.0	1.17
41.0	16.1	1.34	2.95	14.2	1.18
42.0	16.5	1.44	3.17	14.4	1.20
43.0	16.9	1.54	3.40	14.6	1.21
44.0	17.3	1.65	3.64	14.8	1.23
45.0	17.7	1.77	3.90	14.9	1.25
46.0	18.1	1.89	4.16	15.1	1.26
47.0	18.5	2.01	4.43	15.3	1.28
48.0	18.9	2.14	4.72	15.5	1.29
49.0	19.3	2.28	5.02	15.7	1.31
50.0	19.7	2.42	5.33	15.9	1.33
51.0	20.1	2.56	5.65	16.1	1.34
52.0	20.5	2.72	5.99	16.3	1.36
53.0	20.9	2.87	6.34	16.5	1.38
54.0	21.3	3.04	6.70	16.7	1.39
55.0	21.7	3.21	7.08	16.9	1.41
56.0	22.0	3.39	7.46	17.1	1.43
57.0	22.4	3.57	7.87	17.3	1.44
58.0	22.8	3.76	8.29	17.5	1.46
59.0	23.2	3.95	8.72	17.7	1.48
60.0	23.6	4.16	9.16	18.0	1.50
61.0	24.0	4.37	9.63	18.2	1.51
62.0	24.4	4.58	10.10	18.4	1.53
63.0	24.8	4.81	10.60	18.6	1.55
64.0	25.2	5.04	11.10	18.8	1.57
65.0	25.6	5.27	11.63	19.0	1.59
66.0	26.0	5.52	12.17	19.3	1.61
67.0	26.4	5.77	12.72	19.5	1.62
68.0	26.8	6.03	13.30	19.7	1.64
69.0	27.2	6.30	13.89	19.9	1.66
70.0	27.6	6.57	14.49	20.2	1.68
71.0	28.0	6.86	15.12	20.4	1.70
72.0	28.3	7.15	15.76	20.6	1.72
73.0	28.7	7.45	16.42	20.9	1.74

APPENDIX III. LENGTH, WEIGHT, AND AGE OF YELLOWFIN TUNA FROM THE ATLANTIC OCEAN-CONTINUED

LENGTH		WEIGHT		AGE	
CM	IN	KG	LB	MO	YR
74.0	29.1	7.76	17.10	21.1	1.76
75.0	29.5	8.07	17.80	21.3	1.78
76.0	29.9	8.40	18.51	21.6	1.80
77.0	30.3	8.73	19.24	21.8	1.82
78.0	30.7	9.07	20.00	22.1	1.84
79.0	31.1	9.42	20.77	22.3	1.86
80.0	31.5	9.78	21.56	22.5	1.88
81.0	31.9	10.15	22.37	22.8	1.90
82.0	32.3	10.52	23.20	23.1	1.92
83.0	32.7	10.91	24.05	23.3	1.94
84.0	33.1	11.31	24.93	23.6	1.96
85.0	33.5	11.71	25.82	23.8	1.99
86.0	33.9	12.13	26.73	24.1	2.01
87.0	34.3	12.55	27.67	24.3	2.03
88.0	34.6	12.98	28.62	24.6	2.05
89.0	35.0	13.43	29.60	24.9	2.07
90.0	35.4	13.88	30.60	25.2	2.10
91.0	35.8	14.34	31.62	25.4	2.12
92.0	36.2	14.82	32.67	25.7	2.14
93.0	36.6	15.30	33.74	26.0	2.17
94.0	37.0	15.80	34.83	26.3	2.19
95.0	37.4	16.30	35.94	26.5	2.21
96.0	37.8	16.82	37.08	26.8	2.24
97.0	38.2	17.34	38.24	27.1	2.26
98.0	38.6	17.88	39.42	27.4	2.29
99.0	39.0	18.43	40.63	27.7	2.31
100.0	39.4	18.99	41.86	28.0	2.33
101.0	39.8	19.56	43.12	28.3	2.36
102.0	40.2	20.14	44.40	28.6	2.39
103.0	40.6	20.73	45.71	28.9	2.41
104.0	40.9	21.34	47.04	29.2	2.44
105.0	41.3	21.95	48.40	29.6	2.46
106.0	41.7	22.58	49.78	29.9	2.49
107.0	42.1	23.22	51.19	30.2	2.52
108.0	42.5	23.87	52.63	30.5	2.54
109.0	42.9	24.53	54.09	30.9	2.57
110.0	43.3	25.21	55.58	31.2	2.60
111.0	43.7	25.90	57.09	31.5	2.63
112.0	44.1	26.60	58.64	31.9	2.66
113.0	44.5	27.31	60.21	32.2	2.69
114.0	44.9	28.03	61.81	32.6	2.72
115.0	45.3	28.77	63.43	32.9	2.74
116.0	45.7	29.52	65.09	33.3	2.77
117.0	46.1	30.29	66.77	33.7	2.81
118.0	46.5	31.06	68.48	34.0	2.84

APPENDIX III. LENGTH, WEIGHT, AND AGE OF YELLOWFIN TUNA FROM THE ATLANTIC OCEAN-CONTINUED

LENGTH		WEIGHT		AGE	
CM	IN	KG	LB	MO	YR
119.0	46.9	31.85	70.22	34.4	2.87
120.0	47.2	32.65	71.99	34.8	2.90
121.0	47.6	33.47	73.79	35.2	2.93
122.0	48.0	34.30	75.62	35.6	2.96
123.0	48.4	35.14	77.48	36.0	3.00
124.0	48.8	36.00	79.36	36.4	3.03
125.0	49.2	36.87	81.28	36.8	3.06
126.0	49.6	37.75	83.23	37.2	3.10
127.0	50.0	38.65	85.21	37.6	3.13
128.0	50.4	39.56	87.22	38.0	3.17
129.0	50.8	40.49	89.26	38.5	3.20
130.0	51.2	41.43	91.34	38.9	3.24
131.0	51.6	42.38	93.44	39.3	3.28
132.0	52.0	43.35	95.58	39.8	3.32
133.0	52.4	44.34	97.75	40.2	3.35
134.0	52.8	45.34	99.95	40.7	3.39
135.0	53.1	46.35	102.18	41.2	3.43
136.0	53.5	47.38	104.45	41.7	3.47
137.0	53.9	48.42	106.75	42.2	3.51
138.0	54.3	49.48	109.09	42.7	3.55
139.0	54.7	50.55	111.45	43.2	3.60
140.0	55.1	51.64	113.85	43.7	3.64
141.0	55.5	52.75	116.29	44.2	3.68
142.0	55.9	53.87	118.76	44.7	3.73
143.0	56.3	55.00	121.26	45.3	3.77
144.0	56.7	56.16	123.80	45.8	3.82
145.0	57.1	57.32	126.38	46.4	3.87
146.0	57.5	58.51	128.99	47.0	3.92
147.0	57.9	59.71	131.63	47.6	3.97
148.0	58.3	60.92	134.31	48.2	4.02
149.0	58.7	62.15	137.03	48.8	4.07
150.0	59.1	63.40	139.78	49.4	4.12
151.0	59.4	64.67	142.57	50.1	4.17
152.0	59.8	65.95	145.40	50.7	4.23
153.0	60.2	67.25	148.26	51.4	4.28
154.0	60.6	68.56	151.16	52.1	4.34
155.0	61.0	69.90	154.10	52.8	4.40
156.0	61.4	71.25	157.07	53.5	4.46
157.0	61.8	72.61	160.08	54.3	4.52
158.0	62.2	74.00	163.14	55.1	4.59
159.0	62.6	75.40	166.23	55.8	4.65
160.0	63.0	76.82	169.35	56.7	4.72
161.0	63.4	78.25	172.52	57.5	4.79
162.0	63.8	79.71	175.73	58.3	4.86
163.0	64.2	81.18	178.97	59.2	4.94

APPENDIX III. LENGTH, WEIGHT, AND AGE OF YELLOWFIN TUNA FROM THE ATLANTIC OCEAN-CONTINUED

LENGTH		WEIGHT		AGE	
CM	IN	KG	LB	MO	YR
164.0	64.6	82.67	182.26	60.1	5.01
165.0	65.0	84.18	185.58	61.1	5.09
166.0	65.4	85.70	188.95	62.1	5.17
167.0	65.7	87.25	192.35	63.1	5.26
168.0	66.1	88.81	195.80	64.1	5.34
169.0	66.5	90.39	199.28	65.2	5.43
170.0	66.9	91.99	202.81	66.3	5.53
171.0	67.3	93.61	206.38	67.5	5.63
172.0	67.7	95.25	209.99	68.7	5.73
173.0	68.1	96.90	213.64	70.0	5.83
174.0	68.5	98.58	217.33	71.4	5.95
175.0	68.9	100.27	221.07	72.8	6.06
176.0	69.3	101.99	224.84	74.2	6.19
177.0	69.7	103.72	228.66	75.8	6.32
178.0	70.1	105.47	232.53	77.5	6.45
179.0	70.5	107.24	236.43	79.2	6.60
180.0	70.9	109.04	240.38	81.1	6.76
181.0	71.3	110.85	244.38	83.1	6.92
182.0	71.7	112.68	248.41	85.2	7.10
183.0	72.0	114.53	252.49	87.6	7.30
184.0	72.4	116.40	256.62	90.1	7.51
185.0	72.8	118.29	260.79	92.9	7.74
186.0	73.2	120.20	265.00	95.9	7.99
187.0	73.6	122.13	269.26	99.4	8.28
188.0	74.0	124.09	273.57	103.3	8.61
189.0	74.4	126.06	277.91	107.8	8.99
190.0	74.8	128.05	282.31	113.3	9.44