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SOME ASPECTS OF THE BIOLOGY OF SKIPJACK (*KATSUWONUS PELAMIS*) IN PHILIPPINE WATERS*

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Abstract

Aspects of skipjack (*Katsuwonus pelamis*) biology and population dynamics in Philippine waters between 1977 and 1982 are presented. Landings of skipjack in the Philippines are highly seasonal with peaks between February to May and October to November. The mean size at first maturity of skipjack in the Philippines is 43 cm (FL). Two spawning peaks were observed, one from March to May and a lesser one in November. The recruitment pattern of skipjack was similarly bimodal. An analysis of stomach contents showed that the dominant food items in Philippine waters were fish and squids. The estimated optimum capture length of skipjack caught by handlines increased with hook size, as did the selection range. Selection was very pronounced against smaller fishes. The growth parameters of skipjack in Philippine waters were estimated; they suggest a growth performance well within observed values for skipjack elsewhere.

Introduction

Skipjack (*Katsuwonus pelamis* (Linn.)) tuna landings in the Philippines have ranged from 31,000 to 61,000 tonnes·year^{-1} between 1980 and 1985 with an average of 47,000 tonnes (unpublished data), i.e., about 3.8% of the country's total marine landings. Most tuna landed are destined for canning although some skipjack are consumed fresh. Skipjack are caught mainly by ringnets, purse seines and handlines (White and Yesaki 1982). Floyd (1986) gave an account of the economics of the Philippine tuna fishery, and pointed out that it suffers from severe economic overfishing.

Studies on the biology and population dynamics of skipjack from the tropics and subtropics have been reported by many authors due to the general abundance and economic value of this resource. The review of tunas and related species by Collette and Nauen (1983) provides a convenient entry into the diverse literature on skipjack. In the Philippines, various aspects of skipjack biology have been reported upon by Ronquillo (1953; 1964), Buñag (1956), White (1982) and Yesaki (1983). In this paper, we present data on the biology of skipjack sampled in the Bohol Sea and north-western Luzon between 1977 and 1982.

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Materials and Methods

The sources of data analyzed in this paper are summarized in Table 1. Landings of skipjack were sampled at two locations in the Philippines, at Darigayos Cove, north-western Luzon and Opol, northern Mindanao (Fig. 1). The fishery at Darigayos Cove is composed of small (~0.3 gross tons (GT)) vessels from which skipjack are caught by handlines around payaos, i.e., floating fish attraction devices which are particularly common in this area (Floyd and Pauly 1984) (Fig. 1). Sampling in Darigayos Cove covered only May to November 1981 and hence did not cover an entire annual cycle of fishery catches. However, the period covered is that during which hook and line become the major gears as opposed to gill nets, used the rest of the year (Cortes-Zaragoza 1983; Cortes-Zaragoza *et al.* 1987). The fork lengths (snout tip to caudal fork) of each skipjack in the catch were measured to the nearest 0.1 cm and the hook sizes of the handlines employed by the fishermen landing the catch were recorded.

Skipjack are also caught around payaos by larger commercial ringnet vessels (25–56 GT) operating in the Bohol Sea and landing their catch at Opol. Between 1979 and 1981, the length-frequencies of skipjack landed by these vessels were recorded on alternate days of each month. Measurements were made to the nearest 0.1 cm fork length. A minimum of 25 skipjack specimens were measured from each landing. The skipjack and other fishes were segregated by the fishermen prior to landing into different species or species groups but these were not further separated by size. During 1982, the skipjack landings of each ringnet vessel at Opol were also recorded on a daily basis.

The maturation stages of skipjack during 1980 and 1981 were recorded from monthly samples taken in Opol. Sample sizes were relatively small since specimens had to be purchased for dissection. The gonads were exposed by making longitudinal incision in the belly of the fish. Six maturation stages, as given by Orange (1961) for yellowfin and skipjack tuna in the eastern Pacific, were recognized by macroscopic examination:

O	Gonads indistinct	III	Maturing ripe
I	Immature	IV	Ripe
II	Maturing	V	Spent

Hook selectivity of skipjack was estimated using the Baranov/Holt method (Baranov 1914; Holt 1963), reviewed in Gulland (1983) and Pauly (1984). As the length distributions of daily

Table 1. Sources of data used in the present contribution on skipjack tuna in Philippine waters.

Subject	Sampling Location	Years	Source
Hook selection	NW Luzon	1981	Cortes-Zaragoza (1983) Tandog (1984)
Reproduction	NE Mindanao	1977–82	Bureau of Fisheries and Aquatic Resources Regional Office, Region X, Opol
Catch size composition	NE Mindanao	1979–80	Bureau of Fisheries and Aquatic Resources Regional Office & Tandog (1984)
Feeding habits	NE Mindanao		Tandog (1984)
Seasonality of production	Philippines	1980–86	Navotas Fish Port Complex, Manila
	NE Mindanao	1982	Tandog (1984)
	NW Luzon	1981	Cortes-Zaragoza (1983)

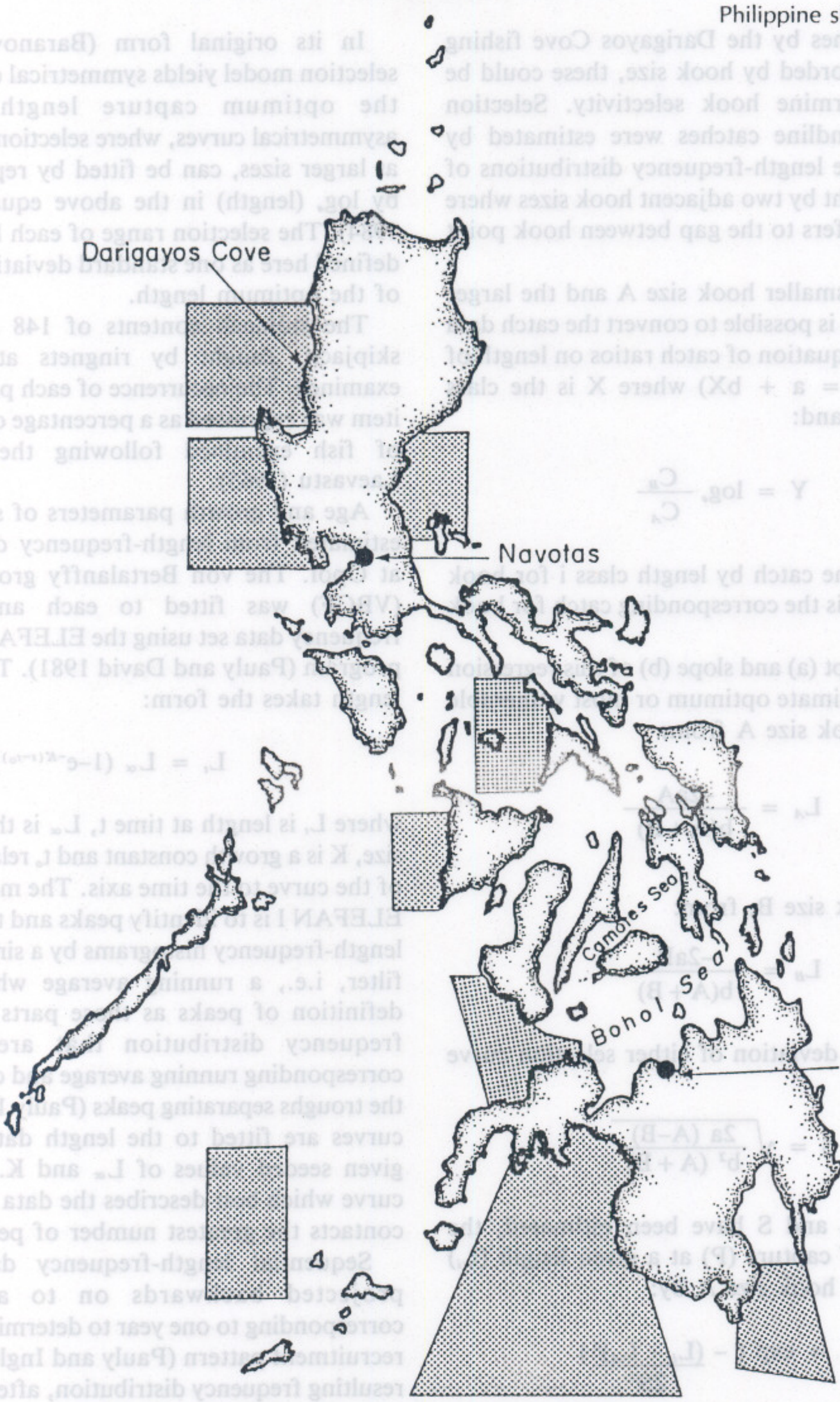


Fig. 1. Map of the Philippines showing where sample data were collected and other locations mentioned in text. Stippled areas show where payaos are concentrated (from Floyd and Pauly 1984).

skipjack catches by the Darigayos Cove fishing fleet were recorded by hook size, these could be used to determine hook selectivity. Selection curves of handline catches were estimated by comparing the length-frequency distributions of skipjack caught by two adjacent hook sizes where 'hook size' refers to the gap between hook point and shank.

Given the smaller hook size A and the larger hook size B, it is possible to convert the catch data into a linear equation of catch ratios on length of the form (Y = a + bX) where X is the class midlength L_i and:

$$Y = \log_e \frac{C_B}{C_A}$$

where C_A is the catch by length class i for hook size A and C_B is the corresponding catch for hook size B.

The intercept (a) and slope (b) of this regression are used to estimate optimum or most vulnerable length for hook size A from:

$$L_A = \frac{-2aA}{b(A+B)}$$

and, for hook size B, from:

$$L_B = \frac{-2aB}{b(A+B)}$$

The standard deviation of either selection curve is given by:

$$S = \sqrt{\frac{2a\,(A-B)}{b^2\,(A+B)}}$$

When L_A, L_B and S have been estimated, the probability of capture (P) at a given length (L_i) is given for a hook size A by:

$$P_A = \exp\left(-\frac{(L_i - L_A)^2}{2S^2}\right)$$

and for hook size B by:

$$P_B = \exp\left(-\frac{(L_i - L_B)^2}{2S^2}\right)$$

In its original form (Baranov 1914), this selection model yields symmetrical curves around the optimum capture length. However, asymmetrical curves, where selection is less intense at larger sizes, can be fitted by replacing length by $\log_e$ (length) in the above equations (Pauly 1984). The selection range of each hook size was defined here as one standard deviation either side of the optimum length.

The stomach contents of 148 specimens of skipjack, caught by ringnets at Opol were examined. The occurrence of each particular food item was expressed as a percentage of the number of fish examined following the method of Laevastu (1965).

Age and growth parameters of skipjack were estimated from length-frequency data collected at Opol. The von Bertalanffy growth function (VBGF) was fitted to each annual length-frequency data set using the ELEFAN I computer program (Pauly and David 1981). The VBGF for length takes the form:

$$L_t = L_\infty \left(1 - e^{-K(t - t_0)}\right)$$

where L_t is length at time t, L_∞ is the asymptotic size, K is a growth constant and t_0 relates the origin of the curve to the time axis. The method used in ELEFAN I is to identify peaks and troughs in the length-frequency histograms by a simple highpass filter, i.e., a running average which leads to definition of peaks as those parts of a length-frequency distribution that are above the corresponding running average and conversely for the troughs separating peaks (Pauly 1987). Growth curves are fitted to the length data iteratively, given seeded values of L_∞ and K. The growth curve which best describes the data is that which contacts the greatest number of peaks.

Sequential length-frequency data may be projected backwards on to a time axis corresponding to one year to determine the annual recruitment pattern (Pauly and Ingles 1981). The resulting frequency distribution, after some minor adjustments, gives the pattern of recruitment over a one-year period. When t_0 is accurately known (which is not the case here), the monthly pattern of recruitment can be ascribed to actual months and compared directly with spawning data. The derivation of recruitment patterns is a feature of the ELEFAN II computer program (Pauly 1987); their decomposition into seasonal 'pulses' of recruitment was based on the method in Soriano (1990).

Results and Discussion

Seasonality of skipjack fisheries

The monthly landings of skipjack at Darigayos Cove during 1981 and Opol during 1982 suggest these fisheries are highly seasonal (Fig. 2). There appear to be two production peaks in landings between February to April and between October to November. These localized trends in landings over a short time period are similar, however, to the general seasonality of skipjack landings in the Philippines. This was determined from a time series of monthly landed volume of skipjack between 1980 and 1986 at the fishing port of Navotas that services the Manila metropolitan area (Philippine Fisheries Development Authority, unpub. data). Skipjack landings at Navotas account for 20% of the total national catch and come from all parts of the Philippines. The mean monthly landings at Navotas are also included in Figure 2. The variation in landed volume of skipjack may reflect changes in abundance but this can only be inferred in the absence of data on fishing effort.

Reproduction

Length at first maturity is conventionally defined as the length at which 50% of the fish of a given stock become sexually mature. Skipjack with stages II–V gonads were here deemed to be sexually mature. The number of fish whose gonads were staged is given in Table 2 as a function of fish length. From this, the 50% maturity length was estimated as 43 cm (the data were insufficient to obtain separate estimates for females and males). A comparison with estimates of mean lengths at first maturity obtained elsewhere is given in Table 3. Our estimate of length at first maturity is well within the range of those for skipjack elsewhere and close to those for Philippine skipjack presented by other authors.

Data on the maturity stages of skipjack from the Bohol Sea from 1981 to 1982 were summarized on a bimonthly basis to attempt some understanding of spawning seasonality (Fig. 3).

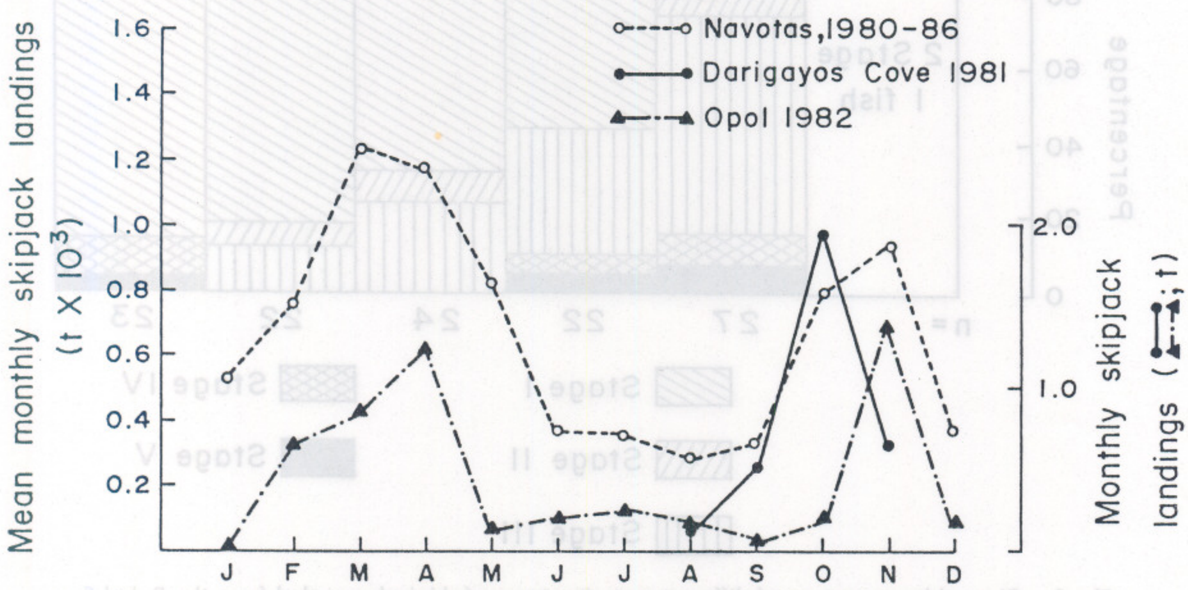


Fig. 2. Seasonality of production of skipjack tuna from different locations in the Philippines.

Table 2. Number of immature (Stage I) vs. mature (Stages II–V) skipjacks (females and males) sampled in 1980–81 at Opol, NE Mindanao, Philippines.

Class Midpoint (FL, cm)	Maturity Stage(s) I	II–V
20	4	0
24	8	0
28	17	0
32	26	0
36	4	0
40	3	1
44	6	8
48		33
52		17
56		12
60		21
64		18
68		7
72		15
76		2
Total	68	134

Table 3. Size at first maturity of skipjack from the Philippines and other locations.

Location	Size range (FL, cm)	Source
Hawaii (USA)	40–50	Brock (1954)
Eastern Pacific	40–55	Orange (1961)
	40–45	Raja (1964)
Marqueras and Tuamotu Island	43	Yoshida (1966)
Papua New Guinea	45	Kearney (1974)
North Carolina (USA)	43.5 45.4	Batts (1972)
Philippines	40	Wade (1950)
Philippines	41.9	Ronquillo (1964)
Philippines	40.5	Buñag (1956)
Philippines	43.1	This Study

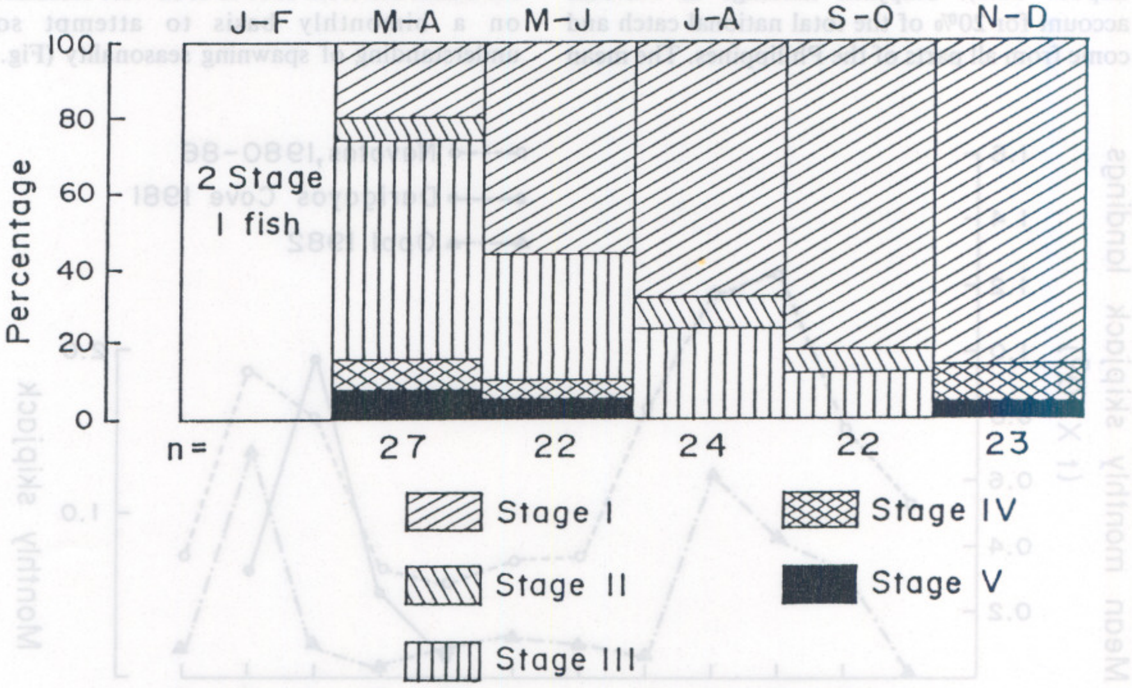


Fig. 3. Bimonthly percentage of different maturity stages of skipjack sampled from the Bohol Sea.

Given the small sample sizes, particularly for January and February, two interpretations of the data are possible. Philippine skipjack may have two peak spawning periods during the year between March and June and later from November to December. Alternatively, there may be just a single spawning peak extending from November to June. Note that the former interpretation, which we prefer, suggests two periods of spawning intensity which would coincide with the twin production peaks of the fishery.

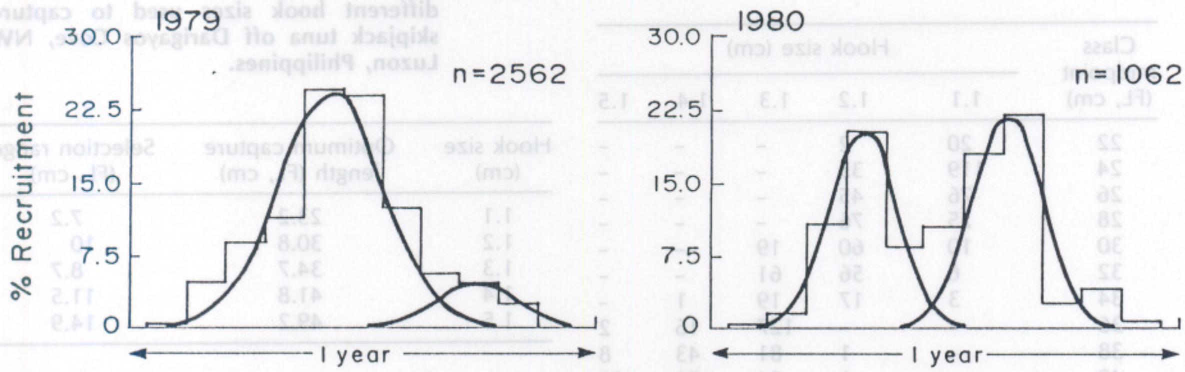
Recruitment patterns

The recruitment patterns generated by ELEFAN II for length-frequency data for skipjack from the Bohol Sea are shown in Figure 4. Two of the three recruitment patterns consist of two well-defined recruitment pulses, which would match the twin spawning peaks discussed above. These results agree with the findings of White (1982) and Yesaki (1983) who suggested twin spawning and recruitment peaks for skipjack in Philippine waters.

Twin recruitment patterns for Philippine marine fisheries have been reported by Pauly and Navaluna (1983), Ingles and Pauly (1984) and Corpuz *et al.* (1985). Pauly and Navaluna (1983) suggested that the spawning and recruitment processes were related to the two monsoon seasons of the Philippines.

Food

Only 31of the 148 skipjack sampled in the Bohol Sea contained any food. The relative occurrence of various items in these 31 stomach contents was as follows: squids (12.3%), anchovies (8.8%), sardines (7%), frigate mackerels (1.7%), euphausids (3.5%), unidentifiable fish (31.6%) and other items, including coconut leaves and



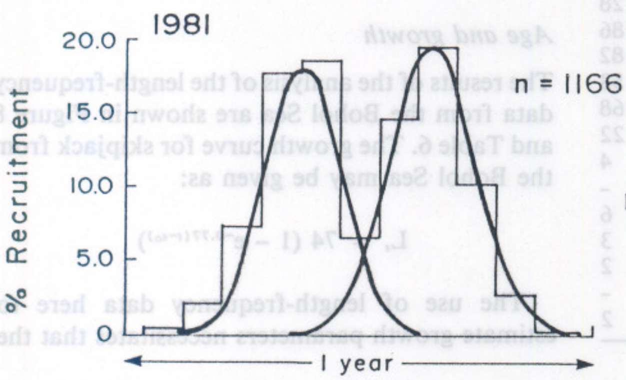


Fig. 4. Recruitment patterns of skipjack caught in the Bohol Sea, 1979–81. Histograms represent estimates of monthly recruitment; the normal curves represent seasonal recruitment pulses which, however, cannot directly be matched to months, because t_o in the VBGF is not known (see text).

pieces of wood and of nylon strings (35.1%). In the Central Pacific, the major component of skipjack stomach contents was fish and mollusks (Alverson 1963; Waldron and King 1963), while in the Eastern Pacific, crustaceans were the dominant food item, followed by squids and fish (Forsbergh 1980). Skipjack appear to be opportunistic feeders which prey on whatever is available to them (see also Ronquillo 1953).

Hook selectivity

The hook sizes used to capture skipjack at Darigayos Cove are 1.1, 1.2, 1.3, 1.4 and 1.5 cm. The data on catch at length are given in Table 4. There were insufficient overlap of fish lengths captured by 1.2 and 1.3 cm hook sizes, but for each of the other adjacent combinations, a double logarithmic plot of the catch ratio on fork length is given in Figure 5.

Table 4. Catch in numbers by length of different hook sizes to estimate their selectivity for *Katsuwonus pelamis*, off Darigayos Cove, NW Luzon, Philippines.

Class midpoint (FL, cm)	Hook size (cm)				
	1.1	1.2	1.3	1.4	1.5
22	20	2	-	-	-
24	119	35	-	-	-
26	76	45	-	-	-
28	25	76	-	-	-
30	10	60	19	-	-
32	6	56	61	-	-
34	3	17	19	1	-
36	-	-	127	16	2
38	-	1	81	43	8
40	-	1	54	70	28
42	-	-	36	130	86
44	-	-	7	60	82
46	-	-	4	24	53
48	-	-	-	14	68
50	-	-	-	3	22
52	-	-	-	1	4
54	-	-	-	2	-
56	-	-	-	-	6
58	-	-	-	-	3
60	-	-	-	-	2
62	-	-	-	-	-
64	-	-	-	-	2

The estimated optimum capture length for each hook size is given in Table 5. The scatter of optimum lengths versus hook size was fitted with a nonlinear function of the form $y = ax^b$ (Fig. 6). A curvilinear function was used since it passes through the origin. The selection range versus optimum length was fitted with a straight line forced through the origin and the means of both variates (Fig. 7).

The simple gill net selection model adapted for fish hooks assumes that the standard deviations of adjacent selection curves are the same. Clearly, this is not the case here, although the use of small increments in hook size minimizes the error. The analyses suggest that larger hooks capture larger skipjack and that larger hooks capture a greater range of fish sizes, with selection, overall, being very strong against smaller skipjack. A similar result was found for yellowfin tunas by Cortez-Zaragoza *et al.* (1989). The selection model applied only to hooks of the type used here. Other designs of fish hook such as the 'tuna circle' hook have different indexes of size (Ralston 1982).

Table 5. Optimum lengths and selection ranges for different hook sizes used to capture skipjack tuna off Darigayos Cove, NW Luzon, Philippines.

Hook size (cm)	Optimum capture length (FL, cm)	Selection range (FL, cm)
1.1	23.2	7.2
1.2	30.8	10
1.3	34.7	8.7
1.4	41.8	11.5
1.5	49.2	14.9

Age and growth

The results of the analysis of the length-frequency data from the Bohol Sea are shown in Figure 8 and Table 6. The growth curve for skipjack from the Bohol Sea may be given as:

$$L_t = 74\,(1 - e^{-0.77(t-t_0)})$$

The use of length-frequency data here to estimate growth parameters necessitates that the

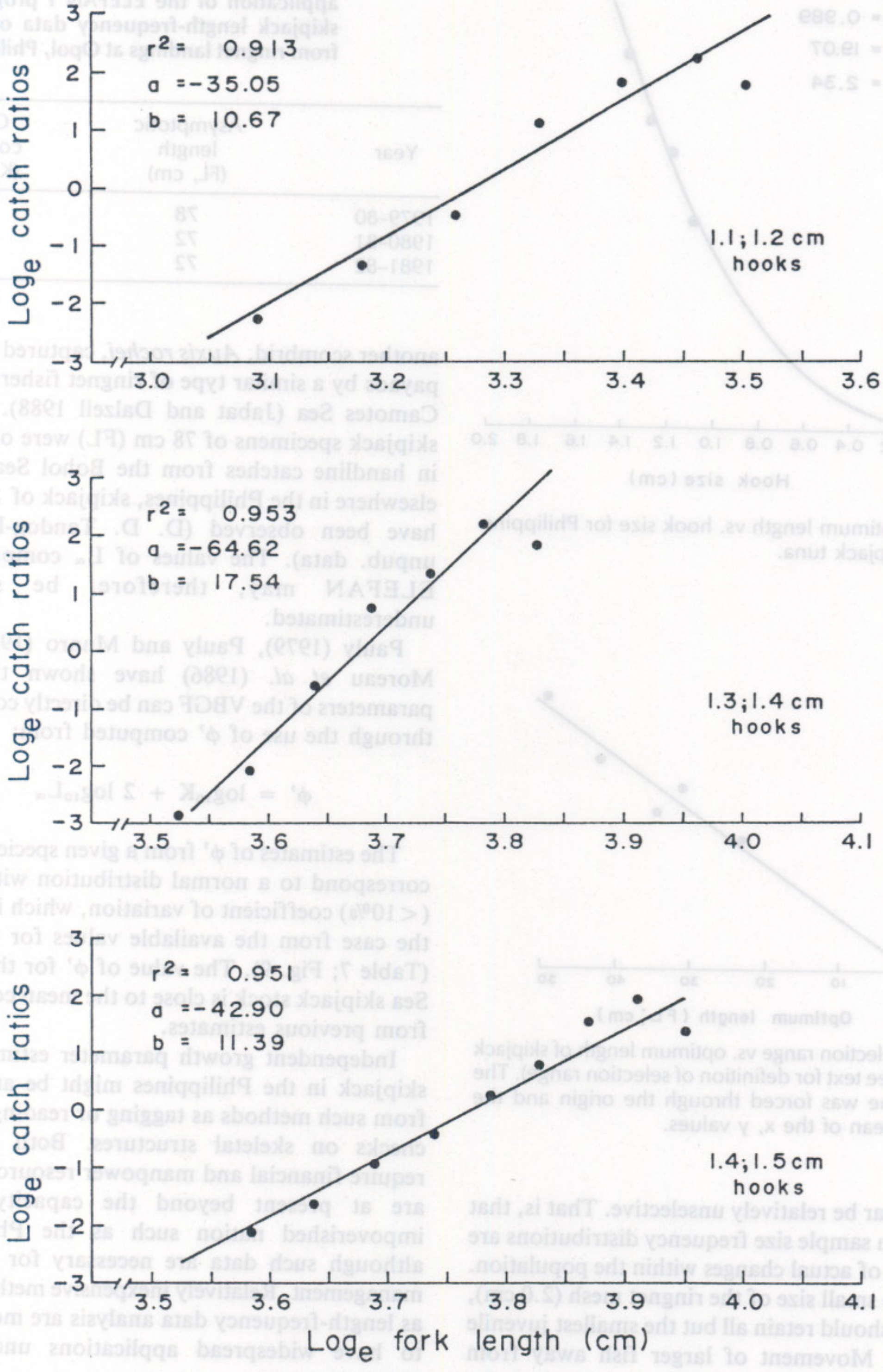


Fig. 5. Catch ratios vs. fork length of skipjack for different combinations of hook sizes.

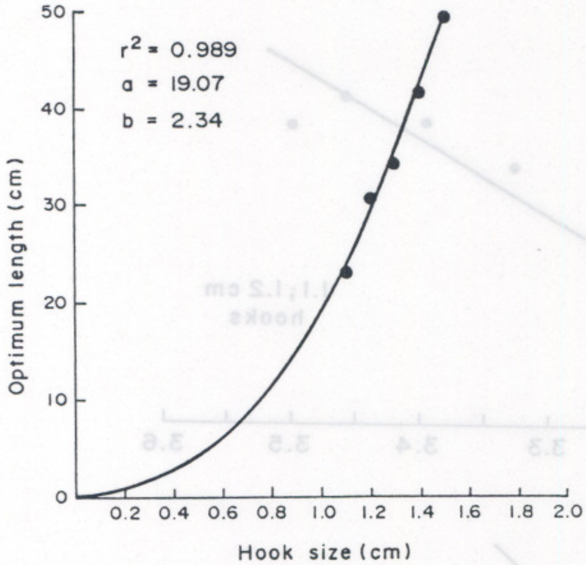


Fig. 6. Optimum length vs. hook size for Philippine skipjack tuna.

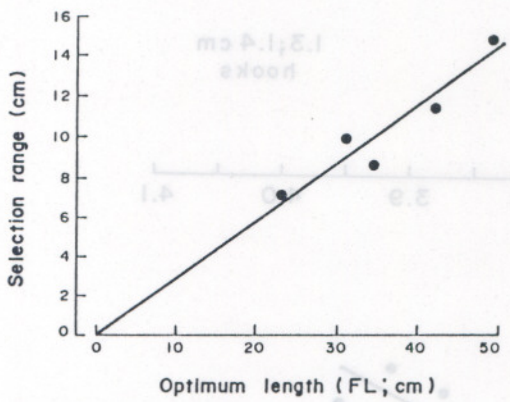


Fig. 7. Selection range vs. optimum length of skipjack (see text for definition of selection range). The line was forced through the origin and the mean of the x, y values.

fishing gear be relatively unselective. That is, that changes in sample size frequency distributions are reflection of actual changes within the population. Given the small size of the ringnet mesh (2.0 cm), this gear should retain all but the smallest juvenile skipjack. Movement of larger fish away from payaos may occur, however, as reported for another scombrid, *Auxis rochei*, captured around payaos by a similar type of ringnet fishery in the Camotes Sea (Jabat and Dalzell 1988). A few skipjack specimens of 78 cm (FL) were observed in handline catches from the Bohol Sea whilst elsewhere in the Philippines, skipjack of >80 cm have been observed (D. D. Tandog-Edralin, unpub. data). The values of L_∞ computed by ELEFAN may, therefore, be slightly underestimated.

Table 6. Growth parameter estimates derived from application of the ELEFAN I program to skipjack length-frequency data obtained from ringnet landings at Opol, Philippines.

Year	Asymptotic length (FL, cm)	Growth coefficient (K; year^{-1})
1979-80	78	0.8
1980-81	72	0.8
1981-82	72	0.7

Pauly (1979), Pauly and Munro (1984) and Moreau *et al.* (1986) have shown that the parameters of the VBGF can be directly compared through the use of ϕ' computed from:

$$\phi' = \log_{10}K + 2\log_{10}L_\infty$$

The estimates of ϕ' from a given species should correspond to a normal distribution with a low (<10%) coefficient of variation, which is indeed the case from the available values for skipjack (Table 7; Fig. 9). The value of ϕ' for the Bohol Sea skipjack stock is close to the mean computed from previous estimates.

Independent growth parameter estimates for skipjack in the Philippines might be attempted from such methods as tagging or reading growth checks on skeletal structures. Both methods require financial and manpower resources which are at present beyond the capacity of an impoverished nation such as the Philippines although such data are necessary for effective management. Relatively inexpensive methods such as length-frequency data analysis are more likely to have widespread applications under such circumstances.

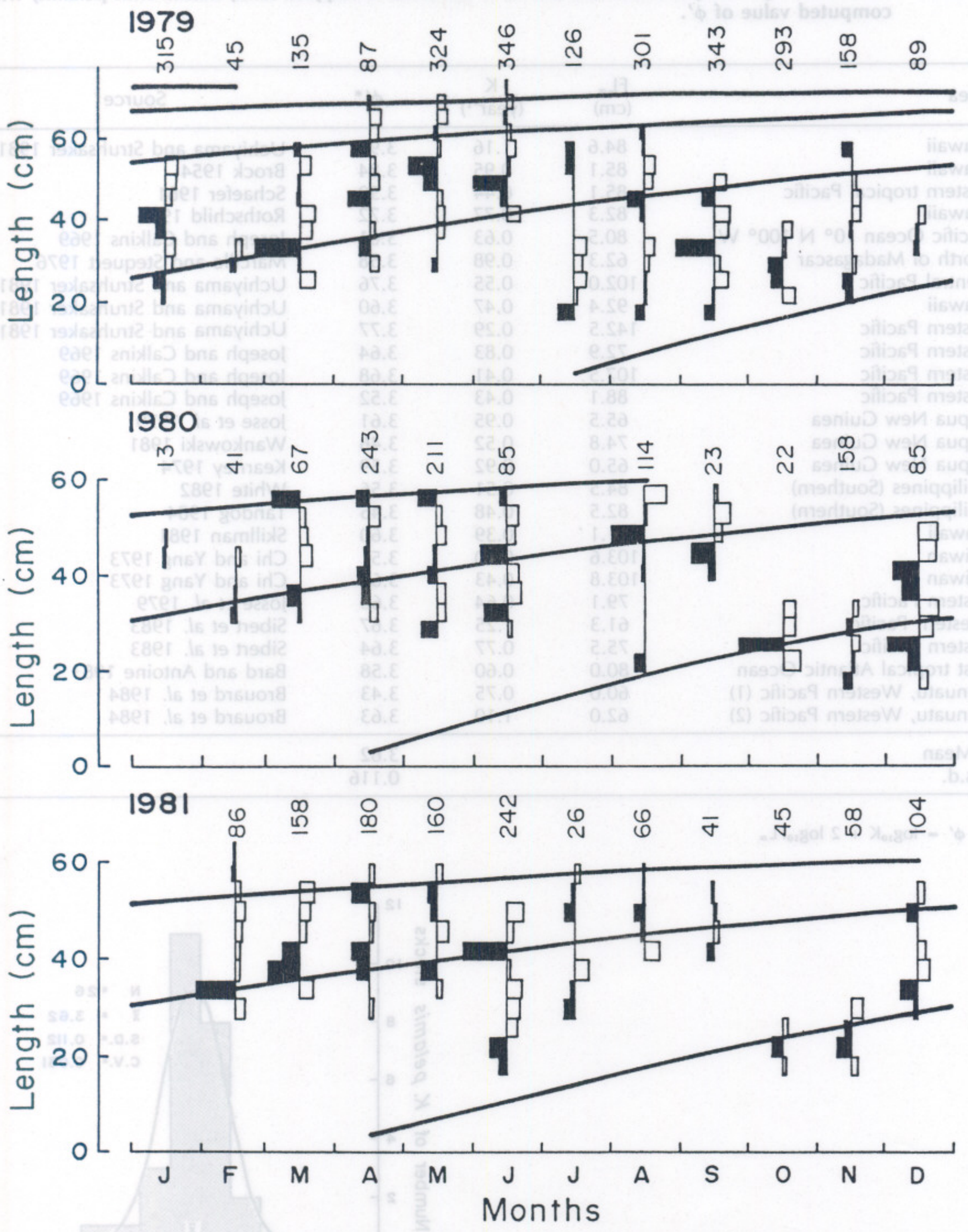


Fig. 8. Growth curves fitted by ELEFAN I to fork length-frequency data (numbers along graphs indicate sample sizes) for skipjack tuna landed from the Bohol Sea at Opol, 1979–81. The length data have been restructured by ELEFAN I into peaks (■)and troughs (□).

Table 7. Estimates of growth parameter (L_∞ and K) in 26 stocks of skipjack tuna, *Katsuwonus pelamis,* with computed value of ϕ'.

Area	FL_∞ (cm)	K ($year^{-1}$)	ϕ'*	Source
Hawaii	84.6	1.16	3.92	Uchiyama and Struhsaker 1981
Hawaii	85.1	0.95	3.84	Brock 1954
Eastern tropical Pacific	85.1	0.44	3.50	Schaefer 1961
Hawaii	82.3	0.77	3.72	Rothschild 1967
Pacific Ocean 10° N 100° W	80.5	0.63	3.61	Joseph and Calkins 1969
North of Madagascar	62.3	0.98	3.58	Marcille and Stequert 1976
Central Pacific	102.0	0.55	3.76	Uchiyama and Struhsaker 1981
Hawaii	92.4	0.47	3.60	Uchiyama and Struhsaker 1981
Eastern Pacific	142.5	0.29	3.77	Uchiyama and Struhsaker 1981
Eastern Pacific	72.9	0.83	3.64	Joseph and Calkins 1969
Eastern Pacific	107.5	0.41	3.68	Joseph and Calkins 1969
Eastern Pacific	88.1	0.43	3.52	Joseph and Calkins 1969
Papua New Guinea	65.5	0.95	3.61	Josse *et al.* 1979
Papua New Guinea	74.8	0.52	3.46	Wankowski 1981
Papua New Guinea	65.0	0.92	3.59	Kearney 1974
Philippines (Southern)	84.5	0.51	3.56	White 1982
Philippines (Southern)	82.5	0.48	3.45	Tandog 1984
Hawaii	101.1	0.39	3.60	Skillman 1981
Taiwan	103.6	0.30	3.51	Chi and Yang 1973
Taiwan	103.8	0.43	3.67	Chi and Yang 1973
Eastern Pacific	79.1	0.64	3.60	Josse *et al.* 1979
Western Pacific	61.3	1.25	3.67	Sibert *et al.* 1983
Eastern Pacific	75.5	0.77	3.64	Sibert *et al.* 1983
East tropical Atlantic Ocean	80.0	0.60	3.58	Bard and Antoine 1983
Vanuatu, Western Pacific (1)	60.0	0.75	3.43	Brouard *et al.* 1984
Vanuatu, Western Pacific (2)	62.0	1.10	3.63	Brouard *et al.* 1984
Mean			3.62	
s.d.			0.116	

* $\phi' = \log_{10}K + 2\log_{10}FL_\infty$

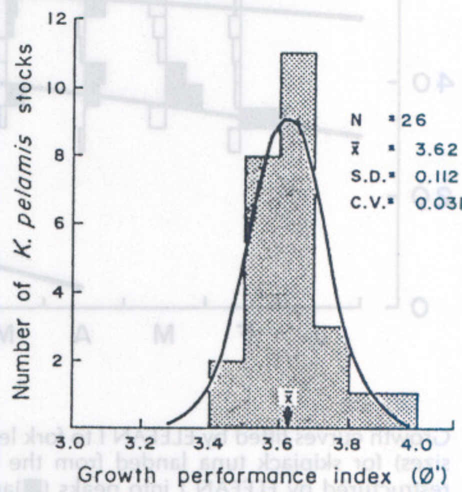


Fig. 9. Frequency distribution of ϕ' ($= \log_{10}K + 2\log_{10}FL_\infty$) in 26 skipjack stocks (see also Table 7).

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